STATE OF CALIFORNIA Edmund G. Brown Jr., *Governor*

PUBLIC UTILITIES COMMISSION
505 VAN NESS AVENUE
SAN FRANCISCO, CA 94102-3298

December 22, 2016

Advice Letter 5028-G-A

Ronald van der Leeden
Director, Regulatory Affairs
Southern California Gas
555 W. Fifth Street, GT14D6
Los Angeles, CA 90013-1011

SUBJECT: Southern California Gas Company Winter Seasonal Savings Pilot Plan

Dear Mr. van der Leeden:

Advice Letter 5028-G-A is effective as of October 15, 2016.

Sincerely,

Edward Randolph
Director, Energy Division

Ronald van der Leeden
Director
Regulatory Affairs

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December 12, 2016

Advice No. 5028-A
(U 904 G)

Public Utilities Commission of the State of California

Subject: Supplement - Southern California Gas Company Winter Seasonal Savings Pilot Plan

Southern California Gas Company (SoCalGas) hereby requests expedited approval from the California Public Utilities Commission (Commission) to implement a Winter Seasonal Savings Pilot. A Pilot Plan, along with supporting documentation, is incorporated as Attachments A through C.

Purpose

This supplemental filing replaces in its entirety Advice No. 5028, Southern California Gas Company Winter Seasonal Savings Pilot Plan, filed on September 15, 2016. The purpose of this Advice Letter is to update Section I of Attachment A with additional Evaluation, Measurement, and Verification (EM&V) plan details made available after meetings with Energy Division staff. The Pilot start date has also been updated from November 2016 to December 2016.

Background

SoCalGas proposes to implement a Winter Seasonal Savings Pilot Program in its service territory to examine the feasibility of achieving incremental energy savings using software controls of existing Nest smart thermostats. The innovative offering is being rolled out as a pilot and, as such, must follow the pilot program protocol set forth by the Commission in Decision (D.) 09-09-047 and the Energy Efficiency Policy Manual.[1] These documents outline the ten elements that must be included in a pilot; the SoCalGas Winter Seasonal Savings Pilot Program Plan which addresses these

[1] D.09-09-047 at p. 48-49 and Energy Efficiency Policy Manual, Version 5, July 2013, Section XII.12 at p. 8-9.

elements is provided in Attachment A. Nest smart thermostats are programmable devices which can be set up to adjust temperature set points based on recurring customer patterns such as when occupancy drops or during sleep hours. Energy savings can be achieved upon installation and programming of these units. The amount of energy savings delivered depends on how much the temperatures are changed compared to before installation and programming of the smart thermostat or simply making manual set point adjustments.

Winter Seasonal Savings Pilot Program

The savings attributed to the use of a standard programmable thermostat have been studied by Nest and others. In their white paper on the subject, Nest noted that the installation of Nest smart thermostats resulted in energy savings equal to about 10%-12% of heating usage and 15% of cooling usage in homes with central air conditioning.[2] Such studies serve as the basis for the development of work papers to document these established energy savings.

SoCalGas is partnering with Nest for the implementation of the innovative, software-driven Winter Seasonal Savings Pilot Program to increase the amount and persistency of energy savings from the normal use of smart thermostats. The pilot program will be conducted over the course of the winter season (December 2016 – March 2017). During this time period, a portion of the SoCalGas residential customers who own Nest smart thermostats will be invited to participate in the free pilot via a message on the thermostat interface. If a customer opts-in to the pilot, customer-specific algorithms will be delivered to make micro-set point adjustments on the Heating, Ventilation, and Air Conditioning (HVAC) equipment over a three-week period. These adjustments are intended to be small enough so as to maintain customer comfort level while still large enough to deliver incremental savings over those achieved with the current use of the energy management device.

Nest describes their third party-designed and proposed Seasonal Savings program as an approach that promotes deployable and persistent energy efficiency. It has been implemented in other states during winter and summer seasons, including a summer season in Southern California.[3] Nest documented the results of their recent Seasonal Savings run in Massachusetts during the winter of 2015; their analysis showed the following results[4]:

- 54% of all eligible thermostats completed the Seasonal Savings algorithm;
- Participants' set points declined by an average of 1.3°F over the course of the three week algorithm deployment; and,

[2] Nest White Paper - Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results, February 2015, p.2.
[3] Southern California Edison rolled out a Summer Seasonal Savings in 2013.
[4] Nest Seasonal Savings: MA DOER Heating Season Impact Evaluation, 2015, p. 1.

- Seasonal Savings reduced heating usage by an average of 3.5% over the course of the winter based on a weather-adjusted analysis of run times that included a control group from neighboring states.

Both Marin Clean Energy (MCE) and Pacific Gas & Electric Company (PG&E) have recently filed Advice Letters that request approval of similar seasonal savings programs in Northern California.[5] However, the proposed SoCalGas pilot program will be the first winter season implementation of the program in Southern California.

The Winter Seasonal Savings Pilot Program addresses the Long-Term Energy Efficiency Strategic Plan goals as well as strategies required for the enactment of legislative initiatives. Results from this pilot program will contribute to the quickly-expanding collective knowledge on the use of smart thermostats and optimization for energy savings.

Funding for the Pilot

The overall budget for the Winter Seasonal Savings Pilot Program is $550,000. SoCalGas proposes to fund this effort from SCG3701 SW-CALS-Energy Advisor. The existing residential program has funds available to support the pilot program.

Attachments

This Advice Letter includes the following attachments:

- **Attachment A**: SoCalGas Winter Seasonal Savings Program Pilot Plan
- **Attachment B**: Nest Seasonal Savings Massachusetts Department of Energy Resources Impact Evaluation
- **Attachment C:** Nest White Paper - Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results

Protests

Anyone may protest this Advice Letter to the Commission. The protest must state the ground upon which it is based, including such items as financial and service impact, and should be submitted expeditiously. At the direction of the Commission's Energy Division, SoCalGas hereby requests that the protest must be made in writing and received by December 19, 2016, which is ten days after the date this Expedited Advice Letter was filed with the Commission. The address for mailing or delivering a protest to the Commission is:

[5] Advice Letter 17-E, Request for Approval of MCE Seasonal Savings Pilot Program, filed August 18, 2016 and Advice 3744-G/4886-E, Request for Approval of PG&E's Assembly Bill 793 Implementation Plan, filed August 1, 2016.

CPUC Energy Division
Attn: Tariff Unit
505 Van Ness Avenue
San Francisco, CA 94102

Copies of the protest should also be sent via e-mail to the Energy Division Tariff Unit (EDTariffUnit@cpuc.ca.gov). A copy of the protest should also be sent via both mail and facsimile to the address shown below on the same date it is mailed or delivered to the Commission.

Attn: Ray B. Ortiz
Tariff Manager - GT14D6
555 West Fifth Street
Los Angeles, CA 90013-1011
Facsimile No. (213) 244-4957
E-mail: ROrtiz@SempraUtilities.com

Attn: Elizabeth Baires
Regulatory Affairs Case Manager
555 West Fifth Street
Los Angeles, CA 90013-1011
Facsimile No. (213) 244-4957
E-mail: EBaires@SempraUtilities.com

Effective Date

SoCalGas believes that this Advice Letter is subject to Energy Division disposition and should be classified as Tier 2 (effective after staff approval) pursuant to General Order (GO) 96-B. This filing is consistent with D.09-09-047. Therefore, SoCalGas respectfully requests that this filing be approved on October 15, 2016, which is the date requested on Advice No. 5028.

Notice

A copy of this Advice Letter is being sent to SoCalGas' GO 96-B service list and the Commission's service lists for R.13-11-005. Address change requests to the GO 96-B should be directed by electronic mail to tariffs@socalgas.com or call 213 244 3387. For changes to all other service lists, please contact the Commission's Process Office at 415-703-2021 or by electronic mail at Process_Office@cpuc.ca.gov.

Ronald van der Leeden
Director – Regulatory Affairs

CALIFORNIA PUBLIC UTILITIES COMMISSION

ADVICE LETTER FILING SUMMARY
ENERGY UTILITY

MUST BE COMPLETED BY UTILITY (Attach additional pages as needed)

Company name/CPUC Utility No. **SOUTHERN CALIFORNIA GAS COMPANY (U 904G)**

Utility type:
☐ ELC ☒ GAS
☐ PLC ☐ HEAT ☐ WATER

Contact Person: Ray B. Ortiz
Phone #: (213) 244-3837
E-mail: ROrtiz@semprautilities.com

EXPLANATION OF UTILITY TYPE

ELC = Electric GAS = Gas
PLC = Pipeline HEAT = Heat WATER = Water

(Date Filed/ Received Stamp by CPUC)

Advice Letter (AL) #: 5028-A

Subject of AL: Supplement - Southern California Gas Company Winter Seasonal Savings Pilot Plan

Keywords (choose from CPUC listing): Energy Efficiency

AL filing type: ☐ Monthly ☐ Quarterly ☐ Annual ☒ One-Time ☐ Other

If AL filed in compliance with a Commission order, indicate relevant Decision/Resolution #:
D.09-09-047

Does AL replace a withdrawn or rejected AL? If so, identify the prior AL No

Summarize differences between the AL and the prior withdrawn or rejected AL[1]: N/A

Does AL request confidential treatment? If so, provide explanation: No

Resolution Required? ☐ Yes ☒ No

Tier Designation: ☐ 1 ☒ 2 ☐ 3

Requested effective date: 10/15/16

No. of tariff sheets: 0

Estimated system annual revenue effect: (%): N/A

Estimated system average rate effect (%): N/A

When rates are affected by AL, include attachment in AL showing average rate effects on customer classes (residential, small commercial, large C/I, agricultural, lighting).

Tariff schedules affected: N/A

Service affected and changes proposed[1]: N/A

Pending advice letters that revise the same tariff sheets: N/A

Protests and all other correspondence regarding this AL are due no later than 20 days after the date of this filing, unless otherwise authorized by the Commission, and shall be sent to:

CPUC, Energy Division
Attention: Tariff Unit
505 Van Ness Ave.,
San Francisco, CA 94102
EDTariffUnit@cpuc.ca.gov

Southern California Gas Company
Attention: Ray B. Ortiz
555 West 5th Street, GT14D6
Los Angeles, CA 90013-1011
ROrtiz@semprautilities.com
Tariffs@socalgas.com

[1] Discuss in AL if more space is needed.

