NAVIGANT

# 2017 Seasonal Savings Evaluation

## Prepared for National Grid

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# EXECUTIVE SUMMARY

In 2017, National Grid offered some of its customers in Massachusetts and Rhode Island a new energy savings opportunity – thermostat optimization. National Grid selected Nest to provide Seasonal Savings (SS), its thermostat optimization program during the 2017 summer season. SS adjusts thermostat setpoint schedules to achieve energy savings and demand reductions during the summer.

In this evaluation report, Navigant Consulting, Inc. (Navigant) presents findings of an impact evaluation of SS.[1] The SS program is designed to make small adjustments to scheduled setpoints over a 3-week period (i.e., tune-up period) while maintaining customer comfort. On average, scheduled setpoints are adjusted up by 1.5°F during the cooling season, with the biggest temperature adjustments typically taking place when customers are away from home (e.g., the middle of weekdays).[2]

Navigant's evaluation confirmed the technical feasibility of using thermostats to reduce household energy consumption and peak demand and identified the energy and demand savings achieved during 2017 in Massachusetts and Rhode Island. The program achieved energy and demand savings of 189 MWh and 366 kW in Massachusetts, and 57 MWh and 134 kW in Rhode Island. These savings were achieved under below average temperatures in July and August in both Massachusetts and Rhode Island and it is not clear how much additional savings would have resulted had the weather been warmer or if the program had started earlier in the season.

## Objectives and Methods

The objectives of the 2017 thermostat optimization evaluation were to answer the questions outlined in Table 1.

**Table 1. Thermostat Optimization Research Questions**

| Research Questions | Evaluation Approach |
|---|---|
| • How many devices/customers enrolled in the program?<br>• Did the program have the intended effect on scheduled setpoints and corresponding impact on cooling runtime? | Exploratory analysis |
| • What are the energy and demand impacts of customers with thermostat optimization (i.e., treated group)?<br>• What are the energy and demand impacts of customers that were randomly assigned to receive thermostat optimization (i.e., intent to treat group)? | Impact analysis |

The SS program was deployed using a randomized encouragement design (RED), in which all customers with a Nest thermostat were randomly assigned into an intent-to-treat (ITT) group or a control group.[3] For eligible customers in the ITT group, the SS program was offered via the device or through the Nest

[1] This evaluation did not examine whether thermostat optimization is cost-effective for the electric system, program administrators, and/or customers.

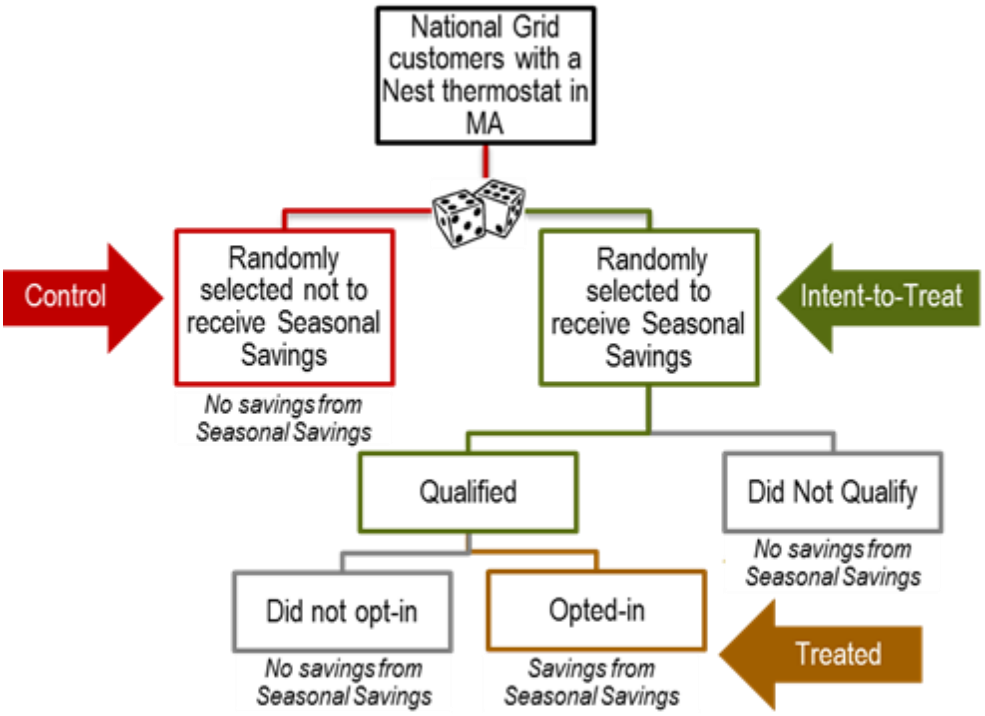
[2] Source: https://nest.com/support/article/What-is-Seasonal-Savings

[3] Some customers in the ITT (and control) group may not qualify to participate in the program. Qualification requirements include: (1) Nest thermostat installed and connected to Wi-Fi, (2) thermostat set to cooling mode, and (3) a programmed setpoint schedule.

mobile application. Customers that opted in to the program (i.e., the treated group) received the SS algorithm. Thermostats that were part of the ITT group but that did not qualify or did not opt-in are part of the untreated group. Refer to Figure 1 for an illustration of the RED.

To complete the evaluation, Navigant performed an exploratory analysis of thermostat telemetry data examining scheduled setpoints and cooling runtime across the ITT, treated, and control groups. In addition, Navigant estimated impacts using regression analysis in which 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 unbiased estimate of the effect of the program intervention on energy use.

