

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

This page left blank.

Prepared by:
Carlyn Aarish
Matei Perussi
Andrew Rietz
Dave Korn

Cadmus: Energy Services Division



Table of Contents

Executive Summary.....	2
Introduction	4
Evaluation Objectives and Methods	6
Methods	6
On-site Data Collection	7
Pre-installation Survey	7
Space Temperature and Air Conditioner Run Time Metering	8
Pre/Post Billing Analysis.....	9
Post-installation Survey	17
Results.....	18
Response Rates.....	18
Energy Savings.....	18
Results of Gas Billing Analysis: Model-Specific Evaluated Savings (Average Participant)	18
Results of Electric Billing Analysis: Model-Specific Evaluated Savings (Average Participant)	19
Benchmarking	20
Participant Temperature Settings and Behavior	22
Pre-Installation Period	22
Post-Installation Period.....	24
Participant Demographics and Satisfaction Ratings.....	33
Demographics	33
Satisfaction with Thermostat.....	36
Conclusions	37
Gas Savings.....	37
Electric Savings.....	37
Participant Satisfaction	37
Interpreting Results	37
Appendix A: Pre-Installation Survey	39
Appendix B: Air Conditioner/Heat Pump Data Collection	45
Appendix C: Post-Installation Customer Surveys.....	50

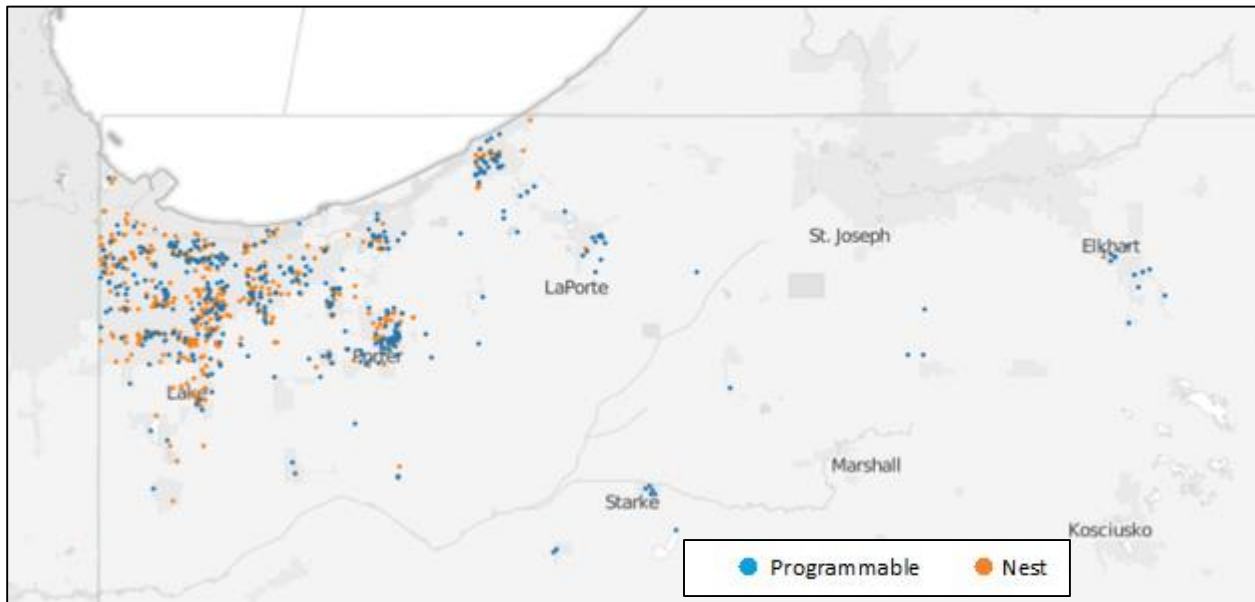


Executive Summary

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



Evaluation Objectives and Methods

The objective of the program was to evaluate the amount (therms) and percentage of gas saved on heating and the amount (kWh) and percentage of electricity saved on cooling using a Nest thermostat compared to conventional manual and programmable thermostats.

Cadmus evaluated energy savings for three groups of customers identified as having a manual thermostat in home energy audit data.⁵

1. 400 households received a Nest thermostat;
2. 400 households received a standard programmable thermostat; and
3. A control group of 800 households continued to use their existing manual thermostat.

We compared energy savings from the Nest and programmable thermostats using a pre-/post-installation billing analysis of participants' energy consumption. We used the control group to determine adjusted gross savings from the Nest and programmable thermostats.

To support the energy billing analysis, we installed indoor temperature loggers and air conditioner run time loggers in half the participant homes. We used the indoor temperature data to determine average indoor temperature by hour and by day of week and categorized the patterns of use. We used the air conditioner run time data to determine average air conditioner run time by hour and day of week. We also conducted pre- and post-installation surveys to assess participant behavior and determine any changes over the study period that might eliminate the participant from the analysis.

Methods

Cadmus assessed energy savings and participant behavior using a combination of billing data, metered data, and customer survey data. Table 4 summarizes the evaluation activities completed to collect and analyze these data.

⁵ A small percentage of participants had programmable thermostats that were unprogrammed and operated as manual thermostats.



Table 4. NIPSCO Thermostat Program Evaluation Activities

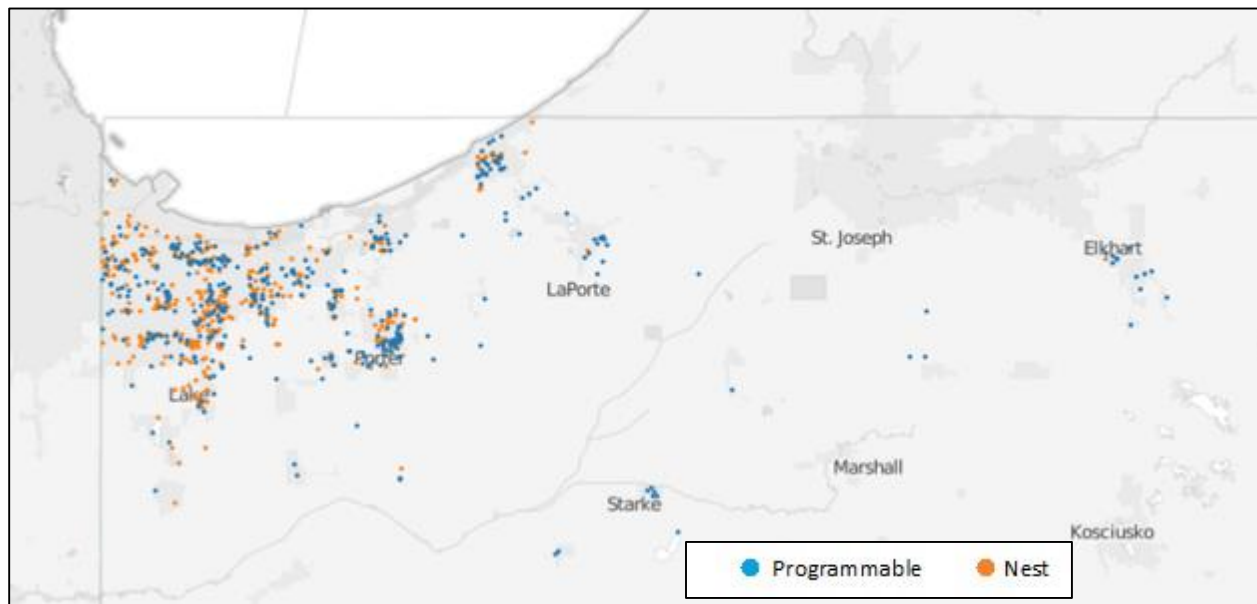
Activity	Group 1: Nest Thermostats	Group 2: Programmable Thermostats	Group 3: Control*
On-site data collection	Y	Y	N
Pre-installation survey	Y	Y	N
Metering ambient household space temperature	Y	Y	N
Metering air conditioner run time	Y	Y	N
Pre- and post-installation billing analysis	Y	Y	Y
Post-installation Survey	Y	Y	N

* This group allowed Cadmus to establish a base case for the billing analysis.

On-site Data Collection

Water and Energy Solutions, Inc. (WES) completed thermostat installations in 800 NIPSCO dual-fuel customer homes between June 28 and September 19, 2013, providing half the homes with a Nest thermostat and half with a standard programmable thermostat. Table 5 shows a map of the thermostat installation locations by thermostat type. WES followed the protocols outlined in Appendix B.

Table 5. Map of Completed Thermostat Installations for NIPSCO Thermostat Program



Pre-installation Survey

At the time of installation, WES used an iPad to survey customers about how they used their old thermostat and to collect demographic information. The survey is attached as Appendix A.



Space Temperature and Air Conditioner Run Time Metering

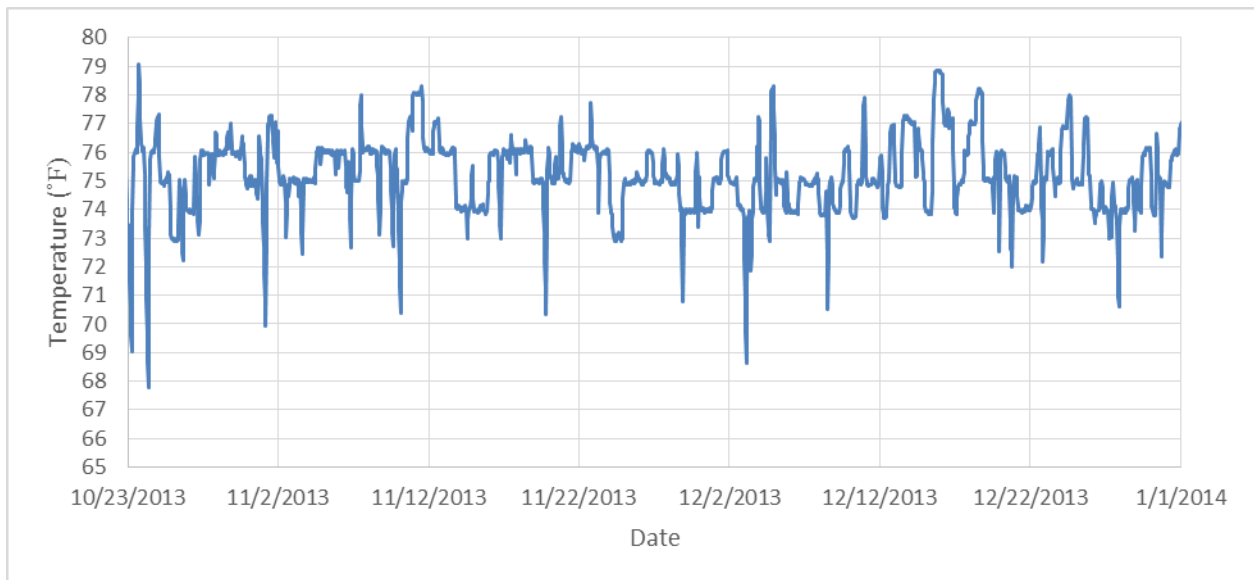
Cadmus collected space temperatures and air conditioner run times from approximately half the Nest and programmable thermostat homes. At the time of the thermostat installation, WES technicians installed an Onset UX100-003 logger next to each participant’s thermostat to record the space temperature every five minutes. WES also installed an Onset UX90-004 logger on each participant’s air conditioner condenser to record air conditioner run time.

WES installed indoor temperature meters and air conditioner run time meters in 437 (55%) of the homes:⁶ Two hundred forty of the Nest participants (60%) received meters and 197 of the programmable thermostat participants (49%) received meters.

Analysis of Participant Behavior

To understand how programmable thermostat participants actually used their thermostats, we assessed space temperature data for each participant who returned a temperature logger. We noted if the participant established a programmed schedule of setbacks or used the programmable thermostat as if it were a manual thermostat. Figure 3 and Figure 4 show example temperature data for two participants, one in each of the two behavior categories.

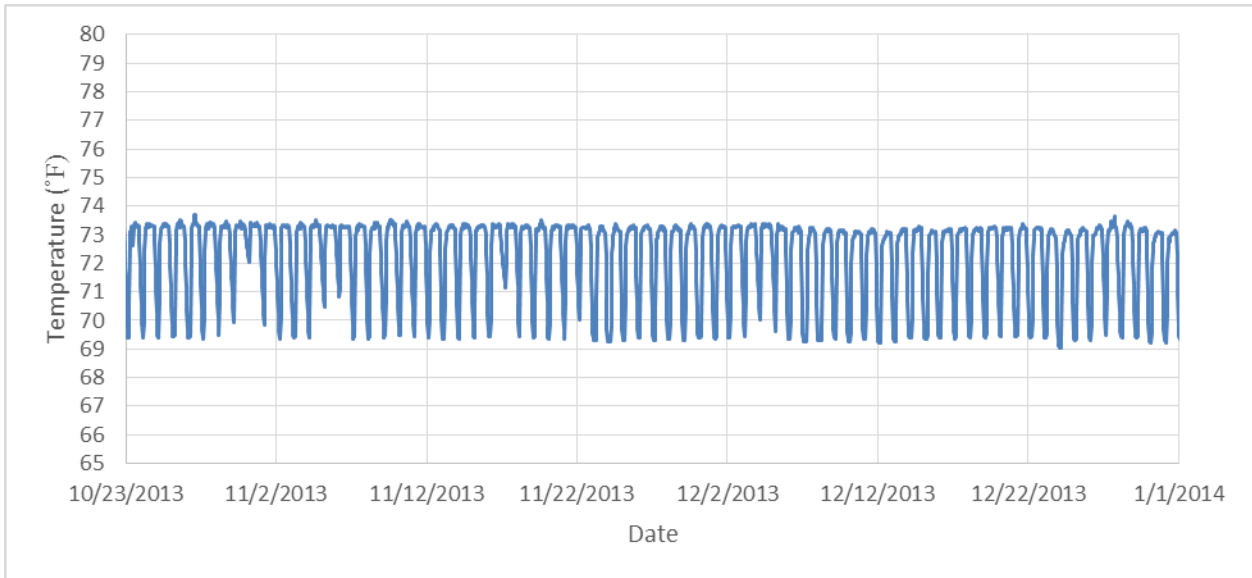
Figure 3. Temperature Data for a Participant with Irregular Settings



⁶ WES collected indoor temperature data so that Cadmus could review and categorize the behavior of participants, and collected air conditioner run time data so that Cadmus could investigate any anomalous findings in the billing analysis.



