DOCKETED

Docket Number:	15-IEPR-01
Project Title:	General/Scope
TN #:	206563
Document Title:	Daniel W. Douglass Comments: Nest IEPR Comments
Description:	N/A
Filer:	System
Organization:	Daniel W. Douglass
Submitter Role:	Public
Submission Date:	11/10/2015 2:03:46 PM
Docketed Date:	11/10/2015

Comment Received From: Daniel W. Douglass
Submitted On: 11/10/2015
Docket Number: 15-IEPR-01

Nest IEPR Comments

Additional submitted attachment is included below.

CALIFORNIA ENERGY COMMISSION
DOCKET 15-IEPR-01

COMMENTS OF NEST LABS, INC. ON THE 2015 DRAFT INTEGRATED ENERGY POLICY REPORT

Daniel W. Douglass
DOUGLASS & LIDDELL
21700 Oxnard Street, Suite 1030
Woodland Hills, CA 91367
Telephone: (818) 961-3001
E-mail: douglass@energyattorney.com

Counsel to
NEST LABS, INC.

November 3, 2015

CALIFORNIA ENERGY COMMISSION
DOCKET 15-IEPR-01

COMMENTS OF NEST LABS, INC. ON THE
2015 DRAFT INTEGRATED ENERGY POLICY REPORT

On October 12, 2015, the California Energy Commission ("CEC") released its draft 2015 Integrated Energy Policy Report ("Draft IEPR Report").[1] State law requires the CEC to issue a "biennial integrated energy policy report that assesses major energy trends and issues facing the state's electricity, natural gas, and transportation fuel sectors and provides policy recommendations to conserve resources; protect the environment; ensure reliable, secure, and diverse energy supplies; enhance the state's economy; and protect public health and safety" (Public Resources Code § 25301[a]). Nest Labs, Inc. ("Nest") offers its comments with respect to the Draft IEPR Report.

I. <u>DESCRIPTION OF NEST LABS</u>

Founded in 2010, Nest Labs is dedicated to reinventing home products like the thermostat and smoke alarm to provide customers with simple, beautiful and thoughtful hardware, software and services helping them reduce energy consumption and keeping families comfortable and safe. Nest manufactures the Nest Learning Thermostat, which is equipped with sensors, Wi-Fi capability, and smart-phone grade processing, to help customers consume less energy: it learns their preferences, turns the temperature down when the house is empty and automatically lowers AC runtime when humidity conditions permit, helping people lower their energy use without sacrificing comfort. Nest also has service offerings for utilities to help address load management needs. Today, Nest products are sold in the U.S.,

[1] California Energy Commission. 2015. *2015 Draft Integrated Energy Policy Report.* Publication Number: CEC-100-2015-001-CMD.

U.K., E.U. and Canada and are installed in more than 120 countries. Nest, a wholly-owned subsidiary of Google Inc., is based in Palo Alto, California.

II. THE USE OF SMART COMMUNICATING THERMOSTATS FOR ENERGY EFFICIENCY PURPOSES

The Draft Report appropriately focuses on the critical importance of energy efficiency in reducing California's energy infrastructure costs by easing energy demand and helping to meet the state's aggressive greenhouse gas ("GHG") emission reduction goals. Nest believes that the final version of the IEPR Report should acknowledge the meaningful contribution to energy efficiency goals that can be achieved through greater use of smart communicating thermostats.

A. Traditional Programmable Thermostats.

Traditional programmable thermostats ("PTs") allow customers to set up a pre-programmed schedule for raising or lowering the temperature in the home, but have neither internet communications capability nor built in intelligence to modify the schedule due to changing conditions or customer preferences. While the ability to program thermostats can be a convenience feature and save energy for some households, there are challenges and difficulties with PTs. For many people they are not intuitive and hard to program; therefore many people never do program them. In that case, they are used just like a non-programmable thermostat with people turning them up or down when they remember. Even if a PT is programmed initially, it is often overridden at some point in the future and then not reprogrammed. This override could happen for any number of reasons; such as a house full of guests or unusual weather.

The United States Environmental Protection Agency originally had an Energy Star designation for PTs to encourage their use compared to non-programmable thermostats but dropped it in 2009 because of the lack of evidence as to actual energy savings and/or environmental benefits. As noted on the Energy Star website, "Manufacturers were required to cease using the ENERGY STAR name and mark in association with all products manufactured on or after December 31, 2009. While EPA recognizes the potential for programmable thermostats to save significant amounts of energy, there continue to be questions concerning the net energy savings and environmental benefits achieved under the previous ENERGY STAR programmable thermostat specification."[2, 3]

B. Smart, Communicating Thermostats.

Smart, communicating thermostats ("SCTs"), such as those provided by Nest and other manufacturers, also allow setting predetermined schedules for temperature. However they have several advantages over traditional programmable thermostats. They are smart in the sense that they can learn a household's habits and preferences and combine that information with environmental data like temperature and humidity to create schedules appropriate to that home and the environment, even if they are not pre-programmed. However, SCTs are also easier to program and modify than traditional PTs if the homeowner desires. SCTs also can be accessed through the internet so that a homeowner can raise or lower the temperature remotely from a mobile phone or let the thermostat know the homeowner will be away for an extended period.

C. Several Studies Show that SCTs Can Save 10 to 15% of HVAC Energy.

A number of recent studies in other jurisdictions have demonstrated the significant energy efficiency benefits provided by SCTs. For example:

---

[2] Energy Star Programmable Thermostats Specification; see: https://www.energystar.gov/index.cfm?c=archives.thermostats_spec.

[3] Nevertheless, PTs continue to be included in DEER. *See*, DEER 2014 Update Draft, July 17, 2013 (D03-073, p. A-4 and D03-401, p. A-9.

- The Pennsylvania Statewide Evaluator ("SWE") included ""Smart Thermostats" in its Energy Efficiency Potential Study which the Pennsylvania Commission is using to inform its decisions on what level to set energy efficiency goals for Phase III. The SWE found that such ""smart thermostats" saved about 11% on electric heating and cooling.[4]

- The Energy Trust of Oregon ("ETO") recently released a study of Nest thermostats used with electric heat pump heating. The Energy Trust, which runs the energy efficiency programs for all the utilities in Oregon, found that the thermostats saved 12% on heating electricity use.[5] (Study excerpts attached).

- Vectren, an electricity and natural gas utility in southern Indiana, recently released a study of Nest thermostats and found that they saved 14% on air-conditioning electric usage.[6] The Vectren study also showed significant savings, in the 10 percent range, on the heating side in natural gas heated homes. (Study excerpts attached).

- NIPSCO, another electric and gas utility in northern Indiana did a similar study with similar results: 16% savings on air-conditioning electric usage.[7] (Study excerpts attached).

- Nest has done its own study on Nest users across the country and found an average 17% savings on air-conditioning electric usage.[8] (Study attached).

---

[4] Energy Efficiency Potential Study for Pennsylvania; Pennsylvania Public Utility Commission; February 2015; Appendix D; Original Measure #2077; p. D-7.

[5] Energy Trust of Oregon Nest Thermostat Heat Pump Control Pilot Evaluation, by Apex Analytics, Oct. 10, 2014, p.1-1; http://energytrust.org/library/reports/Nest_Pilot_Study_Evaluation_wSR.pdf.

[6] Evaluation of the 2013-2014 Programmable and Smart Thermostat Program; prepared for Vectren Corporation; prepared by Cadmus Group, January 29, 2015, p. 3; http://www.cadmusgroup.com/papers-reports/evaluation-2013-2014-programmable-smart-thermostat-program/.

[7] Evaluation of the 2013-2014 Programmable and Smart Thermostat Program; prepared for Northern Indiana Public Service Company; prepared by Cadmus Group, January 22, 2015, p. 3; https://myweb.in.gov/IURC/eds/Modules/Ecms/Cases/Docketed_Cases/ViewDocument.aspx?DocID=0900b631801c5039.

[8] Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results, Nest Labs, February 2015, p. 6.

Finally, Nest wishes to acknowledge the excellent work being done by all four California investor-owned utilities,[9] in partnership with the California Technology Forum, to study energy savings from the Nest Learning Thermostat in California's varying climate zones. Those studies should continue and Nest looks forward to supporting them to generate a statewide work paper based on savings found throughout California.

III. SUGGESTED REVISIONS TO THE DRAFT IEPR REPORT

Thermostats are only mentioned a few times in passing in the Draft IEPR Report. However, a review of the Draft IEPR Report, particularly the energy efficiency section beginning on p. 17, suggests there are opportunities here for the CEC to advocate in the final draft of the IEPR for the use of SCTs. For example:

- "Most existing buildings have cost-effective opportunities for improving their energy performance. About half of the existing buildings were built before the state's building design and construction standards included any energy efficiency requirements." (p. 18)
    - **Comment: SCTs can play a meaningful role in improving the energy performance of existing residential and small business buildings and are a relatively simple retrofit.**
- "The plan articulates the vision of robust and sustainable efficiency markets that deliver multiple benefits to building owners and occupants through physical and operational improvements to existing homes, businesses, and public buildings. The plan describes five discrete goals and delineates multiple strategies to achieve each goal. The plan goals are:
    1. Increased government leadership in energy efficiency.
    2. Data-driven decision making.
    3. Increased building industry innovation and performance.
    4. Recognized value of energy efficiency.
    5. Affordable and accessible energy efficiency solutions." (pp. 18-19)

[9] Pacific Gas and Electric Company, Southern California Edison Company, Southern California Gas Company and San Diego Gas & Electric Company.