**Figure 1. Illustration of RED**




*Source: Navigant*

## Massachusetts

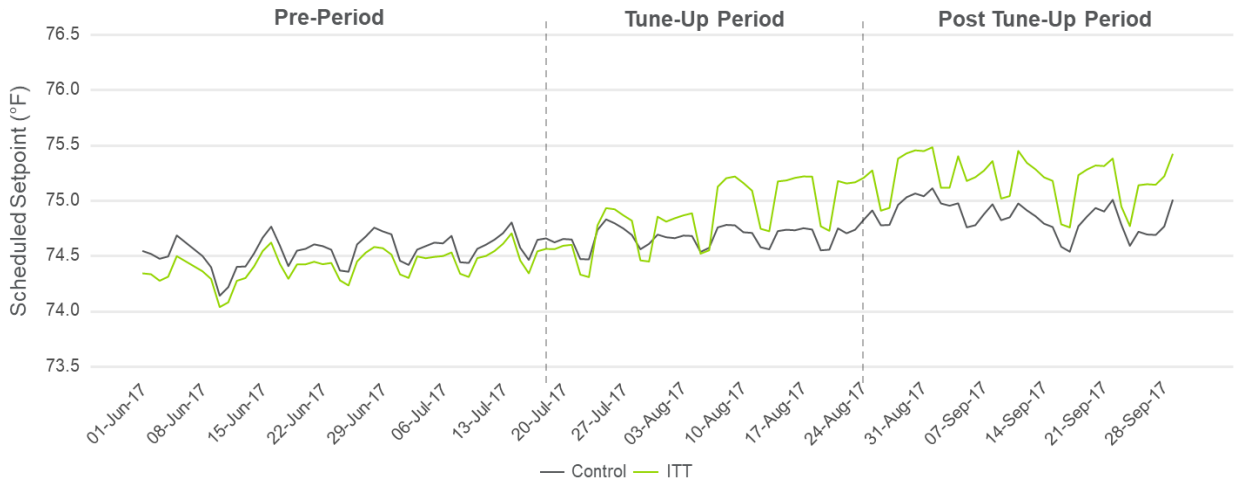
The SS program was deployed in Massachusetts on July 18, 2017. In total, 11,974 devices (76%) were eligible to receive the program offering; of those, 8,336 devices (72% of eligible devices) opted in. This section summarizes the key findings from the exploratory and impact analyses.

### *Exploratory Analysis*

Figure 2 and Figure 3 present the average daily scheduled setpoints and average daily cooling runtime for the ITT group relative to the control group. In Figure 3, the control group is represented by the centerline.

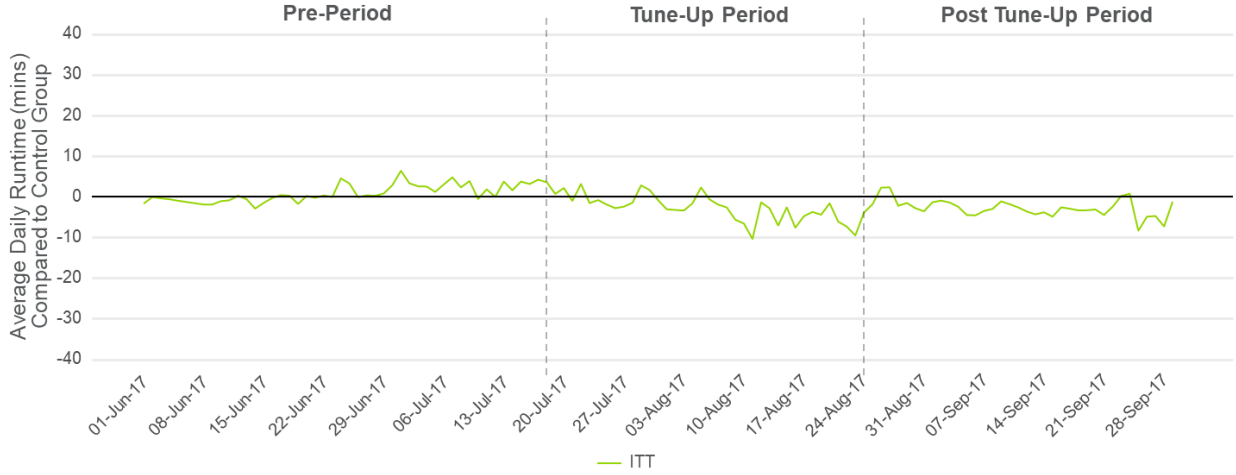
Figure 2 shows the difference in average daily scheduled setpoints increased for both the ITT and control groups during the program period (tune-up and post tune-up periods), but the increase was larger for the ITT group. The evaluation revealed changes in the cooling setpoints were primarily in the middle of weekdays. Figure 3 shows the average daily cooling runtime decreased for the ITT group during the program period. Both figures provide evidence the SS program made the intended setpoint adjustments, resulting in decreased runtime and, consequently, energy savings.

**Figure 2. Average Daily Scheduled Setpoint Comparison, ITT vs. Control: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

**Figure 3. Average Daily Runtime Comparison, ITT vs. Control: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

Table 2 summarizes the changes in scheduled setpoint and cooling runtime. The exploratory analysis of thermostat telemetry data provided evidence that the SS program did make the intended adjustments to scheduled setpoints, yielding reductions in cooling runtime.