Figure 4. Temperature Data for a Participant with Programmed Settings



Pre/Post Billing Analysis

Cadmus provided NIPSCO with the names and addresses of the 800 program participants and 800 nonparticipants (control group) sampled from Energizing Indiana Home Energy Audit data. NIPSCO provided the data fields outlined in Table 6 for each customer’s gas and electric bills from June 2012 through September 2014.

Table 6. Requested Billing Data Fields

Field	Definition
Provided by Cadmus	
Customer name	Customer’s First and Last Names
Service street address	Street Address
Service city	City
Service zip code	Zip Code
Provided by NIPSCO	
Billing Account Number	Customer’s Billing Account Number
Premises/Location Number	Location Account Number (tied to the premises)
Billing Days	Number of Billing Days in Each Month
Usage	Monthly Usage (kwh or therms) for Each Month
Read Date	Date of Meter Reads in Each Month
Meter Read Code	Meter Read Code (indicates whether the meter reading was estimated or true)
Account Status	Indicates Active, Inactive, or Closed



We evaluated gas savings attributable to the program by conducting a billing analysis, following these steps:

1. Matched thermostat installation dates and customer information to the billing data;
2. Used participant zip codes to map to the nearest weather station;
3. Obtained daily average temperature weather data from June 2012 through September 2014 for seven National Oceanic and Atmospheric Administration weather stations, representing all participant zip codes;
4. Used daily temperatures to determine base 45-85 heating degree days (HDDs) and cooling degree days (CDDs) for each weather station; also mapped the typical meteorological year 3 (TMY3) normal heating and cooling degree days by zip code for each home;⁷ and
5. Matched billing data periods with the CDDs and HDDs from associated stations.

Pre- and Post-installation Period Definitions

WES installed thermostats for NIPSCO customers between late June 2013 and September 2013.

For participants, Cadmus defined the pre-installation period as before the installation of the new thermostat, and the post-installation period as after the installation of a new thermostat. For the control group (nonparticipants), Cadmus based the control group pre- and post-installation periods on the average installation dates of the participants. The average participant installation date was July 31, 2013.

Using the billing data from June 2012 through September 2014, Cadmus paired the pre- and post-installation months to ensure that we compared the same months before and after thermostat installation.⁸

Gas Billing Analysis Model

Cadmus estimated savings from each customer using a Princeton Scorekeeping Method (PRISM) specification using pre- and post-installation billing data for each customer in the Nest group, programmable thermostat group, and control group. These models provided weather-normalized pre- and post-installation annual usage for each participant and nonparticipant.

Through this regression model approach, we obtained estimates of energy savings for each group and each customer. For each participant and control home, Cadmus estimated heating-only PRISM models in both the pre- and post-installation periods to weather-normalize raw billing data. Each model allows the heating reference temperature to range from 45 degrees to 85 degrees.

⁷ Cadmus used the PRISM models to select the best base temperature for each home.

⁸ In order to obtain the most reliable estimate of pre-period normalized usage, Cadmus estimated a model using all 12 pre-installation period months.



The PRISM model specification we used is:

$$ADC_{it} = \alpha_i + \beta_1 HDD_{it} + \varepsilon_{it}$$

Where for each customer ‘i’ and month ‘t’:

- ADC_{it} = The average daily gas consumption in the pre- or post-installation program period
- α_i = The participant intercept representing the average daily base load
- β_1 = The model space heating slope
- HDD_{it} = The base 45-85 average daily HDDs for the specific location
- ε_{it} = The error term

From the above model, Cadmus computed weather-normalized annual consumption (NAC) for each heating reference temperature as follows:

$$NAC_i = \alpha_i * 365 + \beta_1 LRHDD_{it} + \varepsilon_{it}$$

Where:

- NAC_i = The normalized annual consumption
- α_i = An intercept representing the average daily base load for each participant
- $\alpha_i * 365$ = The annual base load consumption (non-weather sensitive)
- β_1 = The heating slope (usage per HDD from the model above)
- $LRHDD_{it}$ = Annual, long-term HDDs of a typical month year (TMY3) in the 1991–2005 series from the National Oceanic and Atmospheric Administration, based on home location
- $\beta_1 LRHDD_{it}$ = The weather-normalized, weather-sensitive annual heating usage, also known as HEATNAC
- ε_{it} = The error term

Cadmus screened and removed accounts that yielded negative heating NACs from the analysis. From the various models with correct signs on all of the parameters, we chose the best model of each participant’s pre- and post-installation periods based on that with the highest R-squared value.

Gas Data Screening

Cadmus screened and removed the following gas customers from the analysis:

- Customers with less than seven pre-installation paired months or less than seven post-installation paired months;
- Customers that yielded total NACs less than 200 therms;
- Customers that yielded negative heating NACs;
- Customer bills that contained outliers, vacancies, or equipment changes; and
- Customers whose post-installation survey responses indicated vacancies, changes in occupants, or equipment changes.

Table 7, Table 8, and Table 9 present the gas attrition levels for the Nest, programmable thermostat, and control group customers from the screening criteria above, respectively. For participants, the attrition was primarily due to insufficient paired billing data, removal of outliers, and surveys indicating changes, while the control group attrition was primarily due to insufficient paired billing data.

Table 7. Nest Thermostat Gas Account Attrition

Sample Screen	Remaining		Dropped from Sample	
	Participants	Percentage	Number	Percentage
Original Nest sample	400	100%	0	0%
Insufficient pre- and/or post-installation period data (less than seven pre- and six post-installation period months)	344	86%	56	14%
PRISM screens	344	86%	0	0%
Removal of outliers*	258	65%	86	22%
Surveys indicate changes	238	60%	20	5%
Final Nest Analysis Sample	238	60%	162	41%

* This entailed an account-level inspection of pre- and post-period usage data to assess vacancies, equipment changes, and other anomalies.



Table 8. Programmable Thermostat Gas Account Attrition

Sample Screen	Remaining		Dropped from Sample	
	Participants	Percentage	Number	Percentage
Original programmable thermostat sample	400	100%	0	0%
Insufficient pre- and/or post-installation period data (less than seven pre- and six post-installation period months)	318	80%	82	21%
PRISM screens	317	79%	1	0%
Removal of outliers*	239	60%	78	20%
Surveys indicate changes	217	54%	22	6%
Final Programmable Thermostat Analysis Sample	217	54%	183	46%

* This entailed an account-level inspection of pre- and post-period usage data to assess vacancies, equipment changes, and other anomalies.

Table 9. Control Group Thermostat Gas Account Attrition

Sample Screen	Remaining		Dropped from Sample	
	Participants	Percentage	Number	Percentage
Original Nonparticipant Sample	800	100%	0	0%
Insufficient pre- and/or post-installation period data (less than seven pre- and six post-installation period months)	574	72%	226	28%
PRISM screens	566	71%	8	1%
Removal of outliers*	469	59%	97	12%
Surveys Indicate Changes	469	59%	0	0%
Final Control Group Analysis Sample	469	59%	331	41%

* This entailed an account-level inspection of pre- and post-period usage data to assess vacancies, equipment changes, and other anomalies.

After the screening process was complete, the final gas analysis sample included 238 Nest thermostat participants (60%), 217 programmable thermostat participants (54%), and 469 control group customers (59%).



Electric Billing Analysis Model

Cadmus estimated savings from each customer using a PRIncton Scorekeeping Method (PRISM) specification using pre- and post-installation billing data for each customer in the Nest group, programmable thermostat group, and control group. These models provided weather-normalized pre- and post-installation annual usage for each participant and nonparticipant.

Through this regression model approach, we obtained estimates of energy savings for each group and each customer. For each participant and control home, we estimated heating-only PRISM models in both the pre- and post-installation periods to weather-normalize raw billing data. Each model allows the heating reference temperature to range from 45 degrees to 85 degrees and the cooling reference temperature to range from the heating reference temperature to 85 degrees.

The PRISM model specification we used is:

$$ADC_{it} = \alpha_i + \beta_1 HDD_{it} + \beta_2 CDD_{it} + \varepsilon_{it}$$

Where for each customer ‘i’ and month ‘t’:

ADC_{it}	=	The average daily electric consumption in the pre- or post-installation program period
α_i	=	The participant intercept representing the average daily base load
β_1	=	The model space heating slope
HDD_{it}	=	The base 45-85 average daily HDDs for the specific location
β_2	=	The model space cooling slope
HDD_{it}	=	The base 45-85 average daily CDDs for the specific location
ε_{it}	=	The error term

From the above model, we computed weather-normalized annual consumption (NAC) for each heating and cooling reference temperature as follows:

$$NAC_i = \alpha_i * 365 + \beta_1 LRHDD_{it} + \beta_2 LRCDD_{it} + \varepsilon_{it}$$

Where:

NAC_i	=	The normalized annual consumption
α_i	=	An intercept representing the average daily base load for each participant
$\alpha_i * 365$	=	The annual base load consumption (non-weather sensitive)
β_1	=	The heating slope (usage per HDD from the model above)
$LRHDD_{it}$	=	Annual, long-term HDDs of a typical month year (TMY3) in the 1991–2005 series from the National Oceanic and Atmospheric Administration, based on home location



- $\beta_1 LRHDD_{it}$ = The weather-normalized, weather-sensitive annual heating usage, also known as HEATNAC
- β_2 = The cooling slope (usage per CDD from the model above)
- $LRCDD_{it}$ = Annual, long-term CDDs of a typical month year (TMY3) in the 1991–2005 series from the National Oceanic and Atmospheric Administration, based on home location
- $\beta_2 LRCDD_{it}$ = The weather-normalized, weather-sensitive annual cooling usage, also known as COOLNAC
- ε_{it} = The error term

We screened and removed from the analysis any accounts that yielded negative cooling NACs and negative base load. If a model heating slope was negative, we estimated a cooling-only PRISM model. From the various models with correct signs on all of the parameters, we chose the best model of each participant’s pre- and post-installation periods based on the one with the highest R-squared value.

Electric Data Screening

Cadmus screened and removed the following electric customers from the analysis:

- Customers with less than seven pre-installation paired months or less than seven post-installation paired months;
- Customers that yielded cooling NACs less than 100 kWh;
- Customers that yielded negative base load NACs;
- Customer bills that contained outliers, vacancies, or equipment changes; and
- Customers whose post-installation survey responses indicated vacancies, changes in occupants, or equipment changes.

Table 10, Table 11 and Table 12 present the electric attrition levels for the Nest, programmable thermostat, and control group customers from the screening criteria above, respectively. For participants, the attrition was primarily due to insufficient paired billing data, removal of outliers, and survey data indicating changes, while the control group attrition was primarily due to insufficient paired billing data.



Table 10. Nest Thermostat Electric Account Attrition

Sample Screen	Remaining		Dropped from Sample	
	Participants	Percentage	Number	Percentage
Original Nest sample	400	100%	0	0%
Insufficient pre- and/or post-installation period data (less than seven pre- and six post-installation period months)	351	88%	49	12%
PRISM screens	347	87%	4	1%
Removal of outliers*	261	65%	86	22%
Surveys indicate changes	238	60%	23	6%
Final Nest Analysis Sample	238	60%	162	41%

* This entailed an account-level inspection of pre- and post-installation period usage data to assess vacancies, equipment changes, and other anomalies.

Table 11. Programmable Thermostat Electric Account Attrition

Sample Screen	Remaining		Dropped from Sample	
	Participants	Percentage	Number	Percentage
Original programmable thermostat sample	400	100%	0	0%
Insufficient pre- and/or post-installation period data (less than seven pre- and six post-installation period months)	332	83%	68	17%
PRISM screens	319	80%	13	3%
Removal of outliers*	238	60%	81	20%
Surveys indicate changes	212	53%	26	7%
Final Programmable Thermostat Analysis Sample	212	53%	188	47%

* This entailed an account-level inspection of pre- and post-installation period usage data to assess vacancies, equipment changes, and other anomalies.

Table 12. Control Group Thermostat Electric Account Attrition

Sample Screen	Remaining		Dropped from Sample	
	Participants	Percentage	Number	Percentage
Original Nonparticipant Sample	800	100%	0	0%
Insufficient pre- and/or post-installation period data (less than seven pre- and six post-installation period months)	613	77%	187	23%
PRISM screens	584	73%	29	4%
Removal of outliers*	522	65%	62	8%
Surveys Indicate Changes	522	65%	0	0%
Final Control Group Analysis Sample	522	65%	278	35%

* This entailed an account-level inspection of pre- and post-period usage data to assess vacancies, equipment changes, and other anomalies.



After the screening process was complete, the final electric analysis sample included 238 Nest thermostat participants (60%), 212 programmable thermostat participants (53%), and 522 control group customers (65%).

