NAVIGANT

ComEd CY2018 Nest Seasonal Savings Heating Season Impact Evaluation Report

Energy Efficiency / Demand Response Plan: Program Year 2018 (CY2018) (1/1/2018-12/31/2018)

Presented to Commonwealth Edison Company

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1. INTRODUCTION

This report presents the results of the heating season impact evaluation of ComEd's CY2018 Seasonal Savings (SS) Program. It presents a summary of the energy and demand impacts for the total program and broken out by relevant measure and program structure details. The appendix presents the impact analysis methodology. CY2018 covers January 1, 2018 through December 31, 2018, but this pilot evaluation covers the heating season from November 2017 to April 2018.[1]

2. PROGRAM DESCRIPTION

The SS Program is designed to make small adjustments to participant's scheduled thermostat setpoints over a 3-week period (i.e., tune-up period) while maintaining customer comfort. On average, scheduled setpoints are adjusted down by 1°F during the heating season, with the biggest temperature adjustments taking place when customers are asleep (e.g., the middle of the night) or during regular absences.[2]

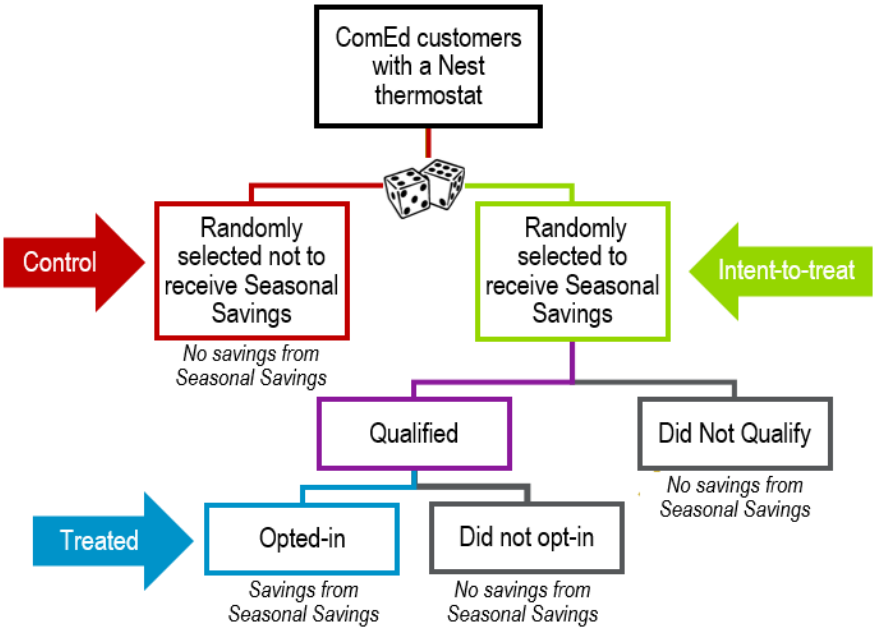
Nest, the program implementer, implemented the SS Program in 2017 using a randomized encouragement design (RED), in which all customers in ComEd's service territory with a Nest thermostat were randomly assigned into one of two groups. These two groups were the intent-to-treat (ITT) group, where participants were randomly assigned to receive the program offering, and the control group, where participants were randomly assigned to *not* receive the program offering.

Some customers in the control and ITT groups (i.e., randomly assigned to receive the program offering) may not qualify to participate in the program. Qualification requirements include: (1) Nest thermostat installed and connected to Wi-Fi, (2) thermostat set to heating mode, and (3) a programmed setpoint schedule. All eligible customers are provided the program offering on the thermostat itself and through Nest's mobile app. Some portion of customers will opt in and enroll in the program, while others will not. The group of customers that opt in is referred to as the treated group. Thermostats that were part of the ITT group but either did not qualify or did not opt-in are part of the untreated group. Refer to Figure 2-1 below for an illustration of the RED design for the SS Program.

[1] This evaluation period has been agreed to by relevant parties as the program is in a pilot stage. If the pilot is converted to a full program Navigant will ensure there is no double counting of savings across the pilot and program stages.

[2] For additional information see: https://nest.com/support/article/What-is-Seasonal-Savings.

Figure 2-1. Illustration of Seasonal Savings RED



Source: Navigant

The program had 72,276 participants (those who enrolled in SS after being offered it) in the heating season of CY2018 and distributed one measure as shown in the following table and graph. The device counts in Table 2-1 reflect the raw participation data Navigant received from Nest. Savings could only be claimed for devices that were in a zip code primarily made up of ComEd households[3] with available telemetry data during the study period. In total, savings were claimed for 107,398 valid ITT devices. See Table 7-1 later in the report for a complete listing of devices dropped, counts of devices used in the analysis, the total valid devices used to calculate savings, and the conditions for savings eligibility.

Table 2-1. CY2018 Volumetric Findings Detail

Category	Device Counts	Percentage
Nests in electric service area	121,618	–
Nests in control group	8,001	7% of Nests
Nests in ITT group	113,617	93% of Nests
Nests enrolled in SS (treated group)	72,276	64% of ITT
Nests in untreated group	41,341	36% of ITT
Nests that did not qualify	14,411	12% of ITT
Nests that did not opt in	26,930	24% of ITT

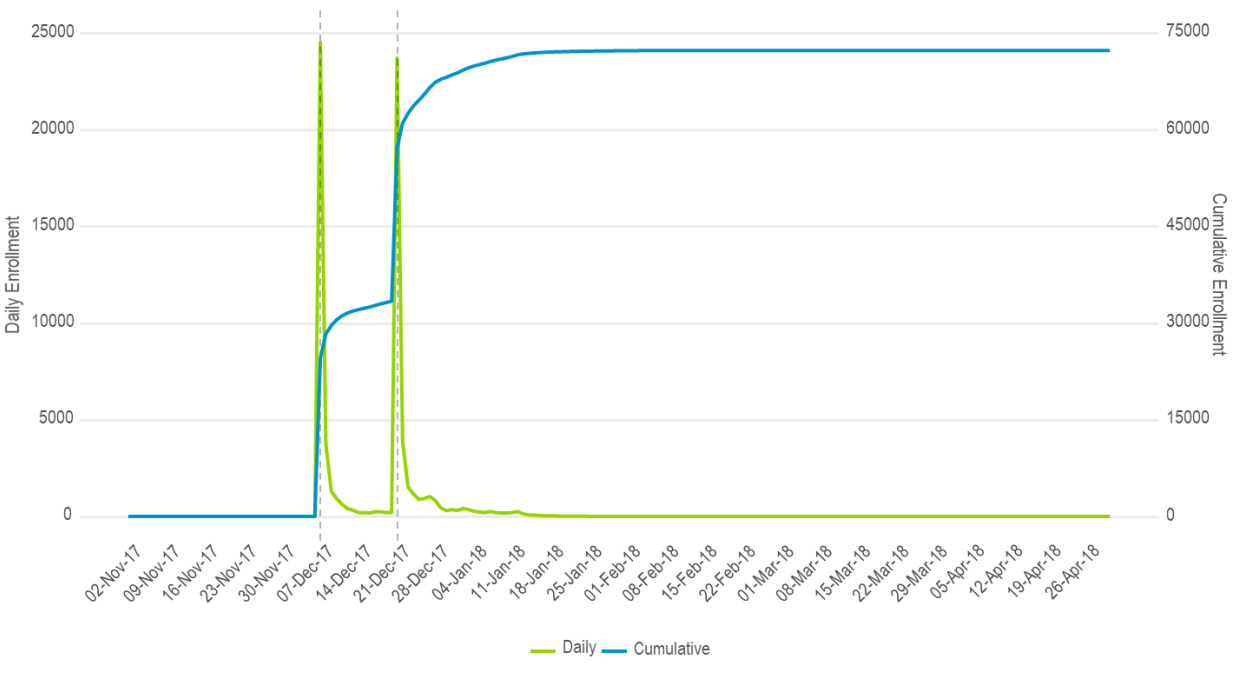
Source: ComEd tracking data and Navigant team analysis.

Figure 2-2 shows the number of thermostats enrolled over the course of the study period. Of the 113,617 devices in the ITT group offered enrollment, 56,000 were offered on December 6, 2017 and the remaining 57,617 were offered on December 20, 2017. These dates are represented by two vertical dotted lines on all daily graphics within this report. Note that no device could enroll in SS before its offer date. Within the

[3] Navigant used a cut-off of at least 95% of households in a zip code having ComEd electric service for this requirement. This removed approximately 3.5% of devices.

first week of enrollment being offered, 87.4% (63,168) of treated devices were enabled with Seasonal Savings. This equates to 55.6% of the ITT population, or 63.7% of the qualified ITT population.

Figure 2-2. Number of Enrolled Thermostats over Time



Source: Navigant analysis of customer enrollment data.

3. Program Savings Detail

Table 3-1 summarizes the incremental energy savings the SS program achieved in CY2018. The gas savings are only those that the gas utilities are not claiming and ComEd can claim.[4] This program evaluation specifically focused on energy savings, and demand savings were not estimated. In addition, this type of analysis estimates net savings and no further net-to-gross (NTG) adjustment is necessary. Because of this, there are no gross values in the table below.

[4] The evaluation will determine which gas savings will be counted toward goal while producing the portfolio-wide Summary Report.