**Table 2. Summary of Exploratory Analysis: Massachusetts**

| Period | Group | Jun 1 – Jul 17 Pre-Period | Jul 18 – Sep 30 Program Period | Δ* | SS Impact** |
|---|---|---|---|---|---|
| **Avg Daily Outdoor Temp (°F)** | | 70.3 | 68.8 | -1.5 | N/A |
| **Avg Daily Scheduled Cooling Setpoints (°F)** | Control | 74.6 | 74.8 | 0.21 | **N/A** |
| | ITT | 74.4 | 75.0 | 0.61 | **0.40** |
| | *Treated* | *74.5* | *75.3* | *0.80* | ***0.59*** |
| | *Untreated* | *74.2* | *74.4* | *0.22* | **N/A** |
| **Avg Daily Cooling Runtime (min)** | Control | 189 | 153 | -36.3 | **N/A** |
| | ITT | 190 | 150 | -40.0 | **-3.66** |
| | *Treated* | *202* | *157* | *-44.6* | ***-8.35*** |
| | *Untreated* | *176* | *141* | *-34.5* | **N/A** |

*The Δ is the difference between the program period and the pre-period.
**The SS impact is the difference between the Δ for the ITT or treated group and the control group.
*Source: Navigant analysis of Nest thermostat telemetry data and National Oceanic and Atmospheric Administration (NOAA) temperature data*

### *Impact Analysis*

Table 3 summarizes the findings of the impact analysis. In Massachusetts, the SS program resulted in energy savings of 22.7 kWh per thermostat, with total savings of 189 MWh between July 18 and September 30, 2017.[4] Average peak demand savings were 0.044 kW per thermostat, with total peak demand savings of 366 kW.

**Table 3. SS Summary from July 18 to September 30, 2017[1]: Massachusetts**

| Statistic | ITT[2] | Treated (Subset of ITT)[2] |
|---|---|---|
| Number of Nest thermostats in control group | 6,742 | |
| Number of Nest thermostats | 15,708 | 8,336 |
| Average energy savings (% of cooling load) | 2.6% ± 1.0% | 5.4% ± 2.1% |
| Average daily energy savings per device (kWh) | 0.17 ± 0.06 *** | 0.34 ± 0.13 *** |
| Average total energy savings per device (kWh)[3] | 12.4 | 22.7 |
| Total energy savings (MWh)[4] | 196 | 189 |
| Average demand savings (% of cooling load) | 4.0% ± 1.0% | 9.0% ± 2.2% |
| Average demand savings per device (kW)[5] | 0.020 ± 0.005 *** | 0.044 ± 0.011 *** |
| Total demand savings (kW)[6] | 306 | 366 |

*Source: Navigant analysis*
[1] The first offer date for the SS program occurred on July 18, 2017. The SS program persists as long as air conditioning systems are in cooling mode. This evaluation relies on data through September 30, 2017.
[2] ITT includes all devices randomly assigned to receive the SS program offering. Treated is a subset of ITT and includes those devices that qualified and opted into the program.
[3] Total savings per device is calculated as average daily savings per device *x* the number of days post tune-up start date.

[4] The program was evaluated through September 30, 2017, but the program continued into October 2017, likely yielding additional savings.

[4] Total savings is calculated as average total energy savings per device *x* the number of treated/ITT devices.
[5] Average demand savings on weekdays, non-holidays, 1 p.m.- 5 p.m., June through August.
[6] Total savings is calculated as average demand savings per device *x* the number of treated/ITT devices.
*** p<0.01, ** p<0.05, * p<0.10, range indicates 90% confidence interval.

## Rhode Island

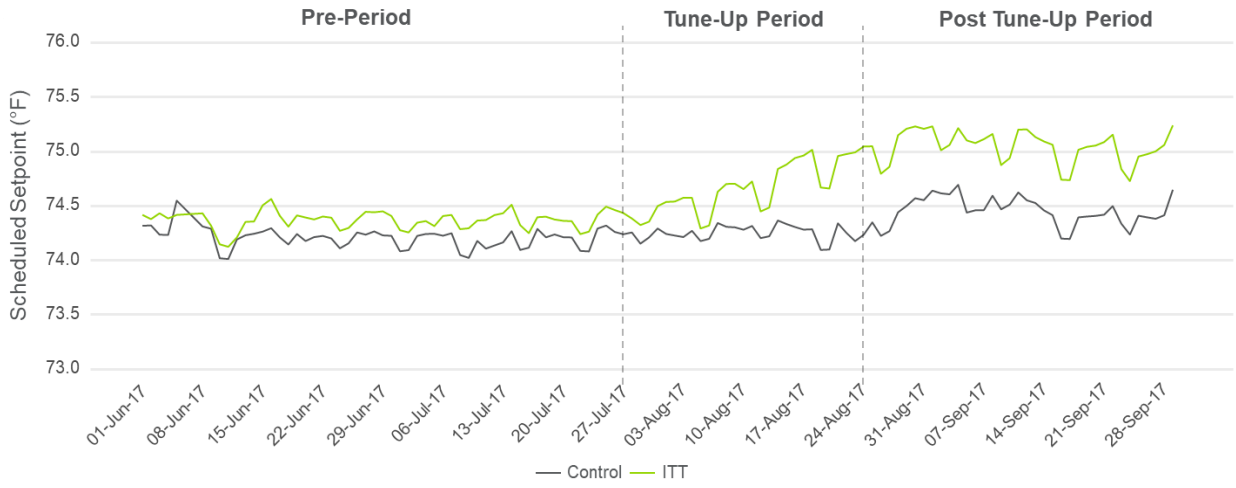
The SS program was deployed in Rhode Island on July 27, 2017. In total, 2,802 devices (76%) were eligible to receive the program offering; of those, 1,966 devices (70% of eligible devices) opted in. This section summarizes the key findings from the exploratory and impact analyses.

### *Exploratory Analysis*

Figure 4 and Figure 5 present the average daily scheduled setpoints and average daily cooling runtime for the ITT group relative to the control group. In Figure 5, the control group is represented by the centerline.