Model-Specific Evaluated Savings (Average Participant)

Since the control group pre-installation period usage was not identical to the participant pre-installation usage, Cadmus used a percentage of pre-installation usage approach to obtain adjusted gross participant savings (via the following formula):

$$Adj. \text{ Gross Savings} = \text{Participant Pre Usage} \left(\frac{\text{Change In Participant Usage}}{\text{Participant Pre Usage}} - \frac{\text{Change in Control Group Usage}}{\text{Control Group Pre Usage}} \right)$$

Through this process, we obtained the percentage reduction of energy use in both the participant groups and the control group (specifically, we determined savings as a percentage of Pre-NAC, PREHEATNAC, or PRECOOLNAC).⁹ Then, we calculated the percentage reduction as the change in participant usage minus the change in control group usage. Multiplying this adjusted gross percentage reduction by the participant pre-installation period usage, we obtained the adjusted gross participant savings, effectively accounting for any differences in pre-installation period heating usage between participants and the control group.

Post-installation Survey

In July 2014, Cadmus distributed a post-installation survey by mail to collect information on participants’ behaviors and satisfaction with their new thermostat. This survey screened out any customers who added equipment, changed equipment, or showed prolonged vacancies. The survey is attached as Appendix C.

⁹ For gas savings, this method was applied both in terms of total usage (NAC) and total heating usage (HEATNAC). For electric savings, this method was applied in terms of cooling usage (COOLNAC).



Results

Response Rates

In July 2014, Cadmus mailed customer surveys to all 800 NIPSCO program participants. We also sent instructions to the 437 participants who received loggers on how to remove and mail back their loggers. Table 13 shows the logger and survey return rates as of October 31, 2014.

Table 13. Logger and Survey Return Rates (as of October 31, 2014)

Returned Item	Count	Response Rate
Temperature Logger	261	60%*
Run time Logger	228	52%*
Surveys	346	43%**

*Return rate as percentage of participants who received loggers (437 participants)

**Return rate as percentage of participants who received surveys (all 800 participants)

Of the participants who received loggers, 60% returned the temperature loggers and 52% returned the run time loggers. These response rates are lower than expected and may be due to the length of the study period. Because the loggers were in place for almost one year, participants may not have felt as responsible for returning them as they may have felt in a shorter study. To increase response rates, we mailed a letter to participants in September, reminding them to return the loggers. After participants received the letters, we called them to see if they received the letter and offered to explain how to remove the loggers.

Cadmus received mail-in surveys back from 43% of participants. This response rate is higher than expected. Mail-in surveys typically yield response rates of 10-15%.

Energy Savings

Results of Gas Billing Analysis: Model-Specific Evaluated Savings (Average Participant)

Table 14 shows the participant and control group changes in heating gas usage by thermostat type.



Table 14. 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%

The control group increased its gas usage for heating by approximately 4%, which may be attributable to a 13% increase in HDDs from the pre to the post-installation period. Cadmus applied the adjusted gross savings formula to determine the difference in these percentage savings. For participants, the Nest thermostats achieved adjusted average gross savings of 106 therms, with a pre-installation period usage of 793 therms. This represents a 13.4% reduction of pre-installation period gas usage for heating. The programmable thermostats achieved adjusted gross savings of 57 therms, with a pre-installation period usage of 739 therms. This represents a 7.8% reduction in pre-installation period gas usage for heating.

Cadmus also evaluated gas savings as a percentage of pre-installation period total gas usage (Table 15).

Table 15. Gas Savings as Percentage of Total Gas Usage

Thermostat Group	Group	Sample Size	Pre Usage (therms)	Savings (therms)	Savings (%)	Range of Savings (therms)	Range of Savings (%)
Nest	Participant	238	1004	77	7.7%	59 to 95	6 to 9%
	Control	469	1017	-30	-3.0%	-19 to -41	-2 to -4%
	Adjusted Gross	238	1004	106	10.6%	86 to 128	9 to 13%
Programmable	Participant	217	899	30	3.3%	19 to 41	2 to 5%
	Control	469	1017	-30	-3.0%	-19 to -41	-2 to -4%
	Adjusted Gross	217	899	57	6.3%	41 to 72	5 to 8%

Of the total gas usage, the Nest thermostats saved 10.6% and the programmable thermostats saved 6.3%.

Results of Electric Billing Analysis: Model-Specific Evaluated Savings (Average Participant)

Table 16 shows the participant and control group changes in electric usage by thermostat type.



Table 16. 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%

The control group increased cooling electric usage by 15.5%. The number of CDDs decreased 7.5%, so this increase in cooling electric usage is due to other behavioral trends in usage. Cadmus applied the adjusted gross savings formula to determine the difference in these percentage savings. For participants, the Nest thermostats achieved adjusted average gross savings of 388 kWh, with a pre-installation period cooling usage of 2,401 kWh. This represents a 16.1% reduction of pre-installation period usage. The programmable thermostats achieved adjusted gross savings of 303 kWh, with a pre-installation period usage of 2,021 kWh. This represents a 15.0% reduction of pre-installation period usage.

Cadmus also compared electric savings as a percentage of total pre-period electric usage (Table 17).

Table 17. Electric Savings as Percentage of Total Electric Usage

Group	Total Pre-Usage (kWh)	% Cooling	Savings (%)	Average SQFT
Control	9,529	20%	N/A	1,729
Nest	9,896	24%	3.9%	1,656
Programmable	8,574	24%	3.9%	1,510

Of total electric usage, both the Nest and programmable thermostats saved 3.9%. Overall, the Nest thermostats are saving approximately the same as the programmable thermostats, both in terms of percentage of cooling electric usage and percentage of total electric usage.

Benchmarking

Table 18 shows a comparison of the gas savings results of this evaluation compared with those from other Cadmus thermostat evaluations using pre/post billing analysis methods.



Table 18. Summary of Cadmus Thermostat Gas Savings Study Results*

Date	Location	T-stat Type	Original Sample Size	Control Group	Evaluated Sample Size	Attrition Rate	Savings per Participant (Therms)	Savings per Participant (%)	Precision at 90% Confidence
July 2011	Indiana	Programmable	68	N/A	61	10%	37	N/A	±21%
July 2011	Indiana	Programmable	283	N/A	255	10%	43	N/A	±21%
July 2011	Indiana	Programmable	371	N/A	334	10%	35	N/A	±21%
September 2012	Massachusetts	Ecobee Wi-Fi	86	N/A	43	50%	86	11%	±31%
July 2013	New Hampshire	Venstar ColorTouch T5800	29	N/A	23	21%	69	8%	±20%
September 2014	Indiana	Nest	400	800	238	41%	106	11%	±20%
September 2014	Indiana	Programmable	400	800	217	46%	57	6%	±27%

*Percentages show gas savings as a percentage of total gas usage

Participant Temperature Settings and Behavior

Cadmus used participant survey responses and space temperature logger data to understand how participants set their thermostats.

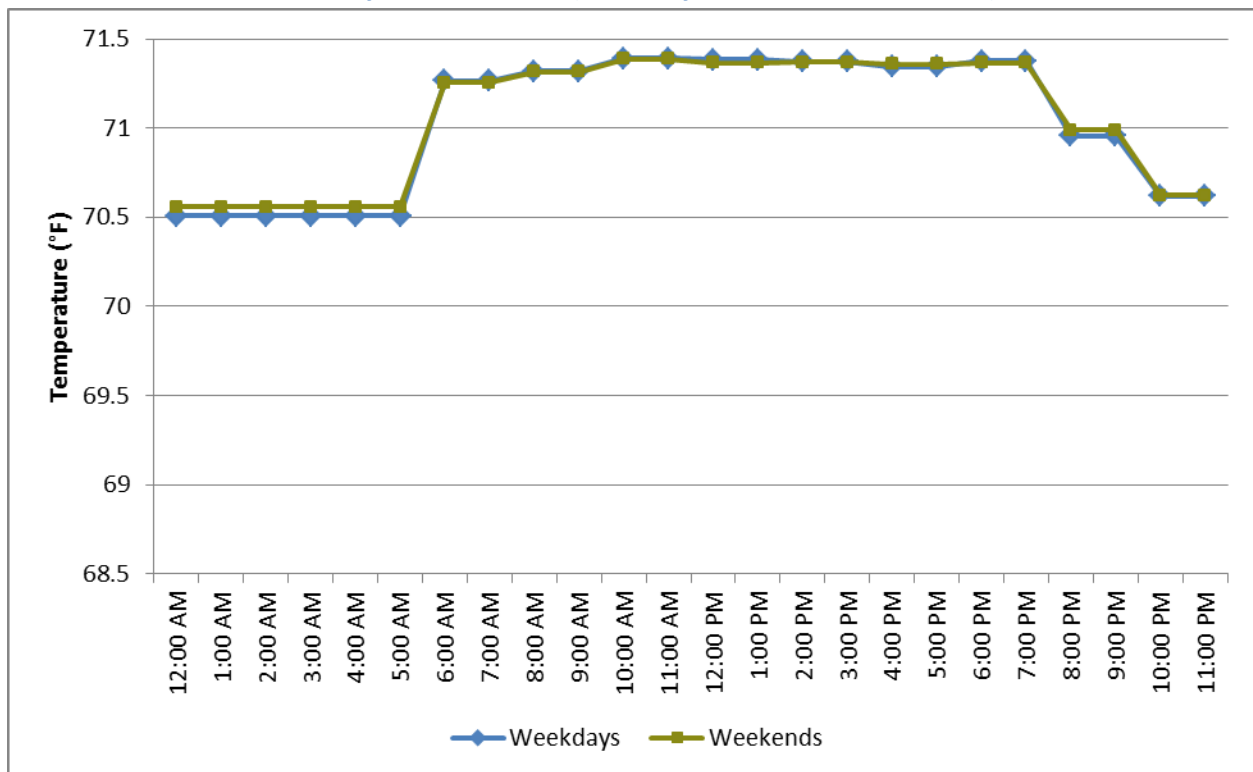
Pre-Installation Period

This section describes the results of Cadmus' temperature setting analysis and participant behavior analysis during the pre-installation period.

Temperature Settings

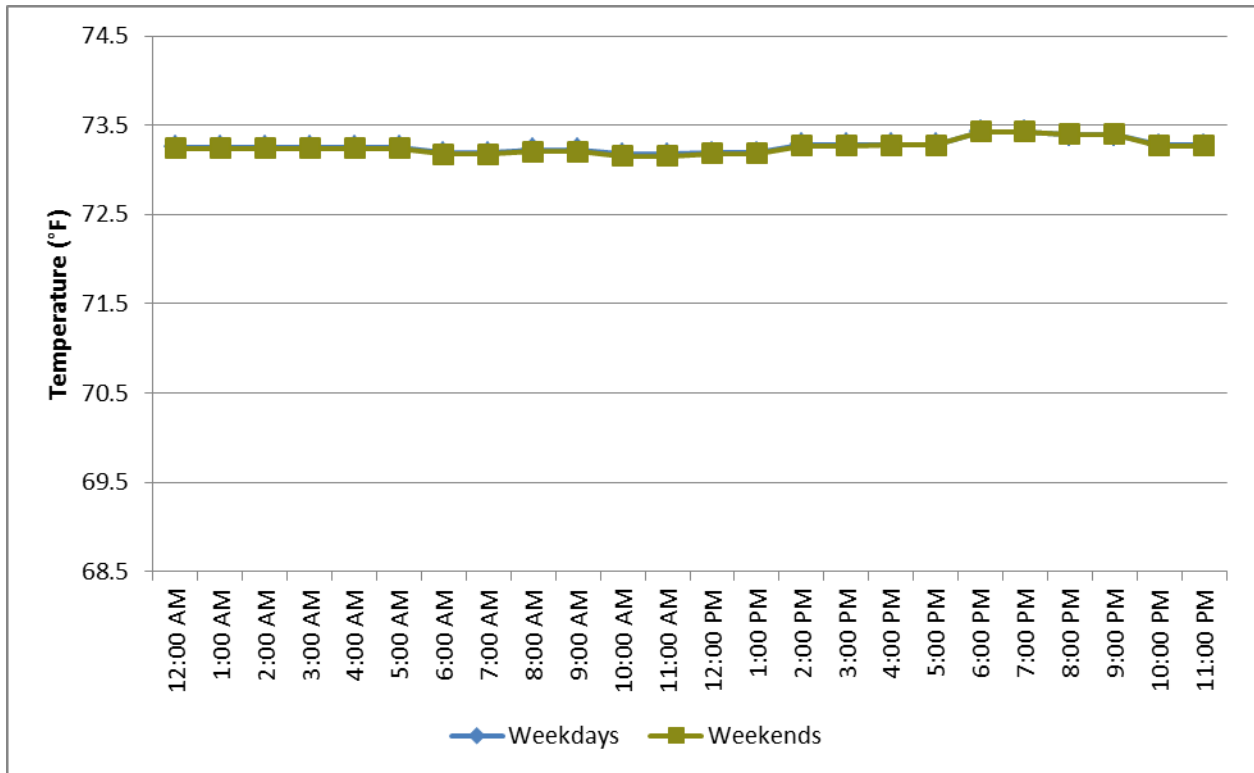
Cadmus used participant responses from the pre-installation customer surveys to assess heating and cooling setpoints by hour and by day of the week in the pre-installation period. These setpoints were reported by participants; we did not verify or measure these numbers. Figure 5 shows the weekday and weekend heating setpoints reported by participants. Figure 6 shows the weekday and weekend cooling setpoints reported by participants.

Figure 5. Self-reported Pre-installation Heating Setpoints Using Manual Thermostat
Weekdays vs. Weekends (Weekday n=743; Weekend n=710)





**Figure 6. Self-reported Pre-installation Cooling Setpoints Using Manual Thermostat
Weekdays vs. Weekend (Weekday n=636; Weekend n=631)**



Seven hundred forty-three program participants (93%) reported their baseline weekday heating setpoints and 710 program participants (89%) reported their baseline weekend heating setpoints. From 6:00 a.m. to 7:00 p.m., the average heating setpoint was reported to be approximately 71.4 degrees on both weekdays and weekends. The average reported heating setpoint decreased approximately 0.8 degrees to 70.6 degrees between 10:00 p.m. and 5:00 a.m., indicating a popular timeframe for participants to use setbacks.