ATTACHMENT A

Advice No. 5028-A

SoCalGas Winter Seasonal Savings Program Pilot Plan

ATTACHMENT A

SOCALGAS WINTER SEASONAL SAVINGS PROGRAM PILOT PLAN

A. A specific statement of the concern, gap, or problem that the pilot seeks to address and the likelihood that the issue can be addressed cost-effectively through utility programs.

As the home energy management technology market evolves to become more accessible to residential customers, it is important to engage customers in opportunities to maximize the energy savings opportunities available from their smart devices. Smart technology often does not generate the expected savings because of usability and design problems.[1] With proven smart technologies being incorporated into its Energy Efficiency portfolio, SoCalGas continues to identify and test additional mechanisms and channels by which to increase the accessibility and persistency of energy savings from these devices.

Programmable or smart thermostats have been available to consumers for many years and the reliability of these devices to consistently deliver predictable energy savings has been debated for almost as long.[2] As Nest describes in their 2015 white paper, savings are expected to result from the automatic set point adjustments made when occupancy drops or other customer patterns dictate regular set point changes. The amount of energy savings depends on how much the temperatures havechanged compared to before installing the thermostat. The Nest white paper notes that the installation of Nest smart thermostats resulted in energy savings equal to about 10%-12% of heating usage and 15% of cooling usage in homes with central air conditioning. Such studies have resulted in the development of smart thermostat work papers to document established energy savings.

SoCalGas is partnering with Nest for the implementation of the innovative, software-driven Winter Seasonal Savings Pilot Program to increase the amount and persistency of energy savings from the normal use of smart thermostats. The pilot program will be conducted over the course of the winter season (December 2016 – March 2017). During this period, a portion of SoCalGas residential customers who own Nest smart thermostats will be invited to participate in the free pilot via a message on the thermostat interface. If a customer opts-in to the pilot, customer-specific algorithms will be delivered to make micro-set point adjustments on the Heating, Ventilation, and Air Conditioning (HVAC) equipment over a three-week period. These adjustments are intended to be small enough to maintain customer comfort level while still

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[1] Nest White Paper - Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results, February 2015, p.3.

[2] Nest White Paper - Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results, February 2015, p.2.

large enough to deliver incremental savings beyond those achieved with the current use of the energy management device.

Nest describes their third party-designed and proposed Seasonal Savings program as an approach that promotes deployable and persistent energy efficiency. It has been implemented in other states during winter and summer seasons, including a summer season in Southern California.[3] Nest documented the results of their recent Seasonal Savings run in Massachusetts during the winter of 2015; their analysis showed the following results[4]:

- 54% of all eligible thermostats completed the Seasonal Savings algorithm;
- Participants' set points declined by an average of 1.3°F over the course of the three week algorithm deployment; and,
- Seasonal Savings reduced heating usage by an average of 3.5% over the course of the winter based on a weather-adjusted analysis of run times that included a control group from neighboring states.

Both Marin Clean Energy (MCE) and Pacific Gas & Electric (PG&E) have recently filed Advice Letters that request approval of similar seasonal savings program in Northern California.[5] However, the proposed SoCalGas pilot program will be the first winter season implementation program in Southern California.

The Winter Seasonal Savings Pilot Program addresses the Long-Term Energy Efficiency Strategic Plan goals as well as strategies required for the enactment of other legislative requirements. Results from this pilot program will contribute to the quickly expanding collective knowledge on the use of smart thermostats and optimization for energy savings.

B. Whether and how the pilot will address a Strategic Plan goal or strategy and market transformation.

The Winter Seasonal Savings Pilot Program addresses Strategic Plan goals as well as strategies required for the enactment of other legislative requirements. In the Marin Clean Energy Advice Letter 17-E requesting approval of a Nest-based Seasonal Savings program in MCE's service territory, MCE provided a detailed outline of how the pilot addresses broader goals and strategies.[6] SoCalGas agrees with MCE's assessment and provides the same goal and strategy relationships for the pilot program in the Southern California territory, as follows:

[3] Southern California Edison rolled out a Summer Seasonal Savings in 2013.
[4] Nest Seasonal Savings: MA DOER Heating Season Impact Evaluation, 2015, p. 1.
[5] Advice Letter 17-E Re: Request for Approval of MCE Seasonal Savings Pilot Program, filed August 18, 2016 and Advice 3744-G/4886-E Request for Approval of PG&E's Assembly Bill 793 Implementation Plan, filed August 1, 2016.
[6] Advice Letter 17-E Re: Request for Approval of MCE Seasonal Savings Pilot Program, filed August 18, 2016, Attachment A: MCE Seasonal Savings Pilot Plan.

Document	Section	Description	Alignment
California Long Term Energy Efficiency Strategic Plan (LTEESP)[7]	Policy tools for market transformation[8]	Technical Assistance	The pilot offers a software service implemented remotely with no customer interaction required beyond the initial opt-in. This experimental program design minimizes the limitations in capturing energy savings due to customer technology comfort and knowledge.
California LTEESP	Policy tools for market transformation	Emerging Technologies	This pilot will demonstrate the energy saving potential of an innovative strategy (software service for set point configuration) used to optimize an emerging energy management technology (smart thermostats).
California LTEESP	"Big Bold" Energy Efficiency Strategies[9]	All new residential construction in California will be zero net energy by 2020.	This pilot will demonstrate the potential role smart thermostats can play in helping residential customers achieve zero net energy homes.
California LTEESP	"Big Bold" Energy Efficiency Strategies	Heating, Ventilation and Air Conditioning (HVAC) will be transformed to ensure that its energy	This pilot is intended to examine the feasibility of capturing incremental savings beyond the proven savings achievable with smart

[7] California LTEESP, January 2011, available at http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5303.
[8] LTEESP, p. 5
[9] LTEESP, p.6.

Document	Section	Description	Alignment
		performance is optimal for California's climate.	thermostats. The pilot will be offered across the SoCalGas territory to eligible customers.
California LTEESP	Demand Side Management Coordination & Integration[10]	Energy efficiency, energy conservation, demand response, advanced metering, and distributed generation technologies are offered as elements of an integrated solution that supports energy and carbon reduction goals.	This pilot will promote the engagement of customers in software driven smart thermostat set point controls, an important step towards enrolling customers in automated demand response programs.
Assembly Bill (AB) 793 (2015)	Section 717	"The commission shall require an electrical or gas corporation to… [d]evelop a program no later than January 1, 2017 […] to provide incentives to a residential or small or medium business customer to acquire energy management technology for use in the customer's home or place of business […]The electrical or gas corporation shall work with third parties, local governments, and other interested parties in	By demonstrating energy savings, this pilot will help establish savings estimates and potentially incentive levels for similar offerings focused on providing incremental and ongoing energy savings from smart thermostats. This will move the State closer to fulfilling the directives outlined in AB 793 regarding providing residential customers with energy management technology.

[10] LTEESP, pp. 67-69.

Document	Section	Description	Alignment
		developing the program. The electrical or gas corporation shall establish incentive amounts based on savings estimation and baseline policies adopted by the commission…. For purposes of this section, ‘energy management technology’ may include a product, service, or software that allows a customer to better understand and manage electricity or gas use in the customer’s home or place of business[…].”[11]	
Senate Bill (SB) 350 (2015)	Sections 2 and 6	“To double the energy efficiency savings in electricity and natural gas final end uses of retail customers through energy efficiency and conservation.”[12] “The targets established in subdivision (c) may be achieved through energy efficiency savings and demand reduction resulting	This pilot intends to prove the viability of the software service to deliver incremental savings on existing smart thermostats installed in customer residences. All energy savings achieved contribute to the goal of doubling energy efficiency savings.

[11] AB 793, Sections 717(a)(1) and 717(b).
[12] SB 350, Section 2(a)(2).

Document	Section	Description	Alignment
		from a variety of programs that include, but are not limited to, the following […] (8) Programs of electrical or gas corporations, local publicly owned electric utilities, or community choice aggregators, that achieve energy efficiency savings through operational, behavioral, and retrocommissioning activities [...].”[13]	
California Existing Buildings Energy Efficiency Action Plan (EBEEAP)[14]	Consumer-Focused Energy Efficiency, Program Design Enhancement (Strategy 2.2)	“Revamp efficiency program designs to respond better to customer needs and values, as well as industry practice[...] Design programs based upon actual, verified performance, rather than ‘deemed’ savings. Design programs to incorporate building operations and behavior.”[15]	This pilot is focused on maximizing energy savings in existing buildings by increasing the potential for energy savings of previously installed energy management devices.

[13] SB 350 Section 6(d).
[14] Existing Buildings Energy Efficiency Action Plan (EBEEAP), September 2015, available at ttp://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-5/TN205919_20150828T153953_Existing_Buildings_Energy_Efficiency_Action_Plan.pdf.
[15] EBEEAP, p. 2.

C. Specific goals, objectives, and end points for the project.

Goals and Objectives

The SoCalGas Winter Seasonal Savings has the following goals and objectives:

1. Determine if the proposed software service can deliver incremental savings beyond the proven energy savings of basic smart thermostat functionality.
2. Examine the willingness of customers to participate in innovative use of energy management technology on a one-time basis as well as potential for future participation for persistent savings.

End Points

The pilot will run from December 2016 through the end of March 2017. After the pilot implementation has been completed, Nest will prepare a report summarizing the results of the pilot. Refer to sections J and K for additional information regarding the steps that will follow the pilot implementation period.