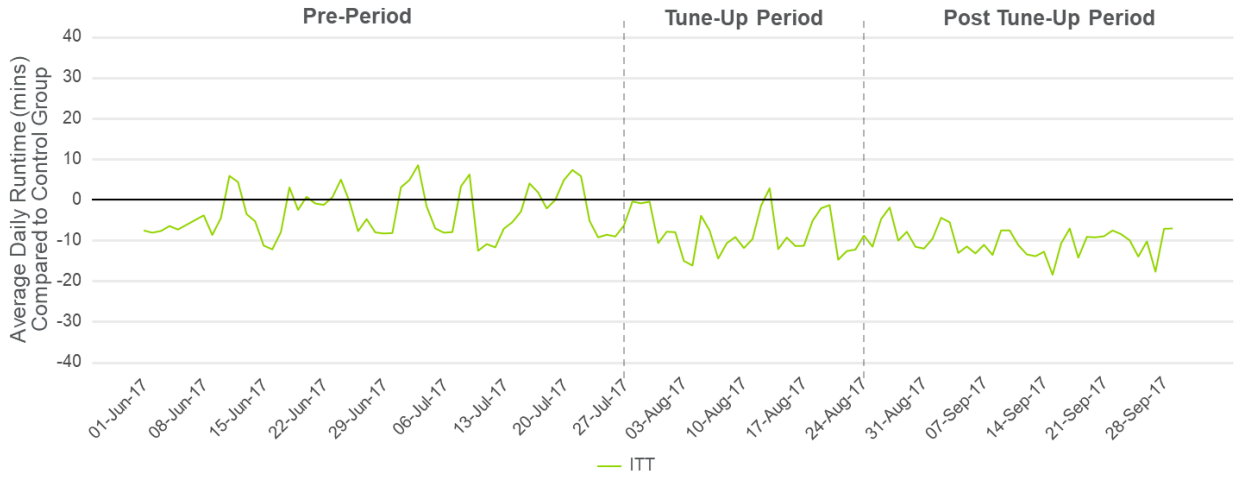
Figure 4 shows the average daily scheduled cooling setpoints increased for the ITT group relative to the control group during the program period. The evaluation revealed changes in the cooling setpoints were primarily in the middle of weekdays. Figure 5 shows the average daily cooling runtime decreased for the ITT group during the program period. Both figures provide evidence the SS program made the intended setpoint adjustments, resulting in decreased runtime and, consequently, energy savings.

**Figure 4. Average Daily Scheduled Setpoint Comparison, ITT vs. Control: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data*

**Figure 5. Average Daily Runtime Comparison, ITT vs. Control: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data*

Table 4 summarizes the changes in scheduled setpoint and cooling runtime. The exploratory analysis of thermostat telemetry data provided evidence that the SS program did make the intended adjustments to scheduled setpoints, yielding reductions in cooling runtime.

**Table 4. Summary of Exploratory Analysis: Rhode Island**

| Period | Group | Jun 1 – July 26 Pre-Period | Jul 27 – Sep 30 Program Period | Δ* | SS Impact** |
|---|---|---|---|---|---|
| **Avg Daily Outdoor Temp (°F)** | | 70.4 | 69.2 | -1.2 | N/A |
| **Avg Daily Scheduled Cooling Setpoints (°F)** | Control | 74.2 | 74.4 | 0.15 | **N/A** |
| | Intent-to-Treat | 74.4 | 74.9 | 0.51 | **0.36** |
| | *Treated* | *74.6* | *75.3* | *0.67* | ***0.52*** |
| | *Untreated* | *73.9* | *74.0* | *0.11* | ***N/A*** |
| **Avg Daily Cooling Runtime (min)** | Control | 201 | 158 | -42.4 | **N/A** |
| | Intent-to-Treat | 197 | 149 | -48.4 | **-6.00** |
| | *Treated* | *206* | *152* | *-54.2* | ***-11.8*** |
| | *Untreated* | *188* | *146* | *-41.8* | ***N/A*** |

*The Δ is the difference between the program period and the pre-period.
**The SS impact is the difference between the Δ for the ITT or treated group and the control group.
*Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data*

### *Impact Analysis*

Table 5 summarizes the findings of the impact analysis. In Rhode Island, the SS program resulted in energy savings of 29.2 kWh per thermostat, with total savings of 57 MWh between July 27 and September 30, 2017.[5] Average peak demand savings were 0.068 kW per thermostat, with total peak demand savings of 134 kW.

[5] The program was evaluated through September 30, 2017, but the program continued into October 2017, likely yielding additional savings.

**Table 5. SS Summary from July 27 to September 30, 2017[1]: Rhode Island**

| Statistic | ITT[2] | Treated (Subset of ITT)[2] |
|---|---|---|
| Number of Nest thermostats in control group | 1,580 | |
| Number of Nest thermostats | 3,701 | 1,966 |
| Average energy savings (% of cooling load) | 3.9% ± 2.3% | 7.6% ± 4.6% |
| Average daily energy savings per device (kWh) | 0.24 ± 0.14 *** | 0.49 ± 0.30 *** |
| Average total energy savings per device (kWh)[3] | 15.9 | 29.2 |
| Total energy savings (MWh)[4] | 59 | 57 |
| Average demand savings (% of cooling load) | 5.7% ± 2.0% | 12.4% ± 4.4% |
| Average demand savings per device (kW)[5] | 0.030 ± 0.011 *** | 0.068 ± 0.024 *** |
| Total demand savings (kW)[6] | 112 | 134 |

*Source: Navigant analysis*
[1] The first offer date for the SS program occurred on July 27, 2017. The SS program persists as long as air conditioning systems are in cooling mode. This evaluation relies on data through September 30, 2017.
[2] ITT includes all devices randomly assigned to receive the SS program offering. Treated is a subset of ITT and includes those devices that qualified and opted into the program.
[3] Total savings per device is calculated as average daily savings per device *x* the number of days post tune-up start date.
[4] Total savings is calculated as total energy savings per device *x* the number of treated/ITT devices.
[5] Average demand savings on weekdays, non-holidays, 1 p.m.-5 p.m., June through August.
[6] Total savings is calculated as average demand savings per device *x* the number of treated/ITT devices.
*** p<0.01, ** p<0.05, * p<0.10, range indicates 90% confidence interval.