Six hundred thirty-six program participants (80%) reported their baseline weekday cooling setpoints and 631 program participants (79%) reported their baseline weekend cooling setpoints. On weekdays and weekends, the reported cooling season temperature settings were within 0.02 degrees for each hour of the day. For both weekdays and weekends, the average reported setpoint is 73.3 degrees. Based on participant responses, there is no period of the day or week where there is a significant setback.

Participant Behavior

Cadmus assessed the baseline behaviors of the participants based on their survey responses (Table 19).



Table 19. Self-reported Pre-installation Behavior Using Manual Thermostat

Behavior	Count	Percentage
I manually change the thermostat settings using a regular daily schedule	291	42%
I manually change the thermostat settings using no set schedule (depending on weather and/or home activity)	272	40%
I use a single setpoint throughout each season (winter, spring, summer, fall)	124	18%
Total	687	100%

Six hundred eighty-seven (86%) of the program participants reported how they controlled their manual thermostats prior to participating in the program. The majority of participants (82%) reported manually changing their temperature settings. These participants were divided approximately in half on how they manually adjusted their settings. Fifty-two percent (42% of total) reported manually changing the thermostat settings using a regular daily schedule. Forty-eight percent (40% of total) reported manually changing the thermostat settings using no set schedule. The remaining participants (18%) reported using a single setpoint.

Cadmus compared these survey responses to research we completed for another client in 2013. The results are summarized in Table 20.

Table 20. Comparison of Self-reported Behavior between NIPSCO Study and 2013 Cadmus Study*

Behavior	Manual Thermostats (2013 Cadmus Study)	Manual Thermostats (2013-2014 NIPSCO Nest Evaluation)
Regular Scheduled Setpoints	48%	42%
Manual With Changing Setpoints	36%	40%
Constant Setpoint	16%	18%

The behavior of NIPSCO program participants does not differ much from the behavior of the participants in the 2013 study. NIPSCO program participants control their thermostats with a regular schedule slightly less frequently and use changing setpoints or a single setpoint slightly more frequently.

Post-Installation Period

This section describes the results of Cadmus’ space temperature, air conditioner run time, and participant behavior analysis for the post-installation period.

Temperature Settings in Heating Season

Two hundred sixty-one program participants (60%) returned their temperature loggers as of October 31, 2014. Cadmus used logger data to evaluate the average heating season home temperatures by hour and by day of the week for the programmable thermostat and Nest treatment groups. Figure 7 and Figure 8 show average indoor temperature in the heating season for programmable thermostats and Nest, respectively.



Figure 7. Average Hourly Metered Indoor Temperature During Heating Season for Programmable Thermostats (n=261)

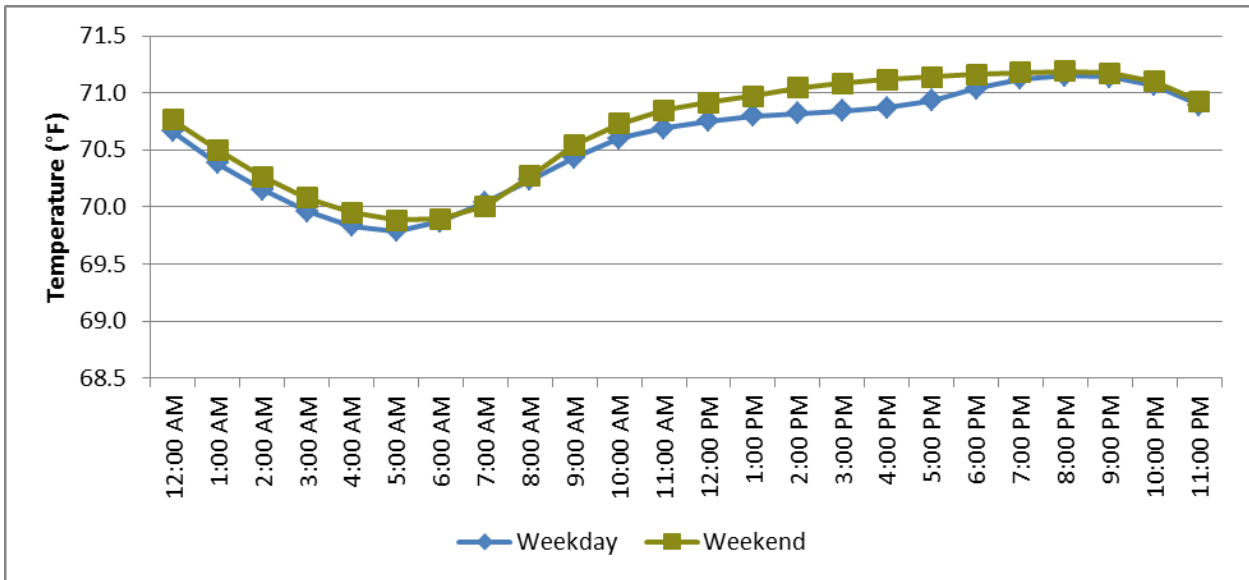
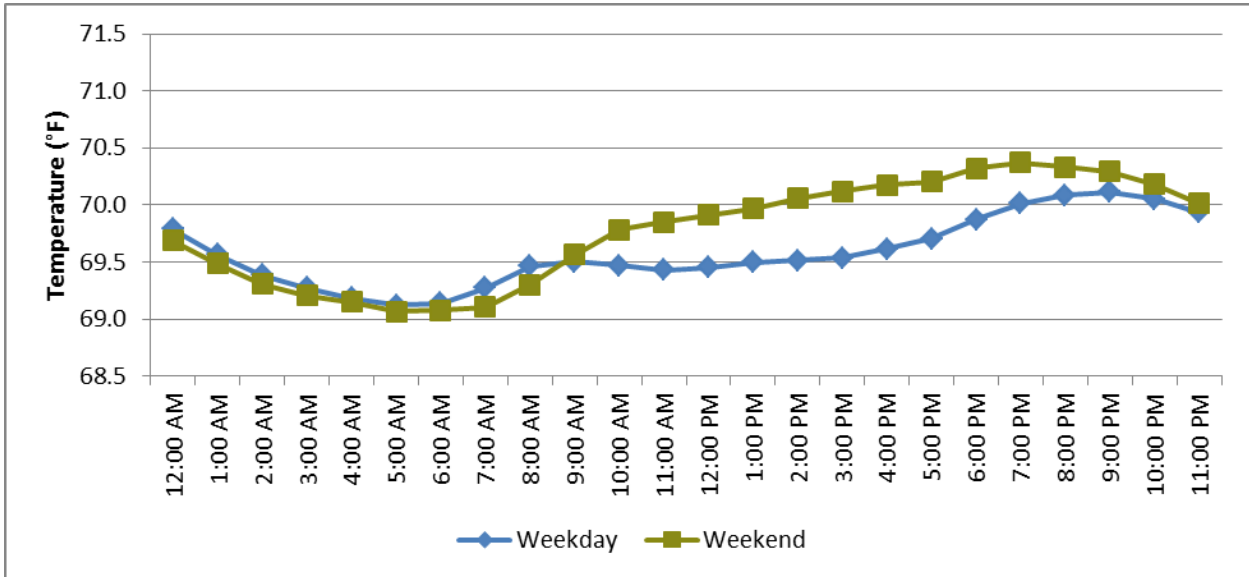


Figure 8. Average Hourly Metered Indoor Temperature During Heating Season for Nest Thermostats (n=261)



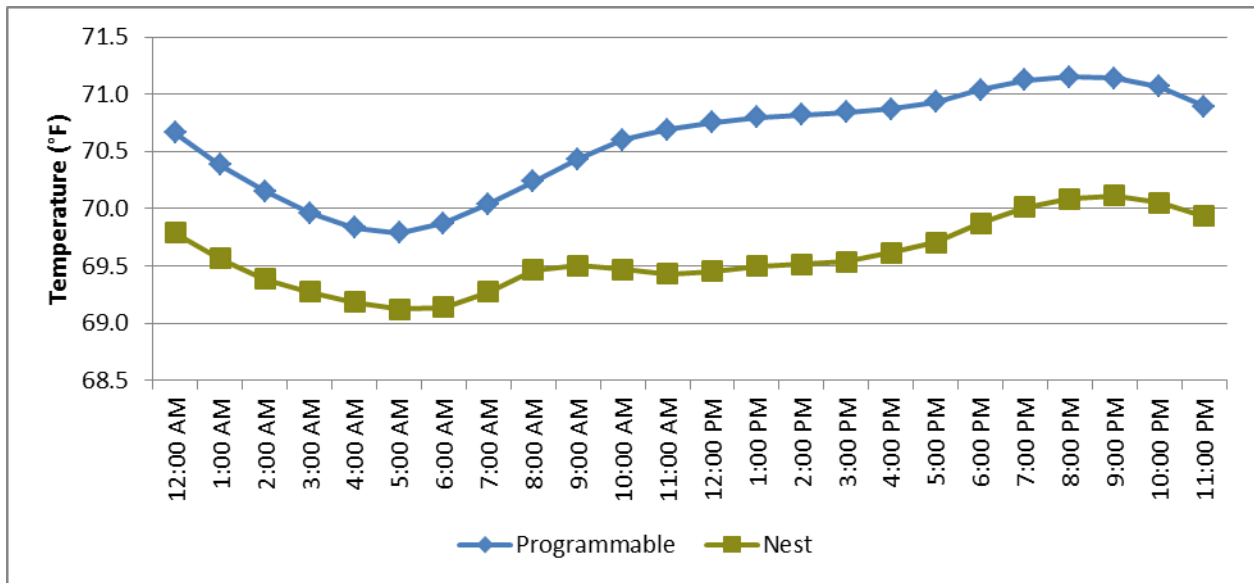
Programmable thermostat users have similar indoor temperatures for weekdays and weekends, while Nest users appear to have a slight reduction in temperature from 10:00 a.m. to 11:00 p.m. on weekdays. During this period, the temperature in Nest homes is on average 0.4 degrees cooler on weekdays than on weekends. Because this is a common time period for homes to be unoccupied, we assume this is attributable to either the Nest’s Auto-Away feature, which automatically triggers a setback when it



senses the home is unoccupied, or its Auto-Schedule feature, which uses data on how participants manually set their thermostat to automatically program a schedule of setbacks.

Figure 9 and Figure 10 show a comparison of programmable thermostat and Nest participant indoor temperatures on weekdays and weekends, respectively.

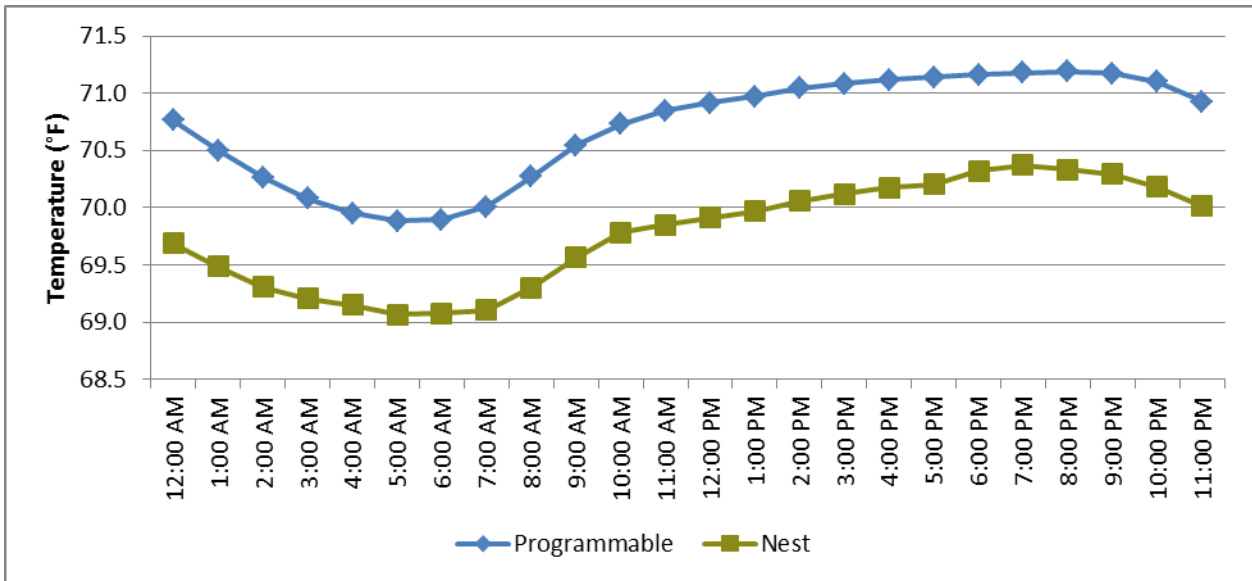
Figure 9. Average Hourly Metered Indoor Temperature on Weekdays During Heating Season (n=261)



During all hours, the average hourly temperature on weekdays in Nest homes is less than in programmable thermostat homes. The difference in average hourly temperature ranges from 0.6 degrees to 1.3 degrees. The greatest temperature difference between programmable and Nest thermostat homes on weekdays is during the period from 10:00 a.m. to 11:00 p.m., when the average difference is 1.2 degrees. These data suggest the Nest thermostat used the Auto-Away feature or Auto-Schedule feature to implement setbacks during daytime hours when many participants were away from home.



Figure 10. Average Hourly Metered Indoor Temperature on Weekends During Heating Season (n=261)



Like on weekdays, the average hourly temperature on weekends in Nest homes is less than in programmable thermostat homes for all hours. The difference in average hourly temperature is, however, more consistent throughout the day than it is on weekdays. The average hourly temperature difference ranges from 0.8 degrees to 1.1 degrees throughout the day. On average, the temperature difference is 0.9 degrees.

