# Nest Learning Thermostat Pilot Program Savings Assessment

# Bonneville Power Administration & Franklin Public Utility District

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# Executive Summary

This report provides the results of the Nest Learning Thermostat ™ field pilot study conducted by BPA and Franklin Public Utility District (FPUD) between years 2013 and 2015. The purpose of this report is to provide BPA with the information necessary for determining accurate Nest thermostat unit energy savings (UES) estimates for inclusion in the residential energy efficiency portfolio. The study placed 176 Nest thermostats in qualifying homes and analyzed the resulting energy savings after the two-year period. BPA and FPUD employed CLEAResult as the primary implementer of the study to recruit participants, screen for qualifying homes, and install Nest thermostats across the PUD territory.

## Analysis Methods

The team used various analysis methods to both characterize the homes participating in the Nest thermostat study and arrive at an average savings estimate per home. These methods included:

- **Regression modeling using billing data provided by FPUD.** The team used three different models employing different common regression methodologies to estimate savings via the impact on customer utility bills.
- **Usage data from Nest Labs for participating thermostats.** Nest provided data on how participants used their Nest thermostat during the pilot study, including temperature settings, efficiency and comfort settings, auto-away settings, and heat pump run times.
- **Participant survey results.** The team conducted two surveys during the pilot study, 1) a preliminary demographics survey to screen for qualified homes, and 2) a follow-up survey asking participants about satisfaction, comfort, ease of use, and how they interacted with the thermostat.

## Results

This section provides the results of each of the analysis methods including the average energy savings estimates for Nest thermostats per home.

### Billing Analysis

The team used three methods to calculate annual electric energy savings:

1. A Prism-like pre-post Normalized Annual Consumption (NAC) model with Variable Base Degree Days (VBDD)
2. A pooled fixed and random effects (mixed effects) model
3. A change point model using ECAM+ software

Table E1 Shows the results of the three regression models used for this study. All three models produce similar results which are not statistically different from one another. The pre-post NAC and the ECAM+ results models are slightly more robust, as they report savings net of the comparison group. The model-estimated savings are between 745 and 955 kWh, roughly 4% of the average pre-treatment household energy consumption and 12% of the average heating and cooling energy consumption. Section 7 provides further detail on the regression models.

**Table E1: Energy Savings Estimates**

| Modeling Method | N | Mean Total Annual Net Savings (kWh) | 95% Lower C.I. | 95% Upper C.I. | Savings as % of Total Consumption | % Savings of Estimated Heating & Cooling Load |
|---|---|---|---|---|---|---|
| **Pre-Post NAC VBDD** | 97 | 841 | 337 | 1,345 | 4% | 12% |
| **ECAM+** | 140 | 745 | 266 | 1,224 | 4% | NA |
| **Fixed Effects** | 167 | 955 | 606 | 1,304 | 4% | NA |

## Nest Lab Data

The team's analysis of the data provided by the Nest laboratory resulted in the following key findings: Most participants (82%) kept their "auto-away" setting turned on which automatically set back their thermostats when no one was in the home. Most participants (64%) also remained on the most efficient "Max Savings" thermostat setting, while a small number of participants (11%) did not have the heat pump settings enabled on the thermostat at all. The Nest heat pump "Max Savings" versus "Max Comfort" settings do appear to impact the level of savings achieved. Finally, households who had lower heating set points, higher cooling set points and who had more aggressive set back temperatures achieved higher energy savings.

## Participant Survey

The team surveyed the 176 pilot study participants on a variety of subjects including satisfaction with the program and with the Nest thermostats. The responses indicated that most households were satisfied with the Nest Thermostat's usability and the level of comfort it provided. Over 85% of participants indicated they were "somewhat" or "completely" satisfied with the Nest thermostat and the pilot program. However, roughly 15% of participants reported having some issues including problems with Wi-Fi connectivity, ability to make adjustments, or experiencing periods of being too cold or too warm.

# 1. Introduction

Bonneville Power Administration (BPA) and Franklin Public Utility District (FPUD), located in Pasco, Washington, conducted a two-year Nest Learning Thermostat™ field pilot study, starting in the summer of 2013 and running through the fall of 2015. The study selected the Nest thermostat because of its capacity to learn the habits of its users and self-program to maximize energy savings and comfort. BPA and FPUD installed 176 Nest thermostats in single-family residences and sub-metering devices in an additional 13 homes to better understand how the Nest optimizes heat pump operation. BPA and FPUD plan to use the results of this pilot study to evaluate electricity savings from residential Air Source Heat Pumps (ASHP) using Nest controls.

# 2. Assessment Objectives

This report documents the estimated annual electric energy savings achieved during the Nest Learning Thermostat™ pilot program and feedback on the participant's experience and satisfaction with the study. The BPA and FPUD team (the team) used a billing analysis approach to assess the energy savings achieved by the Nest thermostat. The study also relies on self-reported survey results from participants regarding satisfaction and ease of use of both the pilot study and the Nest thermostats. BPA may use the results of the analysis to inform the development of UES estimates for residential connected thermostats as an energy efficiency measure in its residential energy efficiency portfolio.

# 3. Nest Thermostat Features

The Nest Learning Thermostat is one of several "smart thermostats" designed to control the heating and cooling equipment in residential homes. Nest has a proprietary learning algorithm that observes the temperature setting behavior of a household, and develops a "self-programming" schedule using the observed temperature set points. Depending on the chosen heat pump settings (e.g., max savings, balanced, or max comfort), the thermostat will attempt to minimize the auxiliary heat use while maintaining occupant comfort via temperature set point settings. The Nest thermostat also has a variety of other features including:

- **Auto-Away**: The set point will automatically revert to the "set-back" temperature if the occupancy sensor senses no activity
- **Early On**: The HVAC equipment will pre-heat or pre-cool the home in order to meet the chosen temperature at the exact specified time
- **Filter Reminder**: Reminds homeowners to change filters based on hours of use
- **Energy History**: Displays the energy use history of the HVAC system
- **Nest Leaf**: Interface shows a green leaf for temperature settings that will save energy

## 4. Participant Recruitment

FPUD contracted a third party, CLEAResult, to manage the recruitment process and the installation of the thermostats. FPUD and CLEAResult reached out to possible participants through direct mail letters and newsletters, and offered a free $250 thermostat along with free professional installation as an incentive to participate. CLEAResult hired a local HVAC contractor to conduct a final on-site pre-screening and install the thermostats in homes meeting qualifications. Qualifying participants had to meet the following criteria:

1. Be a single-family home with an air-source heat pump and no advanced controls
2. Have a working Wi-Fi connection
3. Be residents of the home for at least two years
4. Have conducted no energy efficiency upgrades within the past two years

Some pre-screened customers were unable to meet these on-site criteria and were therefore unable to participate in the study. The HVAC contractor only proceeded with the installation of the thermostat after confirming it would work with the existing heat pump, household wiring, and wireless router. During the installation visit, the HVAC contractor also provided participants with an initial thermostat training, conducted a customer survey, and left behind a thermostat information sheet which included contact details for additional support. In general, the installation process met with no substantial issues due to the professional install and the on-line support maintained by the manufacturer.

Participants were also required to sign a contract allowing FPUD and BPA to obtain data from their thermostat, and prohibited participants from changing their assigned thermostat password for at least two weeks to ensure access to the data. The majority of participants, 80%, did not change their password during the entire pilot period, which was helpful in allowing FPUD to troubleshoot problems later in the study. Most of the remaining 20% who changed their passwords after the first two weeks, were willing to share their new passwords with FPUD if requested.

The HVAC contractors configured the Nest thermostats to obtain maximum energy savings from the heat pumps it controlled by choosing the “heat pump balance” and “max savings” configuration during installation. The “heat pump balance” setting optimizes the use of the heat pumps auxiliary resistance heating element in accordance with the user’s chosen settings. The “max comfort” setting engages the auxiliary heating more frequently to ensure the greatest comfort, while the “max savings” setting minimizes the use of the auxiliary heating element to minimize energy consumption. Within two weeks of the installation, CLEAResult logged in to each participant’s thermostat to ensure the settings were still set to “heat pump balance” and “max savings.” This was a cost-effective means of providing quality assurance and quality control over thermostat configuration.

Throughout the pilot study, FPUD maintained active communication with participants to troubleshoot issues as they arose. FPUD also regularly sent pilot participants a newsletter to ensure participants were satisfied with the equipment. The pilot maintained a zero drop-out rate over the course of the study. To FPUD's knowledge, all 176 thermostats installed for this pilot study are still in place and operational today.

## 5. Participant Survey Results

This section describes the results of the participant survey conducted with the 176 residents taking part in the Nest Thermostat study.

### 5.1. Participant Home Characteristic and Demographic Data

HVAC contractors collected home and occupancy characteristics of participants' homes during the installation of the Nest thermostats. Most homes have 2 or more residents with an average of 3 occupants per home (Figure 1). The participating homes are newer than the typical home in the region, with about half of the participant homes built after 1979 (Figure 2). The average home size is 2,034 square feet and the majority of the homes are smaller than 2,000 square feet (Figure 3). Over 88% of the participant homes already had a programmable thermostat and the majority of these were manufactured by Honeywell.

Figure 1: Number of Occupants (N=176)

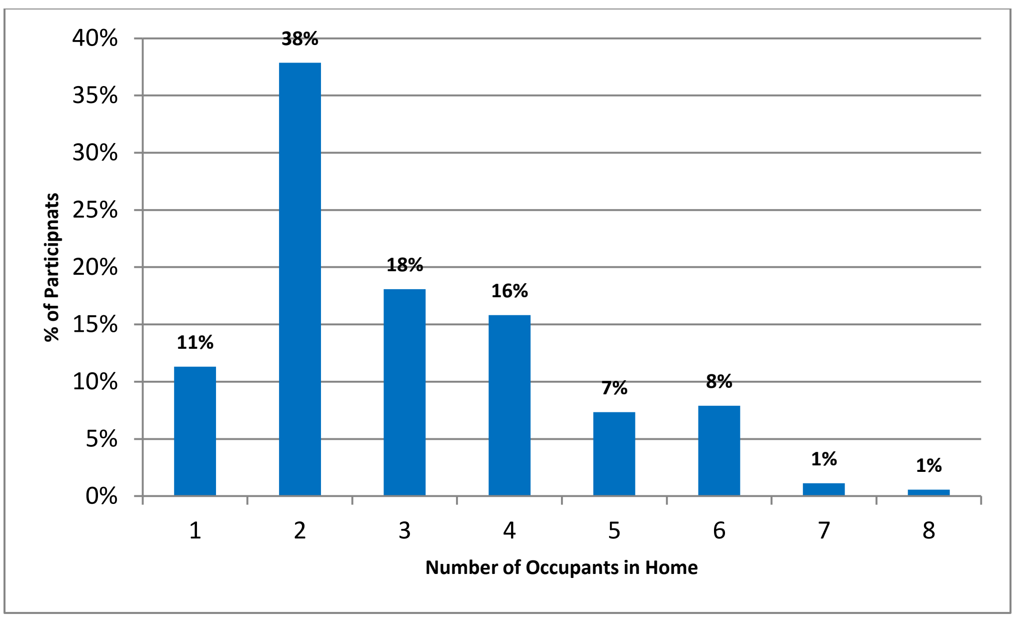


Figure 2: Year Home Built (N=176)