## Conclusions

Navigant's evaluation of the SS program in Massachusetts and Rhode Island found it was successful in testing the technical feasibility of thermostat optimization and in customer acceptance of the offering. The evaluation shows promise for thermostat optimization, though important questions remain regarding incremental savings from future deployments, persistence of savings, and expected savings from a full season deployment under warmer weather conditions. Table 6 summarizes the key evaluation findings, and Table 7 provides recommendations.

**Table 6. Key Findings**

| Key Findings |
|---|
| • 70% of devices eligible to participate opted in to programs in both Massachusetts and Rhode Island—70% in Massachusetts and 70% in Rhode Island. |
| • The setpoint point schedules for the treated thermostats were adjusted upward by 0.6°F during the program period, on average—0.6°F in Massachusetts and 0.5°F in Rhode Island. |
| • The largest setpoint adjustments took place during the middle of the weekdays (1.5°F), when customers were least likely to be at home. |
| • The average impact of the SS program on cooling runtime for SS participants was 9.70 minutes—8.35 minutes in Massachusetts and 11.8 minutes in Rhode Island. |
| • The average energy savings per thermostat from mid/late July and September 30 was 22.7 kWh in Massachusetts and 29.2 kWh in Rhode Island. |
| • The program yielded energy savings of approximately 6% of cooling load between mid/late July and September 30—5.4% in Massachusetts and 7.9% in Rhode Island for program participants. |
| • The average demand savings per thermostat from mid/late July to August 31 was 0.044 kW in Massachusetts and 0.068 kW in Rhode Island. |

| Key Findings |
| --- |
| • The program yielded average peak demand savings of 9.7%—9.0% in Massachusetts and 12.4% in Rhode Island. |
| • The program achieved energy and demand savings of 189 MWh and 366 kW in Massachusetts, and 57 MWh and 134 kW in Rhode Island. |

**Table 7. Recommendations**

| Recommendations |
| --- |
| • Recommendation #1: National Grid should claim average energy savings of 22.7 kWh per thermostat in Massachusetts and 29.2 kWh per thermostat in Rhode Island in 2017. |
| • Recommendation #2: National Grid should claim average demand savings of 0.044 kW in Massachusetts and 0.068 kW in Rhode Island in 2017. |
| • Recommendation #3: Continue offering a summer thermostat optimization program to achieve energy and demand savings and consider offering a winter thermostat optimization program to address electric and gas savings. |
| • Recommendation #4: The summer SS program should be evaluated an additional year to:<br>o assess how customers respond to two summers of schedule adjustments<br>o understand whether customers leave SS during hot weather<br>o seek to ascertain a relationship between savings and weather<br>o develop an approach to incorporate SS into the Massachusetts and Rhode Island Technical Reference Manuals |

# 1. INTRODUCTION

In 2017, National Grid offered many of its customers in Massachusetts and Rhode Island a new energy savings opportunity – thermostat optimization. National Grid selected Nest to provide Seasonal Savings (SS), its thermostat optimization program during the 2017 summer season. SS adjusts thermostat setpoint schedules to achieve energy savings and demand reductions during the summer. In this evaluation report, Navigant Consulting, Inc. (Navigant) presents findings of an impact evaluation of SS.[6]

## 1.1 Program Overview

The SS program is designed to make small adjustments to scheduled setpoints over a 3-week period (i.e., tune-up period) while maintaining customer comfort. On average, scheduled setpoints are adjusted up by 1.5°F during the cooling season, with the biggest temperature adjustments taking place when customers are typically away from home (e.g., the middle of weekdays).[7]

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

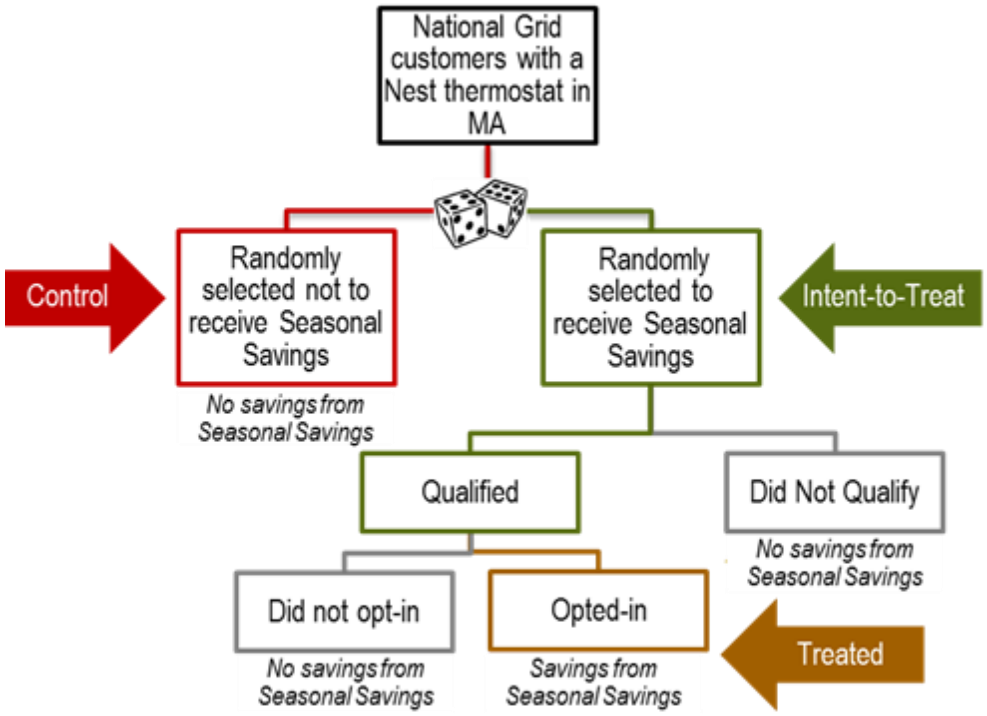
Some customers in the control and ITT group (i.e., randomly assigned to receive the program offering) may not qualify to participate in the program. Qualification requirements include: (1) Nest thermostat installed and connected to Wi-Fi, and (2) thermostat set to cooling mode, and (3) a programmed setpoint 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 that did not qualify or did not opt-in are part of the untreated group.