Table 3-1. CY2018 Total Annual Incremental Electric Savings

Savings Category	Energy Savings (kWh)	Demand Savings (kW)	Summer Peak Demand Savings (kW)
Electricity			
Ex Ante Gross Savings	NA	NA	NA
Program Gross Realization Rate	NA	NA	NA
Verified Gross Savings	NA	NA	NA
Program Net-to-Gross Ratio (NTG)	NA	NA	NA
Verified Net Savings	2,566,785	NA	NA
Converted from Gas*			
Ex Ante Gross Savings	NA	NA	NA
Program Gross Realization Rate	NA	NA	NA
Verified Gross Savings	NA	NA	NA
Program Net-to-Gross Ratio (NTG)	NA	NA	NA
Verified Net Savings	42,840,061	NA	NA
Total Electric Plus Gas			
Ex Ante Gross Savings	NA	NA	NA
Program Gross Realization Rate	NA	NA	NA
Verified Gross Savings	NA	NA	NA
Program Net-to-Gross Ratio (NTG)	NA	NA	NA
Verified Net Savings	45,406,846	NA	NA

* Gas savings converted to kWh by multiplying Therms * 29.31 (which is based on 100,000 Btu/Therm and 3,412 Btu/kWh).
Source: Nest telemetry data and Navigant team analysis.

4. Cumulative Persisting Annual Savings

The measure-specific and total ex ante gross savings for the heating season of the SS Program and the cumulative persisting annual savings (CPAS) for the measures installed in CY2018 are shown in the following tables and figure. The total electric CPAS across all measures is 2,566,785 kWh.[5] The program achieved 42,840,061 kWh CPAS equivalent of gas savings converted to electricity that might be counted toward ComEd's goal[6] (the middle table in the following set of tables). Adding the savings converted from gas savings to the electric savings produces a total of 45,406,846 kWh of total CPAS. In addition, this type of analysis estimates net savings and no further net-to-gross (NTG) adjustment is necessary. Because of this, there is no NTG ratio.

[5] These savings are not weather normalized.
[6] The evaluation will determine which gas savings will be counted toward goal while producing the portfolio-wide Summary Report.

Table 4-1. Cumulative Persisting Annual Savings (CPAS) – Electricity

End Use Type	Research Category	EUL	CY2018 Verified Gross Savings	NTG*	Lifetime Net Savings†	Verified Net kWh Savings 2018	2019	2020	2021	2022	2023	2024	2025	2026
HVAC	Thermostat Optimization - Furnace Fan	1.0	NA	NA	1,296,198	1,296,198								
HVAC	Thermostat Optimization - Electric Heat	1.0	NA	NA	1,270,587	1,270,587								
CY2018 Program Total Electric CPAS			NA		2,566,785	2,566,785	-	-	-	-	-	-	-	-
CY2018 Program Expiring Electric Savings‡							2,566,785	2,566,785	2,566,785	2,566,785	2,566,785	2,566,785	2,566,785	2,566,785

Note: The green highlighted cell shows program total first year electric savings.
* The randomized controlled trial used for this evaluation produces net savings and as such the NTG ratio is not applicable.
† Lifetime savings are the sum of CPAS savings through the EUL.
‡Expiring savings are equal to CPAS Yn-1 - CPAS Yn + Expiring Savings Yn-1.
Source: Navigant analysis of Nest thermostat telemetry data

Table 4-2. Cumulative Persisting Annual Savings (CPAS) – Gas

End Use Type	Research Category	EUL	CY2018 Verified Gross Savings (Therms)	NTG*	Lifetime Net Savings†	Verified Net Therms Savings 2018	2019	2020	2021	2022	2023	2024	2025	2026
HVAC	Thermostat Optimization - Gas Heat	1.0	NA	NA	1,461,619	1,461,619								
CY2018 Program Total Gas CPAS (Therms)			NA		1,461,619	1,461,619	-	-	-	-	-	-	-	-
CY2018 Program Total Gas CPAS (kWh Equivalent)‡					42,840,061	42,840,061	-	-	-	-	-	-	-	-
CY2018 Program Expiring Gas Savings (Therms)§							1,461,619	1,461,619	1,461,619	1,461,619	1,461,619	1,461,619	1,461,619	1,461,619
CY2018 Program Expiring Gas Savings (kWh Equivalent)‡§							42,840,061	42,840,061	42,840,061	42,840,061	42,840,061	42,840,061	42,840,061	42,840,061

Note: The green highlighted cell shows program total first year gas savings in kWh equivalents.
* The randomized controlled trial used for this evaluation produces net savings and as such the NTG ratio is not applicable.
† Lifetime savings are the sum of CPAS savings through the EUL.
‡ kWh equivalent savings are calculated by multiplying therm savings by 29.31.
§ Expiring savings are equal to CPAS Yn-1 - CPAS Yn + Expiring Savings Yn-1.
Source: Navigant analysis of Nest thermostat telemetry data

Table 4-3. Cumulative Persisting Annual Savings (CPAS) – Total

End Use Type	Research Category	EUL	CY2018 Verified Gross Savings	NTG*	Lifetime Net Savings†	Verified Net kWh Savings (Including Those Converted from Gas Savings) 2018	2019	2020	2021	2022	2023	2024	2025	2026
HVAC	Thermostat Optimization - Furnace Fan	1	NA	NA	1,296,198	1,296,198	-	-	-	-	-	-	-	-
HVAC	Thermostat Optimization - Electric Heat	1	NA	NA	1,270,587	1,270,587	-	-	-	-	-	-	-	-
HVAC	Thermostat Optimization - Gas Heat	1	NA	NA	42,840,061	42,840,061	-	-	-	-	-	-	-	-
CY2018 Program Total CPAS			NA		45,406,846	45,406,846	-	-	-	-	-	-	-	-
CY2018 Program Expiring Savings‡							45,406,846	45,406,846	45,406,846	45,406,846	45,406,846	45,406,846	45,406,846	45,406,846

Note: The green highlighted cell shows program total first year electric savings (including direct electric savings and those converted from gas).

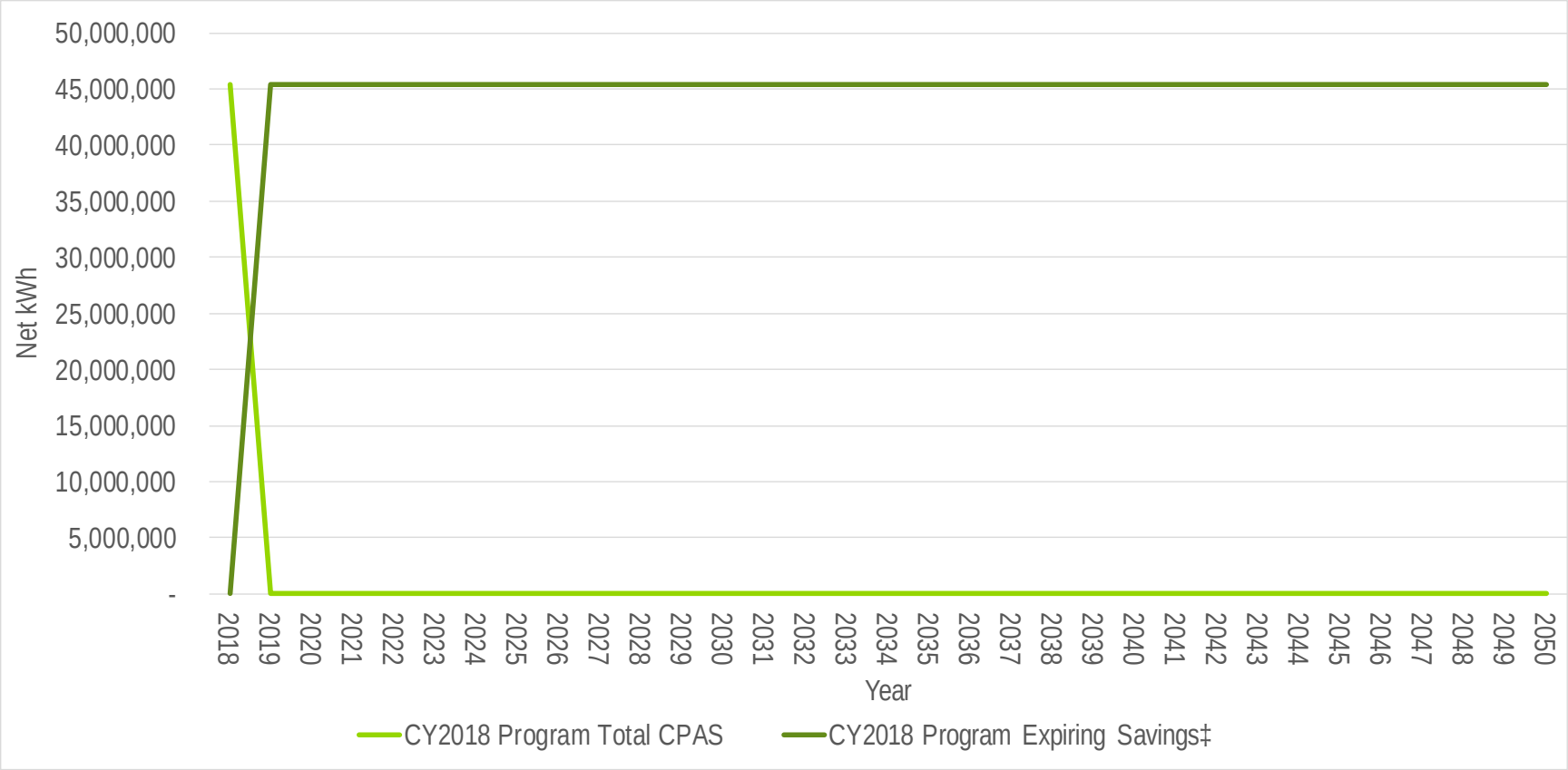
* The randomized controlled trial used for this evaluation produces net savings and as such the NTG ratio is not applicable.

† Lifetime savings are the sum of CPAS net savings through the EUL.