D. New and innovative design, partnerships, concepts, or measure mixes that have not yet been tested or employed.

As previously noted, the installation of smart thermostats has proven to be an effective means of achieving energy savings. This pilot takes that concept one step further by introducing a software algorithm to remotely make set point adjustments, allowing additional energy savings to be captured. Nest refers to this innovation as "deployable" and "persistent" energy efficiency. While PG&E and MCE are offering similar programs and/or pilots this upcoming winter season, the SoCalGas pilot will be the first and only winter Seasonal Savings offering in the Southern California region.[16]

E. A clear budget and timeframe to complete the project and obtain results within a portfolio cycle.

Timeframe

The Winter Seasonal Savings Pilot Program will run through the 2016-2017 Southern California winter season, from December 1, 2016 through March 31, 2017. Customers who enroll in the pilot will commit to a three-week time period during which their Nests thermostat set points will be automatically adjusted using a software algorithm.

Budget

The Winter Seasonal Savings Pilot Program will be funded from available SoCalGas Energy Efficiency residential program funds. The total funds required for the pilot are as shown in Table 1 below:

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[16] Southern California Edison offered a summer Seasonal Savings program in 2013.

Table 1: 2016-2017 Winter Seasonal Savings Pilot Budget

Item	2016	2017
Administration	$26,000	$39,000
Marketing	$4,000	$6,000
Direct Implementation Non-Incentive	$190,000	$285,000
Incentives	$0	$0
Total	**$220,000**	**$330,000**

F. Information on relevant baselines metrics or a plan to develop baseline information against which the project outcomes can be measured.

The Winter Seasonal Savings Pilot Program will be made available to a large portion of the SoCalGas residential customer base that has a Nest smart thermostat installed and functioning in their homes (see EM&V plan, Section I). The data obtained will compare energy usage for the entire group of treatment customers (those that accepted the Seasonal Savings message as well as those that did not) to the control group of customers that were not offered the treatment.

G. Program performance metrics.

As noted, Nest had rolled out the Seasonal Savings programs in other parts of the country.[17] The results of the other implementation efforts were reviewed and used to inform the program performance metrics for this pilot. The Winter Seasonal Savings Pilot Program will identify and measure the program performance metrics identified in the table below:

Table 2: Program Performance Metrics

Program Performance Metric	Goal
Customer enrollment (opt-in) rate	>50%
Early customer exit (opt-out) rate	<5%
Energy Savings based on Heating, Ventilation, and Air Conditioning (HVAC) usage	>2.0%

[17] Nest Seasonal Savings White Paper, 2013; Nest Seasonal Savings Results White Paper – CPS, 2014; Seasonal Savings Results White Paper – ComEd, 2014; and Nest Seasonal Savings: MA DOER Heating Season Impact Evaluation, 2015.

The energy savings goal listed in the table above is in terms of percentage greater for treatment group(s) as compared to the control group.

H. Methodologies to test the cost-effectiveness of the project.

The savings claimed as part of the Winter Seasonal Savings Pilot Program will be evaluated via the *ex-post* custom process. The pilot cost-effectiveness will be assessed using the total resource cost (TRC) calculation, the primary indicator used by the Commission to evaluate EE program cost-effectiveness.[18]

One of the considerations in evaluating the cost-effectiveness of program offerings is the net-to-gross (NTG) ratio, which represents the extent “to which customers would have installed the program measure or equipment even without the financial incentive (e.g., rebate) provided by the program.”[19] Given that customers can only participate in the Winter Seasonal Savings Pilot Program because of the program administrator and implementer’s efforts, the NTG value will default to 1.0.

I. A proposed Evaluation, Measurement, and Verification (EM&V) plan.

<u>EM&V Study Approach</u>
Nest’s Seasonal Savings algorithm deployment lends itself to the Intent-to-Treat (“ITT”) EM&V approach, a style of Randomized Control Trials (“RCT”), because three groups are naturally created by the deployment:

1. A control group consisting of randomly chosen Nest Thermostat owners in SoCalGas service area to whom the algorithm is not deployed.
2. A treatment group consisting of Nest Thermostat owners in SoCalGas service area to whom the algorithm is deployed, which is broken into two groups:
    a. Residential customers who accept the deployment and participate in Seasonal Savings
    b. Residential customers who decline the deployment and do not participate in Seasonal Savings

<u>Evaluation Plan</u>

SoCalGas will work with Nest and the CPUC’s contractor, DNV GL, to execute the pilot evaluation plan. The evaluation plan for the Seasonal Savings pilot starts with the definition of treatment and control groups and culminates in the end-of-season M&V work. DNV GL has identified the following key issues to be addressed by the evaluation plan:

- Identifying participants
- Getting unit savings
- Identifying a suitable sample size for potential expansion

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[18] Energy Efficiency Policy Manual, Version 5, p. 17.
[19] Energy Efficiency Policy Manual, Version 5, p. 19.

Specific information for each step is provided below.

1. Treatment and control group randomization by DNV GL.
    a. ***Timing:** to be completed prior to the deployment of the Seasonal Savings program to end-use customers.*
    b. Nest will provide DNV GL with customer identification (ID) list and sample quotas for each group (by zip code and/or climate zone).
    c. Nest will provide SoCalGas with the customer ID list.
    d. SoCalGas will confirm the customer bill account information based on customer ID list.
    e. DNV GL will randomize the treatment and control groups and return data to Nest.[20]

2. Statewide Seasonal Savings working group creates post-season M&V survey to be deployed to customers via email. The survey will be hosted by a third party M&V firm and Nest will send the email.
    a. Nest will provide DNV GL with a draft survey instrument that will be used to get customer feedback and to acquire as much customer identification as possible.
    b. The survey form and results will be hosted by an M&V consultant, not by Nest. However, Nest will facilitate the delivery of the survey link to customers via an email.
    c. SoCalGas will identify a third party consultant to conduct the survey. If DNV GL is not chosen to conduct the survey, then SoCalGas will provide the survey data to DNV GL.
    d. Assessment of market/installation base size
        i. Nest will provide DNV GL with counts of customers by zip code
        ii. DNV GL will review data to see if a verification scheme, via random dialing telephone surveys, is feasible:
            1. DNV GL will sample on zip code, primarily focusing on high-penetration zip codes, but also looking at a few of the lower penetration zip codes.
            2. DNV GL will develop a short telephone survey to assess Nest ownership.
            3. DNV GL will conduct a large telephone survey that employs random digit dialing to validate Nest penetration estimates. This survey will not be a true validation of the Nest customer

[20] Step D will be completed for SoCalGas' pilot as well as program deployments for PG&E and MCE.

population, but will at least provide evidence that Nest counts provide a reasonable estimate of population size.[21]

e. DNV GL will validate that customers are in service territory.

3. Methods for converting HVAC runtime reduction to energy savings.
   a. Timing: *to be completed in parallel with program launch and prior to ex-post savings estimates are made.*
   a. Nest will provide documentation on conversion from runtime to therms for initial estimates.
   b. DNV GL will review for adequacy (in parallel to program deployment, recommend that ex ante team review this piece, as it includes engineering calculations that the ex ante team has expertise in).
   c. Full statewide working group will determine what updates need to be made to calculation methodology and assumptions.

4. Preliminary program analysis
   a. After completion of winter and summer seasons, Nest will provide data and preliminary analysis.
   b. DNV GL will suggest that analysis should include all pilot customer and control groups, and a separate analysis should be conducted – if possible – on the customers who have self-identified themselves via the email survey above.

5. Nest provides data and analysis code to DNV GL for verification.
   a. DNV GL will review Nest work and potentially reruns Nest models plus variants to probe the run time estimates and to verify, and if necessary adjust, the Nest analysis.

Billing Analysis

Large sample points and significantly more customer participation could enable a billing analysis, if funding is available. All statewide parties and program participants agree that a billing analysis will not be valuable unless the customer response is large enough to warrant such an analysis. A billing analysis performed on too small a subset will not offer a realistic result. However, the billing analysis would mainly serve to provide an independent analysis of per-home savings that can be compared against the ex-post approach of using a runtime analysis, combined with engineering calculations, to estimate savings.

1. Steps for potential billing analysis:
   a. For all identified customers, DNV GL will request an extract of advanced meter infrastructure (AMI) data (hourly for electricity, daily for natural gas) from SoCalGas and other program administrators.[22] Customer identification comes from multiple sources:
      i. Nest follow up surveys that request customers to identify themselves (customers must provide name, service address and account number)
      ii. Customer lists from rebated Nest thermostats
      iii. Customer list from thermostat study (PG&E)
   b. Program administrators will provide requested data to DNV GL.
   c. DNV GL will merge AMI data with customer information (collected for all residential customers from the IOUs as part of general evaluation activities) and weather data (also collected for general evaluation work).
   d. DNV GL will conduct a standard billing analysis using the billing data provided for identified Nest customers.

J. A concrete strategy to identify and disseminate best practices and lessons learned from the pilot to all California IOUs to transfer those practices to resource programs, as well as a schedule and plan to expand the pilot to utility and hopefully statewide usage.

Best Practices and Lessons Learned
At the end of the pilot, SoCalGas will work with Nest to identify the best practices and lessons learned from the Winter Seasonal Savings Pilot Program. The results of the pilot will be communicated through a report, which will be the subject of a webinar to share the results with other program administrators and interested stakeholders. In addition, it is anticipated that the experimental design nature of this pilot will provide opportunities to disseminate the findings through industry conferences and/or publications.

Peak Day Impacts
In addition to identifying the therm savings (Energy Efficiency impacts), SoCalGas may also opt to study and quantify the demand impacts (peak day throughput) of the Winter Seasonal Savings Pilot Program, estimating the savings on the ten peak days of heating system run time in the post treatment period. This analysis could be readily completed with the pilot data that will be available.

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[22] All data sharing must comply with necessary data sharing contractual agreements.

ATTACHMENT B

Advice No. 5028-A

Nest Seasonal Savings Massachusetts Department of Energy Resources Impact Evaluation

Executive Summary

The Massachusetts Department of Energy Resources contracted with Nest Labs in December 2014 to deploy Nest's Seasonal Savings algorithm to all Nest customers in Massachusetts in January 2015 with the goal of reducing residential energy usage in the winter of 2015. This report provides an analysis of the energy savings achieved by the algorithm.

Seasonal Savings offers Nest customers a way to improve the efficiency of their thermostat settings by making small adjustments to the programmed set points over a three week period and learning when and by how much the set points could be adjusted without impacting comfort.