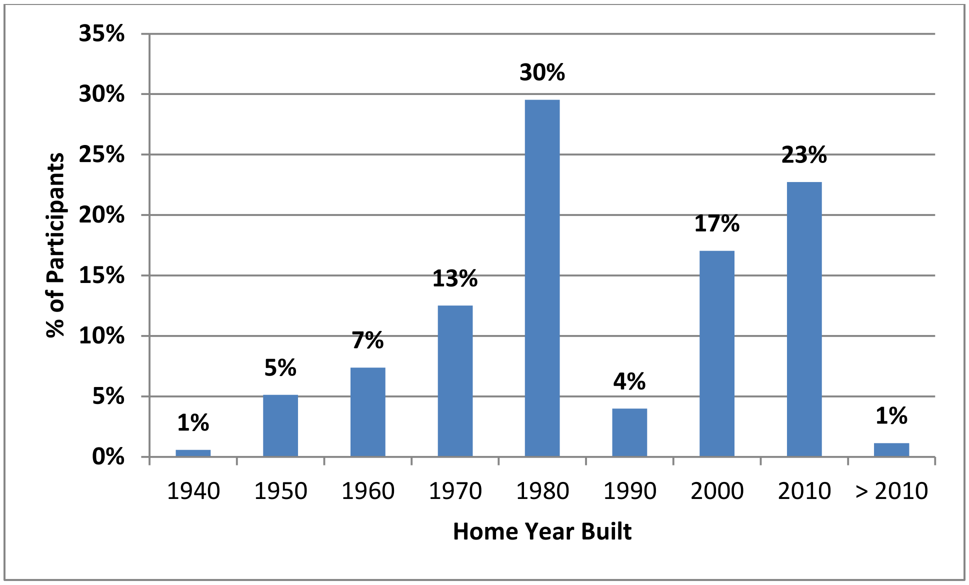



Figure 3: Home Square Footage (N=176)

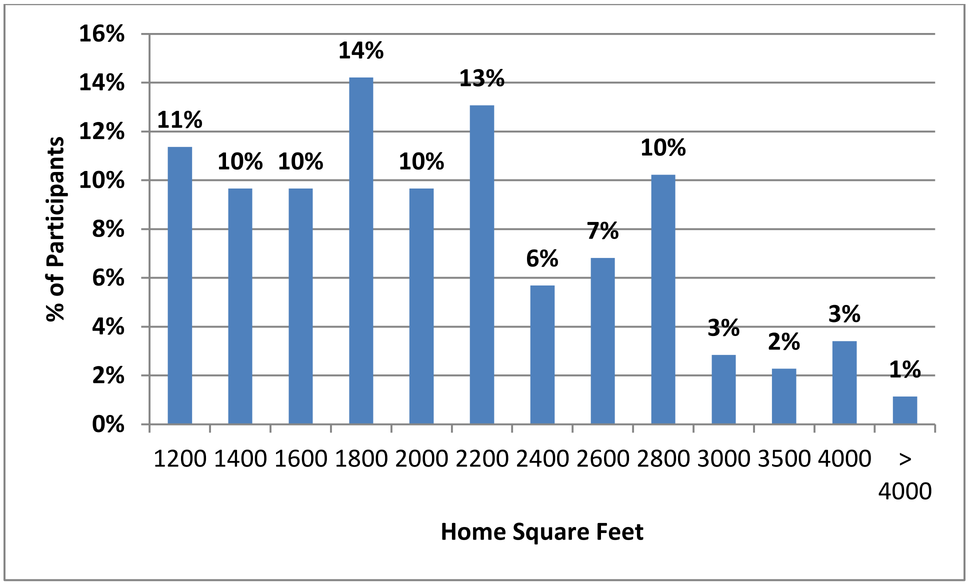
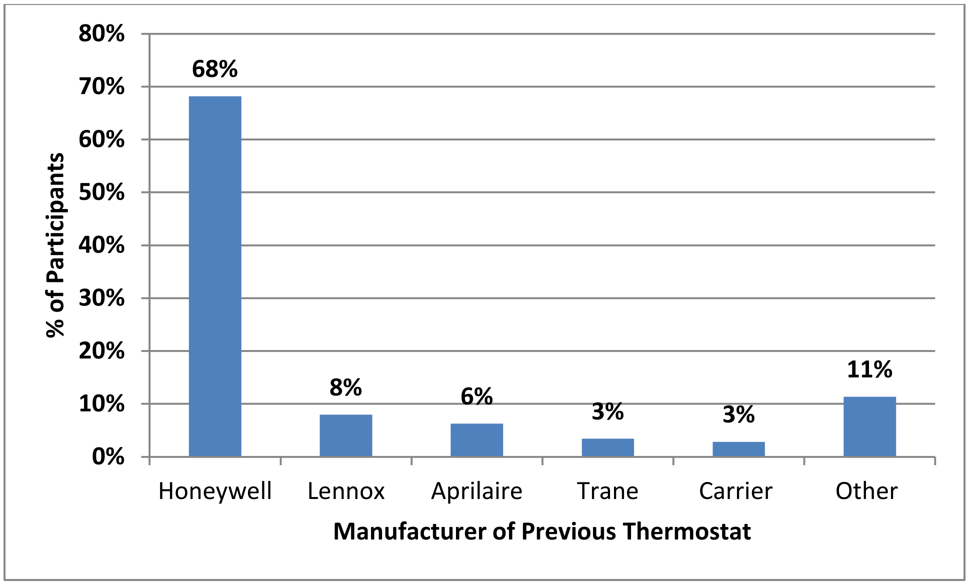


Figure 4: Make of Previous Thermostat (N=176)




## 5.2. Participant Survey Data

In November of 2015, FPUD sent a follow-up survey to all Nest participants to assess overall user satisfaction, product usability, product effectiveness, and satisfaction with various Nest features. FPUD provided the survey in both paper and online forms, and received 84 responses (48% of participants).

Overall satisfaction with the Nest thermostat was good, with 89% of respondents indicating they were either somewhat or completely satisfied with the Nest product (Figure 5). Additionally, 85% indicated they were either somewhat or completely satisfied with the “Nest pilot study being conducted by Franklin PUD Energy Services Staff.” Figure 6 shows that 75% of participants are either somewhat or completely likely to recommend the Nest to others.

Figure 5: Satisfaction (N=78)

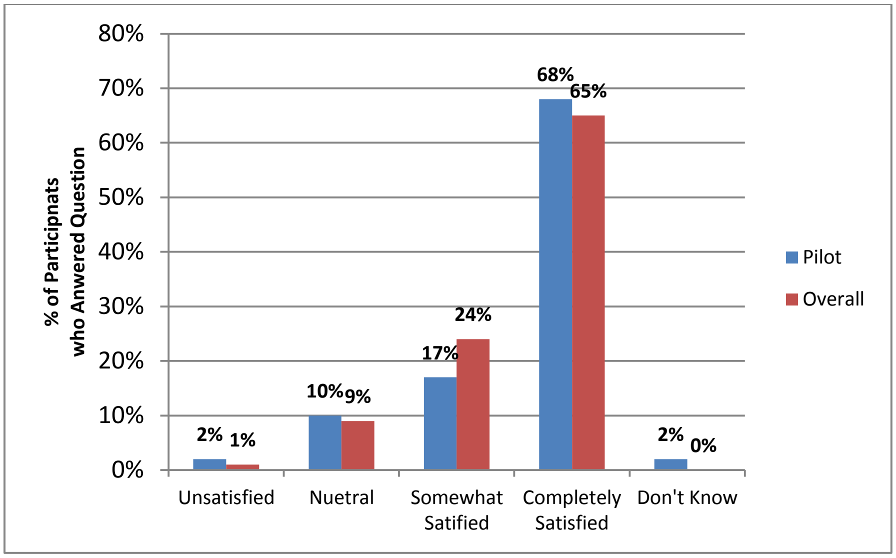
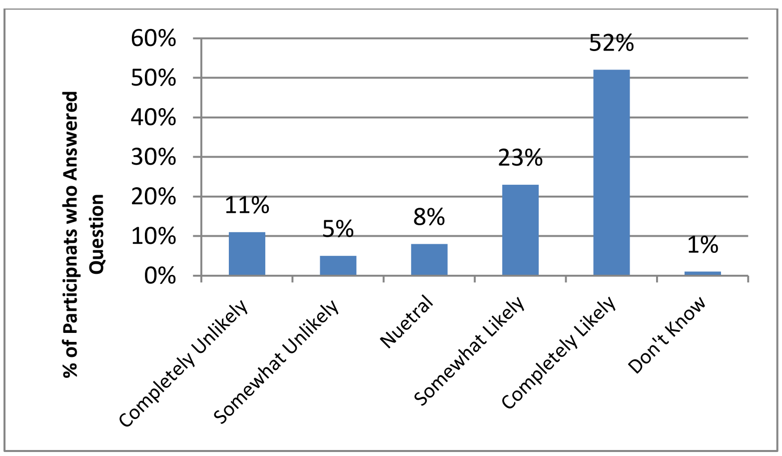
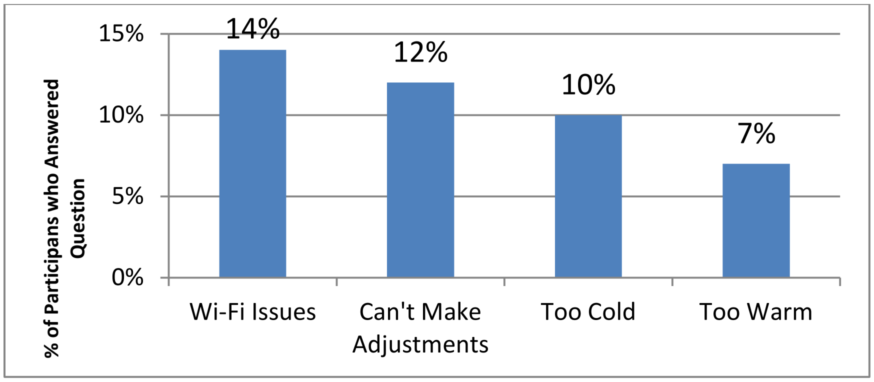



Figure 6: Recommend Nest to Others (N=79)




Despite the high overall satisfaction scores, a significant number of participants mentioned having issues and/or complications with the Nest product at some point during the study. Figure 7 illustrates these issues and provides the percentage of households experiencing each issue. As shown, the majority of these issues were Wi-Fi related (14%), with another 12% indicating they wanted to make adjustments to the settings but were unable. A commonly cited complication with adjustments related to the auto-away setting being enabled when people were actually at home. This can happen if people in the home do not pass by the thermostat for an extended period of time in order to trigger the occupancy sensor.

Figure 7: Issues and Complications (N=26)




The majority of people with issues and complications received support from FPUD, CLEAResult, or Nest Customer Service, but 6 participants indicated that their issues went un-resolved. Two of these participants admitted un-installing their Nest thermostats because of the unresolved issues. Data from these homes are not included in the savings analysis.

The survey asked several questions about how people interacted with their thermostat. Figure 8 shows that people reported adjusting their thermostat temperature infrequently, with 35% indicating that they adjusted the temperature settings less than once per month and another 27% just a few times per month.