‡ Expiring savings are equal to CPAS Yn-1 - CPAS Yn + Expiring Savings Yn-1.

Source: Navigant analysis of Nest thermostat telemetry data

Figure 4-1. Cumulative Persisting Annual Savings



Source: Navigant analysis of Nest thermostat telemetry data

5. Program Savings by Measure

The program includes three measures as shown in the following tables. The three measures were the impact of the thermostat optimization of electric furnace fans, electric heat, and gas heat. The thermostat optimization measures for furnace fans and electric heat had roughly equivalent savings, while the conversion of therms from the gas heat measure to kWh contributed the most savings. Since this evaluation focused specifically on energy savings, demand savings are not shown in the tables below.

Table 5-1. CY2018 Energy Savings by Measure – Electric

End Use Type	Research Category	Ex Ante Gross Savings (kWh)	Verified Gross Realization Rate	Verified Gross Savings (kWh)	NTG*	Verified Net Savings (kWh)	Effective Useful Life
HVAC	Thermostat Optimization - Furnace Fan	NA	NA	NA	NA	1,296,198	1.0
HVAC	Thermostat Optimization - Electric Heat	NA	NA	NA	NA	1,270,587	1.0
	Total	NA	NA	NA	NA	2,566,785	1.0

* The randomized controlled trial used for this evaluation produces net savings and as such the NTG ratio is not applicable.
Source: ComEd tracking data and Navigant team analysis.

Table 5-2. CY2018 Energy Savings by Measure – Gas

End Use Type	Research Category	Ex Ante Gross Savings	Verified Gross Realization Rate	Verified Gross Savings	NTG*	Verified Net Savings (Therms)	Effective Useful Life
HVAC	Thermostat Optimization - Gas Heat	NA	NA	NA	NA	1,461,619	1.0
	Total Therms					1,461,619	
	Total kWh Converted From Therms†	NA	NA	NA	NA	42,840,061	1.0

* The randomized controlled trial used for this evaluation produces net savings and as such the NTG ratio is not applicable.
† Gas savings converted to kWh by multiplying therms * 29.31 (which is based on 100,000 Btu/therm and 3,412 Btu/kWh).
Source: ComEd tracking data and Navigant team analysis.

Table 5-3. CY2018 Energy Savings by Measure – Total Combining Electricity and Gas

End Use Type	Research Category	Ex Ante Gross Savings (kWh)	Verified Gross Realization Rate	Verified Gross Savings (kWh)	NTG*	Verified Net Savings (kWh)
HVAC	Thermostat Optimization - Furnace Fan	NA	NA	NA	NA	1,296,198
HVAC	Thermostat Optimization - Electric Heat	NA	NA	NA	NA	1,270,587
HVAC	Thermostat Optimization - Gas Heat	NA	NA	NA	NA	42,840,061
	Total†	NA	NA	NA	NA	45,406,846

* The randomized controlled trial used for this evaluation produces net savings and as such the NTG ratio is not applicable.
† The total includes the electric equivalent of the total therms.
Source: ComEd tracking data and Navigant team analysis.

6. Impact Analysis Findings and Recommendations

The main report findings and recommendations are detailed below.

Finding 1. Total 2017/18 heating season electricity savings from (1) furnace fans in gas heated homes and (2) heating savings in electrically heated homes were 2,566,785 kWh.[7] Gas

[7] Navigant assumed that 93.5% of homes had gas heating and 6.5% had electric heating based on Measure 5.3.11 (Programmable Thermostats) in Volume 3 of Version 6.0 of the IL TRM.

savings from gas furnace heating were 1,461,619 therms or 42,840,061 kWh equivalent. The average energy savings (excluding gas savings) per treated thermostat for the heating season was 38.77 kWh (or 2.5% of daily heating load).

Finding 2. Just under two-thirds of eligible devices opted into the SS Program (72,276 or 64%). Of these enrollees, 87% signed up within the first week of the program being offered (63,168).

Finding 3. The setpoint point schedules for the treated thermostats were adjusted downward an average of 0.6°F compared to the control group during the program period, with the largest setpoint adjustments taking place during the middle of the night. These setpoint adjustments resulted in heating runtime reductions of approximately 6.8 minutes per day.

Recommendation 1. The heating season SS Program should be evaluated an additional year before being considered for inclusion in the Illinois Technical Reference Manual (IL TRM) to assess how customers respond to two seasons of schedule adjustments, understand reasons for halting the SS Program, and seek to ascertain a relationship between savings and weather.

7. Appendix 1. Impact Analysis Methodology

7.1 Exploratory Analysis

The purpose of the exploratory analysis is to use thermostat telemetry data to:

- Analyze setpoint schedules and thermostat runtime from November 2017 through April 2018 to assess whether the impact of thermostat optimization was evident in the data
- Compare data across several groups, including: ITT versus control and treated versus untreated versus control
- Describe whether there are differences between weekdays and weekends and hour of the day with regards to heating setpoint and heating runtime

7.2 Impact analysis

This impact analysis calculates energy savings from thermostat optimization for both the treated and ITT groups.[8] Navigant relied exclusively on thermostat telemetry data to estimate impacts after converting thermostat heating runtime to an estimate of therms consumed.

7.2.1 Runtime to Therms Conversion

The conversion from runtime to therms is shown in Equation 7-1.

[8] The savings estimate for the ITT group represents an unbiased estimate of the effect of encouragement on energy use while the savings estimate for the treated group represents an estimate of the effect of the program intervention on energy use.

Equation 7-1. Heating Runtime to Therms Conversion

$$Therms = \left(\sum Stage\ 1\ Runtime\ hours \times \frac{80{,}900\ Btu}{hr} + \sum Stage\ 2\ Runtime\ hours \times \frac{49{,}777\ Btu}{hr}\right) \times \frac{1\ therm}{100{,}000\ Btu}$$

To determine furnace capacity, Navigant selected the top five furnace manufacturers and 93 models from Nicor's PY9 Home Energy Efficiency Rebates (HEER) tracking data. These models accounted for 40% of the program's installed measures (23,600 total furnaces). The average single-stage[9] and dual-stage[10] capacity values of those furnaces were 80,900 and 49,777 Btu per hour.

7.2.2 Linear Fixed Effects Regression Model

Navigant used a linear fixed effect (or difference-in-differences) regression model to estimate savings associated with devices that were randomly assigned to receive the program offering (ITT devices). Thus, this model estimated savings for all devices in the ITT group, whether or not they actually enrolled in the program. Formally, the model is specified in Equation 7-2.

Equation 7-2. Linear Fixed Effects Regression Model

$$EDU_{it} = \alpha_i + \gamma_m + \beta_1 Post_t + \beta_2 (Post_t \cdot ITT_i) + \varepsilon_{it}$$

Where:

EDU_{it}	is estimated daily consumption of therms by device *i* on day *t*
α_i	is a customer-specific fixed effect for device *i*; this picks up all customer-specific characteristics that do not change through time, like household square footage
γ_m	is a time-specific fixed effect for month *m;* this picks up temporal differences across months, like weather and daylight hours
$Post_t$	is a binary variable taking a value of 1 when day *t* is in the post period (after December 5, 2017) and 0 otherwise
ITT_i	is a binary variable taking a value of 1 when device *i* is in the ITT group and day *t* is after the start of the SS program (December 6, 2017)
ε_{it}	is the cluster-robust error term for device *i* during day *t;* cluster-robust errors account for heteroskedasticity and autocorrelation at the household level

The coefficient β_2 estimated the program's average daily savings in therms. To calculate total program savings resulting from treatment, Navigant multiplied average daily therms savings by the total number of program days across all devices.

7.2.3 Two-Stage Least Squares Instrumental Variable Model

Navigant used a two-stage least-squares instrumental variables approach to estimate savings associated with receiving the SS algorithm (i.e., this estimated savings just for the portion of the ITT group who enrolled in the program). This approach relied on the random assignment of customers into the ITT group as an instrumental variable for the decision to participate in the program, accounting for the fact that

[9] Any device that only showed run hours for Stage 1 was considered a single stage unit.
[10] Any device that showed run hours for both Stage 1 and Stage 2 was considered a dual-stage unit.

participation was not random and depended on unobserved characteristics that may have been correlated with energy consumption (i.e., participation was endogenous).

In the first stage, program participation was regressed on an indicator for whether the customer was randomly assigned to receive the program offering (ITT). This regression predicted the likelihood of participation. In the second stage, the estimated daily energy consumption was regressed on the predicted likelihood of participation. Formally, the first stage model is specified in Equation 7-3, and the second stage model is specified in Equation 7-4.

Equation 7-3. Two-Stage Least Squares IV Model: First Stage

$$\widehat{Treat}_\iota = \alpha_i + \gamma_t + \beta_1 Post_t + \beta_2 (Post_t \cdot ITT_i) + \varepsilon_{it}$$

Equation 7-4. Two-Stage Least Squares IV Model: Second Stage

$$EDU_{it} = \alpha_i + \gamma_t + \beta_1 Post_t + \beta_2 \left(PostTune_{it} \cdot \widehat{Treat}_\iota\right) + \varepsilon_{it}$$

Where:

EDU_{it}	is estimated daily consumption of therms by device *i* on day *t*
α_i	is a customer-specific fixed effect for device *i*; this picks up all customer-specific characteristics that do not change through time, like household square footage
γ_t	is a time-specific fixed effect for day *t;* this picks up temporal differences across months, like weather and daylight hours
$Post_t$	is a binary variable taking a value of 1 when day *t* is in the post period (after December 5, 2017) and 0 otherwise
$Post_t \cdot ITT_i$	is a binary variable taking a value of 1 when device *i* is in the ITT group and day *t* is after the start of the SS program (December 6, 2017); this is the instrument for $PostTune_{it} \cdot \widehat{Treat}_\iota$ in the second stage of the model
$PostTune_{it} \cdot \widehat{Treat}_\iota$	is a binary variable taking a value of 1 when device *i* is in the treated group (opted in to the SS program) and day *t* is after the start of the SS program (December 6, 2017); this variable is instrumented for by $Post_t \cdot ITT_i$
ε_{it}	is the cluster-robust error term for device *i* during day *t;* cluster-robust errors account for heteroskedasticity and autocorrelation at the household level

The coefficient β_2 from the second stage regression in Equation 7-4 is the estimate of average daily therms savings due to opting into the program. This number illustrates savings for participating devices, but Navigant calculated total savings using the model described in the previous section.