- **Comment: SCTs both provide helpful data to encourage homeowners and businesses to plan for and achieve significant energy savings and are a relatively affordable solution compared to the thousands of dollars for the cost of insulation jobs and tens of thousands of dollars for a solar installation.**

- **"Expand research into plug-load efficiency.** Focus research on advancing the development and deployment of more efficient consumer devices, including electronics and electronic infrastructure supporting the communication between devices. This research includes developing and testing efficient low-cost components and low-cost energy monitoring technologies, and integration of smart and networked controls. Research should also focus on behavior and system-level efficiency." (p. 53)

  - **Comment: The Nest Learning Thermostat is the epitome of a low-cost energy monitoring technology that integrates smart and networked controls. The importance of such energy monitoring technology was recently emphasized by the Legislature in its passage of AB 793[10], which calls on the investor owned utilities to provide "incentives" for "energy management technology" for use in homes and small businesses.**

- "Technologies that enable demand response also help integrate renewable resources, especially demand response that can be reliably dispatched and is resource adequate. Innovative coupling of demand response with other technologies like storage can assure the grid operator of its capability to shed or call on load when needed, and also assure customers that their electricity needs will not be compromised." (p. 85)

  - **Comment: The potential energy savings and grid benefits associated with the Nest Learning Thermostat are significant and Nest has partnered with energy companies to help them realize these benefits at scale. In the spring of 2013, we released our first offerings to address utility load management needs. We called**

---

[10] Assembly Bill No. 793, Chapter 589, Statutes of 2015. Approved by Governor and filed with Secretary of State on October 08, 2015.

these two offerings Rush Hour Rewards and Seasonal Savings. Rush Hour Rewards is a service that helps customers earn money back from their energy company by using less energy when everyone else is using more. It is typically overlaid on top of a utility's demand response program, but can be deployed as a standalone offering as well. Nest offers a turnkey approach of customer recruitment, enrollment, and deployment of software. For a view of how we communicate about Rush Hour Rewards with our customers, please see http://support.nest.com/article/What-is-Rush-Hour-Rewards.

When dispatched, Nest's Rush Hour Rewards uses unique algorithms to determine the best mix of pre-cooling, cycling, and setbacks for each home on each day based on what the thermostat knows about each customer's comfort preferences and occupancy patterns, and the thermal characteristics of their home. This combination is customized to each individual home, and is designed to maximize load reduction within the peak window, while preserving the customer's comfort. For example, in a home that is typically unoccupied during the afternoon, load reduction may be much more aggressive than in a neighboring home that is typically very active in the afternoon. This unique balancing of load reduction with customer comfort goes a long way towards increasing customer satisfaction and voluntary participation. The success is demonstrated in very high customer satisfaction ratings and enrollment retention, as well as very low opt-out rates on specific events. By embracing what we know about each customer's home, we harmonize the energy companies' load shedding goals with the customer's financial interest and comfort.

Seasonal Savings helps customers adjust their temperature set points and schedules to help them consume energy more efficiently, while still keeping their homes comfortable. Most importantly, this is packaged for customers in a way that keeps them fully apprised of what is going on, getting them further engaged in the process. Customers can change the temperature or adjust their schedules at any time, but if they stick with Seasonal Savings' optimized schedule, our studies show that Nest Thermostat owners can save an additional 3 - 5% on HVAC use.

In June of 2014, we announced the Works with Nest program, in which we opened up Nest application programming interfaces (APIs) to developers so they could integrate third-party products with Nest products, thereby expanding the reach of Nest's energy savings capabilities. Iconic brands like Whirlpool, Mercedes and Logitech have created energy saving integrations that Nest customers can opt to use free of charge. The Works with Nest program is already opening up exciting opportunities to extend energy efficiency and demand response impacts to other end points in a customer's home. More information about the Works with Nest program can be found on our website at https://nest.com/works-with-nest/.

The foregoing are just a few examples of areas in the Draft IEPR Report where there could be a meaningful discussion of the benefits of SCTs as well as a directive to the state's public and investor-owned utilities to further encourage their use in order to accelerate the achievement of the state's energy efficiency and demand response goals.

IV. CONCLUSION

Smart, communicating thermostats from Nest Labs, and other manufacturers, are becoming more popular across the country and throughout California because they are consistently demonstrating their value in achieving end-user energy efficiency and cost savings. As noted above, several recent studies indicate that smart, communicating thermostats can save customers 10-15% on their heating and cooling usage.

Therefore, Nest recommends that the CEC include a discussion of smart, communicating thermostats in the final IEPR Report and encourage the state's public and investor-owned utilities to develop programs that will encourage the usage of smart, communicating thermostats in a way that will assist California and this Commission in meeting their ambitious energy efficiency and demand response goals. Nest stands ready to work with the CEC and its staff in achieving these goals.

Energy Trust of Oregon

Nest Thermostat Heat Pump Control

Pilot Evaluation

Prepared for Energy Trust of Oregon

Prepared by Apex Analytics LLC

10/10/2014

MEMO

Date: October 22, 2014
To: Board of Directors
From: Marshall Johnson, Residential Sector Manager, Existing Homes Program
Dan Rubado, Evaluation Project Manager
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.

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.

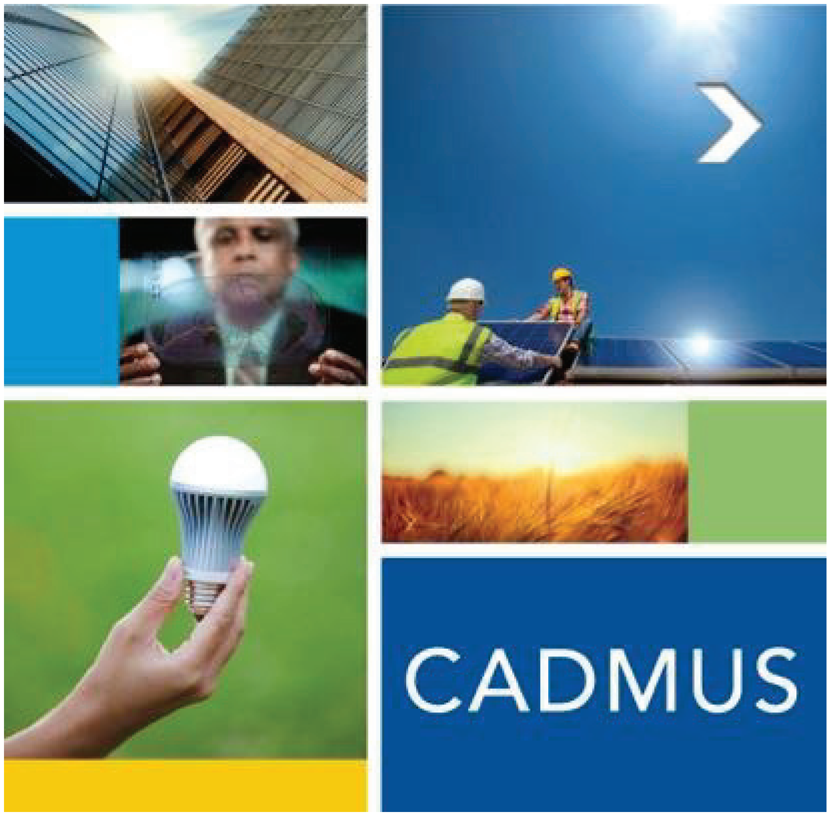
The key findings associated with this report include the following:

- 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.



Evaluation of the 2013–2014 Programmable and Smart Thermostat Program

January 29, 2014

Prepared for:
Vectren Corporation
One Vectren Square
211 N.W. Riverside Drive
Evansville, Indiana 47708

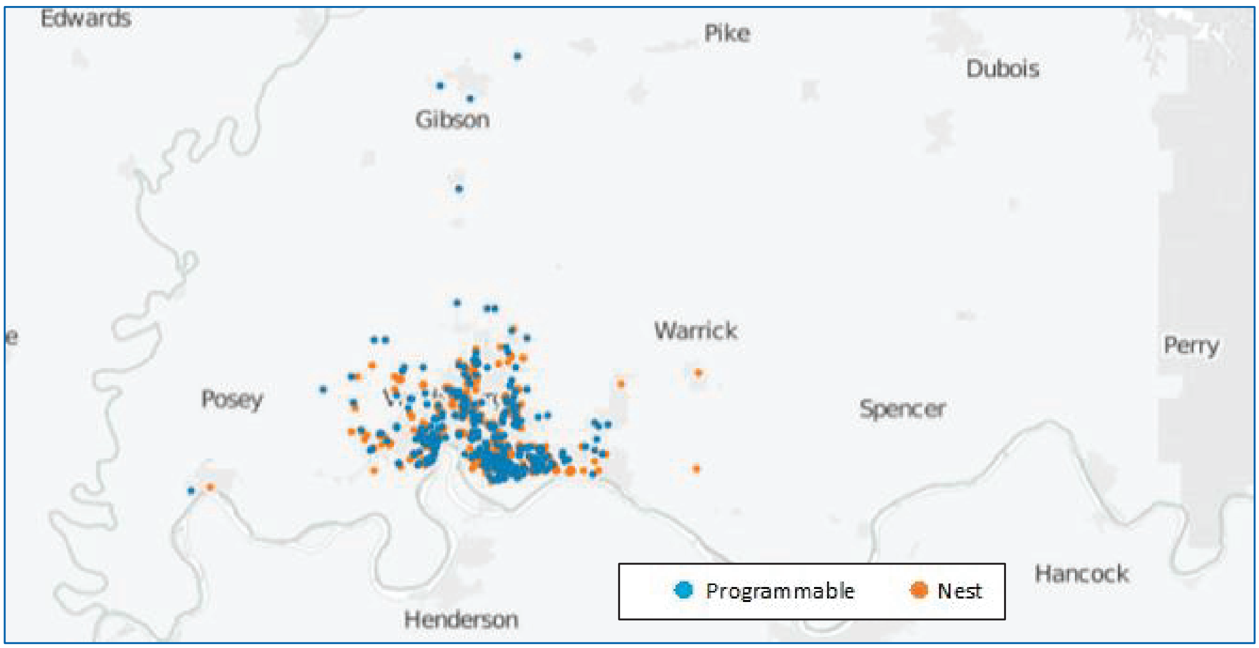
The Cadmus Group, Inc.
An Employee-Owned Company • www.cadmusgroup.com

Executive Summary

In 2013-2014, the Vectren Corporation (Vectren), a natural gas and electric provider, offered a thermostat program to residential customers who used manual thermostats in their homes. CLEAResult, the program administrator, worked with their subcontractor, Water and Energy Solutions, Inc. (WES) to install 300 Nest and 300 programmable thermostats in the homes of randomly selected Vectren natural gas and electric (i.e., dual-fuel) customers who previously underwent a home energy assessment (through the Energizing Indiana Program). In addition to the new thermostats, customers received training on proper operation of their new thermostats.