Figure 8: Frequency of Changing Temperature Settings (N=81)

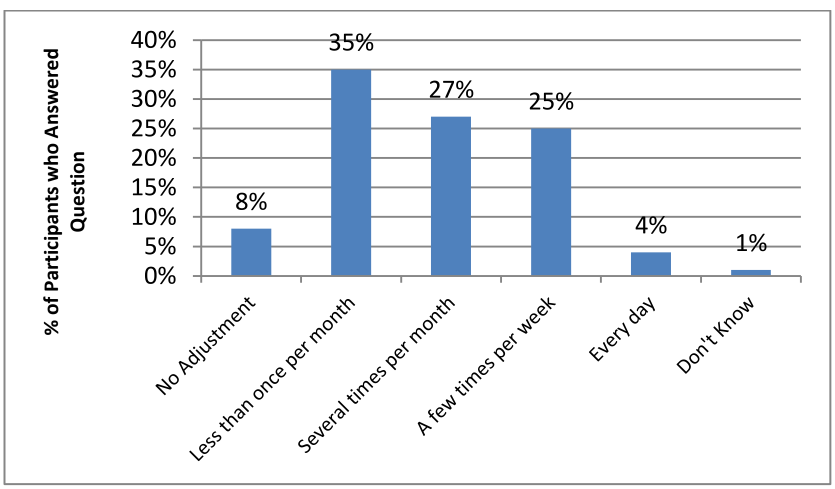
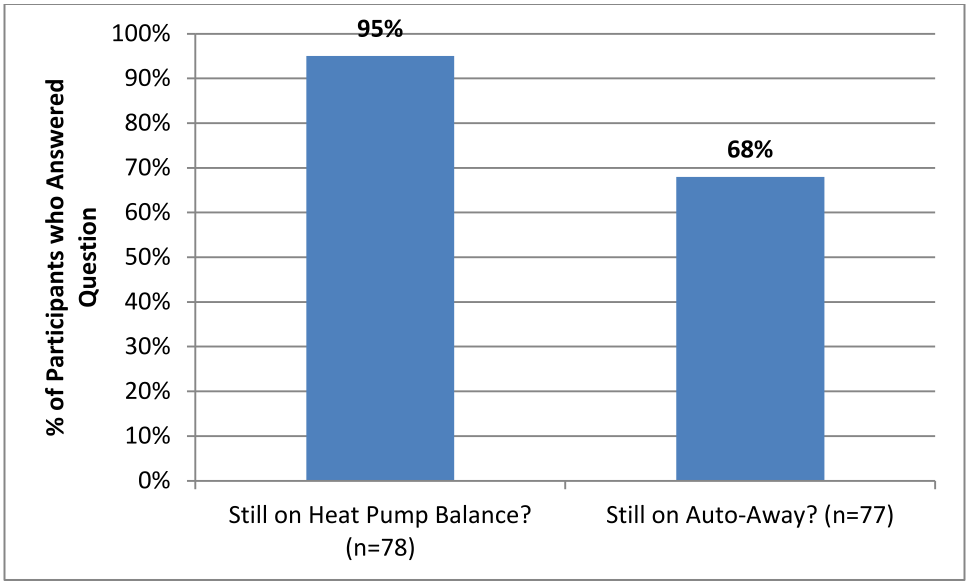



Figure 9 shows that most people reported keeping the same Nest settings as configured during installation: "heat pump balance" and "maximum savings." Fewer people reported keeping the auto-away setting which utilizes the occupancy sensor to revert to the set-back temperature if the home is unoccupied.

Figure 9: Heat Pump Balance and Auto-Away Settings

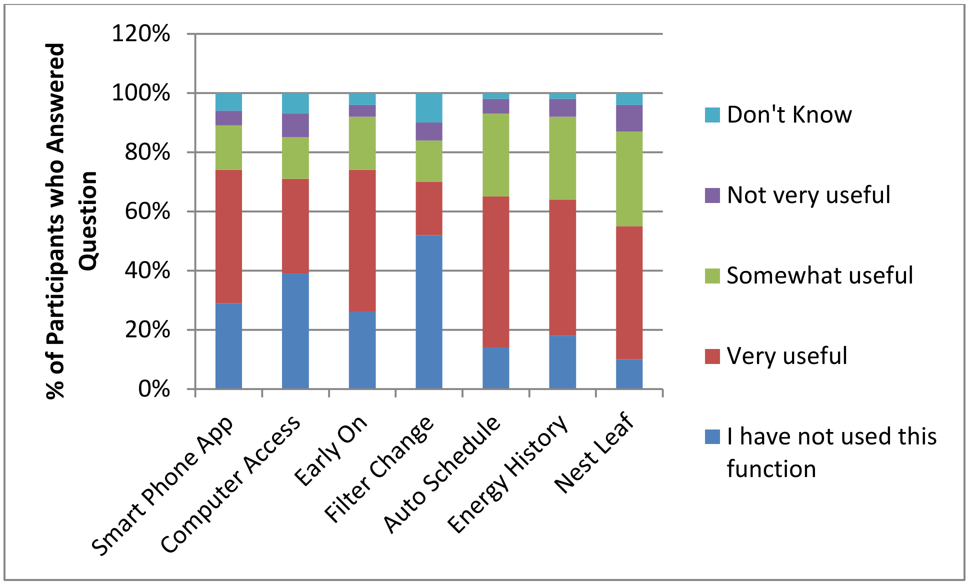



BPA and FPUD also worked with Nest to track actual thermostat settings throughout the study period to compare with the self-reported survey results. BPA provided Nest with the serial numbers for the 176 thermostats installed in the pilot and received anonymous data for 145 of these thermostats.[1] Nest provided BPA with a snapshot of data in mid-April 2016 showing where thermostat settings were at the time as well as run time data dating back to the installation of the thermostat. Analysis on the Nest data showed that only 64% of participants kept the thermostat on the "max savings" setting, and a small number of participants turned off the "heat pump balance" setting. The Nest data also revealed that 82% of participants were still using the auto-away setting, as opposed to the self-reported results of 68%.

The participant survey also asked about any Nest features the homeowners found useful. Figure 10 shows that the most popular features include the auto-scheduling, energy history, and Nest leaf. The least useful feature was the filter change reminder.

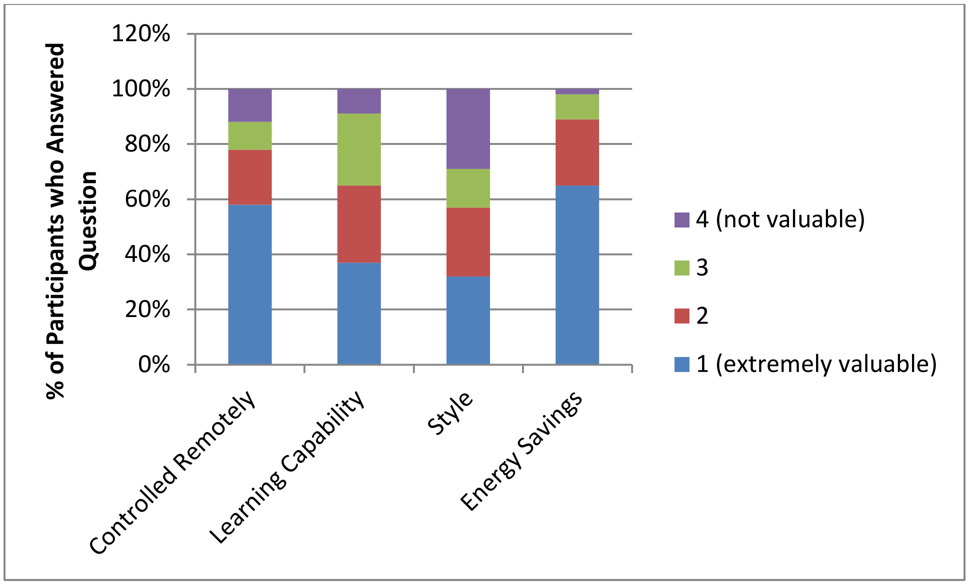
[1] The team found minor issues with tracking data such as serial numbers not matching the Nest system, and the loss of connectivity of some thermostats.

Figure 10: Usefulness of Nest Features (N=80)



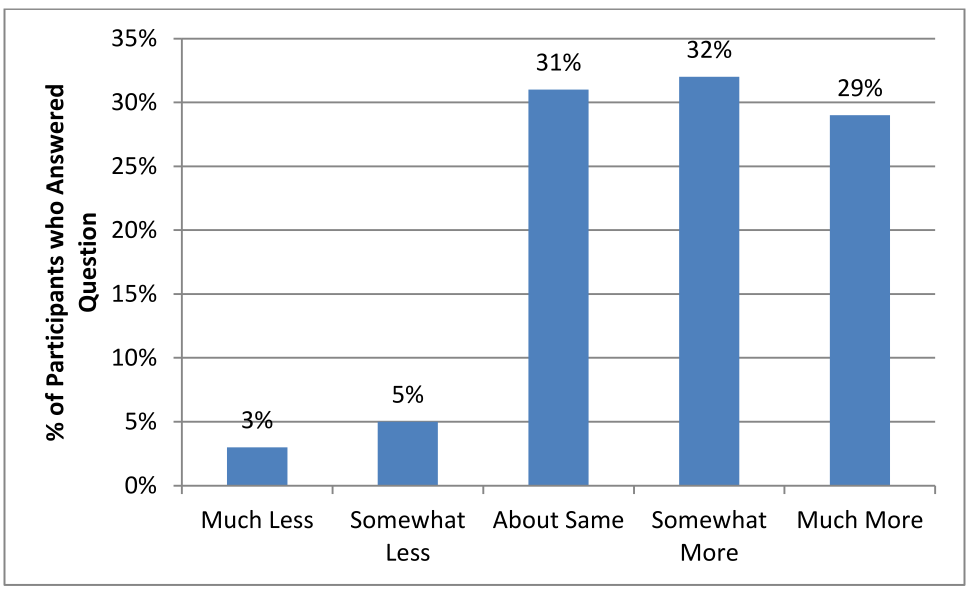

The survey also asked participants to rank how they valued more general features of the Nest thermostat. Figure 11 shows these results where 1 is extremely valuable and 4 is not at all valuable. Participants indicated that energy savings and the ability to control the thermostat remotely are the most valuable features.

Figure 11: Relative Ranking of Nest Features (N=81)



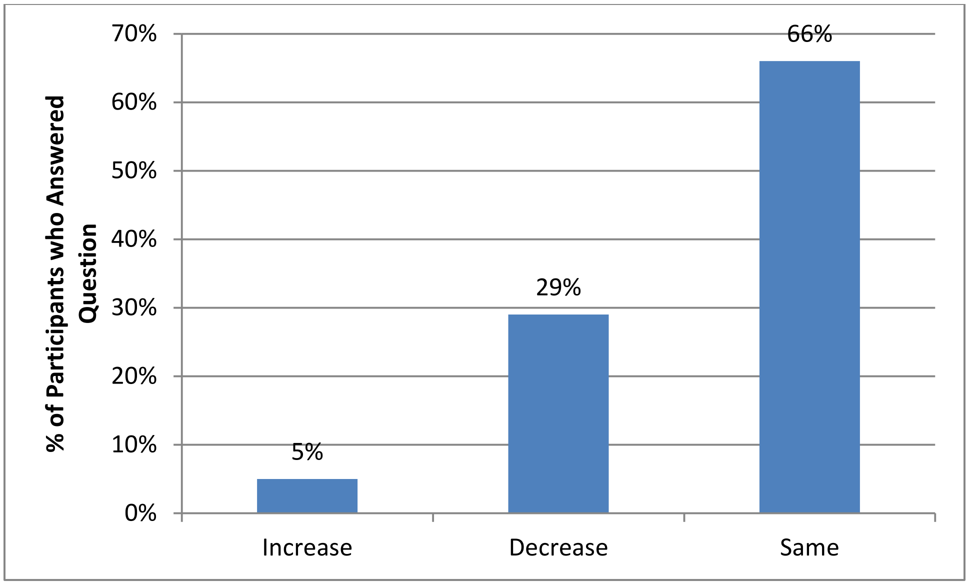

Most participants indicated that the Nest produced the same or greater level of comfort as their previous thermostat (Figure 12).