Figure 11 and Figure 12 compare the metered weekday and weekend temperature settings, respectively, of programmable thermostat and Nest thermostat participants to the baseline setpoints they reported using with their manual thermostats.



Figure 11. Self-reported Setpoints for Manual Thermostats Compared to Metered Indoor Temperatures for Programmable and Nest Thermostats (Weekdays)

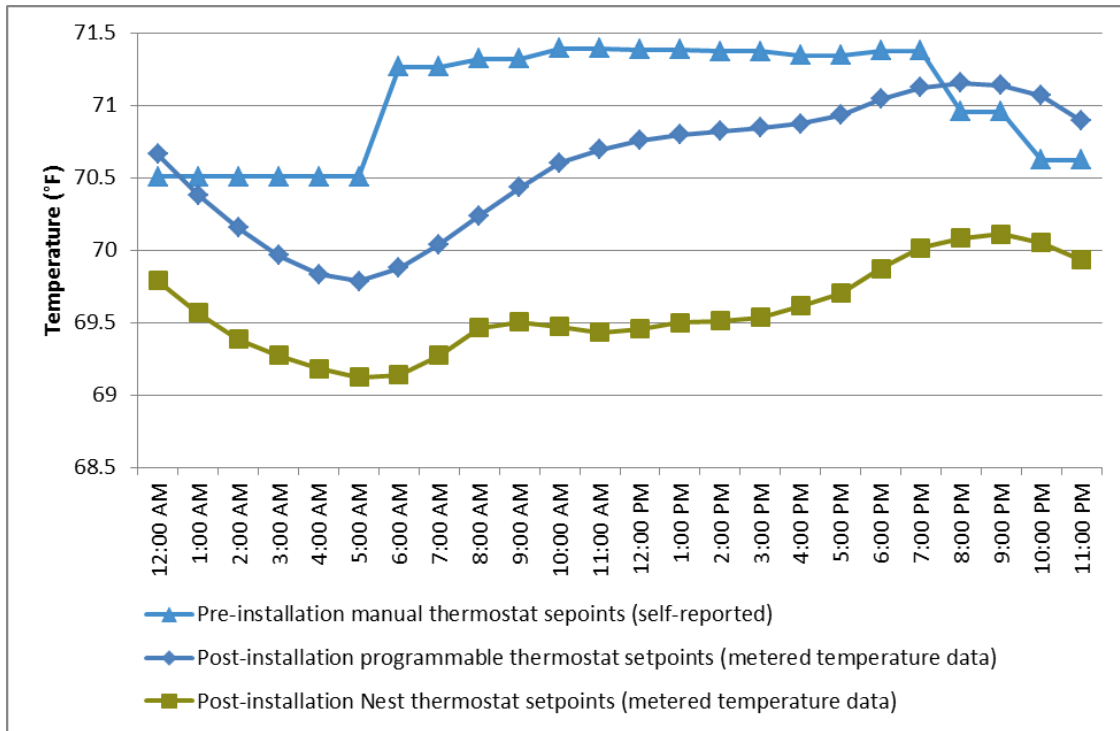
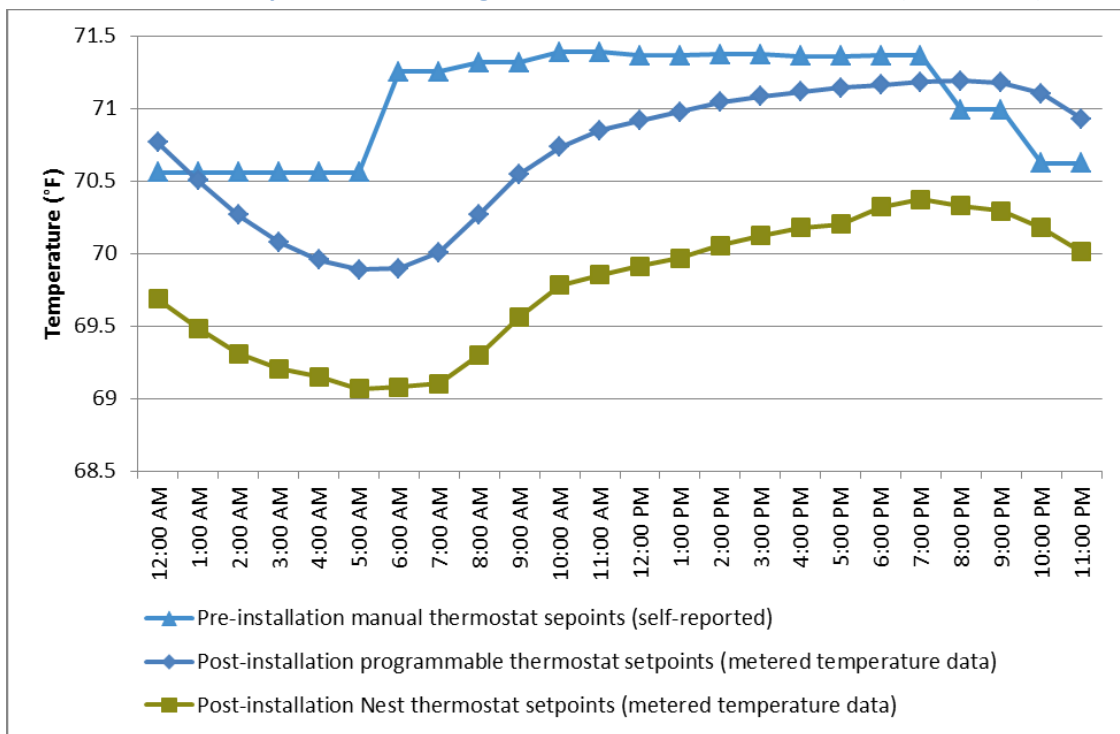


Figure 12. Self-reported Setpoints for Manual Thermostats Compared to Metered Indoor Temperatures for Programmable and Nest Thermostats (Weekends)





Compared to participants' self-reported baseline heating setpoints, participants with Nest and programmable thermostats had lower indoor temperatures during the heating season, with the Nest participants having the lowest temperatures. Homes with Nest thermostats maintained temperatures at least 0.6 degrees lower than homes with programmable thermostats, and up to 1.3 degrees lower. Homes with Nest thermostats had the largest difference in temperature compared to programmable thermostats between the hours of 10:00 AM and 8:00 PM on weekdays, when the average hourly temperature was 1.2 degrees lower than homes with a programmable thermostat. We assume this is attributable either to Nest's Auto-Away feature, which automatically triggers a setback when it senses the home is unoccupied, or its Auto-Schedule feature, which uses data on how participants manually set their thermostat to automatically program a schedule of setbacks. On average, the homes with Nest thermostats had indoor temperatures one degree lower than the homes with the programmable thermostats.

Air Conditioner Run Time in Cooling Season

Cadmus used participant air conditioner run time logger data to understand how participants used their air conditioners. Figure 13 and Figure 14 show the average hourly metered air conditioner run time on weekdays and weekends, respectively.

Figure 13. Average Hourly Metered Air Conditioner Run Time During Cooling Season on Weekdays (n=228)

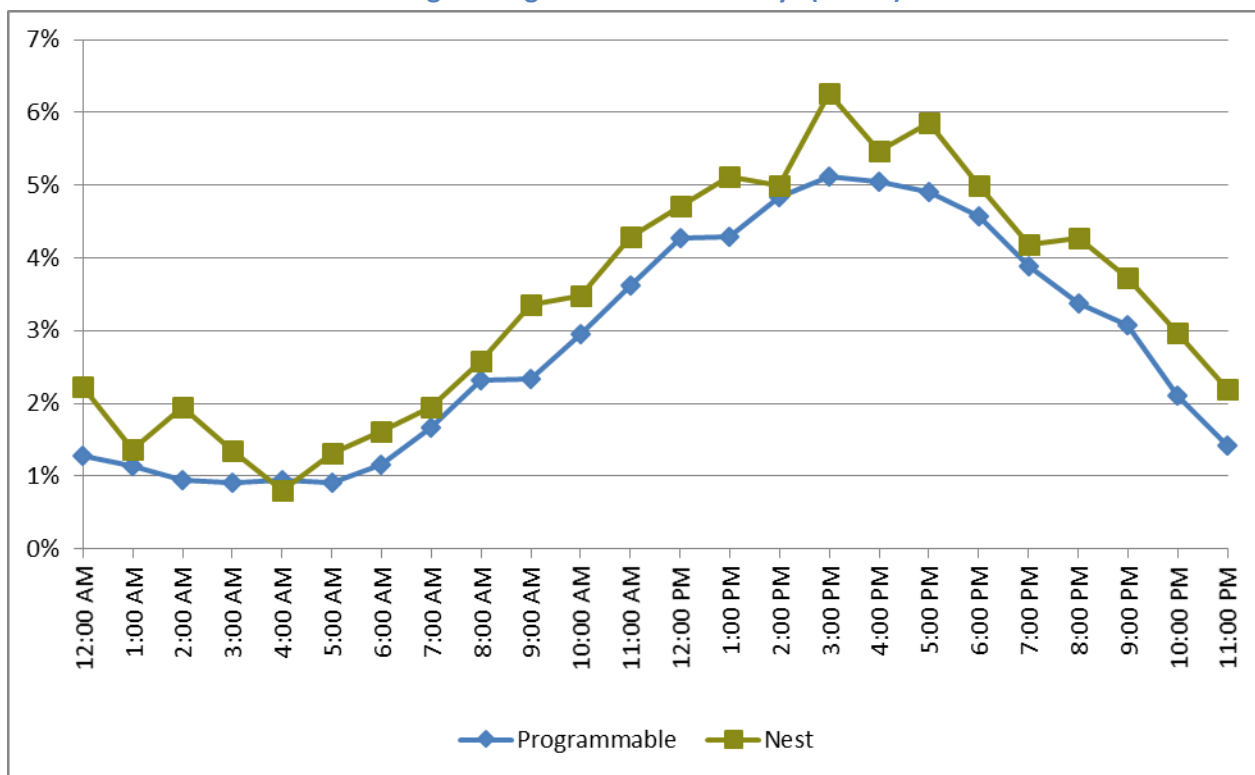
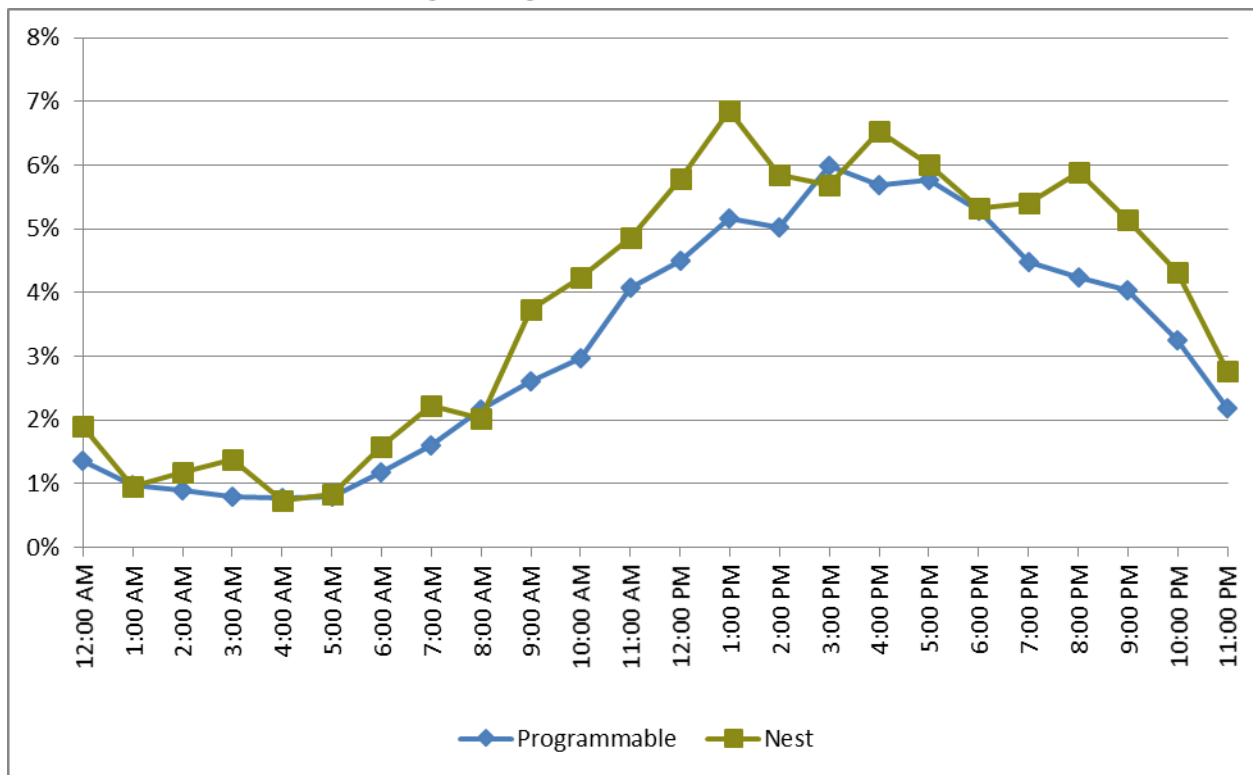




Figure 14. Average Hourly Metered Air Conditioner Run Time During Cooling Season on Weekends (n=228)



On weekdays and weekends, homes with the Nest thermostat had slightly higher air conditioner run times compared to programmable thermostat homes (3.4% compared to 2.8% on weekdays and 3.8% compared to 3.4% on weekends). The overall average run time was 3.4% in Nest homes and 2.8% in programmable thermostat homes. The higher run times in Nest homes is expected because the Nest participant group had a 19% higher pre-installation cooling electric usage. We assume the higher pre-installation usage in the Nest participant group is attributable to the Nest participant homes having higher occupancy (and thus higher cooling loads) compared to programmable thermostat homes (see occupancy data in Demographics section).