The key findings of the evaluation include:

- A total of 20,104 thermostats completed the Seasonal Savings algorithm – equal to 54% of all eligible thermostats in Massachusetts
- Participants' set points declined by an average of 1.3°F over the course of the three week algorithm
- About half of the initial set point reduction was taken back by the end of the winter. The extreme weather and snow-related school and business closings appear to have adversely affected the impacts.
- Seasonal Savings reduced heating usage by an average of 3.5% over the course of the winter based on a weather-adjusted analysis of run times that included a control group from neighboring states. These savings include the effect of the impact reductions over time.
- The heating savings are estimated to have reduced energy bills by $21 per thermostat and $44 per customer, yielding aggregate savings of $427,000. These savings only include impacts from mid-January 2015 through April 2015. They do not include any future savings and also exclude other smaller sources of savings from customers who dropped out and from ancillary electric use of heating systems.

The evaluation found that Seasonal Savings was an effective approach for reducing heating energy use cost-effectively. The savings potential may be larger in winters with less extreme weather.

Program Participation

Nest identified 37,586 thermostats in Massachusetts for potential algorithm deployment. Customers must have an active Nest account; have activated their Nest thermostat by December 25, 2014 (to have sufficient time to develop a schedule); and must have heating controlled by the thermostat. Customers were offered Seasonal Savings on their thermostat (and app) and had to opt-in to participate. The offer was sent out to the thermostats on January 12, 2015. A total of 20,104 thermostats completed the Seasonal Savings process and opted to keep their new schedule. Table 1 summarizes the participation process.

Table 1. Seasonal Savings Participation

Participation	# Thermostats	% of Thermostats
Total Population Sent	37,586	100%
Not Received (not on-line)	1,904	5.1%
Did Not Qualify (primarily devices not in heating mode)	3,108	8.3%
Did Not Opt-In	10,555	28.1%
Exited Early	1,915	5.1%
Completed Seasonal Savings	**20,104**	**53.5%**

About 13% of the targeted customers either did not receive the offer or did not qualify to participate. Overall, 28% of the customers (32% of those qualified) did not choose to participate. About 85% of those who opted to participate completed the Seasonal Savings algorithm.

The timing of the Seasonal Savings algorithm proved to be challenging. The algorithm ran from January 12th through early February[1]. Massachusetts experienced record snowfall with multiple major storms and numerous days of school and business closings. The two biggest storms of the season occurred on January 27th and February 2nd -- both during the three week Seasonal Savings algorithm period. Three more major snow events occurred between February 8th and 15th. These record storms altered occupancy patterns and likely had an adverse impact on the Seasonal Savings algorithm's ability to identify more efficient set point schedules. The extreme weather also may have led customers to revert back toward less efficient set points during the remainder of the winter.

[1] 90% of thermostats completed the algorithm by February 5th and 99% completed by February 10th

Analysis Methods

Nest employed two primary analysis approaches to assessing the energy savings from Seasonal Savings.

- The first approach compares customer schedules before and after running Seasonal Savings and calculates the average change in set point. This change in set point temperature is then multiplied by the estimated heating savings per degree change in set point that has been empirically determined by large scale data analysis Nest has performed on the climate zone level. A second comparison is performed using the set points from 8 weeks after the algorithm finished to assess the longevity of the impacts.
- The second approach is similar to a standard pre/post billing data analysis used for energy efficiency program evaluation – analyzing daily run time as a function of weather. The analysis included two methods – a customer level pre/post weather normalized usage analysis and a pooled regression modeling approach that also explored adjustments for snowfall and Away mode.

The set point approach has the advantage of being directly observable for all customers and, given the short time frame, would not typically require a control group to adjust for population trends -- although the extreme weather led that to not be the case in this instance. The disadvantages include the uncertainty in the relationship between set point changes and heating run-time (which varies by customer and by the timing and magnitude of the changes) and that the approach ignores the impacts of Away mode and manual adjustments to set points -- only looking at changes in the schedule.

The run time approach has the advantage of directly analyzing the outcome of interest -- the run time of the heating system -- and doesn't depend on a model of how set points affect seasonal heating use and implicitly includes the impact of all set point adjustments. The main disadvantages of the run time approach are that the relationship between run time and outdoor temperature may not be well determined for some thermostats and that run time varies with factors other than outdoor temperature (e.g., wind, solar gain, occupancy pattern changes due to holidays and snow storms, etc.) and so the approach requires a control group, which may not be readily available or well matched.

Control Group

A control group[2] was selected to estimate how set points and run time would have changed without Seasonal Savings. For the set point analysis, a control group may not be required in most cases since customer schedules tend to change gradually over time. But due to the extreme weather in Massachusetts during the algorithm deployment and over the rest of the season, we included a control group for both analyses.

[2] Technically speaking it's a comparison group. "Control group" is for use in a randomized control trial.

The Seasonal Savings algorithm was run for all eligible customers in Massachusetts and so the control group needed to be drawn from other states. We used Nest customers in all adjacent states (RI, NH, CT, VT, NY) that were located in counties that border Massachusetts. To better match the control customers to the participants, we divided Massachusetts into 5 regions: Boston & South Shore, North Shore, Cape, Central, and West. The control group for each region was created from Nest customers in bordering counties of neighboring states.

Table 2. Regions and Control Group

Region	Massachusetts Counties	Control Counties
Boston / South Shore	Bristol, Norfolk, Plymouth, Suffolk	Providence RI
North Shore / NE	Essex, Middlesex	Hillsborough NH, Rockingham NH, York, ME
Central	Hampden, Hampshire, Worcester	Cheshire NH, Hartford CT, Tolland CT, Windham CT,
Western	Berkshire, Franklin	Bennington VT, Columbia NY, Litchfield CT, Rensselaer NY, Windham VT
Cape/Islands	Barnstable, Dukes, Nantucket	Bristol RI, Newport RI

The control group differed from the participants in several respects, even within region. There were differences in pre period average set points that were mostly traceable to differences in heating fuels (more bulk fuel in control group) and the use of Away mode (e.g., vacation homes on the Cape). For the run-time analysis we stratified the population on these factors to better match the control customers to the participants.

Findings: Set Points Approach

The set point analysis was based on comparing participant's schedules immediately before and after running the Seasonal Savings algorithm and also analyzing the schedule 8 weeks later to assess the short-term persistence of the changes. Prior Nest analysis had estimated that each 1°F change in heating set point should reduce heating energy use by 4% for homes in Massachusetts. Table 3 summarizes the set point analysis results for customers that completed Seasonal Savings and for the control group.

Table 3. Heating Savings: Set Point Changes °F

	SS Participants	Control	Net Difference
Average set point before SS	65.10	64.58	0.52
Average set point after SS	63.82	64.65	-0.83
Average set point after 8 weeks	64.57	64.74	-0.17
Average set point change	**-1.29**	**+0.06**	**-1.35 ±0.03**
Average set point change after 8 weeks	**-0.52**	**+0.14**	**-0.67 ±0.04**
Estimated Savings: initial	5.2%	-0.2%	5.4%
Estimated Savings: after 8 weeks	2.1%	-0.6%	2.7%
Estimated Savings: Average over period	3.6%	-0.4%	4.0%

The average heating set point declined by 1.29°F (±0.02°F) after Seasonal Savings. The control group set point increased by an average of 0.06°F (±0.02 °F), implying a net 1.35°F set point reduction for participants. At 4% savings per degree set point, heating savings of 5.4% would be expected. But 8 weeks after Seasonal Savings the net set point reduction was only half as large and so estimated savings dropped to 2.7%. Assuming a linear decline over the 8 weeks, average savings are estimated at 4.0% of heating use for the period (or 4.2% if weighted by degree days).

For Seasonal Savings customers that exited early, a comparable analysis found an average set point reduction (net of control group) of 0.61°F immediately after SS and 0.19°F at the end of 8 weeks, leading to estimated average savings of 1.6% (2.4% declining to 0.8%).

The distribution of average set point changes for participants that completed Seasonal Savings is shown in Figure 1 (excluding about 1% of cases with more extreme changes).

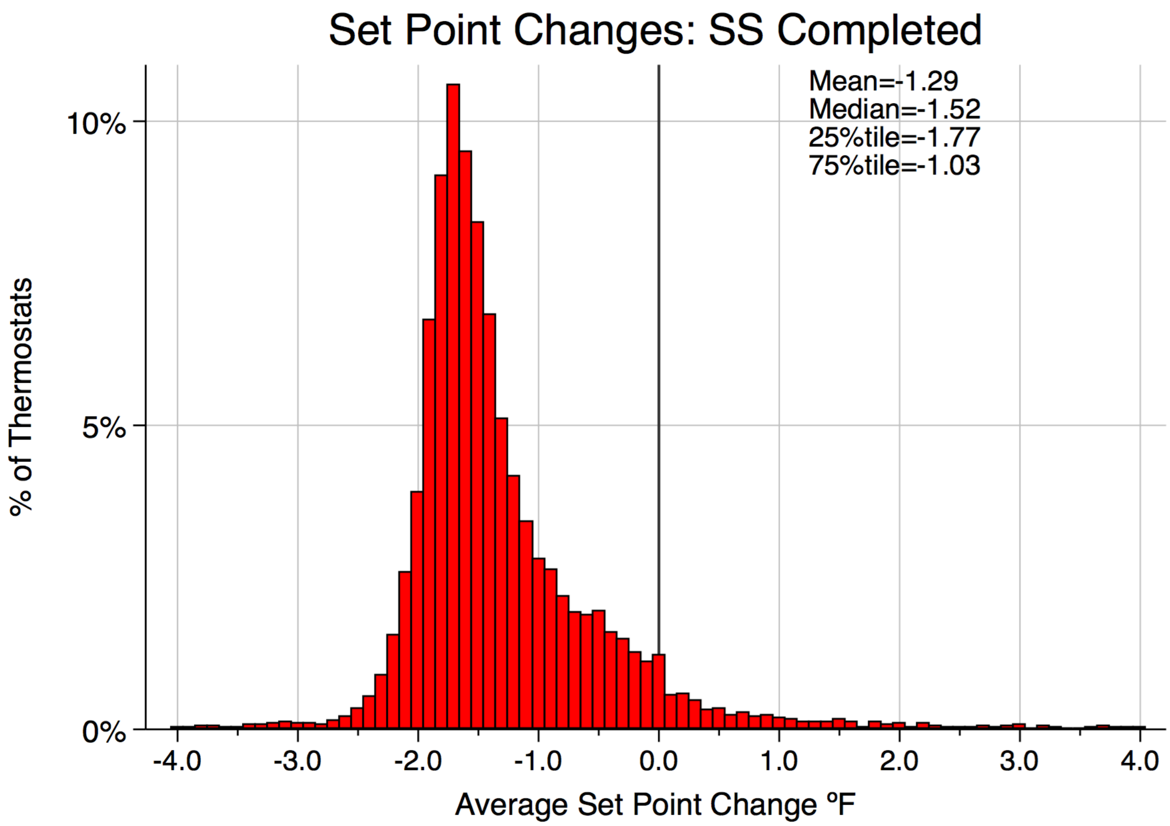

Figure 1. Distribution of schedule set point changes after Seasonal Savings

The plot shows that the most common change in set point was about a 1.7°F reduction but the distribution is skewed right leading to a mean value lower than the median or mode.