Figure 12: Home Comfort (N=78)



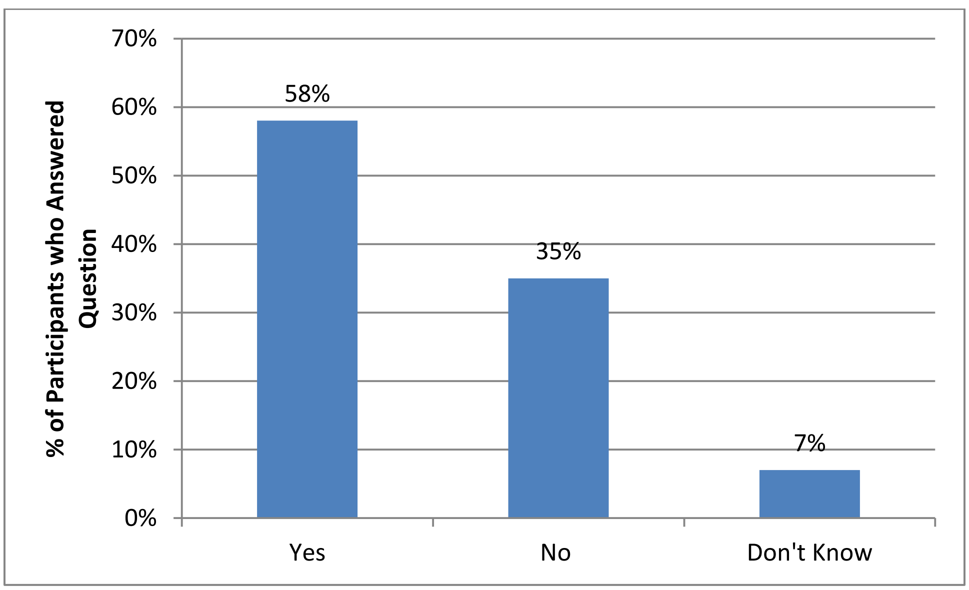

The majority of participants (66%) indicated that they kept the same thermostat settings, while a smaller proportion indicated they decreased their heating temperature settings compared to their previous thermostat (Figure 13).

Figure 13: Temperature Setting (N=77)




Fifty-eight percent of participants indicated that they set-back their previous thermostats—either manually or using a scheduling feature (Figure 14).

Figure 14: Previous Thermostat Setback? (N=74)




Most participants (90%) indicated that there were no changes in occupancy during the pilot period. Eighty-five percent reported that there were no changes to their home after Nest installation, but four households did say they purchased new appliances, one indicated they got a new heat pump, and one added attic insulation.

# 6. Billing Analysis Results

This section presents the estimates of electric energy savings attributable to the Nest Learning Thermostats included in the pilot study. The team used three billing analysis methods to estimate annual electric energy savings: 1) a Prism-like pre-post Normalized Annual Consumption (NAC) model with Variable Base Degree Days (VBDD), 2) a pooled fixed and random effects (mixed effects) model, and 3) a change point model using ECAM+ software. A comparison group allowed the team to account for any systematic changes in energy consumption due to weather, economic effects, or other exogenous variables that may affect energy consumption during the pilot period.

FPUD provided twelve months of electric energy consumption data in the pre- and post-install periods for both the treatment and comparison groups.[2] The team used this data in the billing analysis, using the same pre- and post-consumption periods for all homes in the treatment group. The team also pre-screened the data for completeness and accuracy using the following screens:

- Removing sites with 0 kWh monthly readings (2 sites)
- Removing duplicate meter reads
- Flagging periods shorter than 15 days or longer than 45 days for further inspection (0 sites)
- Ensuring sites have at least 24 monthly meter reads

To create a comparison group, FPUD provided energy consumption data from 62 customers with either an installed heat pump or duct sealing in heat pump home. This ensures a proper comparison with the pilot study homes which use heat pumps as their primary HVAC system.[3]

## 6.1. Pre-Post NAC Model

The team used a Normalized Annual Consumption (NAC) regression model to estimate annual electric use. This NAC model regresses energy consumption (kWh) against heating degree days and cooling degree days per site per day to derive site specific heating, cooling, and base consumption slopes. To calculate the heating and cooling degree days for the NAC model, the team employed a Variable Base Degree Day (VBDD) method using variable base reference temperatures between 40 and 70 degrees. The team ran multiple regressions for these calculations using  the highest R-squared for each site. This method excludes results from sites where there is a low correlation between energy consumption and heating degree days. As detailed in Section 6.3, sites with a pre and post R-squared value less than 0.70 were excluded from the final savings estimate.

[2] The pre-treatment period covered February 2013 through January 2014, and the post period covered September 2014 through August 2015.

[3] The analysis team ensured that the heat pumps and duct sealing installations occurred prior to the billing analysis period of February 2013 through August 2015 so as not to include any energy savings from these measures in a comparison group adjustment.

## 6.2. Data Screening

The analysis team excluded extreme observations considered to be "unlikely to represent program-induced changes" from the final analysis to reduce uncertainty of the overall savings. Such outliers can result from changes in occupancy or other household factors, or simply be errors in the data. The final attribution and overall sample size is illustrated in Table 1.

Table 1: Sample Attribution Table

| Attribution Source | # of Sites | Remaining Sites in Sample |
|---|---|---|
| Nest Installs | | 176 |
| No billing data provided | 5 | 171 |
| Sites with incomplete data | 2 | 169 |
| Sites whose post-consumption increased or decreased by >50% | 2 | 167 |

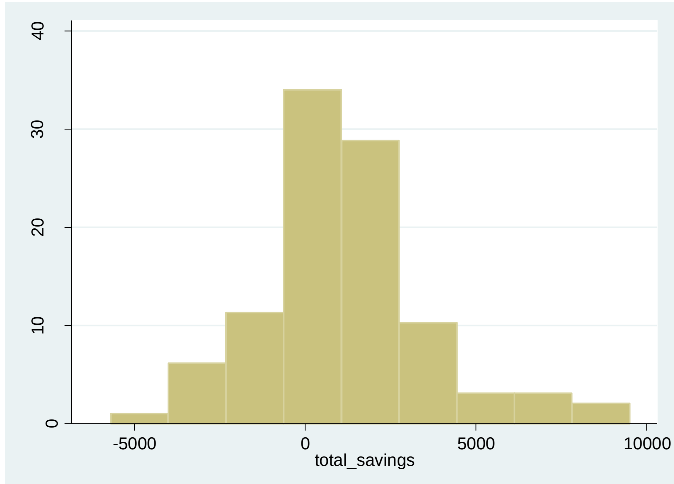
## 6.3. Pre-Post NAC Model Results

The results of the Pre-Post NAC VBDD model indicate significant energy savings with high variability. As Table 2 shows, the average total household energy savings at sites with a good pre- and post-model fit (>= 0.70 R-squared) are 1,103 kWh (95% C.I. 599-1,607 kWh) per year in a sample of 97 sites. If the R-squared screen is removed, the average savings are 855 kWh (95% C.I. 381-1,388 kWh) per year in a sample of 167 sites. The individual site savings range from an increase in consumption of 5,682 kWh to savings of 9,506 kWh. Figure 15 shows the distribution of savings for sites with R-squared greater than or equal to .70.

Table 2: Pre – Post NAC Model Results

| R-Squared Criteria | N | Mean Total Annual Savings (kWh) | 95% Lower C.I. | 95% Upper C.I. | Mean Pre Install Consumption (kWh) | % Total Savings | Mean Pre Install Heating & Cooling Consumption (kWh) | % Savings of Estimated Heating & Cooling Load |
|---|---|---|---|---|---|---|---|---|
| All | 167 | 885 | 381 | 1388 | 21804 | 4.06% | 5150 | 17% |
| >= .50 | 130 | 824 | 314 | 1333 | 21016 | 3.92% | 5435 | 15% |
| >= .60 | 115 | 959 | 419 | 1498 | 20930 | 4.58% | 5661 | 16% |
| >= .70 | 97 | 1103 | 599 | 1607 | 21110 | 5.23% | 5811 | 18% |

Figure 15: Pre – Post NAC Model Distribution of Energy Savings




The team adjusted the final savings estimates using the established comparison group. After applying the same data cleaning method used with the pilot study meter data, the comparison group size dropped from 62 homes to 40 homes. This is not an ideal sample size to use for comparison purposes and leads to variability in the pre- minus post-consumption differences. Table 3 indicates that the comparison group had an average decrease in energy consumption of 262 kWh with a large confidence interval (95% C.I. -710 – 1,234 kWh) that includes 0. Despite the weakness of the comparison group sample size, the team applied the average difference to the final savings estimate.

Table 3: Comparison Group Results- Pre – Post NAC Model

| N | Mean Pre-Post Consumption Difference (kWh) | 95% Lower C.I. | 95% Upper C.I. | R-Squared Criteria | Mean Pre Install Consumption (kWh) |
|---|---|---|---|---|---|
| 40 | 262 | -710 | 1234 | >=.70 | 21,272 |

Table 4 shows the final estimate of average annual savings from the Nest thermostats, including the average comparison group difference of a reduction in 262 kWh. The resulting savings are 841 kWh (95% C.I. 337 – 1,345), which is 4% of total annual electricity consumption and 12% of heating and cooling electricity consumption.[4]

[4] 1000 kWh was added to the average heating and cooling energy usage as an estimate to account for the heating and cooling usage which shows up as base load but is actually heating or cooling energy use.

Table 4: Final Savings Estimate - Pre – Post NAC Model

| R-Squared Criteria | N | Mean Total Annual Net Savings (kWh) | 95% Lower C.I. | 95% Upper C.I. | Mean Pre Install Consumption | % Total Savings | Mean Pre Install Heating & Cooling Consumption | % Savings of Estimated Heating & Cooling Load |
|---|---|---|---|---|---|---|---|---|
| >= .70 | 97 | 841 | 337 | 1345 | 21,110 | 4% | 6,811 | 12% |

## 6.4. Pooled Fixed and Random Effects Model

Another common model for estimating energy savings from smart thermostats is a "pooled fixed" or "random effects regression" model.[5] This approach uses a single linear regression model with customer specific fixed and random effects, but without a comparison group. The model treats each month as its own observation, but each site has a unique intercept for a site specific fixed effect. The model controls for and includes variables for heating and cooling degree days, a post period identifier, and variables for home square footage and vintage. The analysis team then added "random effects" to the model illustrating the grouping structure of the data, and the relationship between heating degree days, square footage, and energy consumption. The result is a "mixed" effect model, estimated in Stata software (Statacorp LP, College Station, TX) using the "mixed" command. The coefficients from the model are directly used to calculate estimated savings.

The following form shows the "best fit" model formula:

$$\boldsymbol{kWhperday_{ij}} = \beta_0 + \beta_1 HDD_{ij} + \beta_2 CDD_{ij} + \beta_3 Post_j + \beta_4\, SQFT_i + u_{oi} + u_{1i} HDD_{ij} + \varepsilon_{ij}$$

Where:
$\boldsymbol{kWhperday_{ij}}$ = The average daily kWh usage for home *i* during month j
$\boldsymbol{\beta_0}$ = Fixed intercept for all homes
$\boldsymbol{HDD_{ij}}$ = Heating Degree Days for home *i* during month *j*
$\boldsymbol{CDD_{ij}}$ = Cooling Degree Days for home *i* during month *j*
$\boldsymbol{Post_j}$ = Dummy variable where 1 indicates post Nest period and 0 indicates pre Nest install
$\boldsymbol{SQFT_i}$ = Square footage for home *i*
$\boldsymbol{u_{oi}}$ = Random intercept for site *i* independent of $\varepsilon_{ij}$
$\boldsymbol{u_{1i}HDD_{ij}}$ = Random slope coefficient of HDD for site *i* and independent of $\varepsilon_{ij}$
$\boldsymbol{\varepsilon_{ij}}$ = Model error for site *i* during billing period *j*

The gross savings results of the random effects model are similar to results from the pre-post NAC VBDD model described in section 6.3. The analysis team configured six different model specifications and Table 5 provides the estimated savings for each. The results are all fairly similar across all model specifications except for the "HDD random effect with year built" model. Every model with year built in the specification indicates that year built has a very low p-

[5] The Energy Trust of Oregon evaluation used a similar model (Apex 2014), as well as Nest's own white paper (Nest 2015).

value indicating that the variable is not significant in the model. Therefore model specification 2 should be considered an outlier. The estimated savings from the fixed and random effects models are between 955 and 970 kWh per year.