7.2.4 Therms Savings to kWh Savings Conversion

After calculating savings in therms, Navigant converted savings to kWh assuming that 93.5% of the participants have gas heating and accrue heating season electric savings through their furnace fan and 6.5% have electric heating and accrued electric savings directly.[11]

Equation 7-5 shows the conversion from total therms saved to total electric furnace fan savings for homes with gas heat and Equation 7-6 shows how Navigant used the percentage savings estimate (based on the LFER model) to estimate per home electric heat savings. Total electric savings from the program were

[11] The assumptions and equations throughout this section are based on Measure 5.3.11 (Programmable Thermostats) in Volume 3 of Version 6.0 of the IL TRM.

calculated by adding electric savings from furnace fans and electric savings from electrically heated homes.

Equation 7-5. Therms Savings to Electric Furnace Fan Savings

$$total\_kWh\_fan\_savings = portion\_gas * therms\_savings * F_e * 29.3$$

Where:

$total\_kWh\_fan\_savings$	is total electric kWh savings from furnace fans
$portion\_gas$	is the portion of homes with gas heating = 97%
$therms\_savings$	is total program savings in therms as estimated by Equation 7-2
F_e	is the furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%
29.3	is kWh per therm

Equation 7-6. Electric Heat Savings

$$total\_kwh\_elec\_heat\_savings = (Elec\_Heating\_Consumption * \%\_savings * HF) * valid\_ITT\_device\_count * portion\_elec$$

$$total\_kwh\_elec\_heat\_savings = (12218 * \%\_savings * (0.9 + (0.65 * 0.1))) * valid\_ITT\_device\_count * 0.065$$

Where:

$total\_kWh\_elec\_heat\_savings$	is electric kWh savings from electric heat
$Elec\_Heating\_Consumption$	is the estimate of annual household heating consumption for electrically heated single-family homes[12]
$\%\_savings$	the percent savings calculated from the LFER model
HF	Household factor, to adjust heating consumption for non-single-family households[13]
$valid\_ITT\_device\_count$	is the number of ITT devices in SS
$portion\_elec$	is the portion of homes with electric heating[14]

Navigant also calculated the kWh equivalent of gas savings from gas furnace heating for those homes with gas heat. This conversion is shown in Equation 7-7.

Equation 7-7. Gas Savings to kWh Equivalent

$$kWh\_equivalent = portion\_gas * therms\_savings * 29.3$$

Where:

$kWh\_equivalent$	is the kWh equivalent of the therms savings from gas furnace heating
$portion\_gas$	is the portion of homes with gas heating = 97%
$therms\_savings$	is total program savings in therms as estimated by Equation 7-2

[12] Navigant assumed all homes are in climate zone 2 (Chicago) and that all electrically heated homes have heat pumps per footnote 387 in Version 6.0 of the IL TRM.
[13] Navigant assumed that 90% of homes were single-family (HF of 1) and 10% were multi-family (HF of 0.65) based on review of ComEd program tracking data for programs that rebate smart thermostats.
[14] Navigant assumed that all of the homes with electric heating have heat pumps per footnote 387 in Version 6.0 of the IL TRM.

29.3 is kWh per therm

7.3 Data Cleaning & Device Validity

For the purposes of the analysis, Navigant devised and performed measures to clean and remove data deemed unsuitable. Table 7-1 details the steps taken that removed whole devices, the number of devices dropped in each category, and the total remaining valid devices eligible to claim savings for each encouragement group.

Table 7-1. Data Cleaning: Devices Dropped

Category	Control		Treated ITT		Untreated ITT	
Raw device count totals	8,001	-	72,276	-	41,341	-
No telemetry data*†	157	*1.96%*	9	*0.01%*	2,174	*5.26%*
Zip code not in a ComEd majority zip code*	137	*1.71%*	1,757	*2.43%*	628	*1.52%*
No actual zip code provided and proxy zip code not in a ComEd majority zip code*	131	*1.64%*	1,023	*1.42%*	612	*1.48%*
No actual or proxy zip code provided*	5	*0.06%*	9	*0.01%*	7	*0.02%*
15-minute intervals missing heating runtime information‡	1	*0.01%*	0	-	13	*0.03%*
Devices with stage 3, alternative, auxiliary, or emergency heating runtime	22	*0.27%*	258	*0.36%*	166	*0.40%*
Devices with no days containing runtime for all 15-minute intervals	4	*0.05%*	6	*<0.01%*	85	*0..21%*
Remaining devices §	7,544	*94.29%*	69,214	*95.76%*	37,656	*91.09%*
Valid devices ‖	-	-	69,478	*96.13%*	37,920	*91.72%*

* Devices dropped via these categories are considered invalid and are not used in calculating final savings.
† Telemetry data intervals for these devices were not included in the data Navigant received from Nest.
‡ These steps removed entire customers when all observations were removed for the described reason.
§ Devices used to calculate per-device average daily energy savings values within the regression framework.
‖ Devices used to calculate season total energy savings.
Source: Navigant analysis of Nest thermostat telemetry data.

7.4 Winter 2017-2018 Temperature

The average temperature experienced by all program devices (control and ITT) in the winter of 2017-2018 is compared to the Chicago O'Hare International Airport 1981-2010 normal temperature in Table 7-2.

Table 7-2. Winter 2017-18 Weather, Illinois

		November	December	January	February	March	April
Average Temperature	Winter 2017-2018	39.9	27.0	24.8	29.0	35.8	40.0
	1981-2010 normal	40.3	27.7	23.8	27.7	37.9	48.9
	Departure	-0.4	-0.7	1.0	2.3	2.1	-8.9

Source: Midwest Regional Climate Center

8. Appendix 2. Impact Analysis Detail

This section presents the details of our exploratory and impact analysis findings.

8.1 Exploratory Analysis

This section presents the findings from the exploratory analysis of the thermostat telemetry data. Table 8-1 provides the average daily scheduled heating setpoint and average daily heating runtime for the control and ITT groups as well as the treated and untreated sub-groups. The analysis compares the pre-program and program period for each group and finds that the SS Program made the intended adjustments to scheduled setpoints, yielding reductions in total heating runtime on average for the treated group compared to the control group in the program period.

Table 8-1. Exploratory Analysis Summary

Period	Group	Nov 1, 2017 – Dec 5, 2017 Pre-Period	Dec 6, 2017 – Apr 29, 2018 Program Period	Δ*	SS Effect †
Avg Daily Outdoor Temp (°F)		40.4	30.8	-9.6	-
Avg Daily Scheduled Heating Setpoints (°F)	Control	68.3	68.4	0.1	-
	ITT	68.2	67.9	-0.3	-0.4
	Treated	*68.2*	*67.7*	*-0.5*	*-0.6*
	Untreated	*68.3*	*68.4*	*0.1*	-
Avg Daily Heating Runtime (minutes)	Control	203.0	307.5	104.5	-
	ITT	202.1	301.7	99.6	-4.9
	Treated	*201.8*	*299.5*	*97.7*	*-6.8*
	Untreated	*202.6*	*305.9*	*103.3*	-

* The Δ is the difference between the program period and the pre-period.
† The SS effect is the difference between the Δ for the ITT or treated group and the control group. These values are per-period averages and do not directly reflect Seasonal Savings program impacts.
Source: Navigant analysis of Nest thermostat telemetry data.