Figure 2 repeats this histogram but changes the vertical scale so that it can be compared to a histogram for the control group using the same scale..

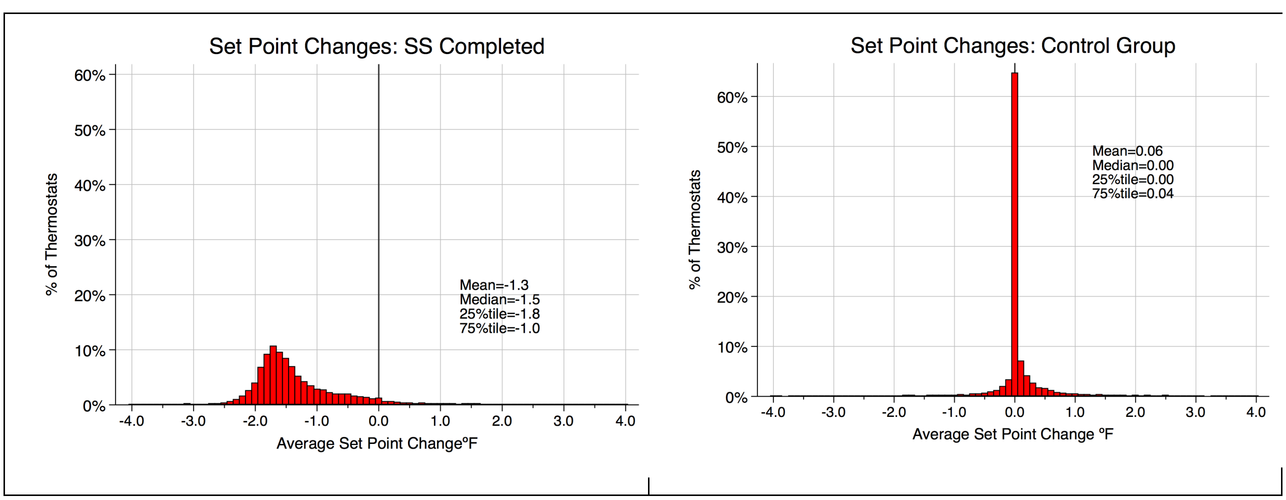

Figure 2. Distribution of schedule set point changes vs. Control Group

The spike at zero for the control group shows that more than 60% of the control group had essentially no change in average set point over the period. There is no segment of the control group that experienced the large set point changes found among participants—showing that self-selection could not explain the large shift in set points over the period.

Figure 3 shows the distribution of set point changes 8 weeks after Seasonal Savings.

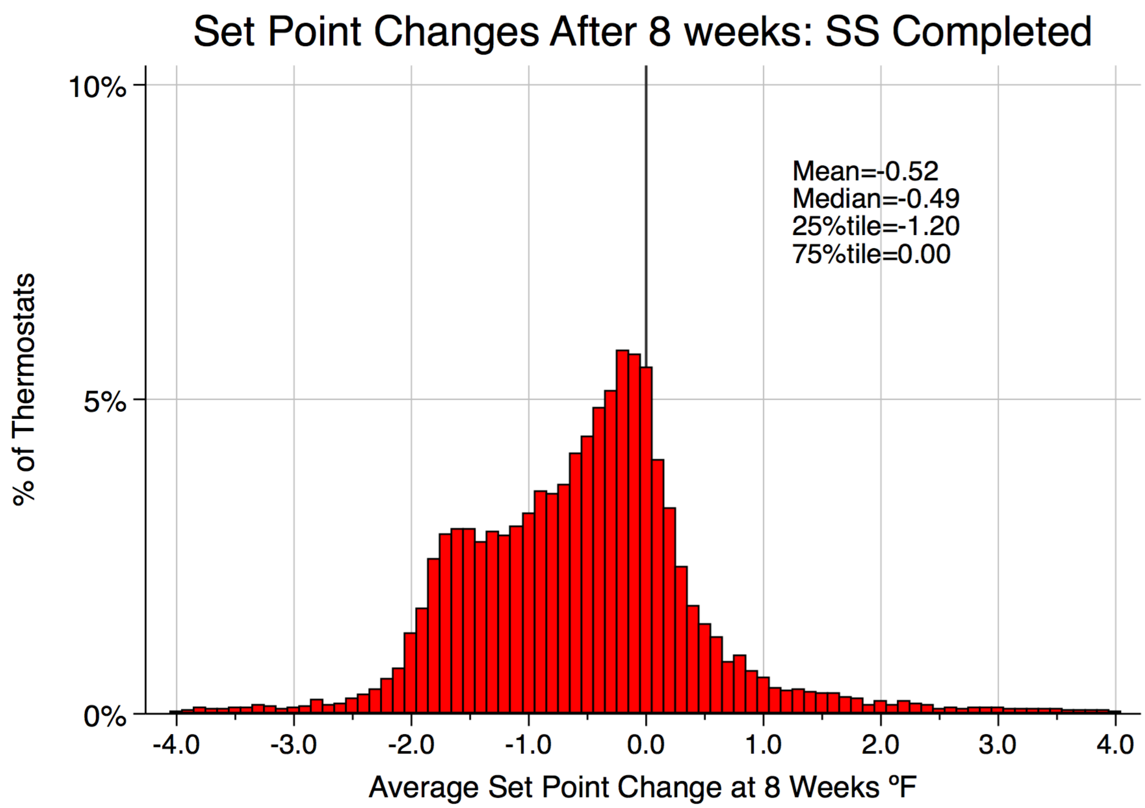

Figure 3. Distribution of schedule set point changes 8 weeks after Seasonal Savings

The distribution shape changed as some customers have apparently reverted back to something close to their old schedules while a significant fraction maintained their new schedules. The control group distribution appeared about the same although the mean set point change increased to 0.14°F.

The hourly profile of the immediate set point changes is shown in Figure 3.

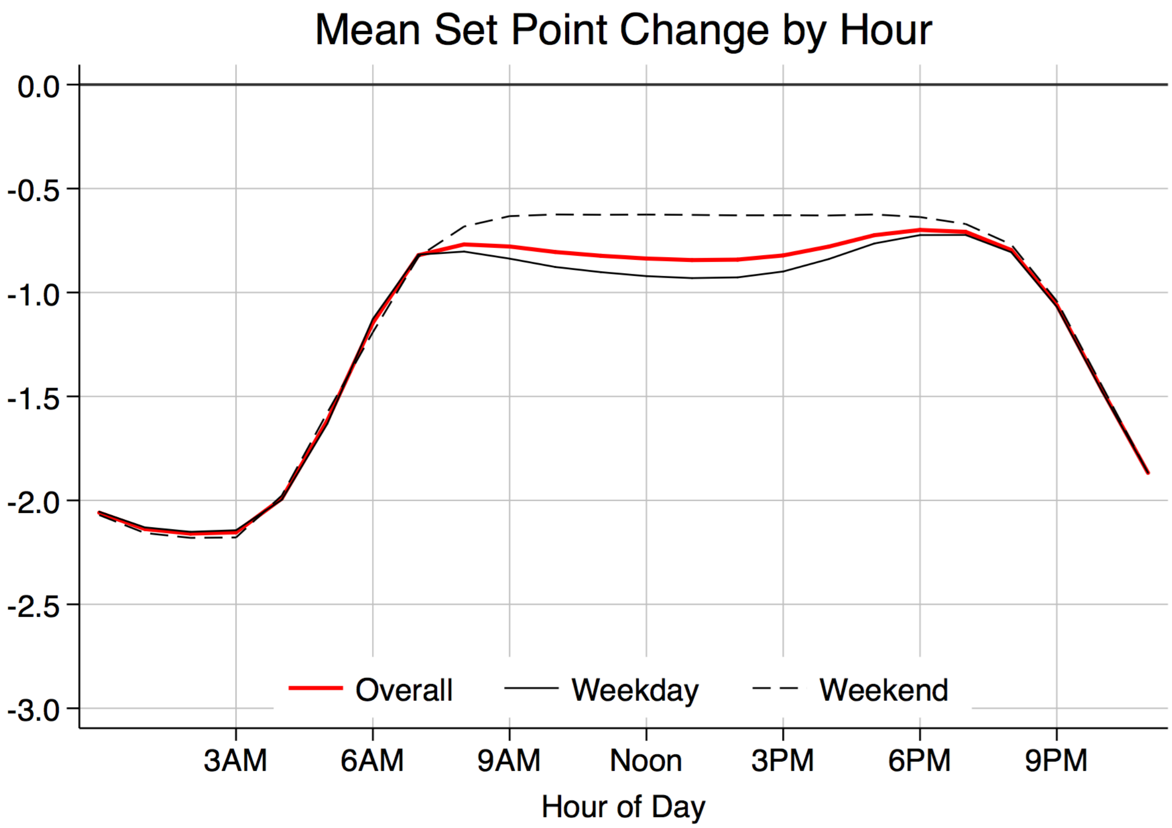

Figure 3. Mean set point changes by hour of day

The plot shows that set point reductions averaged more than 2°F during the night and less than 1°F during the middle of the day. The night setback changes were similar for weekdays and weekends but the daytime reductions were larger on weekdays than weekends -- an expected finding. The smallest changes in set points occurred when people were waking up in the morning and in the prime evening hours. The Seasonal Savings algorithm captures the largest set point improvements at times when they have the least impact on comfort.