Table 5: Fixed and Random Effects Billing Analysis Model Results

| Model Specification | Annual kWh Savings |
|---|---|
| 1. Pure Fixed Effects with year built | 970 |
| 2. Random with HDD Random Effect, with year built | 884 |
| 3. Random without HDD Random Effect, with year built | 965 |
| 4. Random with HDD random Effect, no year built | 955 (95% C.I. 606, 1304)*Best model fit |
| 5. Random without HDD Random Effect, no year built | 969 |
| 6. Random with Square feet Random Effect with year built | 971 |

### 6.5. ECAM+ Regression Model

The analysis team performed a third billing analysis modeling effort to calculate and compare energy savings.[6] The Energy Charting and Metrics plus Building Re-tuning and Measurement (ECAM+) is a Microsoft Excel add-in used to do regression modeling for energy projects. It is typically used for energy savings analysis at the project level in commercial buildings, and has not commonly been used in an evaluation context. It uses linear and change-point linear models, and associated uncertainty based on classical statistics and ASHRAE approaches. The model also uses monthly average temperature as the weather variable instead of heating and cooling degree days. The ASHRAE approaches were developed and documented through research project 1050-RP, *Development of a Toolkit for Calculating Linear, Change-point Linear and Multiple-Linear Inverse Building Energy Analysis Models*, and also documented in ASHRAE Guideline 14, *Measurement of Energy and Demand Savings*.

The ECAM+ savings results for the sites with good model fit (R-squared >= .70) had annual savings of 1,102 kWh. When comparing ECAM+ to the other two models, the savings estimates from each model do overlap within the 95% confidence intervals which indicates the estimates are not statistically different.

Table 6: ECAM+ Model Savings Results

| R-Squared Criteria | N | Mean Total Annual Savings (kWh) | 95% Lower C.I. | 95% Upper C.I. | Mean Pre Install Consumption (Kwh) | % Total Savings |
|---|---|---|---|---|---|---|
| All | 167 | 1,047 | 567 | 1527 | 21,082 | 4.97% |
| >=.50 | 160 | 1,011 | 532 | 1492 | 20,914 | 4.83% |
| >=.60 | 154 | 1,050 | 586 | 1515 | 20,744 | 5.06% |
| >=.70 | 140 | 1,102 | 623 | 1581 | 20,586 | 5.35% |

[6] The team performed the ECAM+ modeling for comparison purposes only and did not use the results in the final energy savings estimations.

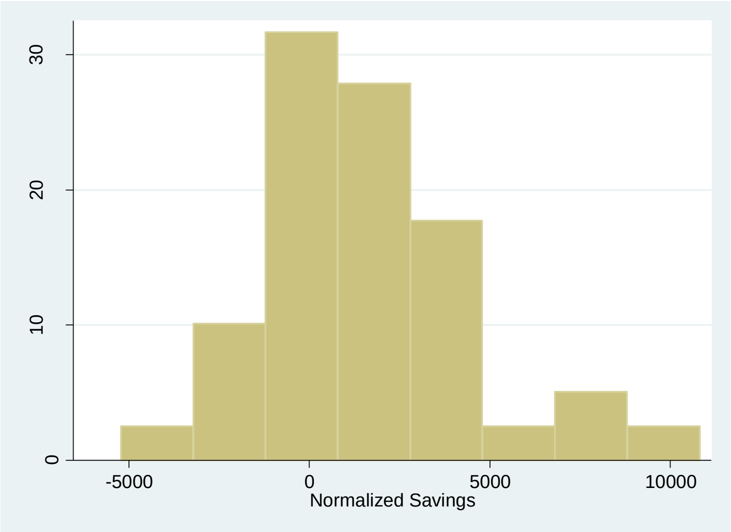
Table 7: Comparison Group Results ECAM+ Model

| N | Mean Pre-Post Consumption Difference (kWh) | 95% Lower C.I. | 95% Upper C.I. | R-Squared Criteria | Mean Pre Install Consumption (kWh) |
|---|---|---|---|---|---|
| 53 | 357 | -520 | 1233 | >=.70 | 21,870 |

Table 8: Final Savings Estimate - ECAM+ Model

| R-Squared Criteria | N | Mean Total Annual Net Savings (kWh) | 95% Lower C.I. | 95% Upper C.I. | Mean Pre Install Consumption (kWh) | % Total Savings |
|---|---|---|---|---|---|---|
| >= .70 | 140 | 745 | 266 | 1224 | 20,586 | 4% |

Figure 16: ECAM+ Distribution of Savings




## 6.6. Summary of Savings Estimates

All three models produce similar estimates of energy savings, which are not statistically different from one another as is shown in Table 9. The pre-post NAC and the ECAM+ results are more robust models since they report savings net of the comparison group. The final savings are between 745 and 955 kWh, roughly 4% of the average pre-treatment household energy consumption and 12% of the average heating and cooling energy consumption.

Table 9: Summary of Savings Estimates

| Modeling Method | N | Mean Total Annual Net Savings (kWh) | 95% Lower C.I. | 95% Upper C.I. | Savings as % of Total Consumption | % Savings of Estimated Heating & Cooling Load |
|---|---|---|---|---|---|---|
| **Pre-Post NAC VBDD** | 97 | 841 | 337 | 1,345 | 4% | 12% |
| **ECAM+** | 140 | 745 | 266 | 1,224 | 4% | NA |
| **Fixed Effects** | 167 | 955 | 606 | 1,304 | 4% | NA |

## 7. Savings Analysis

Analysts reviewed the estimated energy savings results for each participant site in the pilot study and attributed differences in site level savings to variables captured in the data collection. Figure 17 shows a sample of variables and the gross savings associated with the sites modeled in the VBDD model (n= 97).[7] The top variables influencing site level savings are the age of home, presence of a previously installed programmable thermostat, and age of the heat pump. Due to a small sample, none of these differences are statistically significant.

[7] Appendix A provides a comprehensive list of the descriptive statistics for each variable analyzed in the pilot study.

Figure 17: Energy Savings by Characteristics


Many of the analyzed variables correlate with one another. Table 7 shows these correlations and how they impacted overall site level savings. Some significant correlations include:

- Size of heat pump and size of home
- kW capacity of strip heat and size of home
- the strip heat on in first stage heating and the lack of a strip heat control strategy

Table 9: Correlation Matrix of Characteristics

| | yearbu~t | square~t | levels | progra~t | striph~l | first_~t | HP_age | HP_cap~y | kw_str~t |
|---|---|---|---|---|---|---|---|---|---|
| yearbuilt | 1.0000 | | | | | | | | |
| squarefeet | 0.2434 | 1.0000 | | | | | | | |
| levels | 0.0493 | 0.2623 | 1.0000 | | | | | | |
| programmab~t | -0.1194 | 0.0840 | -0.0782 | 1.0000 | | | | | |
| stripheat_~l | 0.2645 | -0.0899 | 0.0239 | -0.0582 | 1.0000 | | | | |
| first_stag~t | 0.0489 | -0.0630 | -0.0780 | -0.1225 | -0.4299 | 1.0000 | | | |
| HP_age | -0.2051 | -0.1054 | -0.0462 | -0.2430 | 0.0811 | 0.0772 | 1.0000 | | |
| HP_capacity | 0.1654 | 0.6376 | 0.3214 | 0.1344 | 0.0409 | -0.0265 | -0.0192 | 1.0000 | |
| kw_stripheat | -0.0533 | 0.4197 | 0.2729 | -0.3007 | -0.0305 | -0.0951 | 0.2418 | 0.3797 | 1.0000 |

### 7.1. Age of Home and Previously Installed Programmable Thermostat

The analysis team looked further into the three top variables influencing site-level savings estimates (Figure 17 above). The age of the home showed the largest disparity in savings between homes built before 1980 and those built in 1980 and later.[8] Homes built before 1980 have average savings of 698 kWh while those built in 1980 and later have an average savings of 1,611 kWh. This is likely due to the more efficient building shells in newer homes. One of the primary drivers of savings appears to be a reduction in indoor air temperature from both the auto-away function and user behavior. A more efficient building shell will retain heat for longer, causing the heat pump to not have to work as hard to get back to the comfort set point after the set back period ends.

The pilot study also found that homes that previously had programmable thermostats installed, have greater average site-level savings (1,285 kWh) than homes without programmable thermostats (461 kWh). Although the sample of homes previously containing non-programmable thermostats is small (n=16), this mirrors a finding from a Nest study conducted by the Energy Trust of Oregon (ETO) in 2014.[9] The point made by the finding in both studies has to do with participant behavior and interaction with the new Nest thermostat. Those with previously installed programmable thermostats are more likely to set their desired temperatures and set-backs and leave them alone. Those participants used to having to manually adjust temperatures on a daily basis, may override some of the Nest's learning functionality by constantly fiddling with comfort levels. It is also possible that households who previously had manual thermostats paid very close attention to their set points, including increasing set points when they want more comfort and decreasing set points consistently when they are away or sleeping. It is plausible that households who had programmable thermostats set and forget it, not adjusting the thermostat for a change in their regular schedule, and heating or cooling their house when no one was home.

[8] The median age home in the final sample is 1979 while the average is 1981. The team split the age of home at 1980 and analyzed the two categories individually.

[9] Apex Analytics. 2014. *Energy Trust of Oregon Nest Thermostat Heat Pump Control Pilot Evaluation* http://assets.energytrust.org/api/assets/reports/Nest_Pilot_Study_Evaluation_wSR.pdf

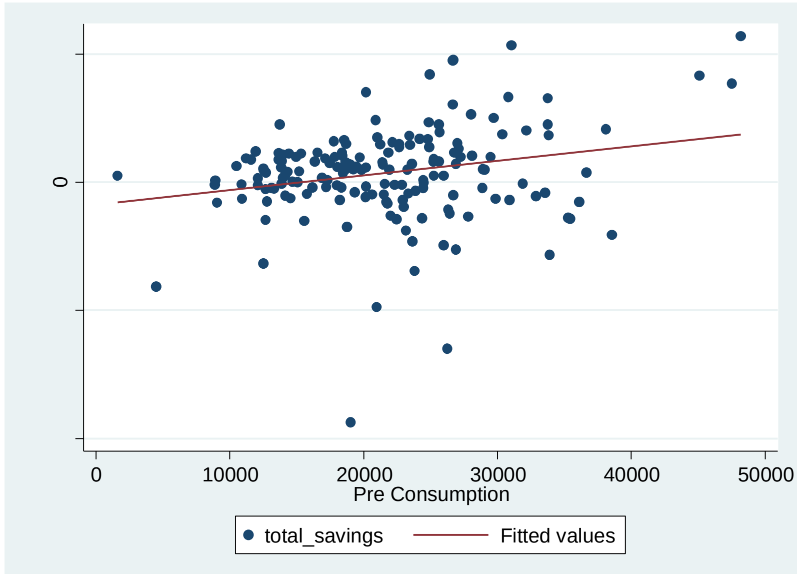
One of the features of the Nest thermostat that makes it particularly suited for heat pumps is its ability to adaptively control the auxiliary strip heat based on the user's defined comfort and savings settings as well as the outdoor air temperature. There are significant differences in savings depending on the strip heat control strategy and kW usage of the strip heat. Nearly 94% of the final sample sites had thermostats that had the capability to lock out the strip heat, but only 45% of the sites had a previous strip heat control strategy in place. It was observed that in over one third (34%) of the sites, the auxiliary heat came on during the first stage heating cycle which should be reserved for compressor-only operation in a properly commissioned heat pump. Figure 17 shows that savings were significantly greater in homes that had a strip heat control strategy in place, or if the auxiliary heat came on in the first stage heating cycle. Figure 17 also shows the relationship between having a lockout control strategy and the prevalence of auxiliary heat coming on in the first stage.