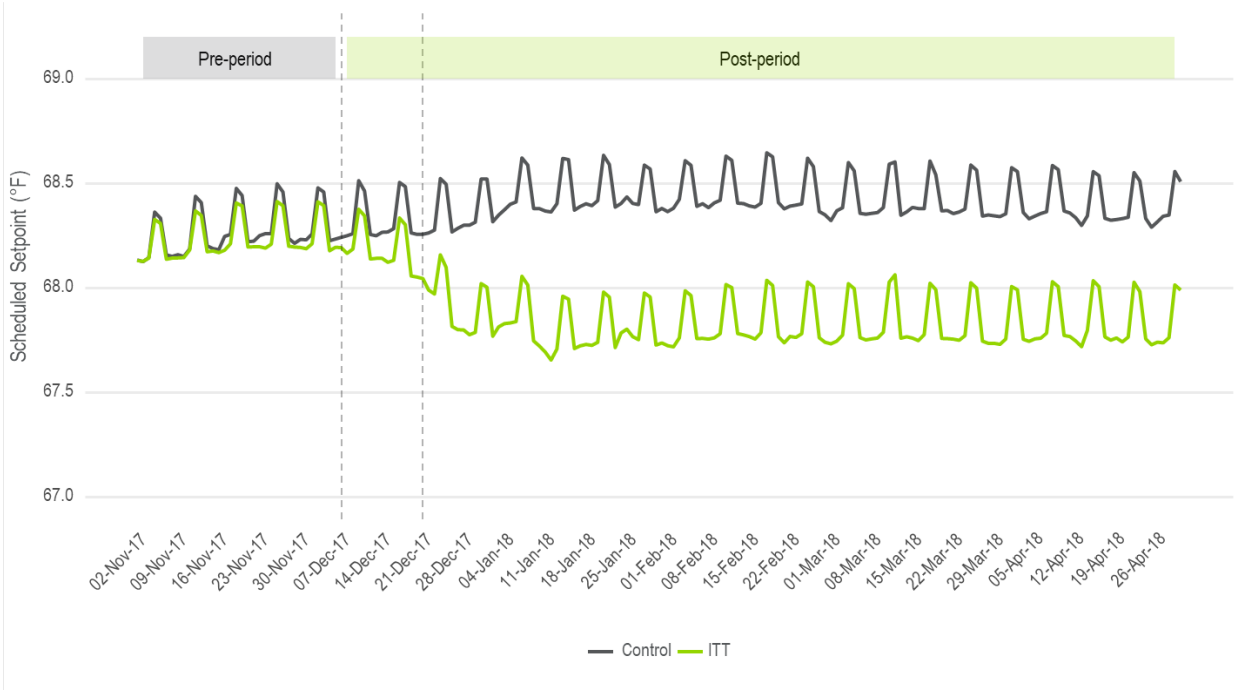
8.1.1 Setpoint Comparisons

Figure 8-1 presents the average daily scheduled setpoints for the ITT and control groups from Nov 1, 2017 through April 29, 2018. Figure 8-2 presents this information as a comparison of average daily scheduled setpoints for the ITT group relative to the control group, where the control group is represented by the bold the horizontal centerline.

- **Pre-program period:** Average daily scheduled setpoints during the pre-period were similar between the ITT and control groups, with a difference of less than 0.1°F on average.[15] This is the expectation of random encouragement where the ITT and control groups are expected to have pre-period average daily setpoint readings that are practically and statistically similar.
- **Program period:** The difference in average daily scheduled setpoints changed for the ITT and control groups during the program period, decreasing for the ITT group and barely increasing for the control group. As a result, average daily scheduled setpoints decreased by approximately 0.4°F for the ITT group relative to the control group over program period. This reduction is evidence that the program had the intended effect of lowering scheduled setpoints on average.

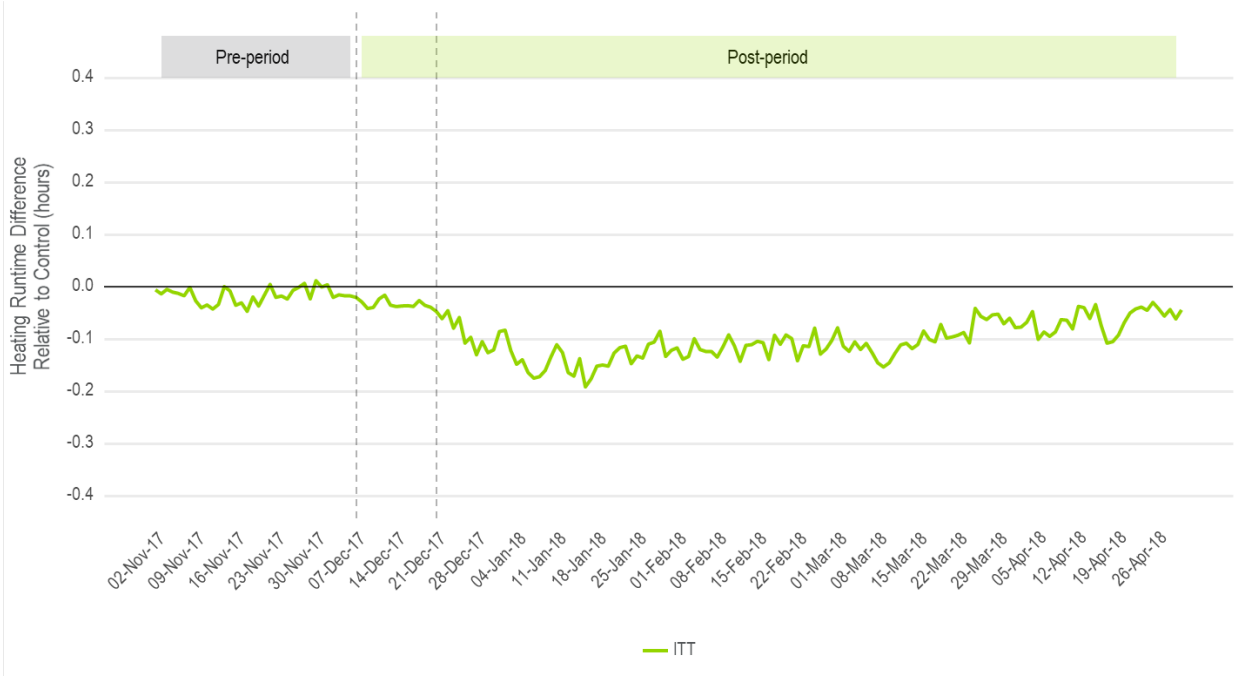
[15] This pre-period difference is not statistically significant.

Figure 8-1. Average Daily Scheduled Setpoints: ITT Groups



Source: Navigant analysis of Nest thermostat telemetry data.

Figure 8-2. Average Daily Scheduled Setpoints Comparison: ITT vs. Control

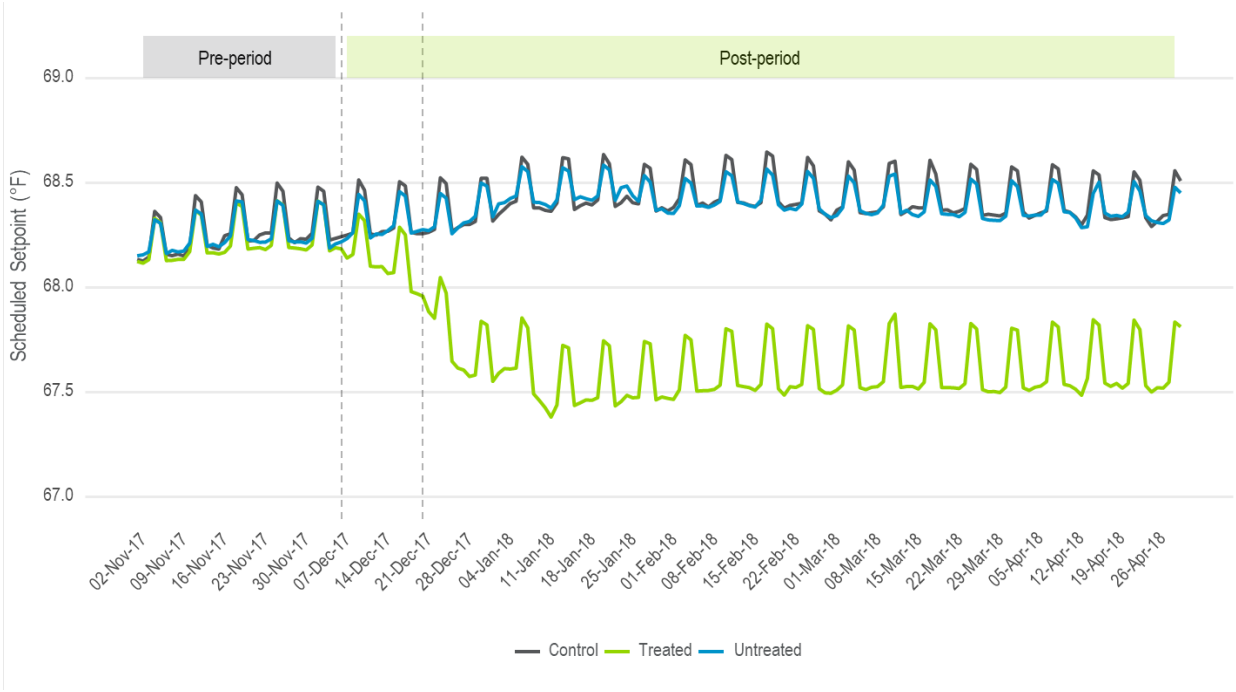


Source: Navigant analysis of Nest thermostat telemetry data.

Figure 8-3 and Figure 8-4 present a similar comparison as above but show the average daily scheduled setpoints for the ITT group split out by its treated and untreated sub-groups, in addition to the control group. Figure 8-3 presents average daily scheduled setpoints, while Figure 8-4 presents this information relative to the control group, where the control group is represented by the bold horizontal centerline.

- **Pre-program period:** The mean difference between average daily scheduled setpoints was less than 0.1°F greater between the treated, untreated, and control groups.[16] The largest difference was between the control and treated groups, where the control group was only 0.05°F greater.
- **Program period:** Average daily scheduled setpoints decreased only for the treated group; the control and untreated groups stayed relatively similar. During the program period average daily scheduled setpoints decreased by 0.6°F for the treated group relative to the control group, whereas it remained essentially unchanged for devices that were untreated relative to the control.