WES installed the thermostats between October 14, 2013, and January 24, 2014. Figure 1 shows a map of the thermostat installation locations by thermostat type.

Figure 1. Map of Completed Thermostat Installations for Vectren Thermostat Program



Vectren hired Cadmus to evaluate the program and determine the energy savings from the Nest thermostat over the baseline (manual thermostats) and conventional programmable thermostats. Specifically, the objectives of the evaluation are to:

1. Evaluate the amount (therms) and percentage of gas saved on heating; and
2. Evaluate the amount (kWh) and percentage of electricity saved on cooling.

Cadmus assessed energy savings using pre- and post-installation billing data. Table 1 shows the evaluated gas savings as a percentage of heating gas usage, and Table 2 shows the evaluated electric savings as a percentage of cooling electric usage.

Table 1. Nest and Programmable Thermostat Gas Savings as Percentage of Heating Gas Usage

Thermostat Group	Group	Sample Size	Pre Usage (therms)	Savings (therms)	Savings (%)	Range of Savings (therms)	Range of Savings (%)
Nest	Participant	197	548	55	10.0%	47 to 63	8 to 11%
	Control	2,611	575	-14	-2.5%	-12 to -17	-2 to -3%
	Adjusted Gross	**197**	**548**	**69**	**12.5%**	**60 to 77**	**11 to 14%**
Programmable	Participant	184	602	15	2.5%	8 to 22	1 to 4%
	Control	2,611	575	-14	-2.5%	-12 to -17	-2 to -3%
	Adjusted Gross	**184**	**602**	**30**	**5.0%**	**22 to 37**	**4 to 6%**

Table 2. Nest and Programmable Thermostat Electric Savings as Percentage of Cooling Electric Usage

Thermostat Group	Group	Sample Size	Pre Usage (kWh)	Savings (kWh)	Savings (%)	Range of Savings (kWh)	Range of Savings (%)
Nest	Participant	191	3,080	357	11.6%	206 to 508	7 to 17%
	Control	2,714	3,001	-70	-2.3%	-18 to -122	-1 to -4%
	Adjusted Gross	**191**	**3,080**	**429**	**13.9%**	**270 to 589**	**9 to 19%**
Programmable	Participant	205	2,537	273	10.8%	131 to 415	5 to 16%
	Control	2,714	3,001	-70	-2.3%	-18 to -122	-1 to -4%
	Adjusted Gross	**205**	**2,537**	**332**	**13.1%**	**181 to 483**	**7 to 19%**

Participants with the Nest thermostat reduced their heating gas consumption by approximately 12.5%, compared to only 5.0% for participants with a programmable thermostat. The Nest saved more gas than the programmable thermostat by keeping the average home temperature approximately 0.2 degrees lower than the homes with a programmable thermostat in the heating season, and an average of 0.7 degrees lower during the daytime on weekdays, when homes are commonly unoccupied. We assume temperature reductions in Nest homes are attributable to its Auto-Away feature, which automatically sets back the temperature when it senses no one is home.

Participants in the Nest and programmable thermostat groups reduced cooling electric consumption by approximately the same amount (13.9% and 13.1%, respectively). Despite nearly the same percentage savings, Nest participants had a slightly higher average air conditioner run time (1.8%) compared to programmable thermostat participants (1.2%). The baseline cooling electric usage in the Nest participant group was 21% higher than the baseline for the programmable thermostat group, so we would expect the air conditioner run time for Nest participants to be higher. We assume the higher baseline usage in the Nest participant group is attributable to the Nest participant homes having higher occupancy (and thus higher cooling loads) compared to the programmable thermostat homes (see occupancy data in Demographics section).

Introduction

In 1995, the U.S. Environmental Protection Agency (EPA) began promoting programmable thermostats with the ENERGY STAR® label. Utility companies started offering rebate programs based on claims that programmable thermostats could save 10% to 30% of residential heating and cooling energy if users programmed setbacks when the home was unoccupied or occupants were sleeping.[1] However, evaluations of these programs showed low realization rates and many studies found that only about half of users actually programmed their thermostats due to the poor user interface designs and complicated settings.

Two conditions can decrease or eliminate savings benefits from programmable thermostats. They are:

1. Some users with manual thermostats already use temperature setbacks regularly, essentially duplicating the operation of a programmable thermostat.
2. Not all users program their programmable thermostats. Some users set the thermostats at a constant temperature setpoint. Several studies have shown that consumers find programmable thermostats difficult to operate, so they often do not program the thermostat at all.[2] One study found that only 47% of programmable thermostats are actually programmed in an energy saving manner.[3]

In a 2013 study, Cadmus observed both conditions (Table 3). Study participants responded to surveys about their thermostat behavior. The portion of thermostats set to regular, scheduled setpoints does not differ much by technology, but programmable thermostats are left at a constant setpoint more often, possibly because of the difficulty of programming.

Table 3. Programmable and Manual Thermostat Behavior Patterns from 2013 Cadmus Study*

Behavior	Manual Thermostats	Programmable Thermostats
Regular Scheduled Setpoints	48%	56%
Manual With Changing Setpoints	36%	14%
Constant Setpoint	16%	29%

*Totals may not sum due to rounding.

---

1. U.S. Environmental Protection Agency. *Summary of Research Findings from the Programmable Thermostat Market.* Memo to Manufacturers on Programmable Thermostat Specification Review. Washington, D.C. 2003. Available online: https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/thermostats/Summary.pdf
2. Nevius, M., and Pigg, S. "Programmable Thermostats That Go Berserk: Taking a Social Perspective on Space Heating in Wisconsin." Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings, 8.233-238.244, 2000.
3. Meier, A., et al. (Lawrence Berkeley National Laboratory and University of California Davis). "How People Actually Use Thermostats." Presented at American Council for an Energy Efficient Economy proceedings, Pacific Grove, California, August 15-20, 2010.

Based in part on the findings of programmable thermostat program evaluations, the EPA suspended ENERGY STAR® labeling of programmable thermostats in 2009. Since then, the nation's top thermostat manufacturers have released a new generation of Wi-Fi-enabled, smart thermostats designed with more user-friendly programming in addition to wireless control options.

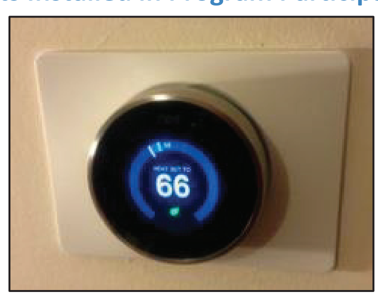
In 2013-2014, Vectren, administered a thermostat program to evaluate the impact of a smart thermostat, the Nest Learning Thermostat (Nest), on energy usage compared to baseline (manual) and programmable thermostats.

The utilities chose to evaluate the Nest because of its unique features. Nest's Auto-Away feature applies proprietary algorithms to occupancy data to determine when the home is unoccupied and activate temperature setbacks. The Auto-Schedule feature learns users' behaviors based on how they set the thermostat and automatically programs a setback schedule. In addition, users can control the Nest remotely using a smartphone, tablet, or computer, and publishes a monthly energy report via e-mail. The thermostat also has features useful to utility programs and evaluators: continuous communication to back-end databases of setpoints, space temperatures, and HVAC run times, among other data. The ability to monitor thermostats via the Internet also allows utilities to offer lower cost demand response programs.

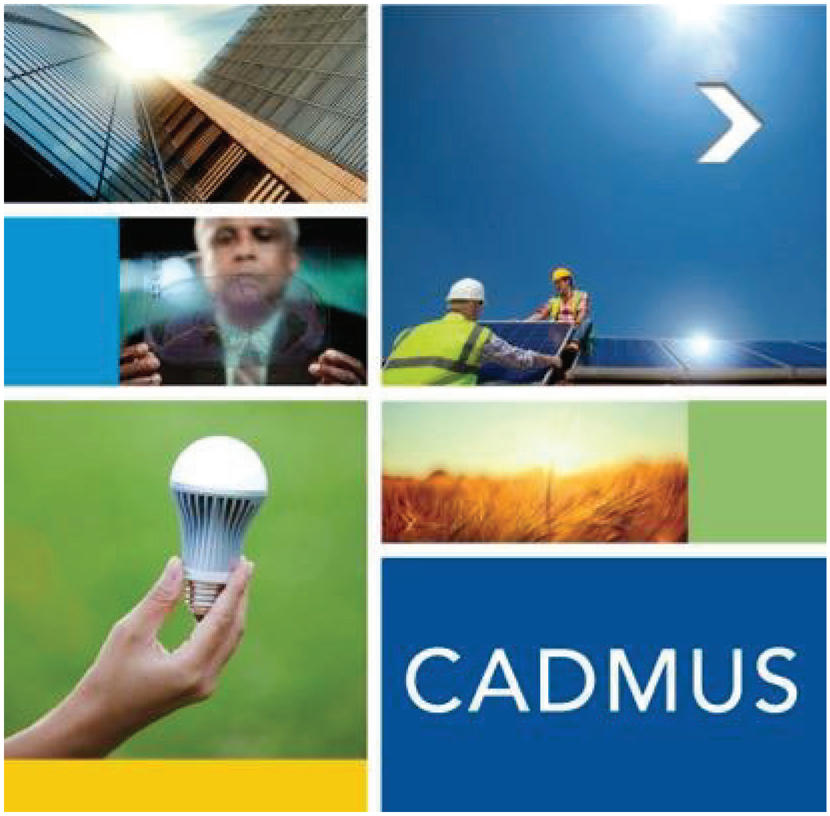
The Vectren program enrolled 600 dual-fuel (gas and electric) customers with manual thermostats.[4] Customers were randomly selected from a database of customers who had received a home energy audit. These customers were assigned to two treatment groups—half received a Nest thermostat and half received a standard programmable thermostat.