The differences in savings related to previous auxiliary heat controls are nuanced. Sites where there was no strip heat control previously in place should have higher savings than sites that already had a lockout in place, however the results are the opposite. This counter intuitive finding is not explained by interactions with other variables such as home size or age. The greater savings in homes where the auxiliary heat came on during the first stage heating cycle does make sense. Nest was presumably able to change the control strategy so that the compressor was preferred to auxiliary heat.

## 7.2. Savings by Pre-Consumption Level

Savings at the site level correlate to the level of pre Nest install energy consumption. Homes that had higher consumption before the Nest study, also had higher energy savings. Figure 18 shows a scatter plot of energy savings by pre-consumption with a linear fit added. The slope of the line suggests a positive correlation between energy savings and pre Nest energy consumption.

Figure 18: Savings by Pre-Consumption




### 7.3. Analysis of Sub-Meter Data

The team installed metering devices in a sub-sample of 13 participant homes to provide a detailed look into how the Nest thermostat controls heat pumps in these homes. Metering devices captured the average power draw in one minute intervals on the heat pump compressor, air handler, and backup resistance heat. Temperature metering devices were also installed near the thermostat of all 13 homes and one home had an outdoor temperature metering device which was a proxy for outdoor air temperature for all of the sub-metered homes. A more thorough discussion of the findings is the topic of a recent paper from the ACEEE Summer Study in Buildings[11].

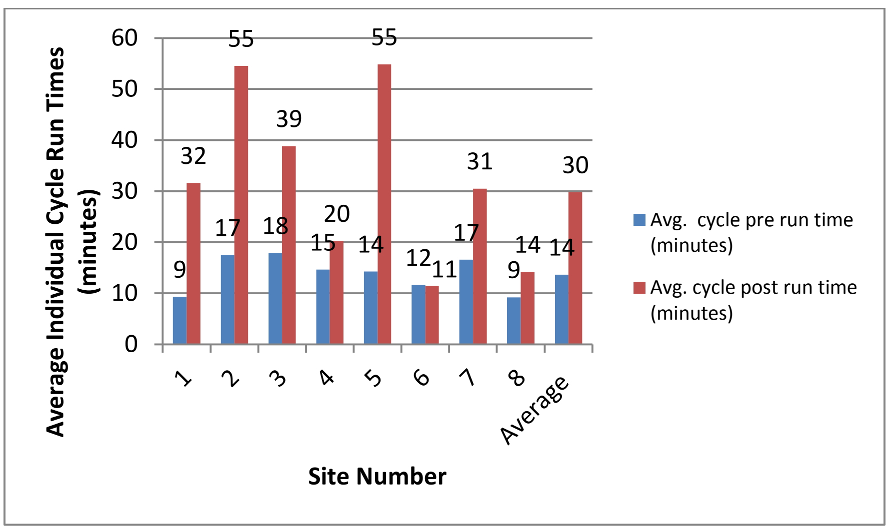
Analysis of the sub-meter data from pre to post Nest install shows significant heat pump compressor aggregate run time reductions (accounting for weather), a reduction in the average indoor air temperature across all homes, and significant reductions in the average individual heat pump cycle run times. The data provide a glimpse into how the Nest saves energy. The auto-away function appears to be a significant driver of energy savings and consequently lowers the average indoor air temperature. However there appears to be something else going on with the heat pump cycling patterns that may be contributing to energy savings.

[11] Kelsven, Phillip and Robert Weber, Eva Urbatsch. "A Look Inside the Eye on the Wall: Sub-metering Data Analysis and Savings Assessment of the Nest Learning Thermostat". 2016 ACEEE Summer Study in Buildings.

The Nest appears to be elongating heat pump cycle run times. Figure 19 shows that the average cycle run times in each of the 8 sub-metered homes pre Nest is about 14 minutes, where the cycle time after Nest is installed is just under 30 minutes. The team suspects that this is primarily caused by the Nest having a larger thermostat temperature “dead band” than the previous thermostats. The “dead band” is the range in temperatures that the thermostat will allow the home to float away from the chosen set point temperature. The average dead band for previous thermostats in the sub-metered homes was .34 degrees meaning that the temperature could rise above or below the chosen set point by about .15 degrees. Post Nest install the average dead band for these homes was about 1.12 degrees, meaning that the temperature could rise about .55 degrees above or below the chosen set point.  For heat pumps this can produce reduced aggregate run times and energy savings.

There are two reasons why significantly increased heat pump cycle times can produce energy savings. Firstly, the longer a heat pump runs the more efficient its coefficient of performance (COP) becomes. Heat pump compressors must ramp up and down in each cycle, during which the unit is not producing warm or cool air.  The less cycles you have, the less you are wasting energy to ramp up and down. Secondly, the rise in temperature to over a half a degree above the chosen set point builds up thermal inertia in the home, allowing the time between cycles to increase. The end result of much longer cycles, and far less of them throughout a typical day is significantly reduced aggregate run times.

Figure 19: Average Individual Heat Pump Cycle Run Times



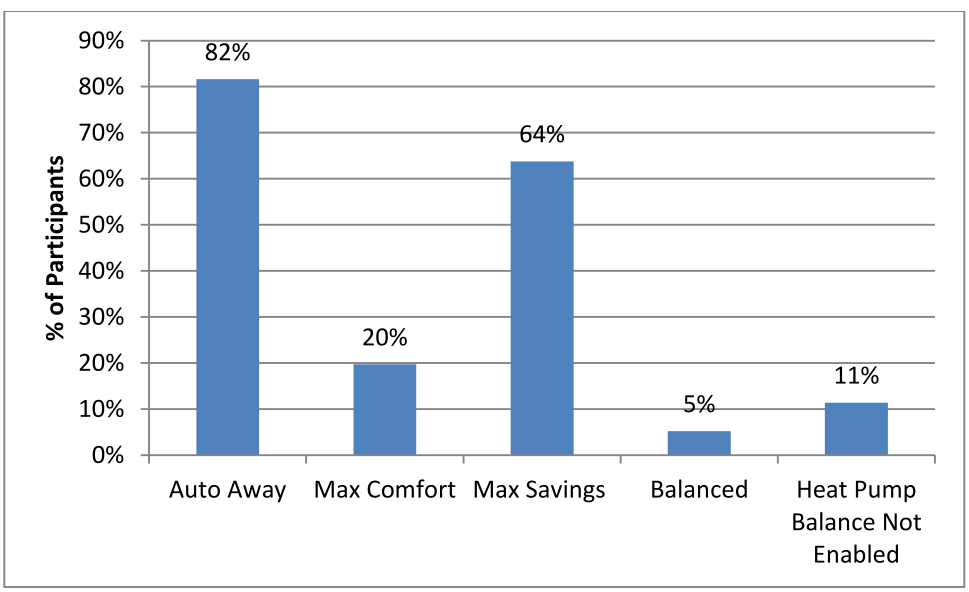
## 8. Nest Thermostat Setting Data Results

This section provides the team's analysis of Nest thermostat setting data focusing on savings correlations between various Nest settings. Nest labs provided anonymous data from 145 Nest thermostats using the serial numbers and sub-groupings supplied by BPA and FPUD. Nest could not provide data for the entire participant pool due to errors in the serial numbers, and because of privacy policies restrictions on the lab to not disclose information for particular units that were found to have issues. The issues found during the pilot study included the loss of Wi-Fi connectivity to some thermostats, and the un-installation of a small number of thermostats by the participants themselves. This section discusses a number of Nest features and the impact they had on pilot study savings estimates.

### 8.1. Auto-Away and Heat Pump Balance Settings

There are two settings that appear to be key factors to the Nest producing energy savings: Auto-away, and heat pump balance. The Auto-away setting uses an occupancy sensor to automatically change temperatures to their programmed set-back point when the home is unoccupied. The heat pump balance settings optimize the use of the back-up resistance heat. Most participants (82%) remained on auto-away at the time of study ending as figure 20 shows. Somewhat less participants (64%) chose to remain on the max savings heat pump balance setting, most moving to max comfort, and a smaller number moving to the "balanced" setting. 11% of the participants ended up having the heat pump balance not enabled which may have been caused by a reset of the thermostat which never got programmed correctly, essentially treating the heat pump like a forced air furnace.

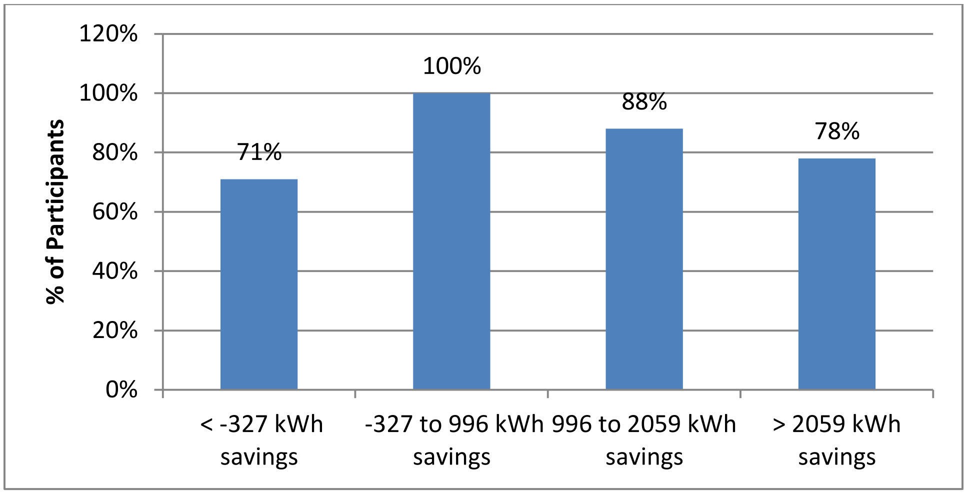
Figure 20: Nest Thermostat Settings at Study Ending (N=145)



### 8.2. Auto Away

Figure 21 shows the percent of participants with auto-away enabled in each of four savings (pre-post NAC model) quartile bins. The savings generated through the pilot study does not directly correlate with the auto-away feature, especially in the larger savings quartiles. This could be due to the sample size or the multitude of other variables involved in energy savings. The only quartile that correlated somewhat to energy savings was the lowest savings bin which also had the lowest percentage of the auto-away feature enabled.

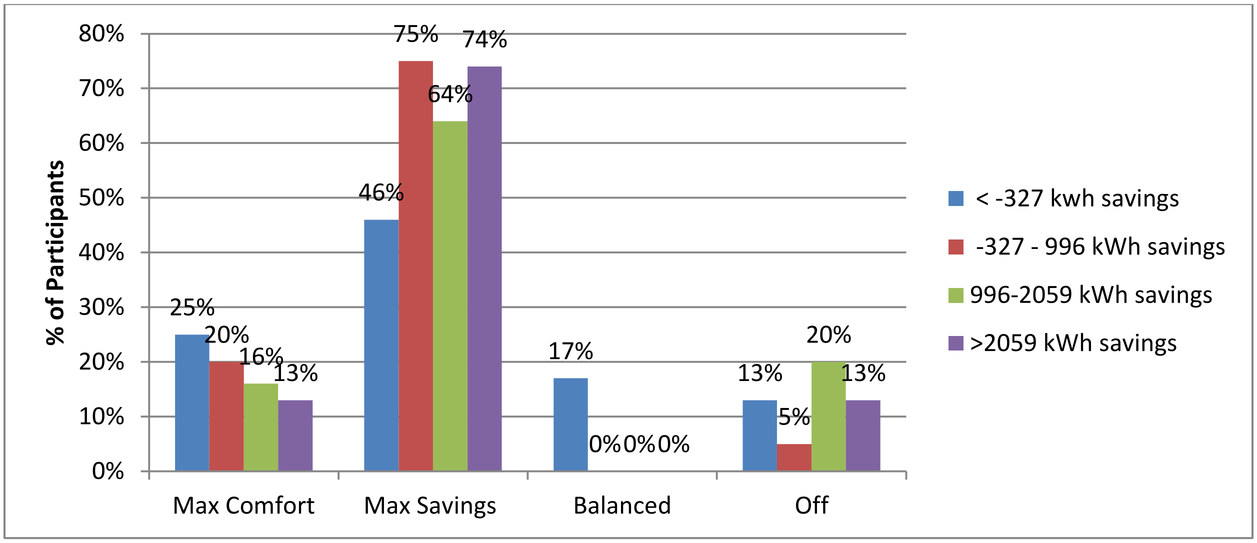
Figure 21: Auto-Away Enabled by Pre-Post NAC Savings Quartile Bin (N=145)




### 8.3. Heat Pump Balance

The heat pump balance settings (e.g., max comfort, max savings, and balance) appears to have more influence on energy savings than the auto-away feature (Figure 22). The Nest data showed the 'max savings' as the most frequently used setting across all four savings quartile bins, however analysts also looked at each quartile bin individually and found a more direct correlation to savings. The quartile bin with the largest amount of savings contained the highest number of Nest thermostats set to 'max savings'. Conversely, the quartile bin with the lowest savings contained the least number of Nest thermostats set to 'max savings'. This lower savings bin (<-327 kWh savings) had more thermostats set to "max comfort" than any other balance setting.