A more detailed look at the set point changes is provided in Figure 4, which is the same data as presented in Figure 3, but also shows the distribution of the changes in set point for each hour using a box plot. The plot shows the mean change as the horizontal black line on each box and shows the median as the white break between the red boxes. The red boxes extend out to the 25th and 75th percentiles. The lines extend out to the 10th and 90th percentiles.

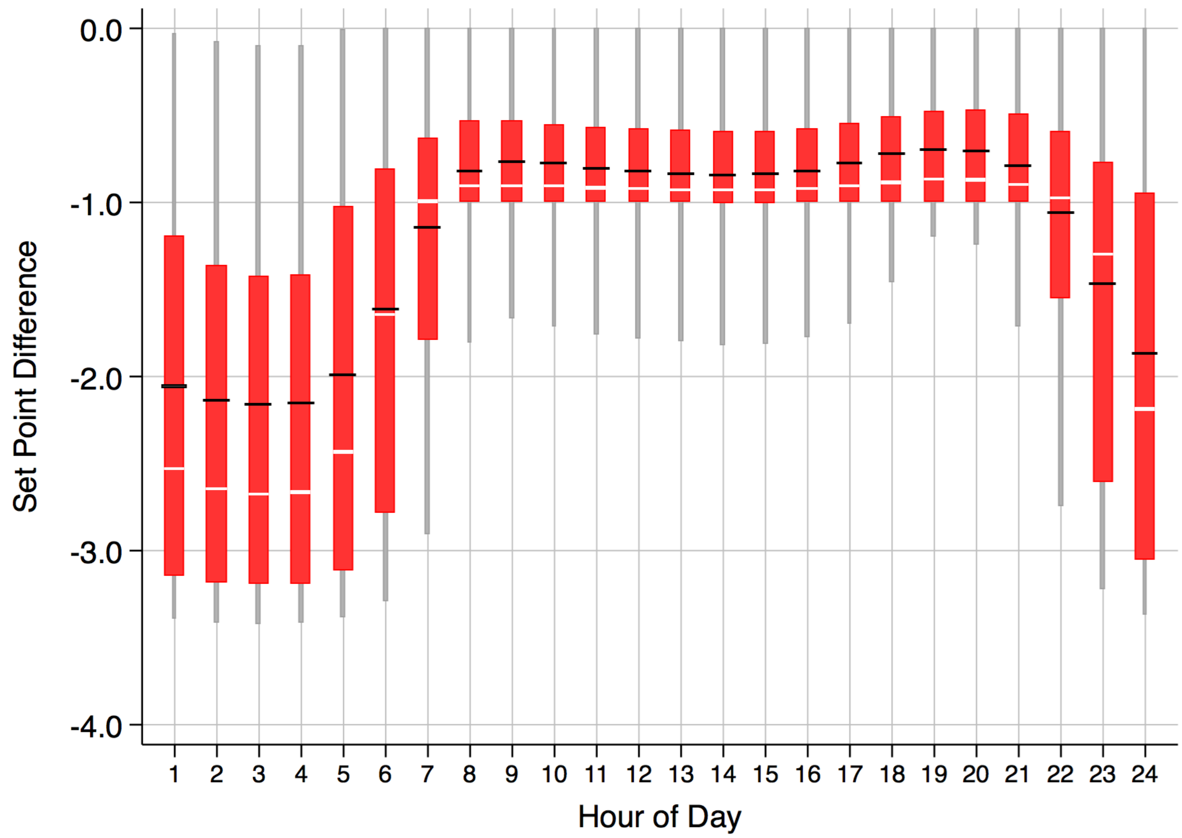

Figure 4. Distribution of set point changes by hour of day

The plot shows how the typical (median) temperature reductions are more than 2.5°F at night and just below 1°F during the day. The lower bound 10th percentiles show that the period of 6PM - 8PM has the least flexibility in set points -- the 10th percentile line barely extends below the -1°F line.

Set Point Changes Over Time

We analyzed the changes in the set point schedules over time in greater detail to better understand the apparent decline in algorithm impacts.

Figure 5 plots the heating schedule set points over the course of this past winter for three groups of customers: Seasonal Savings participants, customers who opted not to participate in Seasonal Savings or dropped out prior to completion, and a control group of customers from neighboring states. The graph shows data for the North Shore region (Northeastern MA and adjacent counties in NH and ME) region. The set points plotted are a 7-day moving average (the average of the prior 7 days for each date). The blue points along the top of the graph show the dates of snowstorms in Eastern Massachusetts.

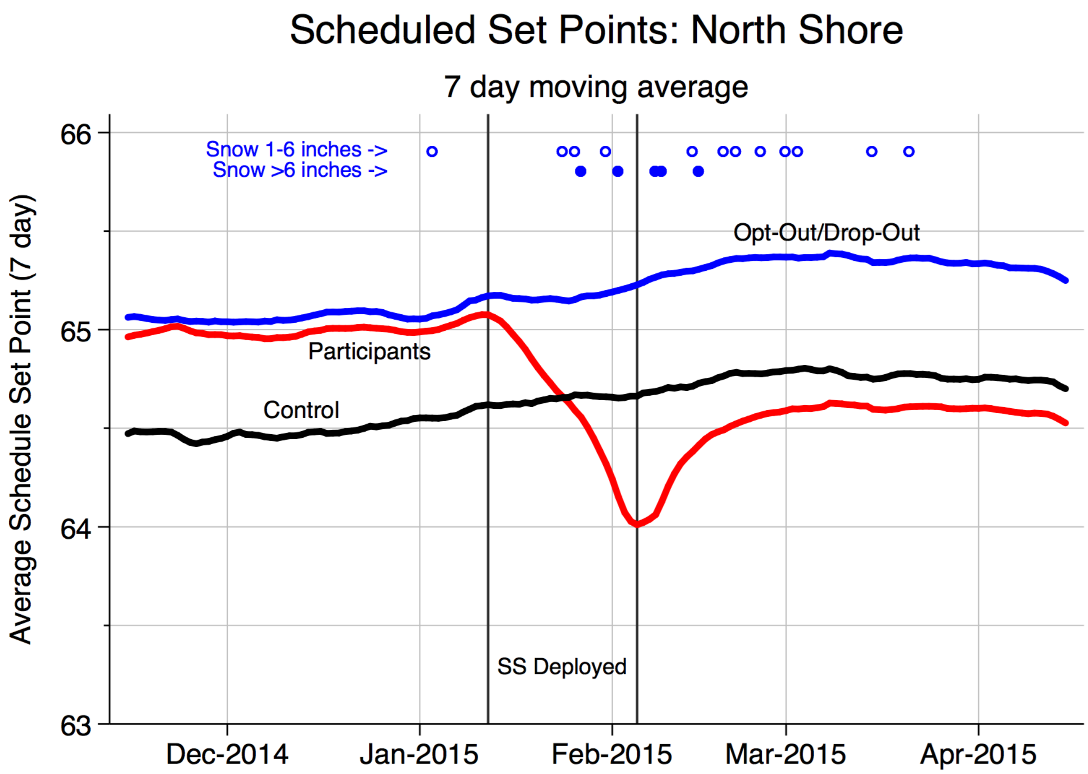

Figure 5. Scheduled Set Points Over Time: North Shore

Prior to deployment of Seasonal Savings, the Massachusetts customers had higher set points than the control group by about a half degree. The participants then show a clear drop of more than 1°F during the algorithm deployment and then a fairly significant increase in the few weeks after Seasonal Savings finished – giving back about half the gains. During this same period the control group and the opt-out groups both experienced gradual but clear increases in set points. The graph show similar behavior over time for the control group and the opt-out group, suggesting that the opt-out group may have served as a viable control group.

A few weeks after the algorithm ran, the set points had stabilized for all three groups, implying that any degradation in impacts occurred quickly and then leveled out. A key question is what role the multiple major snow storms played in suppressing the impact of Seasonal Savings and especially in the set point increases in the following few weeks.

Figure 6 explores the changes in greater detail -- plotting the change in set point for each date compared to the same day seven days prior (therefore accounting for day of week variations).