Participants receiving the Nest were required to have Internet in their home so that they could use the Wi-Fi features. The utilities chose the Honeywell TH211 to represent a conventional programmable thermostat in this evaluation. Figure 2 shows the Honeywell TH211 and Nest thermostat installed in participant homes.

Figure 2. Programmable (left) and Nest (right) Thermostats Installed in Program Participant Homes



[4] A small percentage of participants had programmable thermostats that they operated manually



Evaluation of the 2013–2014 Programmable and Smart Thermostat Program

January 22, 2015

Prepared for:

Northern Indiana Public Service Company
801 E. 86th Avenue
Merrillville, IN 46410

The Cadmus Group, Inc.

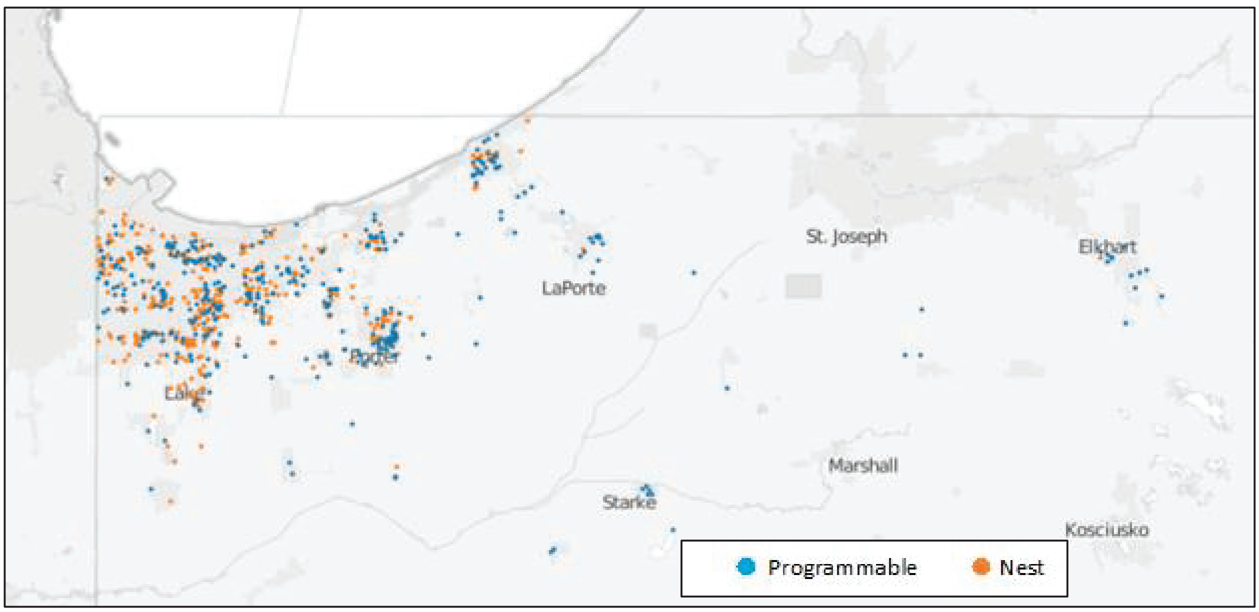
An Employee-Owned Company • www.cadmusgroup.com

Executive Summary

In 2013-2014, the Northern Indiana Public Service Company (NIPSCO), a natural gas and electric provider, offered a thermostat program to residential customers who used manual thermostats in their homes. CLEAResult, the program administrator, worked with their subcontractor, Water and Energy Solutions, Inc. (WES) to install 400 Nest and 400 programmable thermostats in the homes of randomly selected NIPSCO natural gas and electric (i.e., dual-fuel) customers who previously underwent a home energy assessment (through the Energizing Indiana Program). In addition to the new thermostats, customers received training on proper operation of their new thermostats.

WES installed the thermostats between June 28 and September 19, 2013. Figure 1 shows a map of the thermostat installation locations by thermostat type.

Figure 1. Map of Completed Thermostat Installations for NIPSCO Thermostat Program



NIPSCO hired Cadmus to evaluate the program and determine the energy savings from the Nest thermostat over the baseline (manual thermostats) and conventional programmable thermostats. Specifically, the objectives of the evaluation are to:

1. Evaluate the amount (therms) and percentage of gas saved on heating; and
2. Evaluate the amount (kWh) and percentage of electricity saved on cooling.

Cadmus assessed energy savings using pre- and post-installation billing data. Table 1 shows the evaluated gas savings as a percentage of heating gas usage and Table 2 shows the evaluated electric savings as a percentage of cooling electric usage.

Table 1. Nest and Programmable Thermostat Gas Savings as Percentage of Heating Gas Usage

Thermostat Group	Group	Sample Size	Pre-Heating Usage (therms)	Savings (therms)	Savings (%)	Range of Savings (therms)	Range of Savings (%)
Nest	Participant	238	793	77	9.7%	59 to 95	7% to 12%
	Control	469	818	-30	-3.7%	-19 to -41	-2% to -5%
	Adjusted Gross	**238**	**793**	**106**	**13.4%**	**86 to 127**	**11% to 16%**
Programmable	Participant	217	739	30	4.1%	19 to 41	3% to 6%
	Control	469	818	-30	-3.7%	-19 to -41	-2% to -5%
	Adjusted Gross	**217**	**739**	**57**	**7.8%**	**42 to 73**	**6% to 10%**

Table 2. Electric Savings as Percentage of Cooling Electric Usage

Thermostat Group	Group	Sample Size	Pre-Cooling Usage (kWh)	Savings (kWh)	Savings (%)	Range of Savings (kWh)	Range of Savings (%)
Nest	Participant	238	2,401	17	0.7%	-100 to 133	-4 to 6%
	Control	522	1,873	-289	-15.5%	-214 to -365	-11 to -19%
	Adjusted Gross	**238**	**2,401**	**388**	**16.1%**	**249 to 526**	**10 to 22%**
Programmable	Participant	212	2,021	-9	-0.5%	-114 to 96	-6 to 5%
	Control	522	1,873	-289	-15.5%	-214 to -365	-11 to -19%
	Adjusted Gross	**212**	**2,021**	**303**	**15.0%**	**174 to 433**	**9 to 21%**

Participants with the Nest thermostat reduced their heating gas consumption by approximately 13%, compared to only 8% for participants with a programmable thermostat. The Nest saved more gas than the programmable thermostat by keeping the average home temperature approximately one degree lower than the homes with a programmable thermostat in the heating season, and an average of 1.2 degrees lower during the daytime on weekdays, when homes are commonly unoccupied. We assume temperature reductions in Nest homes are attributable to its Auto-Away feature, which automatically sets back the temperature when it senses no one is home.

Participants in the Nest and programmable thermostat groups reduced cooling electric consumption by approximately the same amount (16% and 15%, respectively). Despite nearly the same percentage of savings, Nest participants had a higher average air conditioner run time (3.4%) compared to programmable thermostat participants (2.8%). The baseline cooling electric usage in the Nest participant group was 19% higher than the baseline for the programmable thermostat group, so we would expect the air conditioner run time for Nest participants to be higher. We assume the higher baseline usage in the Nest participant group is attributable to the Nest participant homes having higher occupancy (and thus higher cooling loads) compared to the programmable thermostat homes (see occupancy data in Demographics section).

Introduction

In 1995, the U.S. Environmental Protection Agency (EPA) began promoting programmable thermostats with the ENERGY STAR® label. Utility companies started offering rebate programs based on claims that programmable thermostats could save 10% to 30% of residential heating and cooling energy if users programmed setbacks when the home was unoccupied or occupants were sleeping.[1] However, evaluations of these programs showed low realization rates and many studies found that only about half of users actually programmed their thermostats due to the poor user interface designs and complicated settings.

Two conditions can decrease or eliminate savings benefits from programmable thermostats. They are:

1. Some users with manual thermostats already use temperature setbacks regularly, essentially duplicating the operation of a programmable thermostat.
2. Not all users program their programmable thermostats. Some users set the thermostats at a constant temperature setpoint. Several studies have shown that consumers find programmable thermostats difficult to operate, so they often do not program the thermostat at all.[2] One study found that only 47% of programmable thermostats are actually programmed in an energy saving manner.[3]

In a 2013 study, Cadmus observed both conditions (Table 3). Study participants responded to surveys about their thermostat behavior. The portion of thermostats set to regular, scheduled setpoints does not differ much by technology, but programmable thermostats are left at a constant setpoint more often, possibly because of the difficulty of programming.

Table 3. Programmable and Manual Thermostat Behavior Patterns from 2013 Cadmus Study*

Behavior	Manual Thermostats	Programmable Thermostats
Regular Scheduled Setpoints	48%	56%
Manual With Changing Setpoints	36%	14%
Constant Setpoint	16%	29%

*Totals may not sum due to rounding.