Refer to Figure 1-1 for an illustration of the RED design for the SS program.

[6] This evaluation did not examine whether thermostat optimization is cost-effective for the electric system, program administrators, and/or customers.

[7] Source: https://nest.com/support/article/What-is-Seasonal-Savings

**Figure 1-1. Illustration of RED**




*Source: Navigant*

Table 1-1 summarizes the number of devices, by state, assigned to the ITT and control groups, as well as the number of devices that did not qualify and did/did not opt in. The initial randomization assigned 70% of devices into the ITT group. Of these, approximately 24% did not qualify and another 23% did not opt in, resulting in approximately 53% of devices that were randomly assigned to receive the offering actually receiving thermostat optimization.

**Table 1-1. RED Implementation**

| Category | Massachusetts and Rhode Island | Percentage |
|---|---|---|
| Nests in electric service area | 27,731 | – |
| Nests in control group | 8,322 | 30% of Nests |
| Nests in ITT group | 19,409 | 70% of Nests |
| Nests enrolled in SS (treated group) | 10,302 | 53% of ITT |
| Nests in untreated group | 9,107 | 47% of ITT |
| Nests that did not qualify | 4,633 | 24% of ITT |
| Nests that did not opt in | 4,474 | 23% of ITT |

*Source: Navigant analysis of customer enrollment data*

## 1.2 Objectives and Methods

The 2017 evaluation had several key research questions (identified in Table 1-2) aimed at assessing the effectiveness of the thermostat optimization offering.

**Table 1-2. Thermostat Optimization Research Questions**

| Research Questions | Evaluation Approach |
|---|---|
| • How many devices/customers enrolled in the program?<br>• Did the program have the intended effect on scheduled setpoints and corresponding impact on cooling runtime? | Exploratory analysis |
| • What are the energy and demand impacts of customers with thermostat optimization (i.e., treated group)?<br>• What are the energy and demand impacts of customers that were randomly assigned to receive thermostat optimization (i.e., ITT group)? | Impact analysis |

Navigant's evaluation approach relied on an exploratory analysis and a regression analysis, briefly described below:

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

- Analyze setpoint schedules, thermostat runtime, and daily energy consumption from June 1 through September 30, 2017 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
- Analyze whether there are differences between weekdays/weekends and hour of the day

**Impact analysis:** The purpose of the impact analysis is to estimate the energy savings and peak demand savings from thermostat optimization for both the treated and ITT groups.[8, 9] Because advanced metering infrastructure (AMI) data was unavailable, Navigant relied exclusively on thermostat telemetry data to estimate impacts after converting thermostat runtime to power.[10]

1. ***Impacts – ITT.*** Navigant uses a linear fixed effects (or difference-in-differences) regression model to estimate savings associated with devices that were randomly assigned to receive the program offering. Formally, the model is specified as follows:

$$ADU_{it} = \alpha_i + \gamma_t + \beta_1 Post_t + \beta_2 (Post_t \cdot Treat_i) + \varepsilon_{it}$$

Where,

| | |
|---|---|
| $ADU_{it}$ | is estimated daily consumption of kWh by device *i* on day *t* |
| $\alpha_i$ | 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 |

[8] Peak demand is defined as 1 p.m.-5 p.m. on non-holiday weekdays in the post period through August 31, 2017.

[9] 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 unbiased estimate of the effect of the program intervention on energy use.

[10] Navigant converted thermostat runtime to power based on an analysis of metering data from Phase 2 of the 2017 Massachusetts Baseline Study (n=92) and assumptions regarding average size (3.0 tons) and efficiency (10.7 Energy Efficiency Ratio) of air conditioners based on a field study (n=52) of residential Wi-Fi thermostat demand reduction program participants conducted by Navigant in October 2017. For example, for a 15-minute interval with 100% runtime at 80°F the estimated power is 2.51 kW.

| | |
|---|---|
| $\gamma_t$ | 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 *t* is in the post period (July 18 for Massachusetts and July 27 for Rhode Island) and 0 otherwise |
| $Post_t \cdot Treat_i$ | 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 (July 18 for Massachusetts and July 27 for Rhode Island) |
| $\varepsilon_{it}$ | is the cluster-robust error term for device *i* during day *t;* cluster-robust errors account for heteroskedasticity and autocorrelation at the household level |

Navigant used a similar model specification to estimate peak demand savings, where the unit of analysis is hourly demand rather than daily energy consumption. Additional explanatory variables were included, controlling for hourly weather and day of week.