Figure 22: Pre-Post NAC Savings by Heat Pump Balance Setting (N=145)

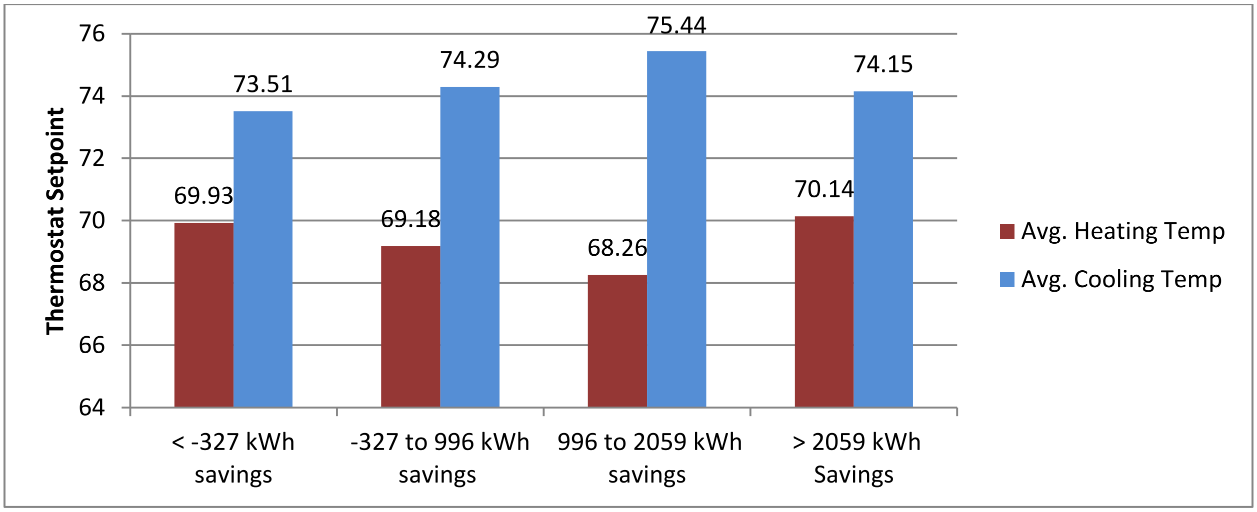



## 8.4. Temperature Settings

Figure 23 shows the average heating and cooling temperature settings in each of the savings quartile bins. As expected, the more mild the temperature settings, the greater the energy savings.[12] The largest savings quartile bin does not follow this expected correlation and has the highest average heating temperature setting. The analysis team attributes this difference to other savings variables at play in this quartile.

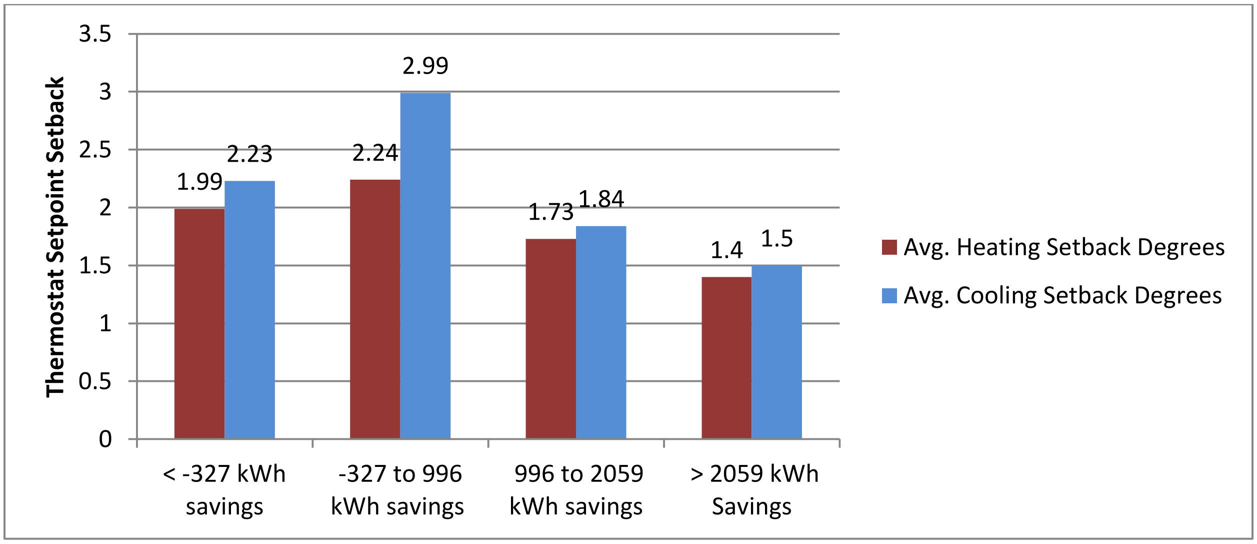
[12] This study defines "mild" temperature settings as lower heating settings in the winter, and higher settings in the summer, which in turn does not require as much heating or cooling from the heat pump.

Figure 23: Pre-Post NAC Savings by Average Heating and Cooling Temperature (N=145)



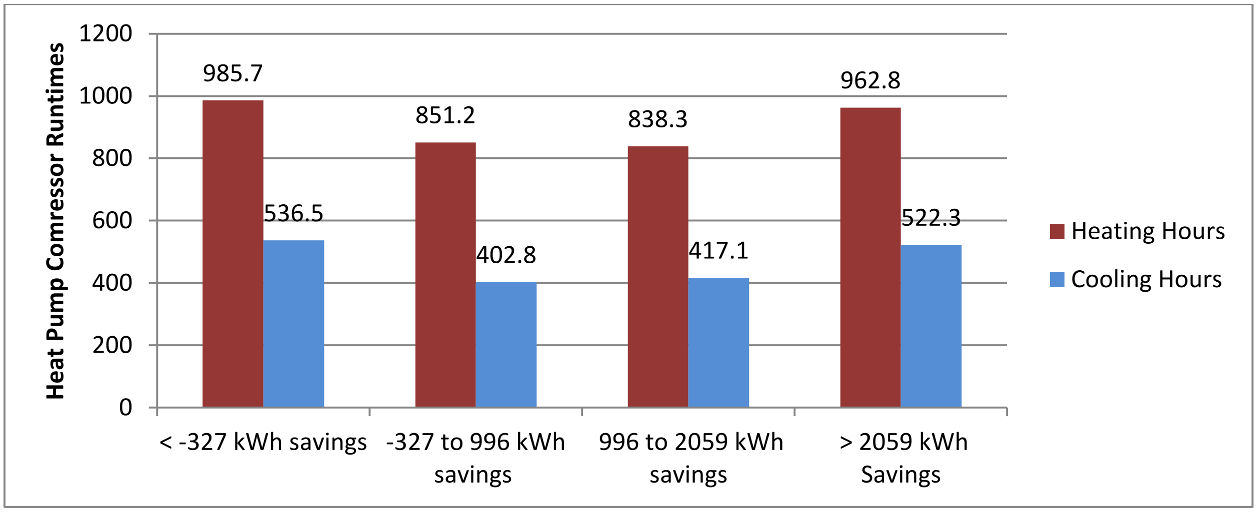

The team found that the change in temperature set-back programmed in the Nest thermostat does not have a clear relationship to energy savings. Figure 24 shows that a larger set-back delta produces greater energy savings in the first two savings quartile bins but the relationship breaks down in the two highest savings quartile bins.

Figure 24: Heating and Cooling Setback Degrees by Savings Quartile Bin (N=145)




There appears to be a correlation between savings and heating and cooling heat pump run time as figure 25 shows. The first three savings quartile bins have the expected relationship of less heating mode run time and higher energy savings. However, the highest savings quartile bin has counterintuitive findings with increased run times.

Figure 25: Heating and Cooling Run Tim by Savings Quartile Bin (N=145)




## 9. Conclusion

The BPA, Franklin PUD, and CLEAResult Nest Heat Pump Pilot was successful in many ways. The pilot was able to successfully install 176 Nest Learning Thermostats and follow up with the study participants to gauge how they interacted with the thermostat as well as estimate energy savings using billing data provided by Franklin PUD in 167 of the homes. Surveys indicate strong overall satisfaction with the product in most of the households. However, issues were identified which caused dissatisfaction including problems with internet connectivity and auto-away being enabled when homes were occupied.

The results show significant average energy savings of between 745 and 955 kWh, which amounts to about 4% of the average pre-treatment household energy consumption, and about 12% of the average heating and cooling energy consumption. Greater energy savings in this sample of homes appear to occur in newer and smaller homes with previous programmable thermostats and newer heat pumps. Greater energy savings also correlate to higher levels of pre-Nest energy consumption. Data from Nest indicates that the heat pump balance settings matter for energy savings. Homes that kept the max savings setting tended to have higher energy savings. Data from Nest also indicates that lower heating temperature settings and higher cooling temperature settings are correlated with greater energy savings. The highest savings quartile bin does have some counterintuitive findings which suggest that the increased level of energy savings in these homes are not explained by available data.