1 U.S. Environmental Protection Agency. *Summary of Research Findings from the Programmable Thermostat Market.* Memo to Manufacturers on Programmable Thermostat Specification Review. Washington, D.C. 2003. Available online: https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/thermostats/Summary.pdf

2 Nevius, M., and Pigg, S. "Programmable Thermostats That Go Berserk: Taking a Social Perspective on Space Heating in Wisconsin." Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings, 8.233-238.244, 2000.

3 Meier, A., et al. (Lawrence Berkeley National Laboratory and University of California Davis). "How People Actually Use Thermostats." Presented at American Council for an Energy Efficient Economy proceedings, Pacific Grove, California, August 15-20, 2010.

Based in part on the findings of programmable thermostat program evaluations, the EPA suspended ENERGY STAR® labeling of programmable thermostats in 2009. Since then, the nation's top thermostat manufacturers have released a new generation of Wi-Fi-enabled, smart thermostats designed with more user-friendly programming in addition to wireless control options.

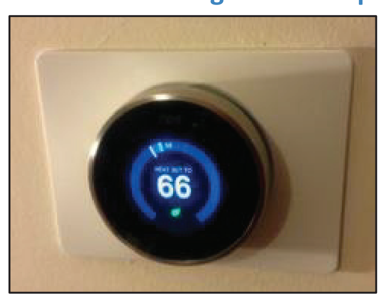
In 2013-2014, the Northern Indiana Public Service Company (NIPSCO), administered a thermostat program to evaluate the impact of a smart thermostat, the Nest Learning Thermostat (Nest), on energy usage compared to baseline (manual) and programmable thermostats.

NIPSCO chose to evaluate the Nest because of its unique features. Nest's Auto-Away feature applies proprietary algorithms to occupancy data to determine when the home is unoccupied and activate temperature setbacks. The Auto-Schedule feature learns users' behaviors based on how they set the thermostat and automatically programs a setback schedule. In addition, users can control the Nest remotely using a smartphone, tablet, or computer, and publishes a monthly energy report via e-mail. The thermostat also has features useful to utility programs and evaluators: continuous communication to back-end databases of setpoints, space temperatures, and HVAC run times, among other data. The ability to monitor thermostats via the Internet also allows utilities to offer lower cost demand response programs.

The program enrolled 800 dual-fuel (gas and electric) customers with manual thermostats.[4] Customers were randomly selected from a database of customers who had received a home energy audit. These customers were assigned to two treatment groups—half received a Nest thermostat and half received a standard programmable thermostat.

Participants receiving the Nest thermostat were required to have Internet in their home so that they could use the Wi-Fi features. NIPSCO chose the Honeywell TH211 to represent a conventional programmable thermostat in this evaluation. Figure 2 shows the Honeywell TH211 and Nest thermostat installed in participant homes.

Figure 2. Programmable (left) and Nest (right) Thermostats Installed in Program Participant Homes



[4] A small percentage of participants had programmable thermostats that they operated manually

WHITE PAPER

Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results

Nest is committed to being an industry leader in measuring and sharing energy savings results. This white paper is one in a continuing series of such empirical reports. The results reported here are averages across broad populations and are not intended as an estimate of savings that any specific user will obtain. Actual savings will vary with a number of factors including occupancy and behavior patterns, energy use, utility rates, and weather. Savings numbers are not a guarantee

February 2015
Nest Labs

Executive Summary

This white paper summarizes the results from three studies of Nest Learning Thermostat energy savings based on comparisons of utility bills from before and after installation. Two of the studies were each independently funded, designed and evaluated -- one conducted in Oregon and the other in Indiana. The third study was performed by Nest using a national sample of Nest customers across 41 states in the U.S. who had also enrolled in Nest's MyEnergy service.

The energy savings results of all three studies were similar -- showing Nest Learning Thermostat savings equal to about 10%-12% of heating usage and electric savings equal to about 15% of cooling usage in homes with central air conditioning. Furthermore, the Oregon study noted that the majority of participants reported feeling more comfortable after the Nest Learning Thermostat was installed.

Although the average savings were similar across the three studies, it's important to note that thermostat savings in any given home can vary significantly from these averages due to differences in how people used their prior thermostat and how they use their Nest Learning Thermostat, as well as due to occupancy patterns, housing characteristics, heating and cooling equipment, and climate. Savings for any given customer may be much higher or lower than the average values. Results from future studies by Nest or third parties may also find higher or lower average savings due to differing characteristics of the populations studied.

Prior Nest analysis based on thermostat data estimated savings of up to 20% of heating use compared to the standard assumed behavior -- used by government and industry -- of maintaining a constant temperature setting all winter. The 10%-12% heating savings in this white paper are consistent with that estimate because survey results indicated that many Nest customers had previously programmed their thermostat or manually adjusted heating and cooling temperature settings. Calculations based on the survey responses suggested that Nest customers averaged about 8%-10% more efficient schedules than just maintaining a constant temperature -- implying expected additional savings in the 10%-12% range.

Nest is committed to being an industry leader in measuring and sharing energy savings results. We expect to have industry-leading measured energy savings, but we prioritize keeping people comfortable and in control of their homes. Our thermostat is designed to capture as much energy savings as feasible without compromising comfort or convenience.

Background

Programmable thermostats have been promoted as an energy savings product for many years. The real world energy savings provided by programmable thermostats has been an area of controversy. The Energy Star program of the US Environmental Protection Agency summarized the issue in 2003:

> *"Consumers are often advised that installing a programmable thermostat can save them anywhere from 10 to 30% on the space heating and cooling portion of their energy bills. While reliant on proper use of the programmable thermostat, such savings are easily true in theory; however, there needs to be more field-tested data to better substantiate savings claims. Analyses from recent field studies have suggested that programmable thermostats may be achieving considerably lower savings than their estimated potential." [EPA 2003]*

The energy savings are primarily expected to come from automatically turning down the heating set point temperature (or turning up the cooling set point) when people either aren't at home or are sleeping (known as "setback"). The magnitude of the savings depends on the how much the temperatures are changed compared to before installing the thermostat.

Field research [see Peffer et al, 2011] has found that many programmable thermostats aren't actually programmed due to usability and design problems, leading to set points that aren't much more efficient than manual thermostat set points and therefore to uncertain energy savings. This research led EPA to end the Energy Star designation for all programmable thermostats in 2009.

Still, the government and manufacturers have continued to explain the energy savings potential of well-programmed thermostats in terms of the possible savings relative to previous set point assumptions. The U.S. Department of Energy (DOE) lists heating savings of 5%-15% for a single eight hour temperature setback per day compared to a constant temperature setting [DOE 2015]. The EPA, although having ended Energy Star certification for programmable thermostats, lists savings of $180 per year for a programmable thermostat [EPA 2015]. The Nest web site states that customers "could cut 20% off your heating and cooling bill" compared to maintaining a constant temperature [Nest Labs 2015], where the constant temperature is based on customer-specific set points. Other thermostat manufacturers make a variety of savings estimates:

- "customers in the US saved an average of 23% on their heating and cooling costs" based on a comparison to an assumed 72°F constant heating set point [Ecobee 2015]
- "homeowners saved an average of 20% on their heating and cooling energy costs" based on a comparison to an assumed 72°F constant heating set point [Carrier 2014]
- "cut your heating bill by up to 31%" compared to a constant set point [Tado 2015]

All of the thermostat savings estimates are based on models of how set points affect energy use and calculate the savings compared to an assumed constant temperature set point. It's been common practice to assume a constant set point as the baseline setting behavior because it provides a clear reference condition, data on prior set points are rarely available, and because field research has found that many programmable thermostats aren't running any program [Meier et al, 2010].

The savings estimates based on the constant set point assumption are a useful guide but may not reflect actual expected savings in a specific home or average savings in a group of homes if the assumptions aren't met -- for example, if people had already been turning down the heating set point at night. Although the methods and assumptions are usually stated with the savings estimates and often include qualifiers like "save up to", it can still differ from actual consumer experience.

To assess the actual savings that customers achieved requires analyzing energy usage from before and after the thermostat installation for large groups of homes. Because such energy usage data is not usually available -- especially to thermostat manufacturers -- there have been very few such studies performed.

In May 2013, Nest acquired MyEnergy -- a company that helps customers track and analyze their utility usage and bills. The tools Nest took over from MyEnergy allow customers to gather all of their utility usage and bills in one place, providing them with the ability to monitor usage and costs month over month, year over year, and can compare performance to friends and other homes in their neighborhood. Nest also uses these insights to help analyze energy usage patterns. By comparing energy use before and after Nest Learning Thermostat installation we are able to evaluate the energy savings achieved in a sample of customers. It is this comparison, presented in a de-identified and aggregated manner, that forms the basis for this white paper. Unlike prior estimates based on assumed pre-thermostat behavior, this evaluation allows an empirical assessment of energy savings by actual consumers based on changes in their energy usage.

Methodology

Evaluating the energy savings achieved by a thermostat (or any efficiency improvement) using energy usage data might appear to be straightforward -- just calculate the difference in usage from the year before the installation to the year after the installation. But the reality is not that simple. A major challenge to evaluating energy savings is that energy usage changes from year to year for many reasons unrelated to the thermostat installation, for example:

- Weather: the winter may be colder or the summer may be milder from one year to the next, causing increased or decreased energy use. Energy savings evaluations employ statistical methods to adjust energy usage for weather variations
- Occupancy patterns: babies are born; children enter school, become teenagers, and may eventually go off to college; people get jobs, lose jobs or start or stop working from home; vacation schedules and holiday hosting vary from year to year. All of these changes can affect thermostat set points and also affect how people use their appliances, lighting, and other energy end uses.
- Home/Equipment/Appliances: people replace heating and cooling systems and appliances, build additions, add insulation, replace windows, and make other physical changes in their homes. Each of these changes can affect energy usage.