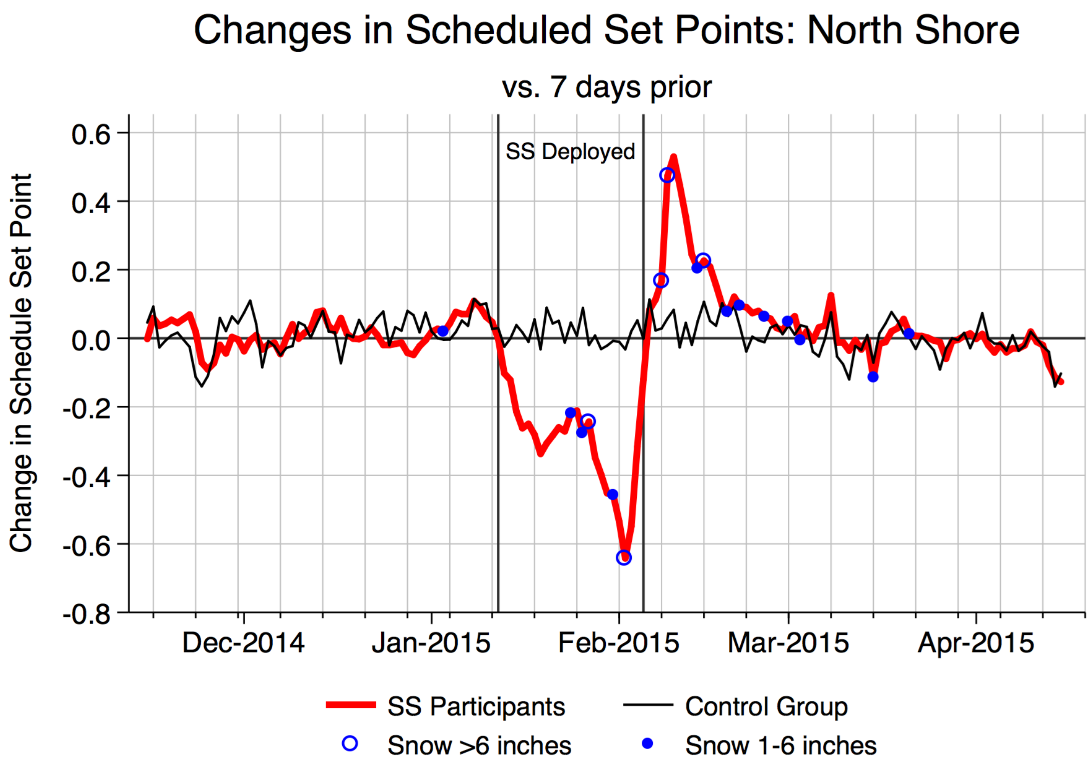

Figure 6. Change in Scheduled Set Point vs. 7 days prior

For clarity, this plot only shows participants and the control group and snowstorms are shown as symbols on the line. It appears that snowstorms may have reduced the algorithm impacts (snow coinciding with the stutter in the set point declines around the middle of the deployment) and also contributed to the reversion in set points shortly after the algorithm completed. After about two or three weeks, participant set point changes settled down and became similar to the control group. The post-deployment decline in algorithm impacts was immediate and short lived, suggesting no further on-going degradation in savings after the initial couple of weeks. Other regions showed similar.

Data from next winter will be needed to confirm that the remaining savings persist, but it appears that they may have based on this data.

Run Time Analysis

The run-time based analysis employed two methods that are each based on standard billing data analysis approaches – a house-level pre/post treatment/comparison weather normalization and a pooled fixed effects econometric analysis. The house level analysis provides useful insights into savings variability but the pooled model is easier to replicate, involves fewer analytical decisions, and can potentially account for the impacts of snowfall and Away mode on run time.

Findings: House Level Run Time Analysis

The house level weather normalization analysis employed a variable-base degree day ratio estimation. Ratio estimation results were screened for reliability based on having at least 10 days of data in the pre and post treatment periods and having a reasonable model fit as indicated by a CV(RMSE) of less than 65%. In addition, a small fraction of cases with extreme changes in usage were classified as outliers (% change in usage greater than 2.5 interquartile ranges from the median percent change in usage). The data screening caused about 25% overall attrition, with the vast majority due to the CV(RMSE) requirement.

An initial analysis was performed based on the standard definition of the post-treatment period as starting when the algorithm deployment finished. This analysis found a net 3.5% reduction in run time, equal to 29 hours in annual runtime reduction. But the significant changes in set points in the few weeks after deployment suggests that this annualized savings value may over-state actual impacts. The ratio estimation was repeated with the post-treatment period starting on the day the algorithm deployed so that the full savings over the course of the winter could be assessed. The impacts for the actual post treatment period through the end of April 2015 were then calculated based on these results. The analysis is summarized in Table 4.

Table 4. Heating Savings: Run-Time Analysis VBDD ratio estimation

		Annual Runtime (hours/year)			
Group	**# T-stats**	**Pre**	**Post**	**Savings**	**%Savings**
Seasonal Savings	14,883	826	776	50	6.1% ±0.4%
Control Group	7,442	797	773	23	2.9% ±0.6%
Net Annual Savings				**27 ±6**	**3.2% ±0.7%**
Net Savings Jan 2015 – Apr 2015				**17.4 ±3.6**	**3.2% ±0.7%**

Note: ± values are 95% confidence intervals on the means

Weather-adjusted annualized run-time for the Seasonal Savings participants declined by 50 hours but the control group experienced an average 23 hour reduction yielding a net savings estimate of 27 hours per year. These savings equal 3.2% of heating use. The savings actually achieved from deployment through the end of April are estimated at 17 hours of run time based on the actual weather experienced.

Savings were estimated to be a little larger for homes with gas heat compared to those with other types of heat (3.6% vs. 2.3%) but the difference was not statistically significant.

Participants in the analysis had an average of 1.9 Nest thermostats per home. Overall, 58% of participants had one Nest thermostat, 28% had two thermostats, and 14% had three or more thermostats. The estimated net savings were larger for homes with two or more thermostats -- averaging 32 hours of run time per thermostat (3.8% ±1.0% heating savings). Based on available customer-reported data, home size averaged 2,572 sq.ft. overall but was 1,811 sq.ft. for homes with one thermostat compared to 3,016 sq.ft. for homes with multiple thermostats (2,558 sq.ft. for homes with two thermostats, and 3,610 sq.ft. for homes with three or more thermostats).

The 3.2% savings reported in Table 4 are a little less than the 4.0% savings reported in Table 3 from the set point analysis averaged over the 8 weeks. But this difference should be expected given two potential sources of over-estimation in the set point analysis -- being based solely on schedule set points (omitting the impact of Away mode and manual adjustments) and the larger set point reductions at night (which may save less than 4%/°F since night set back temperatures aren't always binding).

Findings: Pooled Run Time Analysis

The pooled run time analysis involved using a single regression model of the daily run time for all participants and control group customers. This type of pooled modeling is commonly employed in billing data analysis studies. Two different model specifications were analyzed:

1. a base model that fit daily heating run time as a function of heating degree days (HDD base 60°F), and indicator variables for participation and for the post treatment period and interactions between degree days and participation and also the post treatment period.
2. An expansion of the base model to include variables for snowfall and for time spent in Away mode and an interaction between Away mode and HDD60. Away mode was considered an exogenous factor unrelated to Seasonal Savings participation. The purpose of the expanded model was to account for additional factors expected to affect heating run time and develop more precise estimates.

The models were fit using a fixed-effects regression model that included thermostat-specific effects. Differences in the relative size of the control group for each region and the potential for different impacts in different regions led to fitting a separate model for each region and then combining the estimated impacts based on the size of the participant population in each region.

The models defined the pre and post treatment periods as before and after January 12, 2015 – just as in the ratio estimation approach. The inclusion of the algorithm deployment period should lead to slightly lower percent savings but capture a greater overall level of savings. The results of this analysis are summarized in Table 5. The detailed regression modeling output is shown in Table 6.

Table 5. Heating Savings: Run Time Analysis Pooled Fixed Effects

		Analysis Sample Size		% Heating Savings	
Region	% Pop	Participants	Device-Days	Base Model	Full Model
Boston & South Shore	34.3%	6,645	1,343,505	4.0% ±0.4%	4.0% ±0.4%
North Shore /NE	46.2%	9,501	2,057,098	2.5% ±0.3%	2.9% ±0.3%
Central	9.2%	1,900	735,816	4.3% ±0.4%	4.2% ±0.4%
Western	1.8%	246	427,004	-1.9% ±1.4%	-1.1% ±1.4%
Cape/islands	8.5%	923	300,106	5.9% ±0.9%	5.2% ±0.9%
Total	**100%**	**19,215**	**4,863,529**	**3.4%** ±0.4%	**3.5%** ±0.4%

Table 6. Pooled Fixed Effects Model Output

	Boston/ S Shore		North Shore / NE		Central		Western		Cape/Islands	
Model specification->	Basic	Full	Basic	Full	Basic	Full	Basic	Full	Basic	Full
# observations	1,343,505	1,343,505	2,057,098	2,057,098	735,816	735,816	427,004	427,004	300,106	300,106
SS customers	6,645	6,645	9,501	9,501	1,900	1,900	246	246	923	923
Control Customers	1,860	1,860	3,572	3,572	2,798	2,798	2,502	2,502	974	974
Coefficients / t-stats										
hdd60	0.1728	0.1838	0.156	0.1666	0.1671	0.1758	0.1561	0.1744	0.1615	0.1788
	286.15	305.19	357.94	381.2	338.88	350.39	212.04	226.28	158.53	173.94
hdd60_treat	-0.0008	-0.0005	0.0182	0.0155	-0.0008	-0.0019	0.0148	0.0081	0.0079	0.0094
	-1.12	-0.79	35.64	30.88	-1.11	-2.47	5.76	3.34	5.42	6.69
Post	-0.0167	-0.0151	0.0337	0.0347	0.1495	0.1399	-0.0472	0.0278	-0.2519	-0.2192
	-0.87	-0.8	2.21	2.32	9.16	8.68	-1.75	1.09	-8.05	-7.25
post_treat	0	-0.0024	0.013	-0.003	0.0432	0.0325	0.2919	0.2788	-0.0696	-0.1173
	0	-0.11	0.74	-0.18	1.68	1.28	3.09	3.13	-1.55	-2.71
post_hdd60	-0.0006	-0.0012	-0.0052	-0.005	-0.0035	-0.0032	-0.0022	-0.0022	0.0112	0.0102
	-0.82	-1.7	-10.21	-9.98	-6.07	-5.64	-2.58	-2.7	9.1	8.52
post_hdd60_treat	-0.0063	-0.0062	-0.0044	-0.0045	-0.008	-0.0075	-0.0061	-0.0069	-0.0068	-0.0039
	-7.76	-7.85	-7.45	-7.63	-9.01	-8.55	-2.07	-2.5	-3.77	-2.24
awayhrs		0.0124		-0.0007		0.0078		-0.0625		-0.0364
		17.37		-1.15		7.79		-52.38		-29.79
awayhrs_hdd60		-0.003		-0.0025		-0.0026		-0.0024		-0.0026
		-121.78		-135.53		-80.03		-73.69		-62.62
snowfall		-0.0007		-0.0037		-0.0084		-0.0108		0.0391
		-0.72		-5.27		-4.63		-3.23		11.68
constant	-0.3555	-0.3846	-0.4317	-0.398	-0.5017	-0.5032	-0.7175	-0.0491	-0.3632	-0.0499
	-50.5	-50.95	-70.61	-61.64	-48.4	-46.05	-33.76	-2.12	-21.94	-2.66

Both pooled models estimated that Seasonal Savings reduced heating usage by about 3.5% -- very close to the 3.2% found from the house level ratio estimation approach. The addition of the snowfall and Away mode variables barely affected the overall estimated savings but did reduce the variance in estimates across regions – implying that the estimates are more reliable.