# 10. Appendix A

## Descriptive Statistics of Home Characteristics and Demographics From Initial Participant Survey

| Total # Occupants | Freq. | Percent | Cum. |
|---|---|---|---|
| 1 | 19 | 11.52 | 11.52 |
| 2 | 62 | 37.58 | 49.09 |
| 3 | 29 | 17.58 | 66.67 |
| 4 | 26 | 15.76 | 82.42 |
| 5 | 12 | 7.27 | 89.70 |
| 6 | 14 | 8.48 | 98.18 |
| 7 | 2 | 1.21 | 99.39 |
| 8 | 1 | 0.61 | 100.00 |
| Total | 165 | 100.00 | |

| Occupancy Change in Last 2 yrs | Freq. | Percent | Cum. |
|---|---|---|---|
| No | 137 | 84.05 | 84.05 |
| Yes | 2 | 1.23 | 85.28 |
| Yes, see note | 24 | 14.72 | 100.00 |
| Total | 163 | 100.00 | |

Year Built

| | Percentiles | Smallest | | |
|---|---|---|---|---|
| 1% | 1942 | 1931 | | |
| 5% | 1950 | 1942 | | |
| 10% | 1956 | 1945 | Obs | 165 |
| 25% | 1969 | 1946 | Sum of Wgt. | 165 |
| 50% | 1978 | | Mean | 1982.236 |
| | | Largest | Std. Dev. | 18.78404 |
| 75% | 2000 | 2010 | | |
| 90% | 2008 | 2010 | Variance | 352.8401 |
| 95% | 2010 | 2011 | Skewness | -.177292 |
| 99% | 2011 | 2012 | Kurtosis | 2.138157 |

Square Feet

| | Percentiles | Smallest | | |
|---|---|---|---|---|
| 1% | 912 | 900 | | |
| 5% | 1144 | 912 | | |
| 10% | 1200 | 968 | Obs | 165 |
| 25% | 1550 | 1000 | Sum of Wgt. | 165 |
| 50% | 1900 | | Mean | 2040.582 |
| | | Largest | Std. Dev. | 692.5127 |
| 75% | 2500 | 3700 | | |
| 90% | 2900 | 4000 | Variance | 479573.8 |
| 95% | 3210 | 4200 | Skewness | .7878171 |
| 99% | 4200 | 4300 | Kurtosis | 3.485449 |

| Levels | Freq. | Percent | Cum. |
|---|---|---|---|
| 1 | 137 | 83.03 | 83.03 |
| 2 | 28 | 16.97 | 100.00 |
| Total | 165 | 100.00 | |

| Existing Thermostat Type | Freq. | Percent | Cum. |
|---|---|---|---|
| Non-Programmable | 21 | 13.13 | 13.13 |
| Programmable | 139 | 86.88 | 100.00 |
| Total | 160 | 100.00 | |

| Heat pump existing lockout? (Yes/No) | Freq. | Percent | Cum. |
|---|---|---|---|
| No | 154 | 93.90 | 93.90 |
| Yes | 10 | 6.10 | 100.00 |
| Total | 164 | 100.00 | |

| Is there existing working strip heat control strategy in place? (Yes/No) | Freq. | Percent | Cum. |
|---|---|---|---|
| NA | 1 | 0.61 | 0.61 |
| No | 93 | 57.06 | 57.67 |
| Yes | 69 | 42.33 | 100.00 |
| Total | 163 | 100.00 | |

| Approximate age of heat pump | Freq. | Percent | Cum. |
|---|---|---|---|
| 1 | 2 | 1.23 | 1.23 |
| 2 | 8 | 4.94 | 6.17 |
| 2.5 | 1 | 0.62 | 6.79 |
| 3 | 8 | 4.94 | 11.73 |
| 4 | 13 | 8.02 | 19.75 |
| 5 | 13 | 8.02 | 27.78 |
| 6 | 6 | 3.70 | 31.48 |
| 7 | 5 | 3.09 | 34.57 |
| 8 | 7 | 4.32 | 38.89 |
| 9 | 6 | 3.70 | 42.59 |
| 10 | 8 | 4.94 | 47.53 |
| 11 | 15 | 9.26 | 56.79 |
| 12 | 13 | 8.02 | 64.81 |
| 13 | 6 | 3.70 | 68.52 |
| 14 | 10 | 6.17 | 74.69 |
| 15 | 8 | 4.94 | 79.63 |
| 16 | 5 | 3.09 | 82.72 |
| 17 | 6 | 3.70 | 86.42 |
| 18 | 3 | 1.85 | 88.27 |
| 19 | 3 | 1.85 | 90.12 |
| 20 | 4 | 2.47 | 92.59 |
| 21 | 3 | 1.85 | 94.44 |
| 24 | 1 | 0.62 | 95.06 |
| 25 | 3 | 1.85 | 96.91 |
| 28 | 1 | 0.62 | 97.53 |
| 30 | 2 | 1.23 | 98.77 |
| 34 | 1 | 0.62 | 99.38 |
| 44 | 1 | 0.62 | 100.00 |
| Total | 162 | 100.00 | |

| Outdoor unit capacity | Freq. | Percent | Cum. |
|---|---|---|---|
| 2 | 13 | 7.98 | 7.98 |
| 2.5 | 49 | 30.06 | 38.04 |
| 3 | 44 | 26.99 | 65.03 |
| 3.5 | 25 | 15.34 | 80.37 |
| 4 | 23 | 14.11 | 94.48 |
| 4.5 | 3 | 1.84 | 96.32 |
| 5 | 5 | 3.07 | 99.39 |
| blank | 1 | 0.61 | 100.00 |
| Total | 163 | 100.00 | |

| Single Family/Manufactured Home | Freq. | Percent | Cum. |
|---|---|---|---|
| Manufactured Home | 5 | 3.03 | 3.03 |
| Single Family | 160 | 96.97 | 100.00 |
| Total | 165 | 100.00 | |

| Basement Type | Freq. | Percent | Cum. |
|---:|---:|---:|---:|
| Crawlspace - uncond | 3 | 1.82 | 1.82 |
| Crawlspace - unimproved | 91 | 55.15 | 56.97 |
| Crawlspace - with vapor barrier | 11 | 6.67 | 63.64 |
| Full basement | 30 | 18.18 | 81.82 |
| Garage/basement combo | 1 | 0.61 | 82.42 |
| Half basement | 9 | 5.45 | 87.88 |
| None | 5 | 3.03 | 90.91 |
| Slab on grade | 15 | 9.09 | 100.00 |
| Total | 165 | 100.00 | |

| Existing Thermostat Model | Freq. | Percent | Cum. |
|---:|---:|---:|---:|
| Aprilaire | 11 | 6.71 | 6.71 |
| Braeburn | 1 | 0.61 | 7.32 |
| Bryant | 1 | 0.61 | 7.93 |
| Carrier | 5 | 3.05 | 10.98 |
| Coleman | 1 | 0.61 | 11.59 |
| Filtrete | 1 | 0.61 | 12.20 |
| Honeywell | 109 | 66.46 | 78.66 |
| Hunter | 1 | 0.61 | 79.27 |
| Janitrol | 1 | 0.61 | 79.88 |
| Lennox | 14 | 8.54 | 88.41 |
| Lux | 1 | 0.61 | 89.02 |
| Lux | 1 | 0.61 | 89.63 |
| LuxPro | 2 | 1.22 | 90.85 |
| Ritetemp | 1 | 0.61 | 91.46 |
| Simple Comfort | 1 | 0.61 | 92.07 |
| Sitetemp | 1 | 0.61 | 92.68 |
| Trane | 6 | 3.66 | 96.34 |
| Venstar | 1 | 0.61 | 96.95 |
| Vivant | 2 | 1.22 | 98.17 |
| White Rogers | 2 | 1.22 | 99.39 |
| blank | 1 | 0.61 | 100.00 |
| Total | 164 | 100.00 | |

| Wifi connection at thermostat | Freq. | Percent | Cum. |
|---:|---:|---:|---:|
| Average | 58 | 39.19 | 39.19 |
| Good | 86 | 58.11 | 97.30 |
| Poor | 4 | 2.70 | 100.00 |
| Total | 148 | 100.00 | |

| Heating Temp Setting | Freq. | Percent | Cum. |
|---:|---:|---:|---:|
| 55 | 1 | 0.66 | 0.66 |
| 60 | 2 | 1.32 | 1.99 |
| 62 | 3 | 1.99 | 3.97 |
| 63 | 1 | 0.66 | 4.64 |
| 64 | 1 | 0.66 | 5.30 |
| 65 | 14 | 9.27 | 14.57 |
| 66 | 12 | 7.95 | 22.52 |
| 67 | 2 | 1.32 | 23.84 |
| 68 | 68 | 45.03 | 68.87 |
| 69 | 7 | 4.64 | 73.51 |
| 70 | 22 | 14.57 | 88.08 |
| 71 | 2 | 1.32 | 89.40 |
| 72 | 8 | 5.30 | 94.70 |
| 73 | 3 | 1.99 | 96.69 |
| 74 | 3 | 1.99 | 98.68 |
| 77 | 1 | 0.66 | 99.34 |
| 78 | 1 | 0.66 | 100.00 |
| Total | 151 | 100.00 | |

| Cooling Temp Setting | Freq. | Percent | Cum. |
|---|---|---|---|
| 65 | 1 | 0.66 | 0.66 |
| 69 | 1 | 0.66 | 1.32 |
| 71 | 4 | 2.65 | 3.97 |
| 72 | 5 | 3.31 | 7.28 |
| 73 | 11 | 7.28 | 14.57 |
| 74 | 12 | 7.95 | 22.52 |
| 75 | 12 | 7.95 | 30.46 |
| 76 | 8 | 5.30 | 35.76 |
| 77 | 8 | 5.30 | 41.06 |
| 78 | 78 | 51.66 | 92.72 |
| 79 | 2 | 1.32 | 94.04 |
| 80 | 6 | 3.97 | 98.01 |
| 82 | 1 | 0.66 | 98.68 |
| 83 | 1 | 0.66 | 99.34 |
| 84 | 1 | 0.66 | 100.00 |
| Total | 151 | 100.00 | |

| Location of Existing Tstat | Freq. | Percent | Cum. |
|---|---|---|---|
| ? | 1 | 0.62 | 0.62 |
| dining | 9 | 5.56 | 6.17 |
| downstairs | 2 | 1.23 | 7.41 |
| entry | 8 | 4.94 | 12.35 |
| family rm | 4 | 2.47 | 14.81 |
| family rm, upstairs | 1 | 0.62 | 15.43 |
| hall | 102 | 62.96 | 78.40 |
| kitchen | 1 | 0.62 | 79.01 |
| kitchen/dining | 1 | 0.62 | 79.63 |
| living rm | 24 | 14.81 | 94.44 |
| living rm, upstairs | 6 | 3.70 | 98.15 |
| main | 1 | 0.62 | 98.77 |
| upstairs | 2 | 1.23 | 100.00 |
| Total | 162 | 100.00 | |

| Strip heat on for 1st stage heat? (Yes/No) | Freq. | Percent | Cum. |
|---|---|---|---|
| NA | 1 | 0.61 | 0.61 |
| No | 110 | 67.48 | 68.10 |
| Yes | 52 | 31.90 | 100.00 |
| Total | 163 | 100.00 | |

| kW of strip heat | Freq. | Percent | Cum. |
|---|---|---|---|
| 10 | 23 | 14.29 | 14.29 |
| 12.5 | 2 | 1.24 | 15.53 |
| 15 | 78 | 48.45 | 63.98 |
| 16 | 1 | 0.62 | 64.60 |
| 19.2/14.4 | 1 | 0.62 | 65.22 |
| 20 | 55 | 34.16 | 99.38 |
| 25 | 1 | 0.62 | 100.00 |
| Total | 161 | 100.00 | |

| Discharge air temp control that Nest will not override? (Yes/No) | Freq. | Percent | Cum. |
|---|---|---|---|
| NA | 1 | 0.62 | 0.62 |
| No | 159 | 98.15 | 98.77 |
| Yes | 2 | 1.23 | 100.00 |
| Total | 162 | 100.00 | |

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| Outdoor unit make | Freq. | Percent | Cum. |
|---|---|---|---|
| Aire-Flo | 1 | 0.61 | 0.61 |
| American Standard | 5 | 3.03 | 3.64 |
| Bryant | 2 | 1.21 | 4.85 |
| Carrier | 12 | 7.27 | 12.12 |
| Coleman | 6 | 3.64 | 15.76 |
| Comfort Aire A/C Unit | 1 | 0.61 | 16.36 |
| General Electric | 1 | 0.61 | 16.97 |
| Goodman | 16 | 9.70 | 26.67 |
| ICP | 1 | 0.61 | 27.27 |
| Kelvinator | 2 | 1.21 | 28.48 |
| Lennox | 81 | 49.09 | 77.58 |
| Lennox Electric Furnace | 1 | 0.61 | 78.18 |
| Marathon | 1 | 0.61 | 78.79 |
| Nordyne | 3 | 1.82 | 80.61 |
| Payne | 1 | 0.61 | 81.21 |
| Rheem | 2 | 1.21 | 82.42 |
| Rheem Central AC | 1 | 0.61 | 83.03 |
| Ruud | 5 | 3.03 | 86.06 |
| Trane | 12 | 7.27 | 93.33 |
| York | 10 | 6.06 | 99.39 |
| lennox | 1 | 0.61 | 100.00 |
| Total | 165 | 100.00 | |