Things people do and how they live causes energy use to vary from year to year (see Figure 1 on page 8). Two main approaches are used to deal with these variations in energy use. First, energy savings studies are based on large groups of homes rather than taking results for any one home at face value. The use of larger samples allows random usage variations to average out -- with some homes increasing their energy usage due to these factors while others decrease their energy usage. Second, to account for any general trends towards increasing or decreasing energy usage (e.g. changes in energy prices, employment rates, birth rates, etc.) a control group[1] of homes not installing the thermostat is analyzed in a parallel manner to adjust the results.

In performing this energy savings analysis, we followed industry standard practices as defined by the US DOE Uniform Methods Project [DOE 2013] -- specifically, the guidelines found in “Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol” [Agnew and Goldberg 2013]. The protocol describes two primary approaches for analyzing utility energy usage data -- the “two stage” approach and the “pooled” approach.

The “two stage” approach involves analyzing the energy usage data for each customer from before and after the installation using a weather normalization procedure (a variable-base degree day regression model) and then summarizing the annualized usage and savings across homes for both the installation group and a control group of non-participant homes.

The “pooled” approach involves fitting a single linear regression model to all of the energy usage data across all homes. The model includes variables to account for degree days and variables to estimate the changes in energy use after installation (interacted with degree days). In addition, these models include customer-specific fixed effects and often include time period specific effects as well. The overall average energy savings are calculated directly from the model coefficients.

1 actually, more appropriately called a “comparison group” as the term “control group” is often reserved for only randomized experiments.

In this analysis, we employed both the “two stage” and “pooled” approaches. The analysis involved the following steps (see appendix for more details):

1. assemble and prepare the utility usage data collected through MyEnergy
2. identify Nest customers and parse energy use data into pre and post Nest Learning Thermostat installation periods
3. parse the control group (i.e., non-Nest MyEnergy customers) energy use data into comparable pre and post ”installation” periods by randomly assigning installation dates to each customer from the Nest customer sample
4. calculate heating and cooling degree days for each meter reading for each Nest customer
5. calculate weather normalized energy usage for the pre and post installation periods for each customer and fuel using variable-base degree day regression models. The electric analysis involved fitting models with and without heating and cooling terms to select the best model type for each home.
6. fit pooled time-series cross-sectional fixed effects regression models to the monthly gas and electric usage data using degree day terms and interactions and with month-specific indicator variables for the gas analysis to account for the polar vortex (an extreme cold weather system that affected the eastern half of the US in January 2014).

The electric analysis focused on homes with central air conditioning loads (defined as >500 kWh/yr in estimated cooling use) and without electric heat (there were too few electrically heated homes in the sample to reliably evaluate). The gas analysis excluded homes where electric heating usage was also detected.

A reliable savings analysis requires about a year of energy use data from before and after the installation. Due to the limited amount of historical energy usage data maintained online by most utilities and the timing of the MyEnergy acquisition and Nest customer enrollments, the vast majority of MyEnergy+Nest customers did not have sufficient pre-Nest energy use data for reliable analysis or had installed their Nest Learning Thermostats too recently to be included in the current analysis.

These data requirements led to the final sample sizes of 735 homes for the gas usage analysis and 624 homes for the electric analysis. Although these samples are large enough to estimate average overall savings, they’re not large enough to provide for more detailed analyses, especially given the heterogeneous nature of a national sample. The natural gas sample includes customers from 36 different states. California was the most common state with 15% of the sample and Illinois, Massachusetts Oregon, Texas, and Utah each represented more than 5% of the sample. The average heating season climate across these homes was moderately cold -- 4,533 heating degree days (HDD65) per year, comparable to Baltimore, MD. The electric sample included customers from 39 different states with California again being most common (19% of sample), and Texas and Massachusetts each at 10% of the sample. The electric sample homes averaged 1,729 cooling degree days (CDD65), comparable to Charlotte, North Carolina.

Findings: Gas and Electric Savings

The two energy usage analysis approaches -- pre/post and pooled -- yielded similar savings estimates (differences between approaches were not statistically significant), but the potential bias in weather normalization from the 2014 polar vortex (see more details in the appendix), led us to select the pooled approach as the best estimate of savings. The results of the analysis are summarized in Table 1.

Table 1. Gas and Electric Savings Results

		Pre-Nest Usage		Energy Savings	
Fuel	N	Total	HVAC	Total	**% of HVAC**
Natural Gas (therms/yr)	735	774	584	56 ±12	**9.6% ±2.1%**
Electricity (kWh/yr)	624	12,355	3,351	585 ±97	**17.5% ±2.9%**

Natural gas savings averaged 56 therms per year equal to 9.6% of pre-Nest heating use. Electricity savings averaged 585 kWh per year equal to 17.5% of pre-Nest HVAC[2] usage.

Most of the homes in the analysis had just a single Nest Learning Thermostat, but 19% of the gas analysis homes and 25% of the electric analysis homes had two or more Nest Learning Thermostats. We ran the analysis for just the homes with a single thermostat and found average savings of 11.0% for gas heating (60 th/yr out of 547 th heating use) and 15.5% of electric HVAC (448 kWh out of 2,897 HVAC use). The differences between these values and the overall values in the table are not statistically significant.

We calculated the estimated value of the energy savings using two approaches. In the first approach, we applied the most recent (October 2014) average U.S. residential electric and natural gas prices of 12.6¢/kwh and $13.15/mcf ($1.28/therm), as reported by the EIA [EIA 2014a], to the average therm and kWh savings, which yields $145 in annual savings. In the second approach, we applied the percent heating and cooling savings to the most recent average annual U.S. heating and cooling costs according [EIA 2014b, EIA 2015]. This calculation estimates the annual savings at $131 (9.6% of $988 for heating and 15% of $240 for cooling). The two approaches provide similar estimates. Of course both of these figures are just rough estimates of savings because energy prices vary between energy providers and change over time and marginal costs may differ from average costs. In addition, these savings are estimates for homes that have gas heating and also use central air conditioning and have average energy use consistent with the values found here. Dollar savings vary with energy savings as well as with fuel type and local energy costs.

Energy Usage and Savings Variability

Figure 1 shows the distribution of percent natural gas "savings" for the comparison group of homes that did not install Nest Learning Thermostats. This distribution is approximately symmetric around zero (no change in usage) and also shows a wide range of usage changes -- 34% of the homes experienced a change in weather normalized total natural gas use of more than 10% from year to year.

2 Although we screened out homes that were electrically heated, most homes have some winter seasonal electricity usage -- some of which is related to furnace fan power draw. To account for the savings and usage not related to cooling we expressed electric savings as a percent of HVAC use.

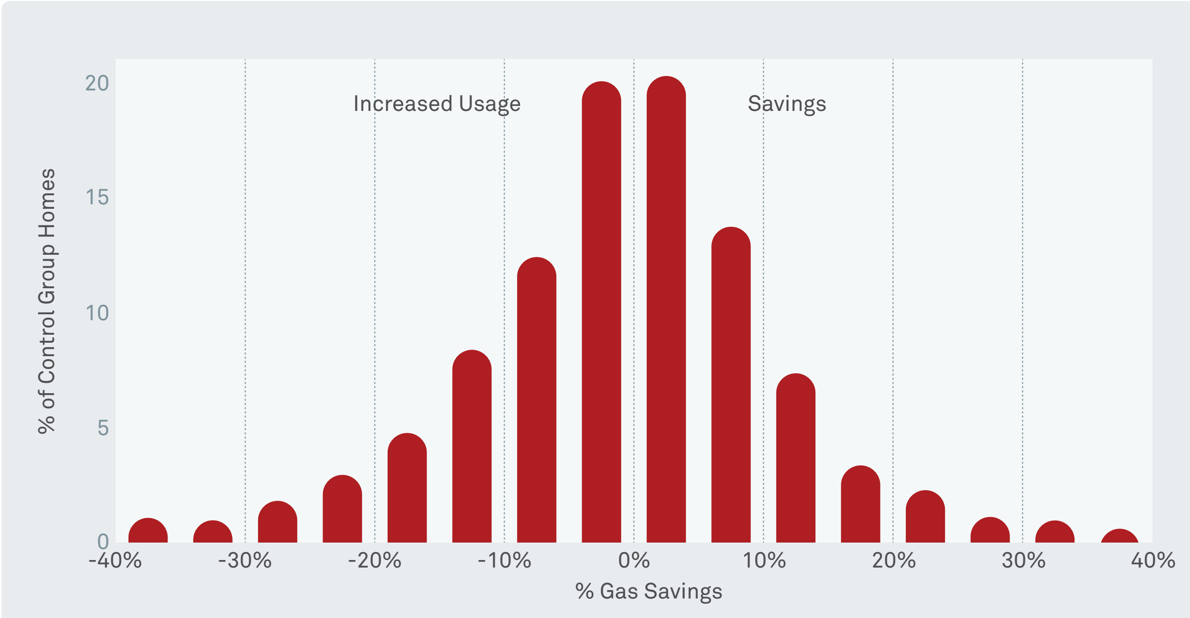


Figure 1. Distribution of Natural Gas "Savings" for non-Nest comparison group

Figure 2 shows the same graph for the Nest customers in the analysis. The peak is clearly to the right of the 0% vertical line -- indicating savings, but there's a lot of variability - including many homes where the gas usage seemed to increase.