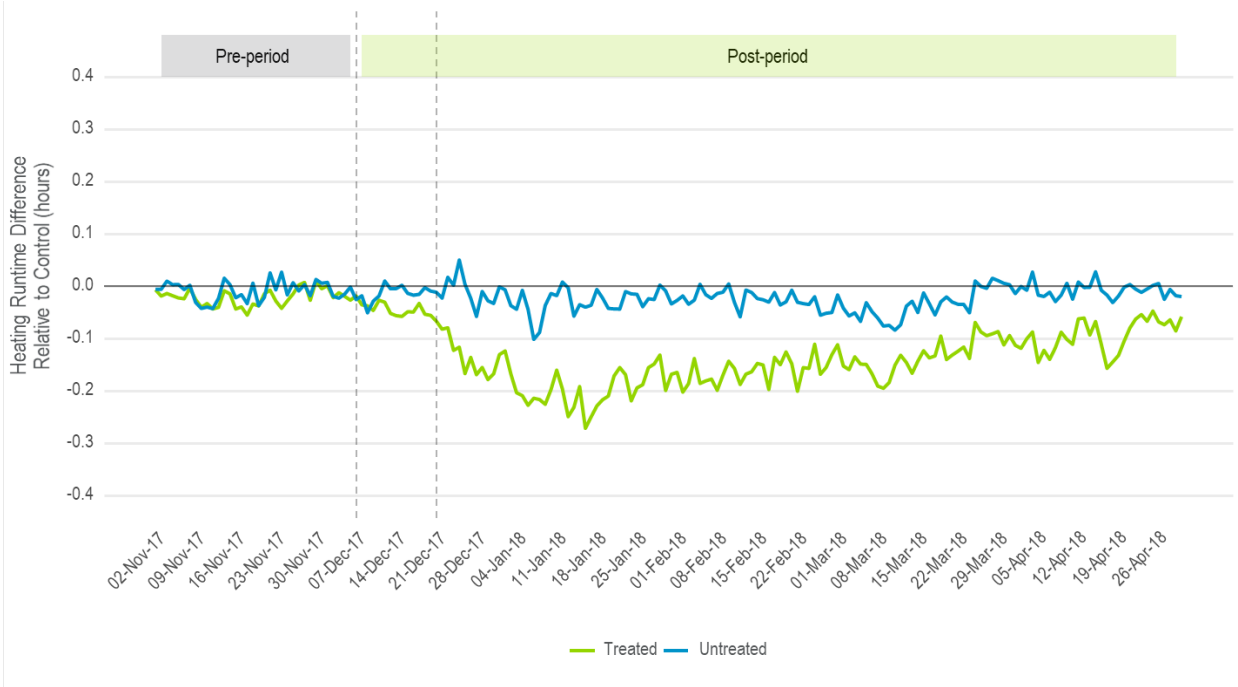
Figure 8-3. Average Daily Scheduled Setpoints: Treatment Groups



Source: Navigant analysis of Nest thermostat telemetry data.

[16] These pre-period differences were not statistically different.

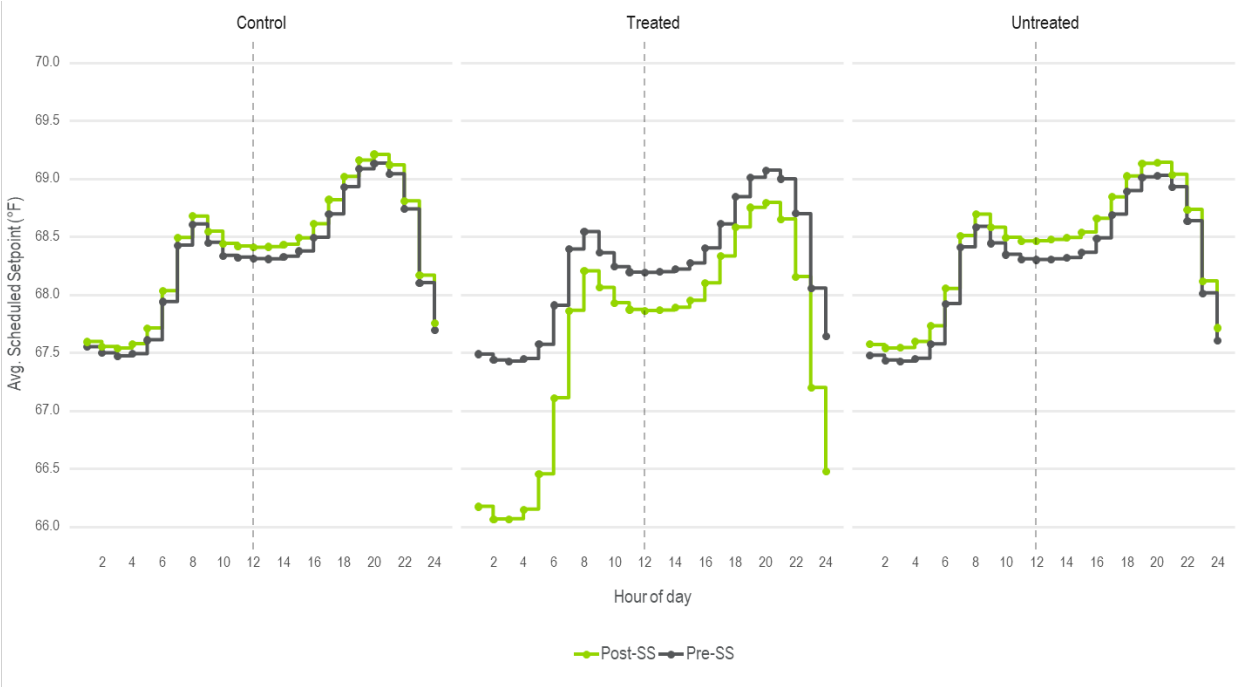
Figure 8-4. Average Daily Scheduled Setpoints Comparison: Treated & Untreated vs. Control



Source: Navigant analysis of Nest thermostat telemetry data.

Figure 8-5 presents a comparison of average hourly scheduled heating setpoints based on the weeks of November 29–December 5, 2017 (the week preceding enrollment, "pre-week") and December 28, 2017–January 3, 2018 ("post-week") for the treated, untreated, and control groups. The differences in these values for treatment and control during these periods are further broken down in Table 8-2 by weekday, weekend, and overall (weekday plus weekend) differences and across daytime hours and nighttime hours. These figures illustrate that while the control and untreated groups had slight increases in their scheduled setpoint, the treatment group instead saw comparatively significant decreases on average. The program is designed to make the largest adjustments during nighttime and smaller adjustments during times of regular absence from home. Both intended adjustment types are evident in Figure 8-5.

Figure 8-5. Mean Hourly Scheduled Setpoints Comparison: Before & After SS



Note: Hour of the day represents the hourly end time (e.g., 8:00AM includes all interval data from 7:00AM – 8:00AM)
Source: Navigant analysis of Nest thermostat telemetry data.

Table 8-2. Differences in Mean Hourly Scheduled Setpoints: Before & After SS

Day Type	Period	Treated*	Control*	Δ†
Weekday	8 am to 10 pm (day)	-0.33°F	0.11°F	-0.44°F
	10 pm to 8 am (night)	-0.65°F	0.10°F	-0.75°F
Weekend	8 am to 10 pm (day)	-0.26°F	0.07°F	-0.34°F
	10 pm to 8 am (night)	-0.62°F	0.05°F	-0.67°F
Overall	8 am to 10 pm (day)	-0.31°F	0.10°F	-0.41°F
	10 pm to 8 am (night)	-0.64°F	0.08°F	-0.72°F

* Values presented in these columns are post-SS less pre-SS grouped averages for the given hours. Pre-SS is the week of Nov 29 – Dec 5, 2017 and post-SS is the week of Dec 28, 2017 – Jan 3, 2018. Note that the post week here begins 23 days after the first deployment wave (Dec 6) and 8 days after the second deployment wave (Dec 20).
† Treated value less Control value, or the average effect of SS on scheduled heating setpoint over the given time frame.
Source: Navigant analysis of Nest thermostat telemetry data.

In comparison to the control group, overall average scheduled setpoints for treated devices decreased by 0.72°F between the nighttime hours of 10 pm through 8 am on average; these nighttime decreases were as much as 1.5°F at certain times. For the daytime hours, this decrease was less significant at 0.41°F with the largest decrease occurring mid-day. On the other hand, changes in setpoint for the untreated group are comparable to those of the control group, with untreated devices showing only slightly greater increases in heating setpoints in the post-week over the control group.

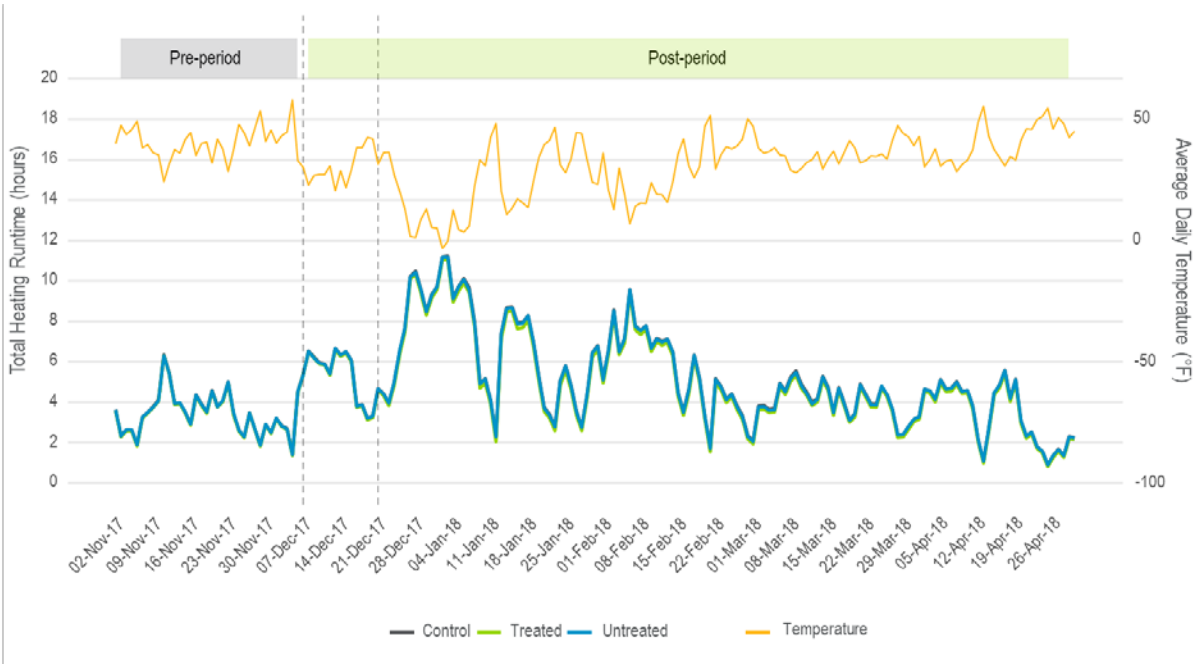
8.1.2 Runtime Comparisons

Similar to the exploratory analysis of average scheduled setpoints, this section presents findings from the exploratory analysis of average daily thermostat heating runtime. Since the heating runtime has direct (negative) correlation with outdoor temperature, Figure 8-6 presents the comparisons between average daily heating runtime totals (stage 1 plus stage 2 heating) for all treatment groups juxtaposed with average daily outdoor temperature. Note that the average outdoor temperatures during the pre-program and program periods were 40.4°F and 30.8°F, respectively (from Table 8-1).