Participant Behavior

Participant behavior is a primary driving factor for achieving energy savings with thermostats. To assess participant behavior among programmable thermostat users, Cadmus evaluated how participants operated their thermostats using their survey data and metered indoor temperature data. To assess behavior among Nest participants, we evaluated participant engagement with the thermostat by looking at Wi-Fi connectivity.

Programmable Thermostat Operation

Cadmus categorized the programmable thermostat participants' post-installation behaviors based on their survey responses and space temperature data. Table 21 shows programmable thermostat participant behavior based on their survey responses.



Table 21. Self-Reported Programmable Thermostat Participant Behavior (Based on Survey Responses)

Participant Behavior	Manual (Baseline) (n=642)	Programmable (n=340)
I manually change the thermostat settings	83%	61%
I use a single setpoint	17%	18%
I rely on my thermostat to change	N/A*	21%
Total	100%	100%

*Manual thermostat users cannot rely on their thermostat to change because they cannot program schedules.

Compared to the baseline (pre-installation) case, approximately the same percentage of programmable thermostat participants reported using a single setpoint (17% and 18%, respectively). Based on participant responses, programmable thermostats converted approximately one-fifth of participants from manually adjusting their thermostat to programming their thermostat.

Table 22 shows participants' categorized behavior based on temperature data compared to their survey responses for programmable thermostat users.

Table 22. Programmable Thermostat Behavior (Based on Metered Temperature Data)

Assumed Thermostat Setting	Survey Responses (n=163)	Temperature Logger Data (n=110)
Rely on Thermostat Program	21%	33%
Override Thermostat Program	79%	61%
Cannot Determine	N/A	6%
Total	100%	100%

After comparing the results of the temperature data analysis and survey responses, we found that programmable thermostat participants appear to rely on their thermostat program more than they reported. Participants appear to operate their thermostat using a programmed schedule 12 percentage points more than they reported. This may be because some participants manually adjusted their thermostat with regular setbacks, making their temperature setting profile appear like a programmed schedule. Overall, the majority of participants appear to prefer to control their thermostat manually rather than rely on a programmed schedule.

Nest Participant Engagement

Cadmus also assessed Nest participants' engagement with their thermostat using data provided by Nest Labs. Table 23 shows the level of customer engagement of program participants with Nest thermostats compared to the general (nonparticipant) population of Nest users in Indiana who ordered a thermostat from nest.com.



Table 23. Customer Engagement of Program Nest Population Compared to Indiana Nest Population*

Population of Nest Users	Nests Shipped	Nests Connected**	Nests Connected (%)	Nests Registered***	Nests Registered (% of Connected)	Nests Registered (% of Total)
Program	400	329	82.3%	159	48.3%	39.8%
Indiana****	N/A	N/A	95.3%	N/A	90.0%	85.8%

*Data provided by Nest Labs

**Connected thermostats include all Nests that were ever connected to the internet

***Registered Nests include all Nests that were "paired" to a structure, which occurs when the customer sets up an account so they can use the app, web account, etc.

**** The Indiana Nest population "connected" rate is based on Indiana orders from nest.com. The "registered" rate is based on all Indiana connected devices.

Program participants with the Nest thermostat were less likely to connect their thermostat to the internet and register their Nest compared to the general population of Nest users in Indiana who ordered a thermostat from nest.com. Eighty-two percent of program participants connected their Nest thermostat to the internet, whereas 95% of general Nest users in Indiana (nonparticipants) connected their thermostats to the internet. Readers should note that we would expect users who use the internet to order a thermostat from nest.com to be more likely to connect their thermostat to the internet.

Although the Nest’s Auto-Schedule and Auto-Away features work without an internet connection, there are several features participants cannot use without an internet connection: the Nest’s HVAC control algorithms cannot receive the latest updates, participants cannot control their thermostat remotely using a smartphone, tablet or computer, and participants cannot receive the monthly e-mailed energy reports. Because participants who did not connect their Nest could not use these features, the program population might have less potential for energy savings than the general population of Indiana residents who purchased a Nest thermostat outside of the program. Readers should note, however, that Cadmus did not evaluate the impact of algorithm updates, remote control, or monthly energy reports on participant energy use.

Of the participants who did connect their thermostats to the internet, 48% of program participants registered their thermostats compared to 90% of users in Indiana with internet-connected Nests. The low percentage of registered Nests among program participants could indicate that they were less engaged with their thermostats than the general population of Nest users in Indiana. The reason for this disparity in engagement might be because the program was designed to offer the Nest for free; customers were not necessarily motivated to engage with their Nest on their own. The low level of engagement in registering the thermostat could be an indicator of low levels of engagement in using Nest’s features (such as the remote control and energy reports) and could consequently be an indicator of lower potential for energy savings compared to registered thermostats. A program designed to offer incented thermostats, rather than free thermostats, could attract customers who are more likely to be engaged with their thermostat and consequently increase energy savings potential.



Participant Demographics and Satisfaction Ratings

Cadmus used participant surveys to collect demographic and satisfaction ratings from program participants. This section assesses the differences in demographics between the programmable and Nest thermostat groups and how these might have caused the observed differences in energy savings and indoor temperatures. Evaluated demographics include participant age, occupancy, household income, and home age.

Demographics

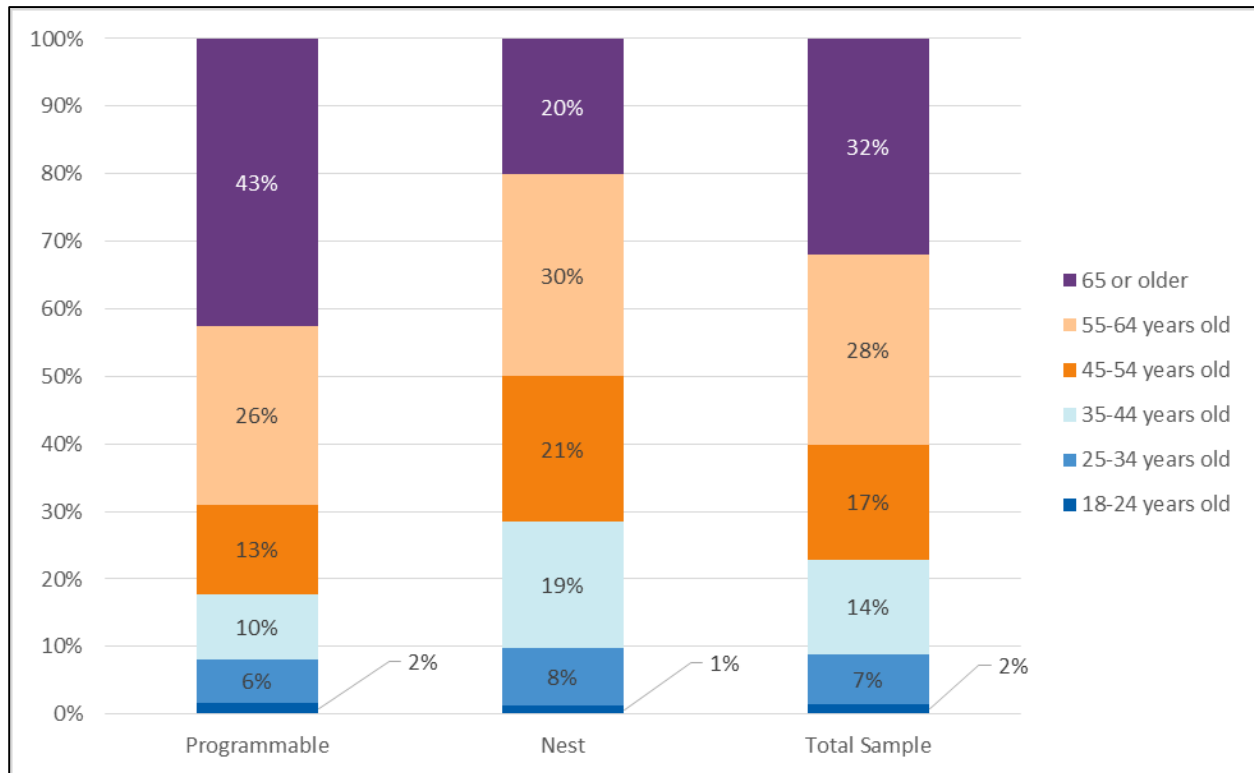
Cadmus used the pre-installation survey to assess the demographics of the participant population.

Participant Age

Of the 675 participants who responded to the pre-installation survey, 383 (57%) provided their age. Figure 15 shows the ages of participants as reported in the participant surveys.

Figure 15. Age of Participant Population by Participant Group

(n_{programmable}=174, n_{nest}=154, n_{total}=328)



Of the participants who reported their age, more than half the total sample (60%) is over 55 years of age, with 32% over the age of 65. Based on the survey responses, the programmable thermostat group had more than twice the participants over age 65 compared to the Nest thermostat group (43% compared to 20%). Participants over the age of 65 are more likely to be retired and home on weekdays. Assuming this is true for the sample, the potential for energy savings from weekday daytime setbacks is



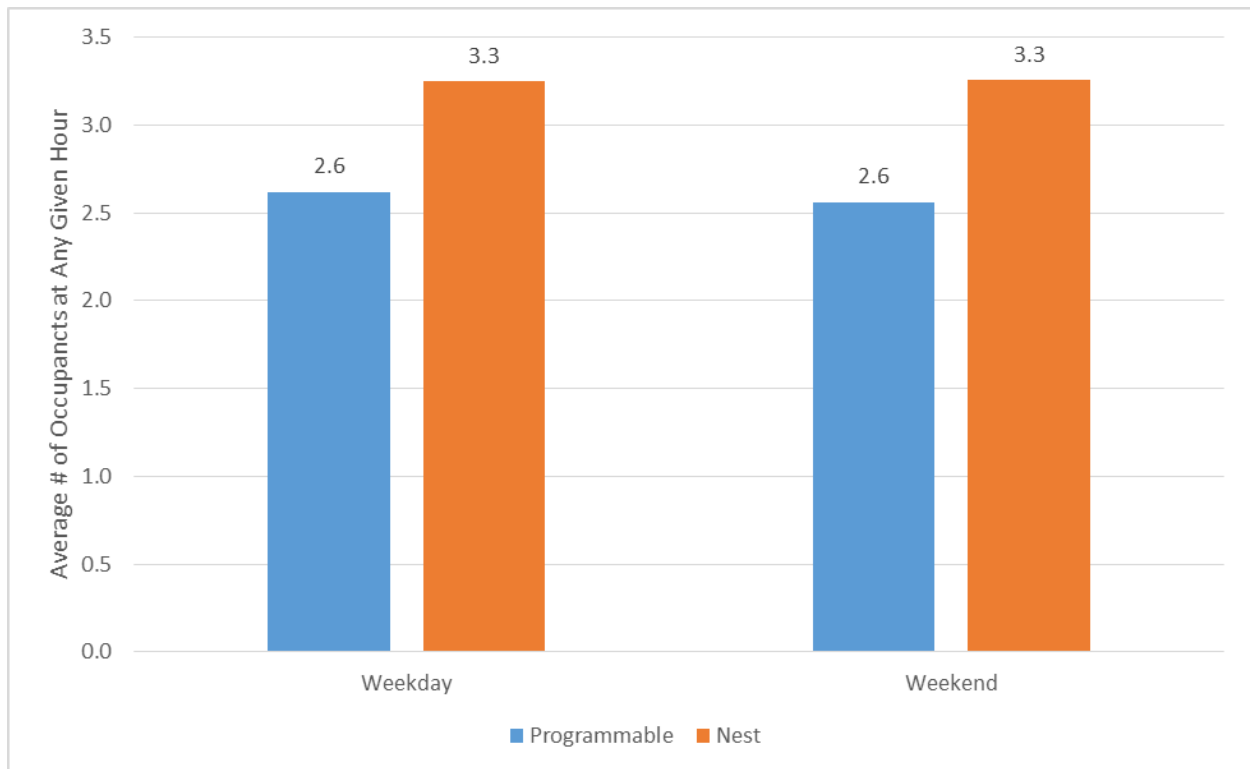
lower in homes with participants over age 65 compared to under age 65. The loss of potential for weekday daytime savings for this demographic is greater in homes with the Nest than programmable thermostat because Nest’s Auto-Away and Auto-Schedule features have the largest impact on savings during this period (as shown in temperature data analysis). In addition, assuming participants over age 65 are less likely to use smartphone, tablet, and computer technologies, this demographic is less likely to control Nest remotely and view monthly energy report e-mails.

Occupancy

In the pre-installation survey, we asked participants to provide the number of home occupants for each hour of the day on weekdays and weekends. Of the 675 participants who responded to the survey, 461 (68%) reported their home occupancy. Based on survey responses, there was no significant difference in occupancy during daytime versus nighttime, so we averaged the reported occupancy for each hour. The average number of occupants for any given hour on weekdays and weekends are shown by participant group in Figure 16.