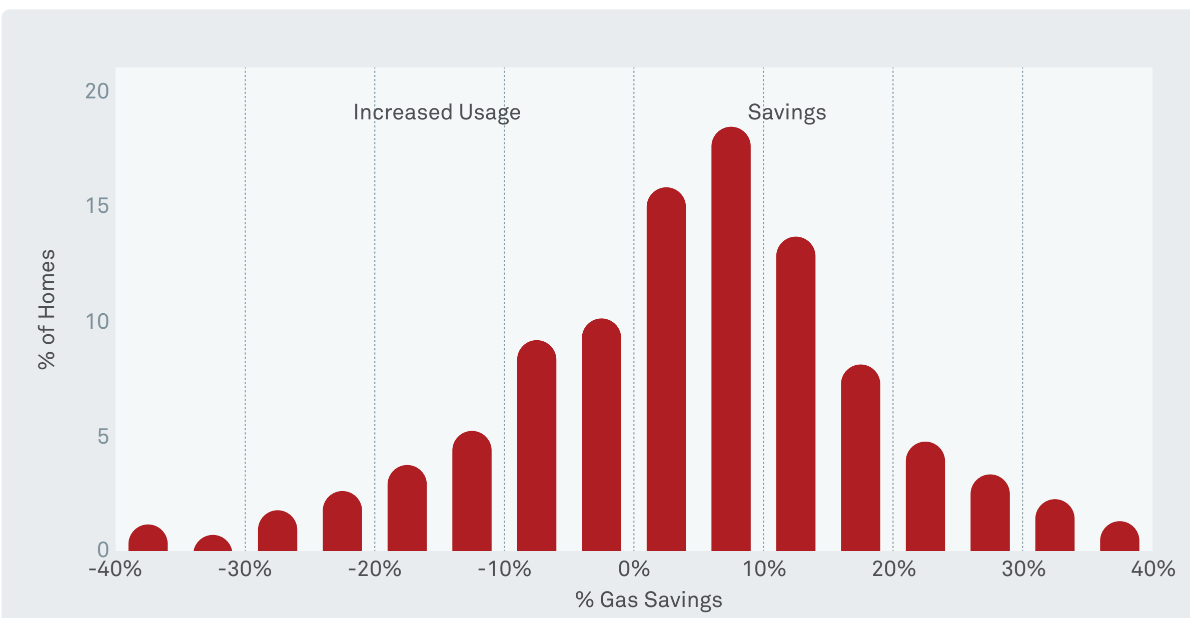


Figure 2. Distribution of Natural Gas Savings for Nest MyEnergy customers

These graphs illustrate that the change in energy use for a given home after installing a Nest Learning Thermostat (or making any other change) is not just the energy savings from the Nest Learning Thermostat but is the total change in energy usage from everything that happened over the period -- including all other changes in people's homes and how they use them. The true energy savings attributable to the thermostat is the difference between the actual energy use with the Nest Learning

Thermostat and the energy use a customer *would have had* if they hadn't installed the Nest Learning Thermostat. But what we can actually observe in people's bills is the change in usage from the year before to the year after, which includes a host of factors unrelated to the Nest Learning Thermostat.

If a thermostat saved every customer exactly 10% of their total gas usage then the savings in Figure 2 would look just like Figure 1 above, except shifted over by 10%. We would still see homes that increased their energy usage while we would see other homes with larger decreases in usage.

While Nest would love to be able to take credit for all of the energy savings when a customer's usage drops by 40% we know that there's a good chance that other things changed in their home or how they use it that may be responsible for some of that savings. Similarly, when the energy use of some customers stays the same or increases, the blame could be due to many other things that changed over time.

Thus, the actual savings we ascribe to Nest is, in essence, the difference between the results of Figure 1 (i.e., the natural year-to-year variability of energy usage) and the results of Figure 2 (i.e., the year-to-year variability of energy usage in homes installing a Nest Learning Thermostat).

Assessment of Potential Bias: Evaluating MyEnergy Customers

Like most evaluations of energy efficiency upgrades, this study is not a designed experiment or randomized control trial but is instead an "observational study". Observational studies need to consider potential sources of bias since the participants may not represent the larger population of customers or the comparison group may differ from the participants. In addition, extraneous factors such as extreme weather or energy price changes may have affected energy use in ways that differ between groups or aren't otherwise accounted for properly in the analysis.

In this study, the analysis group comprises people who purchased a Nest Learning Thermostat and also chose to sign up for MyEnergy. People who enroll in MyEnergy are interested in tracking their energy use and so they tend to be more energy conscious and efficient than the average Nest customer. Although it may seem counterintuitive, this greater interest in energy efficiency may lead to lower energy savings from a Nest Learning Thermostat. The most energy conscious customers are the ones more likely to have had efficient thermostat settings -- either because they put in the effort to properly use their old programmable thermostat or they consistently set back temperatures whenever feasible prior to having a Nest. The prior behavior has a large impact on savings potential.

We explored the potential bias from the sample composition through an email survey and an analysis of Nest settings. Table 2 summarizes some key findings from the survey.

Table 2. MyEnergy Customers compared to average Nest customers

	MyEnergy	Other Nest	Difference
Customer Survey Findings			
Had Programmable Thermostat	74%	65%	+9%
Most Efficient: Programmable with double setback	37%	28%	+9%
Least Efficient: No Regular Setback	26%	36%	-10%

Nest Device Settings			
Average Heating Set Point	66.2°F	67.2°F	-1.0°F
Average Night Setback	4.9°F	4.0°F	+0.84°F

note: Survey results are based on 657 MyEnergy and 763 other Nest customers.

The table shows that the MyEnergy customers reported having more efficient set points prior to installing the Nest than the average Nest customer surveyed. Compared to the other Nest customers, MyEnergy customers were more likely to have a programmable thermostat, more likely to employ two or more setbacks per day, and less likely to have practiced no setbacks prior to having the Nest. These differences all suggest that MyEnergy Nest customers have less potential for saving energy since they were already more efficient. We assessed the magnitude of this effect using energy modeling and estimate that the MyEnergy customers have about 2% lower savings potential than the average Nest customer -- their set points were calculated to be about 10% more efficient than a constant baseline compared to about 8% more efficient for the average Nest customer.

The last two rows of the table summarize the actual Nest Learning Thermostat customer set points during February and March 2014 for the survey homes. The MyEnergy Nest customers maintained a lower average heating set point than the average Nest customer and also had greater night temperature setbacks (primarily more frequent rather than deeper). Differences were also found for other settings, such as daytime setbacks, and for the use of Nest features such as Heat Pump Balance (more than twice as likely to select "Max Savings"). We used energy modeling to estimate the impact of these differences and calculated that the MyEnergy customers were about 2% more efficient with their Nest set points than the average Nest customer.

Based on this analysis, it appears that the MyEnergy customers were more efficient than the average Nest customer both before and after installing their Nest and the magnitude of these differences was about the same -- implying no significant bias between the groups.

It's also worth noting that both groups of Nest customers reported more efficient prior thermostat practices compared to studies of typical US household thermostat use. A literature review [Peffer et al, 2011] reported that 42% of US households had programmable thermostats in 2008 and 47% of programmable thermostats were running a program. In contrast, 65% of non-MyEnergy Nest customers reported having a programmable thermostat and 71% of those were running a program. These results indicate that Nest customers tended to have more efficient set points than the average U.S. household, which reduced the potential for savings.

Another potential source of bias is the comparison group. The comparison group of non-participants comprises people who signed up for MyEnergy on their own. The fact that they chose to enroll on their own implies that they may differ from the MyEnergy customers that were recruited by Nest. This difference could introduce a downward bias on savings if, for example, the non-Nest MyEnergy customers were more likely to pursue other efficiency upgrades on their own -- which may have led them to sign up for MyEnergy.

Overall, our analysis did not uncover any evidence of a large bias from having the study focus on MyEnergy customers, although the comparison group issue suggests any likely bias would lead toward finding lower energy savings than the average Nest customer might achieve.

Other Recent Studies of Nest Learning Thermostat Savings

Two studies have been released recently by independent third parties that evaluated the energy savings from Nest Learning Thermostat installations -- one in Oregon and one in Indiana.

Energy Trust of Oregon Heat Pump Pilot

The Oregon study [Apex Analytics, 2014] was a pilot project designed, funded, and overseen by the non-profit Energy Trust of Oregon. In the fall of 2013, the Energy Trust had a contractor install Nest Learning Thermostats in 185 homes heated by heat pumps. The Energy Trust hired an independent firm to analyze changes in energy bills and also survey participants about their experiences. The main findings from the energy billing data analysis and final customer survey included:

- customers experienced an average 12% reduction in electric heating use (781 kWh/year per home) relative to their pre-Nest usage
- 89% of customers were satisfied with their Nest Learning Thermostat
- 66% of participants reported feeling more comfortable after the Nest Learning Thermostat was installed
- 34% of participants reported that they thought the Nest Learning Thermostat was worth the full retail price even if it had provided no energy savings at all

The report cited the Nest Learning Thermostat's unique "Heat Pump Balance" feature as a key element in providing the savings. The 12% heating savings for heat pumps in Oregon is especially noteworthy given that programmable thermostats are typically not recommended for heat pumps.

The US DOE web page on thermostats (http://energy.gov/energysaver/articles/thermostats accessed 21-Jan-2015) notes:

> *"Programmable thermostats are generally not recommended for heat pumps… when a heat pump is in its heating mode, setting back its thermostat can cause the unit to operate inefficiently, thereby canceling out any savings achieved by lowering the temperature setting"*

But it goes on to note that "some companies have begun selling specially designed programmable thermostats for heat pumps, which make setting back the thermostat cost-effective". The study suggests that the Nest Learning Thermostat algorithms have succeeded in this challenge of achieving savings from setback for heat pumps.