Figure 8-7 then presents runtime differences for the treated and untreated groups relative to the control group which is represented by the x-axis (the horizontal centerline).

- **Pre-program period:** Differences in average daily runtime during the pre-period between the treated and untreated sub-groups and the control group were negligible. The treated group had 1.2 minutes less runtime than the control group, whereas the untreated group had only 0.4 minutes less than the control.[17]
- **Program period:** During the program period, average daily runtime increased for all groups, but the increase was smallest for the treated group. As a result, average daily heating runtime decreased by an average of 6.8 mins during the program period for the treated group relative to the control group. This is evidence that, on average, less additional heating took place for the treated group over time because of the program. In contrast, the untreated group saw a 1.2 mins decrease in heating runtime for the program period relative to the control group when compared to the pre-program period. When looking at the ITT group overall, this difference is instead a decrease of 4.9 mins on average (see Table 8-1).

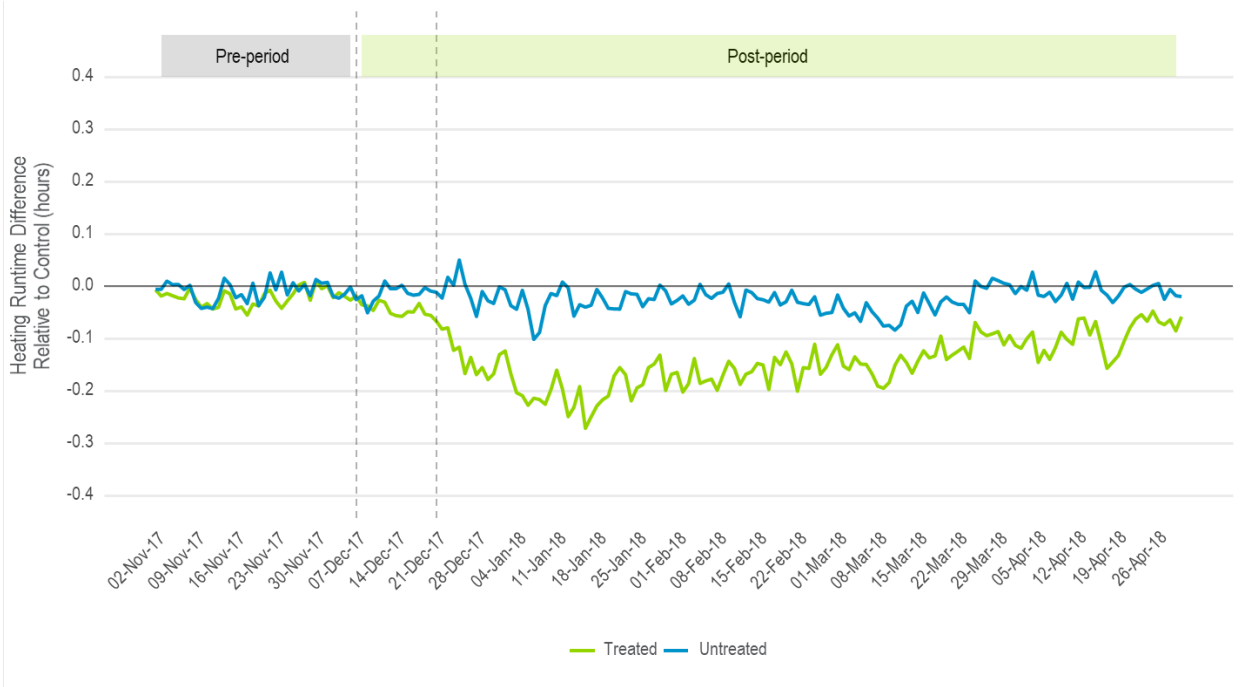
Figure 8-6. Average Daily Runtime Comparison: All Groups, w/ Avg. Daily Temperature



Source: Navigant analysis of Nest thermostat telemetry data.

[17] Pre-period differences between ITT sub-groups and the control group were not statistically significant.

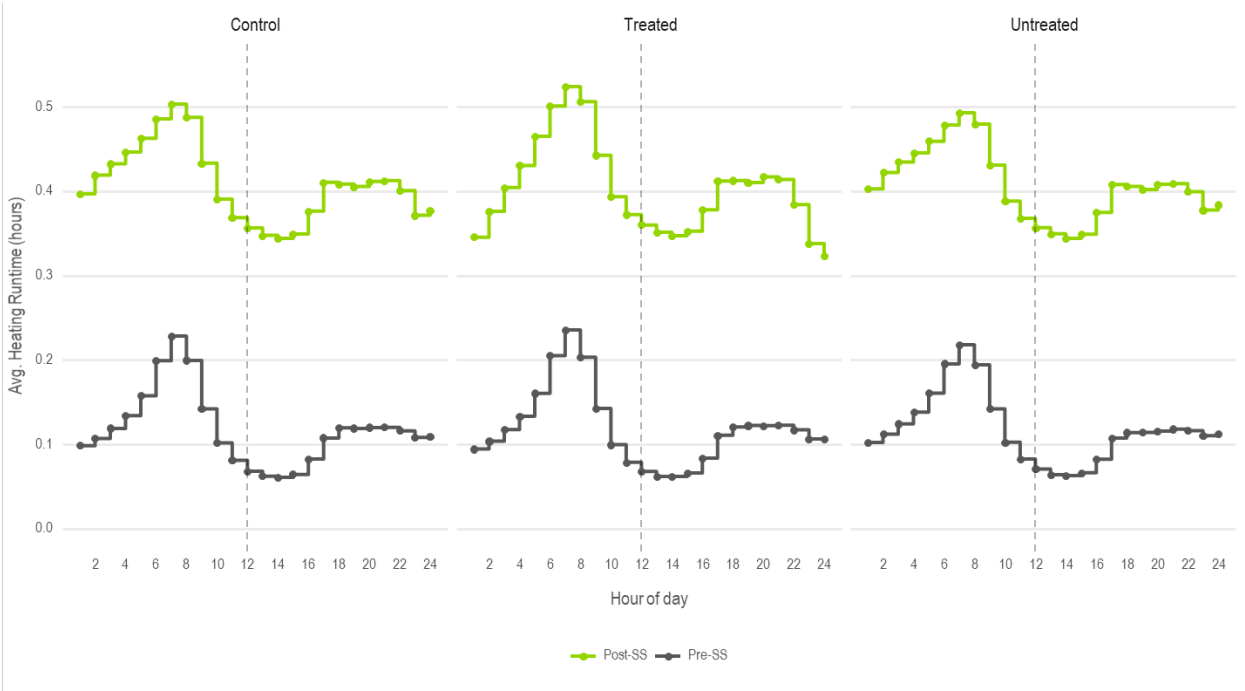
Figure 8-7. Average Daily Runtime Comparison: Treated & Untreated vs. Control



Source: Navigant analysis of Nest thermostat telemetry data.