To calculate total ITT program savings, Navigant multiplied average daily energy savings by the number of program days (post tune-up) and the number of devices in the ITT group. Similarly, to calculate total ITT demand savings, Navigant multiplied average hourly demand savings by the number of devices in the ITT group.

2. ***Impacts – Treated.*** Navigant uses a two-stage least-squares instrumental variables approach to estimate savings associated with receiving the SS algorithm. This approach relies 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 participation is not random and depends on unobserved characteristics that may be correlated with energy consumption (i.e., participation is endogenous).

   In the first stage, program participation is regressed on an indicator for whether the customer was randomly assigned to receive the program offering (ITT). This regression is used to predict the likelihood of participation. In the second stage, average daily energy consumption is regressed on the predicted likelihood of participation. Formally, the models are specified as follows:

   First Stage: $\widehat{Treat}_i = \alpha_i + \gamma_t + \beta_1 Post_t + \beta_2 (Post_t \cdot ITT_i) + \varepsilon_{it}$

   Second Stage: $ADU_{it} = \alpha_i + \gamma_t + \beta_1 Post_t + \beta_2 \left(PostTune_{it} \cdot \widehat{Treat}_i\right) + \varepsilon_{it}$

   Where,

| | |
|---|---|
| $ADU_{it}$ | is estimated daily consumption of kWh by device *i* on day *t* |
| $\alpha_i$ | 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 |
| $\gamma_t$ | 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 *t* is in the post period (July 18 for Massachusetts and July 27 for Rhode Island) and 0 otherwise |
| $Post_t \cdot Treat_i$ | 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 (July 18 for Massachusetts and July 27 for Rhode Island); this is the instrument for $PostTune_{it} \cdot \widehat{Treat}_i$ in the second stage of the model |

| | |
|---|---|
| $PostTune_{it} \cdot \widehat{Treat_i}$ | 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 tune-up; this variable is instrumented for $Post_t \cdot Treat_i$ |
| $\varepsilon_{it}$ | is the cluster-robust error term for device *i* during day *t;* cluster-robust errors account for heteroskedasticity and autocorrelation at the household level |

Navigant used a similar model specification to estimate peak demand savings where the unit of analysis is hourly demand rather than daily energy consumption. Additional explanatory variables were included, controlling for hourly weather and day of week.

To calculate total program savings resulting from treatment, Navigant multiplied average daily energy savings by the number of program days (post tune-up) and the number of participating devices. Similarly, to calculate total demand savings, Navigant multiplied average hourly demand savings by the number of participating devices.

## 1.3 Summer 2017 Weather

The average temperature in Massachusetts and Rhode Island was below the 1981-2010 normal during July and August 2017 and there no days when the average temperature reached 90°F after the first SS offer day in both Massachusetts and Rhode Island. The average temperature and cooling degree days for 2017 are compared to the 1981-2010 normal in Table 1-3 and Table 1-4.

In Massachusetts the average June temperature was 0.7°F above the 1981-2010 normal, before being below normal in July and August, by 0.4°F and 0.9°F, respectively. Average temperature in September was 3.7°F above normal. Although the average temperature in September was above average, the number of cooling degree days was less than August. Also, after SS was first offered on July 18 there were no days with average daily temperatures above 90°F when air conditioning use would have more significant.

**Table 1-3. Summer 2017 Weather: Massachusetts**

| | | June | July | August | September |
|---|---|---|---|---|---|
| Average Temperature | 2017 | 66.0 | 70.0 | 68.1 | 65.0 |
| | 1981-2010 normal | 65.3 | 70.4 | 69.0 | 61.3 |
| | Departure | 0.7 | -0.4 | -0.9 | 3.7 |
| Cooling Degree Days (base 65°F) | 2017 | 78 | 178 | 137 | 66 |
| | 1981-2010 normal | 70 | 192 | 159 | 25 |
| | Departure | 8 | -14 | -22 | 41 |

*Source: Northeast Regional Climate Center*

In Rhode Island the average June temperature was 0.6°F above the 1981-2010 normal, before being below normal in July and August, by 0.4°F and 0.6°F, respectively. Average temperature in September was 3.4°F above normal. Although the average temperature in September was above average, the number of cooling degree days was less than August. Also, after SS was first offered on July 27 there were no days with average daily temperatures above 90°F when air conditioning use would have more significant.

**Table 1-4. Summer 2017 Weather: Rhode Island**

| | | June | July | August | September |
|---|---|---|---|---|---|
| Average Temperature | 2017 | 66.7 | 71.1 | 69.7 | 66.3 |
| | 1981-2010 Normal | 66.1 | 71.5 | 70.3 | 62.9 |
| | Departure | 0.6 | -0.4 | -0.6 | 3.4 |
| Cooling Degree Days (base 65°F) | 2017 | 81 | 193 | 157 | 78 |
| | 1981-2010 Normal | 75 | 206 | 177 | 34 |
| | Departure | 6 | -13 | -20 | 44 |