Figure 16. Household Occupancy by Participant Group

($n_{\text{programmable}}=242$, $n_{\text{nest}}=219$)



The average number of occupants for any given hour was higher in Nest homes compared to programmable thermostat homes. On weekdays and weekends, Nest thermostat homes reported having an average of 3.3 occupants, whereas programmable thermostat homes reported having an average of 2.6 occupants. The higher occupancy in Nest thermostat homes could explain why the



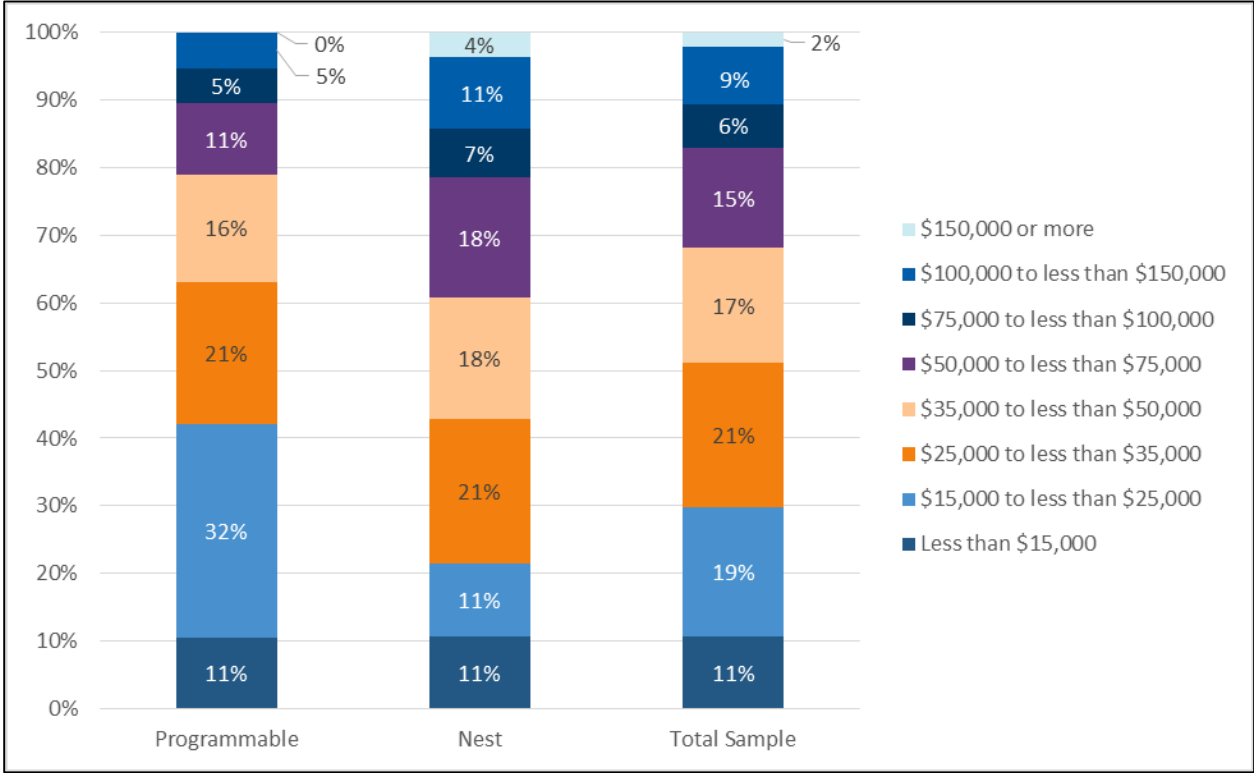
baseline cooling loads were 8% higher per square foot in Nest homes compared to programmable thermostat homes (1.4 kWh/sqft compared to 1.3kWh/sqft) and why the air conditioner run times were higher in Nest homes compared to programmable thermostat homes (3.4% compared to 2.8%).

Household Income

Of the 675 participants who responded to the survey, 47 (7%) reported their income. Income levels by participant group are shown in Figure 17.

Figure 17. Reported Household Income by Participant Group

(n_{programmable}=19, n_{nest}=28; n_{total}=47)



Based on survey responses, the household incomes in the Nest participant group were higher compared to the programmable thermostat participant group. In the Nest participant group, 40% reported household incomes \$50,000 or greater, compared to 21% of the participants in the programmable thermostat group. When interpreting these results, readers should note that only 7% of program participants reported their household income, and 47% more Nest participants reported their income compared to programmable thermostat participants (28 Nest participants compared to 19 programmable thermostat participants).

Home Age

Of the 675 participants who responded to the survey, 79% (534) reported their home age. We received similar response rates from both participant groups: 64% (256) Nest participants and 70% (278) of



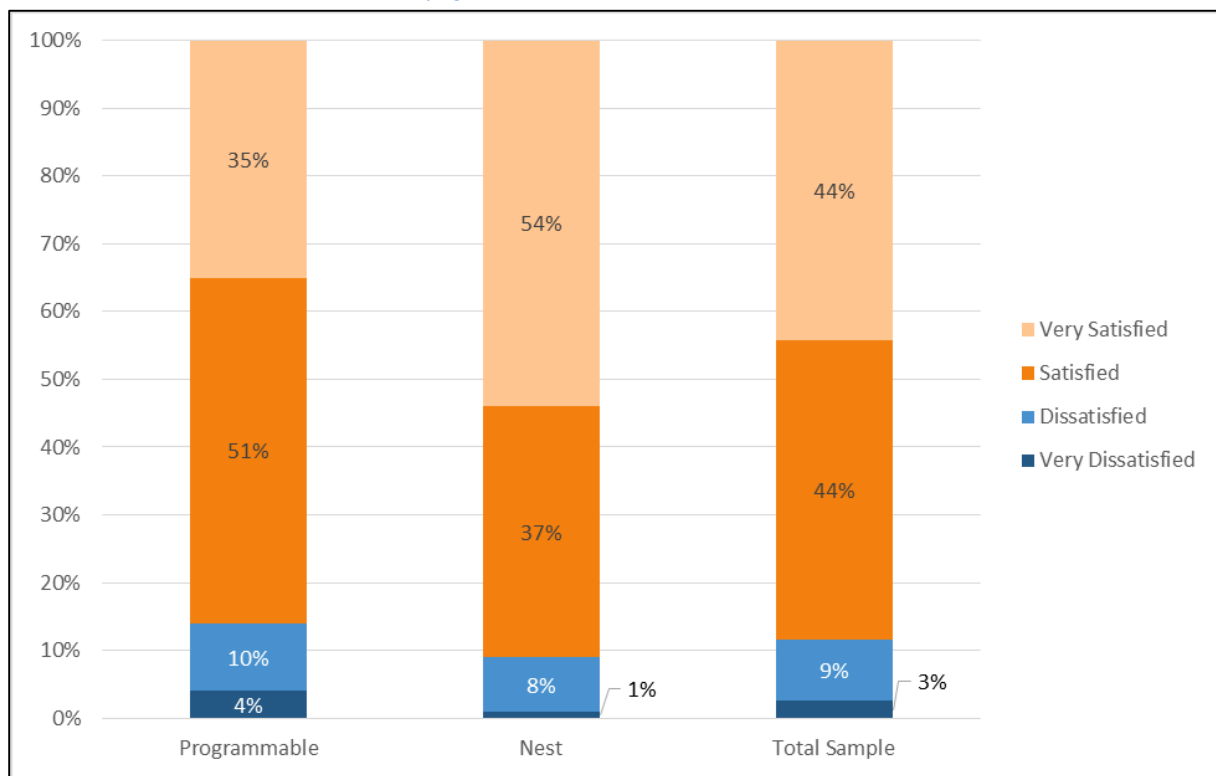
programmable thermostat participants reported home age. The average year of home construction in the Nest participant group was three years older than the programmable thermostat group (1963 compared to 1966).

Satisfaction with Thermostat

Cadmus used the post-installation survey to assess participants' satisfaction with their thermostats. Figure 18 shows participant satisfaction with the programmable and Nest thermostats, respectively, as reported in their customer surveys.

Figure 18. Satisfaction with Thermostat by Participant Group

($n_{\text{programmable}}=173$, $n_{\text{nest}}=163$; $n_{\text{total}}=336$)



More participants with the Nest thermostat reported high satisfaction ratings than participants with a standard programmable thermostat. Eighty-six percent of survey respondents with a programmable thermostat and 91% of survey respondents with a Nest thermostat reported that they were “satisfied” or “very satisfied” with their thermostat. Participants with a standard programmable thermostat were more likely than participants with a Nest thermostat to be “very dissatisfied” with their thermostat. Four percent of survey respondents with a programmable thermostat and 1% of survey respondents with a Nest thermostat reported being “very dissatisfied.”



Conclusions

Gas Savings

Overall, participants with the Nest thermostat reduced their heating gas consumption by approximately 13%, compared to only 8% for those who used a standard programmable thermostat. Our findings indicate the gas savings are higher in the Nest thermostat homes due to a reduction in indoor temperature during the daytime on weekdays. On weekdays between 10:00 a.m. and 11:00 p.m., the temperatures in Nest homes was an average of 1.2 degrees lower than homes with a programmable thermostat. Because this is a common time for homes to be unoccupied, we assume the reduction in temperature during this period is attributable either to Nest’s Auto-Away feature, which automatically triggers a setback when it senses the home is unoccupied, or its Auto-Schedule feature, which uses a data on how participants manually set their thermostat to automatically program a schedule of setbacks.

The Auto-Away feature has an especially significant impact on participants who frequently override their thermostat setbacks by automatically reinstating setbacks when they go away. (Note that programmable thermostat cannot reinstate an overridden setback until the next setback period.) Based on our analysis of thermostat operation, 61-79% of programmable thermostat users override their programmed schedule. As a result, the Nest has greater potential than the programmable thermostat to capture savings during the daytime on weekdays, when many participants might leave home without turning down their thermostats.

Electric Savings

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.

Participant Satisfaction

Participants with a Nest thermostat were more likely to report being satisfied with their thermostat than participants with a programmable thermostat. Of participants who responded to a customer survey, 86% of programmable thermostat users and 91% of Nest thermostat users reported that they were “satisfied” or “very satisfied” with their thermostat.

Interpreting Results

When interpreting the results of this study, readers should take the following considerations into account.



Program Design

Depending on the design of future thermostat programs, this program might not represent an appropriate comparison of the Nest and programmable thermostat savings. This program design included professional installation of the Nest and programmable thermostats. Without a professional installer, a major advantage of the Nest thermostat is that it is designed to be easy for the user to adopt a schedule of setbacks. With the Auto-Schedule feature, the Nest automatically programs a schedule of setbacks using data on how participants manually set their thermostat. Alternatively, a standard programmable thermostat must be programmed by the user. As described in the introduction, and as shown in our analysis of thermostat operation, many users discontinue (or never start) using a programmed schedule. If future program designs do not include professional installation of the thermostats, then the Nest might yield more savings in comparison to the programmable thermostat than this study indicates.

Another characteristic of this program design that might reduce the energy savings potential compared to other program designs is the offering of the thermostats for free. Because the thermostats were free, customers were not necessarily motivated to engage with their programmable or smart thermostat on their own. A program designed to offer incented thermostats, rather than free thermostats, could attract customers who are more likely to be engaged with their thermostat and consequently increase energy savings potential.

Persistence of Savings

When interpreting the results of this study, readers should note that this evaluation only assessed the energy savings impact of Nest and programmable thermostats in the first year after the thermostat installation; the energy savings impact might change over time. Savings from a standard programmable thermostat might degrade over time if users override their schedules. Based on our analysis of thermostat operation, 61-79% of programmable thermostat users override their programmed schedule. In contrast, savings from the Nest thermostat have the potential to increase over time due to the Auto-Schedule feature learning over time and automatically scheduling setbacks, and due to automatic algorithm updates for thermostats connected to internet.

Energy Savings Potential

When comparing the energy savings potential between the Nest and programmable thermostats, readers should note that because the Nest is connected to the internet, users have the potential to participate in additional energy efficiency utility programs that programmable thermostat users cannot. For example, two programs Nest offers to utility partners are the Rush Hour Rewards program and Seasonal Savings program. The Rush Hour Rewards program is a demand response program that pays participants for allowing the Nest thermostat to automatically adjust their temperature settings before and during peak demand hours to reduce demand. The Seasonal Savings program tunes-up participants' setback schedules at the beginning of each winter and summer season in an effort to ensure users maintain energy-efficient schedules. Readers should note that Cadmus has not evaluated the energy savings impact of any of Nest's utility programs.



Appendix A: Pre-Installation Survey

Program Explanation

Thank you for participating in the NIPSCO thermostat study. The information gathered from this survey will help us evaluate your thermostat technology.

Estimated Time: 10-15 minutes

Program Awareness

1. What motivated you to participate in this study? Please check all that apply.

- Keep up with latest technology and trends
- Saving money on my energy bills
- Saving energy
- Having a thermostat that gives me more control over room temperature
- Getting a free thermostat
- Wanting to replace a broken thermostat
- Wanting to replace a poorly working thermostat
- Participating in another NIPSCO program (if yes, please specify below)
NIPSCO program (if applicable): _____

General Thermostat Settings

2. Which of the following best describes how you use your current thermostat?

- I manually change the settings using a regular schedule
- I manually change the settings using no regular schedule (depending on weather and/or home activity)
- I use a single setpoint throughout each season (winter, spring, summer, fall)
- Other: _____

3. How do you plan to use your new thermostat?

- I plan to program my thermostat with different temperatures for different times of day
 - I plan to let my thermostat learn my schedule and program itself (Nest participants only)
 - Other: _____
-



4. In general, how do you decide what temperature to set your thermostat to? Please check all that apply.

- Based on comfort
- Based on trying to keep my utility bill low

5. Please select any supplemental heating you use:

- Electric space heater
- Gas fireplace
- Wood burning stove/fireplace
- Other supplemental heating (if applicable): _____
- N/A

Heating Season Settings

6. How do you typically set your thermostat on a weekday during the heating season?

6am-8am	8am-10am	10am-12pm	12pm-2pm	2pm-4pm	4pm-6pm	6pm-8pm	8pm-10pm	10pm-12am	12am-6am

7. How do you typically set your thermostat on a weekend during the heating season?

6am-8am	8am-10am	10am-12pm	12pm-2pm	2pm-4pm	4pm-6pm	6pm-8pm	8pm-10pm	10pm-12am	12am-6am

8. How do you typically set you thermostat when you are away for an extended period of time, such as for vacation, during the heating season?