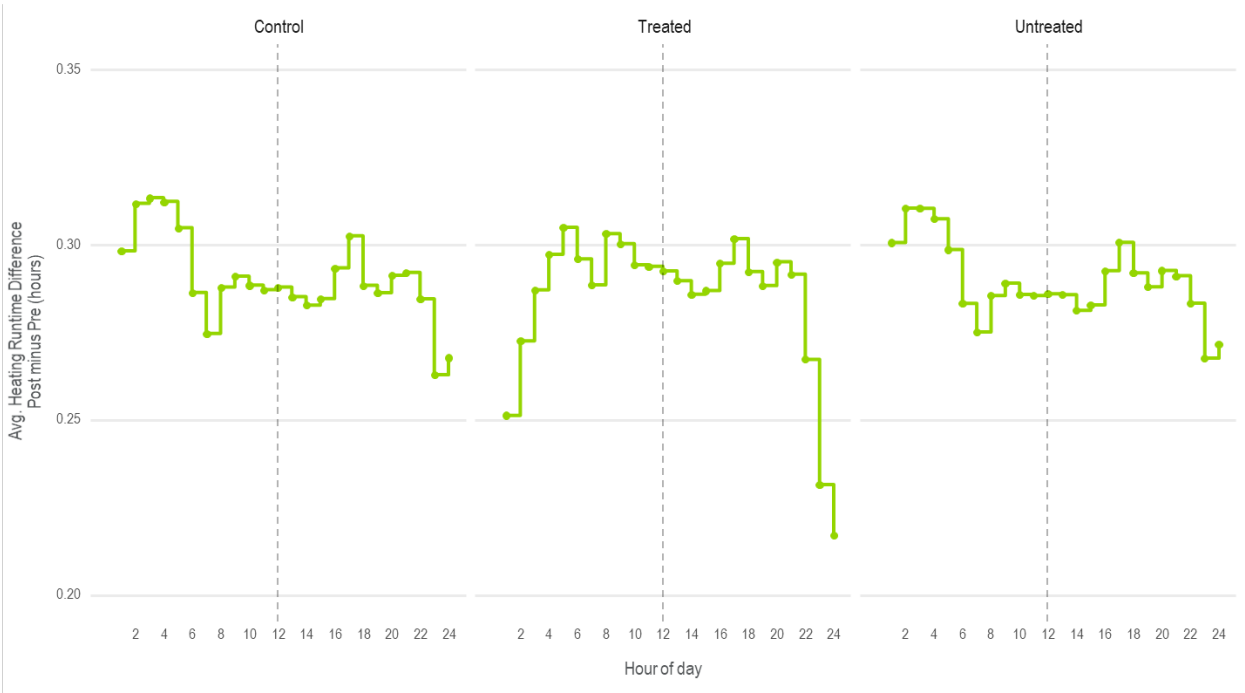
Figure 8-8 presents a comparison of average hourly heating runtime based on the weeks of November 29–December 5, 2017 (the week preceding enrollment, "pre-week") and December 28, 2017–January 3, 2018 ("post-week") for the treated, untreated, and control groups. The differences in these values for treatment and control during these periods are further broken down in Table 8-3 by weekday, weekend, and overall (weekday plus weekend) differences and across daytime hours and nighttime hours. These comparisons illustrate that, while average runtime increased for all groups, the changes for the treated group were the smallest. As discussed previously, the program is designed dial back heating time the most during the nighttime hours. To better depict this, Figure 8-9 shows the difference in the post-week less the pre-week that are presented in Figure 8-8, demonstrating a lower increase in runtime during the evening hours when comparing the treated group to either the untreated or controls. In comparison to the control group, overall average heating runtime decreased by 0.4 minutes during the nighttime hours of 10 pm through 8 am for treated devices, as identified by the bold figures in Table 8-3.

Figure 8-8. Mean Hourly Runtime Comparison: Before & After SS



Source: Navigant analysis of Nest thermostat telemetry data.

Figure 8-9. Differenced Mean Hourly Runtime Comparison: Before & After SS



Source: Navigant analysis of Nest thermostat telemetry data.

Table 8-3. Differences in Mean Hourly Runtime: Before & After SS

Day Type	Period	Treated*	Control*	Δ†
Weekday	8 am to 10 pm (day)	18.2	17.9	0.3
	10 pm to 8 am (night)	17.1	17.6	-0.5
Weekend	8 am to 10 pm (day)	16.9	16.2	0.7
	10 pm to 8 am (night)	16.6	17.0	-0.4
Overall	8 am to 10 pm (day)	17.8	17.4	0.4
	10 pm to 8 am (night)	17.0	17.4	-0.4

* Values presented in these columns are post-SS less pre-SS grouped averages for the given hours. Pre-SS is the week of Nov 29 – Dec 5, 2017 and post-SS is the week of Dec 28, 2017 – Jan 3, 2018. Note that the post week here begins 23 days after the first deployment wave (Dec 6) and 8 days after the second deployment wave (Dec 20).

† Treated value less Control value, or the average effect of SS on scheduled heating setpoint over the given time frame.

Source: Navigant analysis of Nest thermostat telemetry data.

8.2 Impact Analysis

This section presents the findings from the impact analysis, summarized in Table 8-4. ITT savings estimates were calculated using the LFER model and Treated savings estimates were calculated using the IV model. Total estimated energy savings from random encouragement was 1,506,824 therms or 42,840,061 kWh from December 6, 2017 through April 29, 2018. Conversely, total estimated savings for only those devices that opted-in to treatment was 1,564,496 therms or 44,479,716 kWh (calculated from individual devices opt-in dates through April 29, 2018). These values were not statistically different[18] and Navigant considers the ITT savings estimate more appropriate as this estimate is known to be an unbiased estimate of the impact of the encouragement.

[18] Wald test performed at the 90% confidence level.

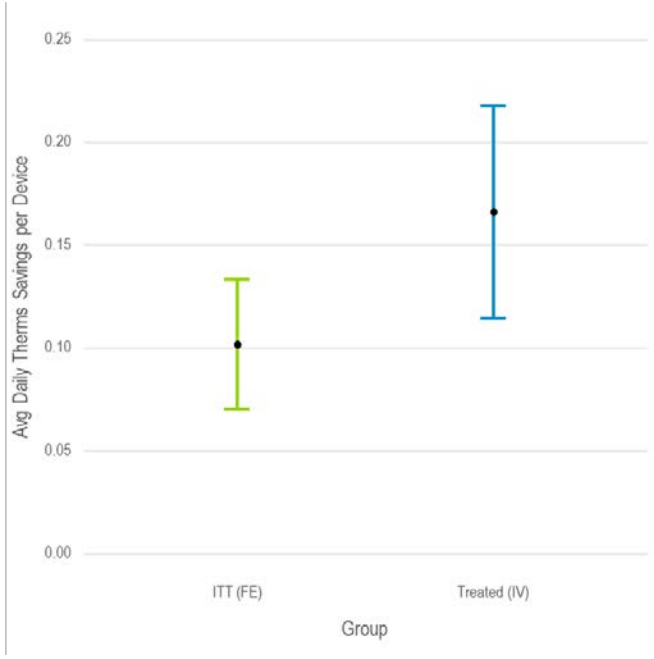
Table 8-4. Impact Analysis Findings

Statistic	ITT *	Treated (Subset of ITT) *
Number of Nest thermostats in control group	7,544	7,544
Number of valid Nest thermostats	107,398	69,478
Average daily energy savings (% of heating load)	1.5% ± 0.3%	2.5% ± 0.5%
Average daily energy savings per device (Therms)	0.10 ± 0.03 ***	0.17 ± 0.05 ***
Average total energy savings per device (Therms) †	14.03	22.52
Total energy savings (Therms) ‡	1,506,824	1,564,496
Furnace fan savings (kWh) §	1,296,198	1,345,809
Electric heat savings (kWh) ||	1,270,587	1,348,318
Total electric savings (kWh)	2,566,785	2,694,127
kWh equivalent gas savings #	42,840,061	44,479,716

Significance levels: *** p < 0.01; range indicates 90% confidence interval.
Note: The first offer date occurred on Dec 6, 2017. The measure persisted while HVAC systems were in heating mode. This evaluation relied on data through April 29, 2018.
* ITT includes all devices randomly assigned to receive SS. Treated is a subset of ITT and includes those devices that qualified and opted into the program.
† Total savings per device is calculated as average daily savings per device times the number of days post SS enrollment.
‡ Total savings is calculated as total energy savings per device times the number of treated/ITT devices.
§ See Equation 7-5.
|| See Equation 7-6.
See Equation 7-7.
Source: Navigant analysis.

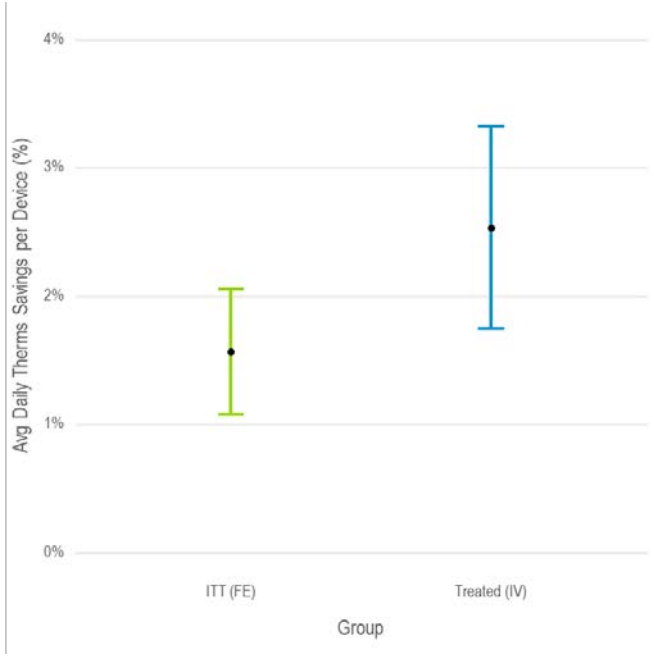
Figure 8-10 and Figure 8-11 show per-device savings for fixed effects and independent variable regression models with 90% confidence intervals.

Figure 8-10. Average Daily Therms Savings per Device



Source: Navigant analysis

Figure 8-11. Average Daily Therms Savings per Device (as % of heating load)



Source: Navigant analysis

9. Appendix 3. Total Resource Cost Detail

Table 9-1, below, shows the Total Resource Cost variable table. It includes only the cost-effectiveness analysis inputs available at the time of finalizing this impact evaluation report. Additional required cost data (e.g., measure costs, program level incentive and non-incentive costs) are not included in this table and will be provided to the evaluation team later. Effective Useful Life numbers in this table are subject to change and are not final.

Table 9-1. Total Resource Cost Savings Summary

End Use Type	Research Category	Units	Quantity	Effective Useful Life	Ex Ante Gross Savings (kWh)	Ex Ante Gross Peak Demand Reduction (kW)	Verified Gross Savings (kWh)*	Verified Gross Peak Demand Reduction (kW)
HVAC	Thermostat Optimization - Furnace Fan	Device	107,398	1.0	NA	NA	1,296,198	NA
HVAC	Thermostat Optimization - Electric Heat	Device	107,398	1.0	NA	NA	1,270,587	NA

* Due to the design of the program, this evaluation inherently estimates net savings which are listed here.
Source: Navigant analysis of Nest telemetry data.