The study findings about high customer satisfaction and improved comfort listed above are particularly noteworthy. Given the importance of behavior in energy savings from thermostats, user satisfaction with the technology and their feeling that their energy savings have not come at the expense of comfort mean that the Nest Learning Thermostat can serve its dual role as a comfort control device and an energy control device without putting those objectives in conflict. This has not always been the case with new energy-saving technologies, which can become ineffective if they force users to choose between comfort and efficiency.

Indiana Utility Pilot

The Indiana study [Aarish et al, 2015] was a pilot project designed to assess the energy savings of Nest Learning Thermostats. The project was designed, funded, and overseen by Vectren Energy, a gas and electric utility in Indiana. In the fall of 2013, Vectren hired a contractor to install Nest Learning Thermostats in 300 homes and standard programmable thermostats (Honeywell TH211 Pro 2000 series) in 300 homes. Vectren hired the Cadmus Group to perform the evaluation. The main findings from the evaluation included:

- Homes that received a Nest Learning Thermostat had average natural gas savings of 69 therms/year, equal to 12.5% (±1.5%) of the heating use
- Nest homes had average electricity savings of 429 kWh/yr, equal to 13.9% (±5%) of cooling use
- Homes that received a standard programmable thermostat averaged savings of 30 therms/yr equal to 5.0% (±1.3%) of heating use. In terms of electricity usage, they saved 332 kWh/yr equal to 13.1% (±6%) of cooling use

The Nest customers saved more than twice as much heating energy as the standard programmable thermostat customers and this difference was statistically significant. The electricity savings estimates had much larger uncertainty than the gas results and pre-existing differences in cooling use and occupancy between the groups makes it hard to draw any firm conclusions about the difference in cooling savings.

There were two aspects of the pilot that may have affected the savings comparison:

- The pilot offered thermostats for free and the resulting sample of customers were much less likely to install and use the Nest phone or tablet apps or connect to WiFi than typical Nest customers -- potentially lowering the savings from Nest Learning Thermostat features.
- Both types of thermostats were professionally installed and set up by a contractor. One of the key features of the Nest Learning Thermostat compared to standard thermostats is the ease of creating a program through the learning feature. The pilot design created a best case scenario for a standard programmable thermostat in terms of being programmed.

Furthermore, thermostat research has found that many standard programmable thermostats eventually end up with no program or set to “hold” and the Indiana study found some evidence of this behavior already. The study reported that “only 37% of participants appear to have relied on their thermostat program by the end of the study period”. Therefore, savings from a standard programmable thermostat could be expected to degrade over time as more users override their schedules.

Real World Thermostat Energy Savings

The results from the MyEnergy customer analysis and the two independent studies suggest that Nest customers are saving about 10%-12% of heating use. Although these savings are less than the 20% projected by Nest from energy modeling, the results are consistent once the different baseline behaviors are taken into account. The 20% projection was based on the standard assumption of a constant temperature setting without the Nest Learning Thermostat, but the email survey found that Nest customers reported having set points that were about 8%-10% more efficient than the constant baseline (and also more efficient than the average U.S. home). Therefore, the 10%-12% heating savings are in fact consistent with the 20% projection when adjusted for the more efficient baseline. This suggests that the modeling itself was accurate and the baseline assumption is responsible for the difference in savings.

The MyEnergy and Indiana studies found electric savings in homes with central air conditioning (and not electric heat) of about 15% of cooling use. Due to the inherently greater variability a electric use, these savings have greater uncertainty than the gas savings and larger samples and more studies would help to draw stronger conclusions about the impacts.

The real energy savings achieved from installing a Nest Learning Thermostat is expected to vary based on many factors. Table 3 lists some of the behaviors and characteristics associated with higher or lower heating savings potential from installing a Nest Learning Thermostat. A similar list would apply to cooling savings.

Table 3. Factors Associated with Higher or Lower Thermostat Savings

Larger Savings Potential	Behavior / Characteristic	Smaller Savings Potential
Rarely or never used setback, but willing to	Nighttime setback: before installing Nest	Always used setback
Often away during the day but didn't use setback	Daytime occupancy / prior setback	Home during the day or already used setback regularly
Often go away for days or weekends or vacations and forget to turn down heat; vacation homes	Vacations and other away periods	Never go away or always remember to turn down heat when away
Keep nest features enabled: auto-schedule, auto-away; set heat pump balance to max savings	Nest settings	Disable energy saving features; select less efficient settings (heat pump balance max comfort)
Colder climates (but % savings may be less)	Climate	Milder climates (but % savings may be greater)
Heat pumps with typical or excess auxiliary heat use	HVAC type	Heat pumps with little auxiliary heat use, heat pumps due to limits on setbacks from aux. Heat requirements; condensing boilers if often running in condensing mode
Leakier, less insulated homes lose heat faster during setback, save more	Building shell efficiency	Tighter, better insulated homes lose heat slowly and save less from setback
Low mass homes cool down more quickly and save more from setback	Building mass	High mass homes (e.g., Masonry) cool down more slowly and save less from setback

The dominant factor affecting energy savings will often be the efficiency of the prior schedule / set points combined with the Nest Learning Thermostat's ability to create a more efficient schedule.

Higher energy savings would be expected for a customer who would like to have night and day setbacks but can't figure out (or doesn't want to bother to figure out) how to do it automatically with his or her current thermostat and can't remember or be bothered with manually adjusting the thermostat multiple times each day.

Lower energy savings would be expected for a customer who already sets back the temperature every night and day and always remembers to turn down the heat when leaving for an extended period. Such households are already operating their HVAC efficiently and provide less opportunity for savings, but they may still want a Nest Learning Thermostat for the convenience, functionality, and design in addition to the energy savings from other Nest features.

Conclusions

This white paper has presented results from three studies of Nest Learning Thermostat energy savings based on comparisons of energy bills from before and after installation of a Nest Learning Thermostat. The results of the studies were generally similar -- showing Nest Learning Thermostat heating savings of about 10%-12% and electric savings of about 15% of cooling use in homes with central air conditioning. Although the average savings were similar across the three studies, savings can be expected to vary significantly between homes due to variations in how people set their temperatures before installing the Nest Learning Thermostat as well as due to occupancy patterns, house characteristics, and climate. Future studies by Nest or other third parties may find higher or lower average savings due to differing characteristics of the populations studied. Nest is committed to being an industry leader in measuring and sharing energy savings results. We will continue to highlight new results as they become available.

At Nest, we expect to achieve industry-leading measured energy savings, but we prioritize keeping people comfortable and in control of their homes. If we didn't care about our customers' comfort, we could probably achieve greater energy savings, but we would have failed in our primary mission. Instead, we designed our thermostat to capture as much energy savings as feasible without compromising our customers' comfort or convenience.

References

Aarish, C., M. Perussi, A. Rietz, and D. Korn. *Evaluation of the 2013–2014 Programmable and Smart Thermostat Program.* Prepared by Cadmus for Vectren Corporation. 2015.

Agnew, K. and M. Goldberg, "Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol", National Renewable Energy Laboratory report NREL/SR-7A30-53827 April 2013. accessed from http://energy.gov/sites/prod/files/2013/11/f5/53827-8.pdf

Apex Analytics LLC, "Energy Trust of Oregon Nest Learning Thermostat Heat Pump Control Pilot Evaluation", October 10, 2014 accessed from http://energytrust.org/library/reports/Nest_Pilot_Study_Evaluation_wSR.pdf

Carrier Corp. "TP--WEM01 Performance™ Series AC/HP Wi--Fi Thermostat Carrier Côr™ Thermostat" from http://dms.hvacpartners.com/docs/1009/public/02/tp-wem-01pd.pdf

Ecobee, 2015. https://www.ecobee.com/savings/

Fels, M. "PRISM: An Introduction", Energy and Buildings 9, #1-2, pp. 5-18, 1986.

Meier, A., C. Aragon, B. Hurwitz, D. Mujumdar, D. Perry, T. Peffer, M. Pritoni, "How People Actually Use Thermostats", in Proceedings of the 2010 ACEEE Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, 2010. accessed from https://www.aceee.org/files/proceedings/2010/data/papers/1963.pdf

Nest Labs, 2015. https://nest.com/thermostat/saving-energy

Peffer, T., M. Pritoni, A. Meier, C. Aragon, D. Perry, "How people use thermostats in homes: A review", Building and Environment 46 (2011) 2529-2541.

Tado, 2015. https://www.tado.com/gb/heatingcontrol-savings

U.S. Department of Energy (DOE), "Uniform Methods Project For Determining Energy Efficiency Program Savings", 2013. at http://energy.gov/eere/about-us/initiatives-and-projects/uniform-methods-project-determining-energy-efficiency-progr-0

U.S. DOE 2015 http://energy.gov/energysaver/articles/thermostats

U.S. Energy Information Administration (EIA) October 2014 residential energy prices, 2014a accessed from http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a and http://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PRS_DMcf_m.htm

U.S. EIA "Short-Term Energy Outlook - January 2015" see "Table WF01. Average Consumer Prices and Expenditures for Heating Fuels During the Winter", January 2015. accessed from http://www.eia.gov/forecasts/steo/tables/pdf/wf-table.pdf

U.S. EIA, "Annual Energy Outlook 2014, early release" on-line query table "Residential Key Indicators and Consumption" 2014b accessed at http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014ER&subject=0-AEO2014ER&table=4-AEO2014ER&region=0-0&cases=full2013-d102312a,ref2014er-d102413a cooling energy costs calculated based on unit conversion to kWh and average price per kWh (from EIA 2014a).

U.S. Environmental Protection Agency (EPA) "Summary of Research Findings From the Programmable Thermostat Market", 2003 accessed from http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/thermostats/Summary.pdf

U.S. EPA 2015 http://www.energystar.gov/index.cfm?c=heat_cool.pr_hvac