The estimated savings varied by region, but the estimates for the Western and Cape/Island regions were based on fairly small samples with larger uncertainty and only represent about 10% of the overall participant population.

The run time savings for this past winter were calculated using the actual elapsed heating degree days and days. The resulting estimate is a 15.1 hour reduction in run time – a little less than the 17.4 hours estimated from the ratio estimation approach. The slightly higher percent savings yet slightly lower absolute hours savings can be explained by differences in the sample composition and weighting – the ratio estimation sample is about 25% smaller primarily due to screening criteria on the thermostat-specific model fit.

Peak Day Impacts

One of the goals of the analysis was to estimate the impacts of Seasonal Savings on peak day gas throughput. We used the pooled model results to estimate the savings on the ten peak days of heating system run time in the post treatment period. Heating system run time on these ten peaks days ranged from 7 to 9 hours and averaged 7.6 hours. For the 14,756 gas heated homes, the aggregate reduction in peak day gas use is estimated at 305 Mcf and ranged from 282 Mcf to 361 Mcf.

Fuel and Cost Savings

The three analysis methods provided fairly consistent estimates of the impacts of Seasonal Savings – 3.2%-3.5% for the run time analysis results and about 4.0% for the analysis based on set points. Considering the potential biases and the advantages and disadvantages of each approach, we believe the pooled fixed effects estimate using the full model is the best estimate to use for the overall savings. Converting this estimate into fuel and cost savings requires making assumptions about system fuel input rates and appropriate energy costs.

We estimated an average heating system input rate of 80,000 Btu/hour based on data from a recent evaluation of the Massachusetts High Efficiency Heating Equipment program[3]. As a cross check, we calculated the implied annual gas heating usage using this input rate and the 826 hours of average annualized run time from the ratio estimation, yielding 661 therms per thermostat. This value is about 13% less than the 760 therm annual household average natural gas use estimate on the DOER web site[4] but it makes sense given the frequency of multi-system homes.

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[3] see p.53 in http://ma-eeac.org/wordpress/wp-content/uploads/High-Efficiency-Heating-Equipment-Impact-Evaluation-Final-Report.pdf

[4] see http://www.mass.gov/eea/energy-utilities-clean-tech/misc/household-heating-costs.htm

We used the same 80 Kbtu/hr estimated input for all fuels, although it is likely an under-estimate for oil (equal to just 0.58 gph).

For the few homes with electric heat pumps, we assumed an overall seasonal efficiency of 2.5 COP and adjusted the Btu input accordingly. For energy costs, we estimated \$1.55/therm of natural gas, \$3.13/gallon of heating oil, \$3.09/gallon of propane, and \$0.15/kWh of electricity based on data from the DOER web site.

Table 7 summarizes the fuel and cost savings based on these heating system input rates and energy costs and using the 2015 run time savings of 15.1 hours from the pooled model.

Table 7. Fuel and Cost Savings: Winter 2015

		Savings/Unit		Savings/Home		Aggregate Savings	
Fuel	**% Units**	**Fuel**	**$**	**Fuel**	**$**	**Fuel**	**$**
Natural Gas (therms)	73.4%	12.1	$18.72	25.0	$38.76	178,257	$276,297
Oil (gals)	20.7%	8.7	$27.20	18.3	$57.12	36,096	$112,982
Propane (gals)	3.4%	13.0	$40.14	31.2	$96.33	8,748	$27,031
Electric (kWh)	2.6%	142	$21.24	256.3	$38.45	73,455	$11,018
Total	**100%**		$21.26		$44.47		$427,329

The overall savings is estimated at about \$21 per thermostat, \$44 per customer and more than \$400,000 in aggregate.

The fuel and cost savings reported don't include three more sources of additional savings:

- savings that occurred (or will occur) after April 2015
- savings for customers who opted in to Seasonal Savings but exited early (although they showed some set point reductions)
- savings in electricity consumption of fuel-fired heating systems due to furnace fans, boiler pumps, and other electric use. These savings may have been about \$1 per thermostat.

The overall savings from these factors may be significant relative to the savings reported in Table 7.

Further Observations

In addition to the issue of excluding savings after April 2015 and from early exit customers, there are two other factors that may have limited the savings from this specific deployment of the Seasonal Savings algorithm:

1. The record setting snowfall and associated school and business closings during this past winter coincided with the algorithm deployment and may have reduced the impacts from Seasonal Savings and contributed to the decline in savings over time.
2. The algorithm wasn't deployed until January 12th and ran through early/mid February, limiting the savings to about half the winter. If the algorithm had been deployed at the start of December, the savings for this winter would have been about 40% larger than the 15 hours reported here.

ATTACHMENT C

Advice No. 5028-A

Nest White Paper – Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results

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.

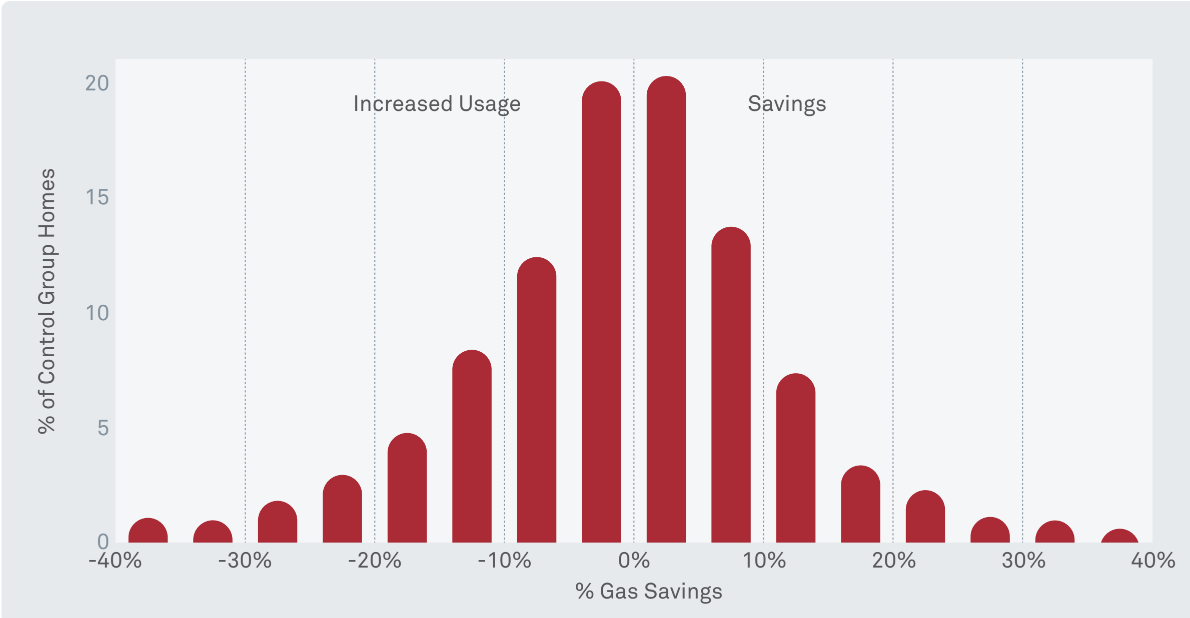

Figure 1. Distribution of Natural Gas "Savings" for non-Nest comparison group

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.

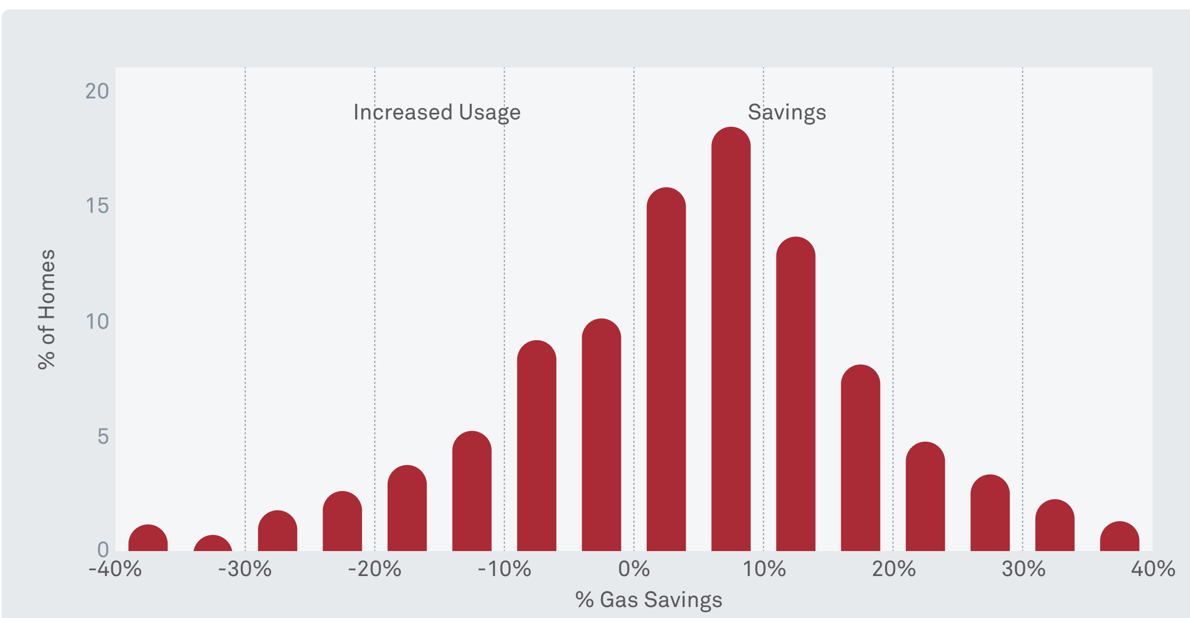

Figure 2. Distribution of Natural Gas Savings for Nest MyEnergy customers

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.

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