- Temperature: _____
- I turn my thermostat off





I do not adjust my thermostat when away for an extended time

Cooling Season

9. How do you typically set your thermostat on a weekday during the cooling season?

6am-8am	8am-10am	10am-12pm	12pm-2pm	2pm-4pm	4pm-6pm	6pm-8pm	8pm-10pm	10pm-12am	12am-6am

10. How do you typically set your thermostat on a weekend during the cooling season?

6am-8am	8am-10am	10am-12pm	12pm-2pm	2pm-4pm	4pm-6pm	6pm-8pm	8pm-10pm	10pm-12am	12am-6am

11. How do you typically set your thermostat when you are away for an extended period of time, such as for vacation, during the cooling season?

- Temp: _____
- Off
- I do not adjust my thermostat when away during the daytime

12. I plan to continue using the same weekday, weekend, and away thermostat settings with my new thermostat.

- True
- False

If you selected False, please describe how you plan to change your thermostat settings.

Demographics

13. How informed are you about all the ways you can save energy in your home?

- Very informed



- Somewhat informed
- Neither informed nor uninformed
- Somewhat uninformed
- Very uninformed

14. Do you own or rent your home?

- Own
- Rent

15. What is the approximate age of your home?

- _____ years
- Don't know

16. How many people typically occupy your home during weekdays?

Temp	6am-8am	8am-10am	10am-12pm	12pm-2pm	2pm-4pm	4pm-6pm	6pm-8pm	8pm-10pm	10pm-12am	12am-6am
Adults										
Teenagers										
Children										
Infants										

17. How many people typically occupy your home during weekends?

Temp	6am-8am	8am-10am	10am-12pm	12pm-2pm	2pm-4pm	4pm-6pm	6pm-8pm	8pm-10pm	10pm-12am	12am-6am
Adults										
Teenagers										
Children										
Infants										

18. Which of the following best describes your total annual household income before taxes?

- Less than \$15,000
- \$15,000 to less than \$25,000
- \$25,000 to less than \$35,000





- \$35,000 to less than \$50,000
- \$50,000 to less than \$75,000
- \$75,000 to less than \$100,000
- \$100,000 to less than \$150,000
- \$150,000 or more
- I prefer not to answer this question

19. Which of the following best describes your age?

- Less than 18 years old
- 18-24 years old
- 25-34 years old
- 35-44 years old
- 45-54 years old
- 55-64 years old
- 65 years or older

20. Gender

- Male
- Female

Customer Satisfaction

Please select a rating to indicate your satisfaction with the following:

21. The contractor was knowledgeable about the Nest Thermostat Program.

- 1—Strongly Disagree 2—Disagree 3—Neutral 4—Agree 5—Strongly Agree

22. The contractor conducted himself/herself in a professional manner.

- 1—Strongly Disagree 2—Disagree 3—Neutral 4—Agree 5—Strongly Agree

23. I was satisfied with the time it took for my thermostat to be installed.

- 1—Strongly Disagree 2—Disagree 3—Neutral 4—Agree 5—Strongly Agree

24. My overall experience in the NIPSCO program was positive.



1—Strongly Disagree 2—Disagree 3—Neutral 4—Agree 5—Strongly Agree

25. Additional Comments:



NIPSCO Smart Thermostat Release Information

As a participant in NIPSCO’s Nest Thermostat Program and upon completion of installation, you will be required to provide an electronic signature on the Customer Agreement of Terms & Conditions form. By signing the form, you agree to the following terms and conditions: NIPSCO reserves the right to alter or discontinue the programmable thermostat program offer and other NIPSCO rebate offers at any time without notice.

- Programmable thermostats are limited and are available on a first-come, first-served basis.
- NIPSCO does not guarantee that energy efficiency measures installed, or services provided through this program, will result in energy and costs savings.
- NIPSCO reserves the right to deny or limit any request for services.
- No warranties on product or service installations are provided by NIPSCO. The program provider, WES, warrants installation services and all products for defects in workmanship or materials for one (1) year following installation. Home owners should call (866) 611-5404 for service.
- NIPSCO and the Program Administrator, CLEAResult, disclaim any and all liability, loss or damage, and make no guarantees related to participation in the programmable thermostat program, including liability arising out of the use or installation of the equipment, sharing of any energy usage information with third parties, and any taxes that may be imposed as a result of participation in the program.
- Participant agrees and consents to NIPSCO sharing participant’s energy usage data collected during the data collection period with other third parties. Participant agrees to waive any and all liability arising out of NIPSCO sharing participant’s energy usage information with other third parties.

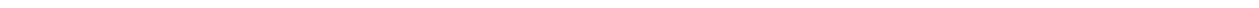
Please Sign Below to Accept

Email



Click to Accept and Complete Survey

[The website then notified customer if they had missed any questions in the survey. If complete, the site provides a timestamp of when the survey was completed.]





Appendix B: Air Conditioner/Heat Pump Data Collection

This appendix outlines the types of air conditioner and heat pump data Cadmus collected to analyze savings for the Nest Thermostat Program.

Condenser

Cadmus collected the following information on the program participant condensers:

- Information collected:
 - Type (air conditioner or heat pump)
 - Make
 - Model number
 - Serial number
 - Refrigerant type (e.g., R-410A or R-22)
 - Year or age (as available)
 - Efficiency rating as available (SEER, EER, HSPF (for heat pump only), COP (for heat pump only))
- Photographs (such as those shown in Table 24) taken of:
 - Condenser
 - Nameplate (must be legible)

Table 24. (Left to right): Standard 2.5-Ton Carrier Air Conditioner, Standard 2.5-Ton Carrier Heat Pump, Nameplate of Heat Pump



Evaporator

Cadmus collected the following data of the program participant and evaporators:

- Information collected:
 - Make
 - Model number
-



- Serial number
- Metering device (e.g., fixed orifice or TXV)
- Photographs (such as that shown to the right) taken of nameplate

Air Handler

Cadmus collected the following information and photographs of the program participant air handlers:

- Information collected:
 - Make
 - Model number
 - Serial number
 - Fan motor type (PSC or ECM)
- Photographs (such as those shown above) taken of fan motor (where accessible)

Survey Collection

Cadmus field technicians had participant customers fill out a program survey while they were on-site installing equipment. The homeowner would fill out a survey, which was contained on an iPad tablet and took about 10 minutes.

Thermostat and HVAC Meter Installation

Data Collection

Cadmus collected heating and cooling system make and model information, as well as thermostat type and homeowner-preferred setpoints for each season. We recorded a description of the thermostat's scheduled program (where applicable).

Types of Loggers

Cadmus installed the following types of loggers:

- Thermostat temperature and humidity (Onset UX100-003 Temp/RH Logger, shown below)



- Motor on/off (Onset UX90-004 State Logger, shown below)
-



Installation Procedure – Thermostat Logger

Cadmus' installation procedure for thermostat loggers was to calibrate and launch them prior to arriving at the home. To install, Cadmus placed the thermostat temperature logger on or near each thermostat in the home. Table 25 shows proper placement of a thermostat logger.

Table 25. Thermostat Logger Installed Near Programmable (left) and Nest (right) Thermostats



If Cadmus could not place the logger on top of the thermostat, we used 3M double-sided adhesive to attach it to the thermostat. We avoided using adhesive on any walls, as removal can be difficult. If Cadmus could not place the logger on or attach it to the thermostat, or if the homeowner preferred to have it out of sight, Cadmus asked the homeowner to suggest a location that is representative of the indoor temperature controlled by the thermostat.

In order to ensure accurate data collection, Cadmus did not place any loggers in the following areas:

- Drawers or closet
 - Near lights
-



- Near windows
- Near doors
- In or near the kitchen
- Near auxiliary heat sources, such as a unitary electric heater or fireplace, with the exception of rooms that are heated by secondary sources and do not contain the primary heating thermostat
- In or near bathrooms
- Near any type of electric load that generates heat (such as a TV or computer)

Cadmus recorded the following data during site visits, in addition to taking a photograph of the logger:

- Thermostat location
- Logger type and serial number
- Site identification number

Installation Procedure – Air Conditioner Logger

Cadmus installed run-time loggers to record the precise time the air conditioner condensers turned on and off. The run-time data loggers recorded motor on and off conditions by sensing an alternating current magnetic field. These motor loggers are not normally weatherproof, so Cadmus placed them in weatherproof heat-sealed plastic bags. We calibrated each logger’s sensitivity (set to maximum sensitivity) and launched it prior to arriving at the home. Cadmus installed these loggers either on top of the condenser (Table 26) or on the conduit to the condenser (Table 27).

Table 26. Motor Logger on Condenser







Table 27. Motor Logger on Electric Conduit to Condenser



Cadmus verified proper placement of each motor logger by noting the logger response when the motor was running. Table 28 shows the LED icons the logger displayed to show when the motor was on or off.

Table 28. Logger Display

	The motor is off (internal sensor).
	The motor is on (internal sensor).

In addition to taking a photograph of each air conditioner logger, Cadmus recorded the following information during the site visit:

- Condenser location
- Logger type and serial number
- Site identification number



Appendix C: Post-Installation Customer Surveys

Cadmus mailed post-installation customer surveys to participants on July 17, 2014. We created one version for participants who received loggers, which included instruction on removing and returning the loggers, and one version for participants who did not receive loggers. Blank copies of each survey version are below.

Instructions

1. Please fill in each bubble completely.
2. Please return by July 25, 2014.
3. To return, place in pre-paid bubble mailer with temperature sensor and air conditioner logger and leave in any USPS mailbox.
4. If your mailbox has a signal flag, you can leave package in your mailbox and raise the flag to signal pick-up.

1. What type of thermostat do you have?

- Honeywell Nest



2. How do you control your thermostat?

- I manually adjust the temperature as needed
 I use a single temperature setting
 I rely on my thermostat to change the temperature at different times of day
 I use a mobile app to adjust the temperature as needed (Nest owners only)

3. Did the number of occupants in your home increase or decrease since your thermostat was installed?

- Yes, increased (# of additional occupants: ____)
 Yes, decreased (# of fewer occupants: ____)
 No

4. Since your thermostat was installed, were any new appliances or equipment installed in your home that required additional **natural gas** usage?

- Yes (Items: _____)
 No

5. Since your thermostat was installed, were any new appliances or equipment installed in your home that required additional **electricity** usage?

- Yes (Items: _____)
 No

6. Were you away from your home during the heating season (winter months)?

- Yes (approximate # of days: ____)
 No

7. If you answered "Yes", were you away more, less, or about the same as the previous winter?

- More
 Less
 About the same

8. Were you away from your home during the cooling season (summer months)?

- Yes (approximate # of days: ____)
 No

9. If you answered "Yes", were you away more, less, or about the same as the previous summer?

- More
 Less
 About the same

10. Other than the weather impact, were there any other changes that occurred since your thermostat was installed that would cause your energy usage to be higher or lower than the previous year?

- Yes, higher
 Yes, lower
 No
 If Yes, describe: _____

11. How satisfied are you with your current thermostat?

- Very satisfied
 Satisfied
 Dissatisfied
 Very dissatisfied

12. If you answered "Dissatisfied" or "Very dissatisfied", please describe why: _____

13. How satisfied are you with the NIPSCO thermostat program?

- Very satisfied
 Somewhat satisfied
 Not too satisfied
 Not at all satisfied

14. If you answered "Dissatisfied" or "Very dissatisfied", please describe why: _____

15. Please provide us with any feedback about the program? _____

Thank You!

Your feedback will help to improve our programs.



For questions about this survey, please contact Cadmus Group at 617-673-7139.

Instructions

- 5. Please fill in each bubble completely.
- 6. Please return by July 25, 2014.
- 7. To return, fold survey in thirds, seal with included sticker, and leave in any USPS mailbox. Postage is already paid.
- 8. If your mailbox has a signal flag, you can leave envelope in your mailbox and raise the flag to signal pick-up.

16. What type of thermostat do you have?
- Honeywell
 - Nest



17. How do you control your thermostat?
- I manually adjust the temperature as needed
 - I use a single temperature setting
 - I rely on my thermostat to change the temperature at different times of day
 - I use a mobile app to adjust the temperature as needed (Nest owners only)
18. Did the number of occupants in your home increase or decrease since your thermostat was installed?
- Yes, increased (# of additional occupants: _____)
 - Yes, decreased (# of fewer occupants: _____)
 - No
19. Since your thermostat was installed, were any new appliances or equipment installed in your home that required additional **natural gas** usage?
- Yes (Items: _____)
 - No

20. Since your thermostat was installed, were any new appliances or equipment installed in your home that required additional **electricity** usage?
- Yes (Items: _____)
 - No
21. Were you away from your home during the heating season (winter months)?
- Yes (approximate # of days: _____)
 - No
22. If you answered “Yes”, were you away more, less, or about the same as the previous winter?
- More
 - Less
 - About the same
23. Were you away from your home during the cooling season (summer months)?
- Yes (approximate # of days: _____)
 - No
24. If you answered “Yes”, were you away more, less, or about the same as the previous summer?
- More
 - Less
 - About the same
25. Other than the weather impact, were there any other changes that occurred since your thermostat was installed that would cause your energy usage to be higher or lower than the previous year?
- Yes, higher
 - Yes, lower
 - No
 - If Yes, describe: _____

26. How satisfied are you with your current thermostat?
- Very satisfied
 - Satisfied
 - Dissatisfied
 - Very dissatisfied
27. If you answered “Dissatisfied” or “Very dissatisfied”, please describe why: _____
28. How satisfied are you with the NIPSCO thermostat program?
- Very satisfied
 - Somewhat satisfied
 - Not too satisfied
 - Not at all satisfied
29. If you answered “Dissatisfied” or “Very dissatisfied”, please describe why: _____
30. Please provide us with any feedback about the program? _____

Thank You!

Your feedback will help to improve our programs.



For questions about this survey, please contact Cadmus Group at 617-673-7139.