*Source: Northeast Regional Climate Center*

# 2. MASSACHUSETTS PROGRAM

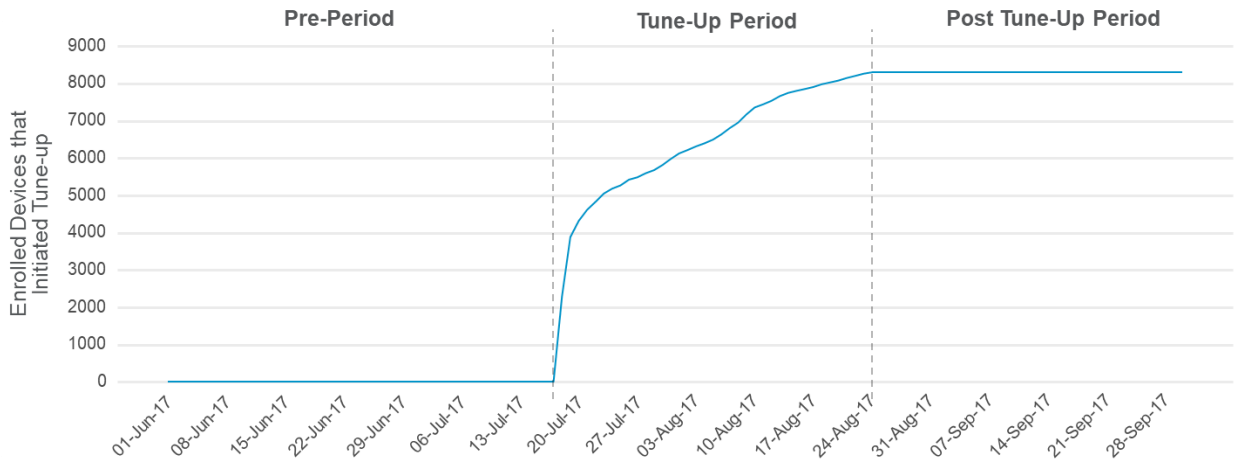
This section presents the findings from Navigant's evaluation of the SS program in 2017 in Massachusetts. The remainder of this section is organized as follows:

- Section 2.1: Program Enrollment
- Section 2.2: Exploratory Analysis
- Section 2.3: Impact Analysis

## 2.1 Program Enrollment

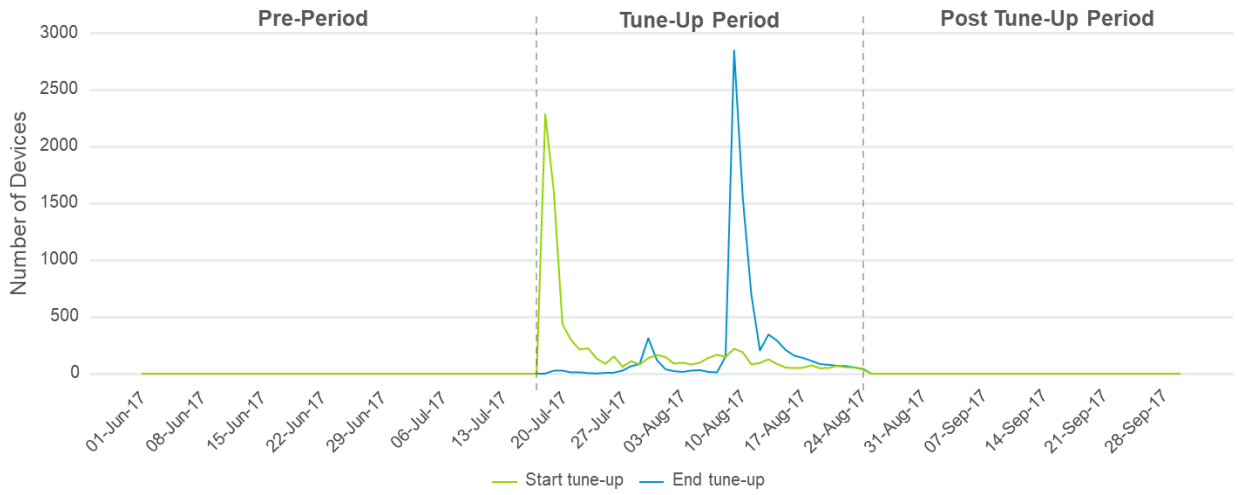
As of August 24, 2017—the end of the tune-up period—there were 8,336 thermostats enrolled in the SS program in Massachusetts. Figure 2-1 shows the number of thermostats enrolled in the program, with a steady increase throughout the 5-week enrollment and tune-up period. Figure 2-2 presents the number of devices entering and exiting the tune-up phase over time. Customers were quick to enroll in the program, with 62% of devices (5,188) enrolling in the first week of the program offering.

**Figure 2-1. Number of Enrolled Thermostats: Massachusetts**




*Source: Navigant analysis of customer enrollment data*

**Figure 2-2. Number of Thermostats Entering and Leaving Tune-Up: Massachusetts**




*Source: Navigant analysis of customer enrollment data*

Table 2-1 summarizes the number of devices assigned to the ITT and control groups, as well as the number of devices that did not qualify or did/did not opt in. The initial randomization assigned 70% of devices into the ITT group. Of these, approximately 24% did not qualify and another 23% did not opt in, resulting in approximately 53% of devices that were randomly assigned to receive the program offering actually receiving thermostat optimization.

**Table 2-1. Implementation of SS: Massachusetts**

| Category | Number | Percentage |
|---|---|---|
| Nests in electric service area | 22,450 | - |
| Nests in control group | 6,742 | 30% of Nests |
| Nests in ITT group | 15,708 | 70% of Nests |
| Nests enrolled in SS (treated group) | 8,336 | 53% of ITT |
| Nests in untreated group | 7,372 | 47% of ITT |
| Nests that did not qualify | 3,734 | 24% of ITT |
| Nests that did not opt in | 3,638 | 23% of ITT |

*Source: Navigant analysis of customer enrollment data*

## 2.2 Exploratory Analysis

This section presents the findings from the exploratory analysis of the thermostat telemetry data. Table 2-2 provides the average daily scheduled setpoint and average daily cooling runtime for the control, ITT, and 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 cooling runtime. The tables in Appendix A.1 provide the same statistics for the tune-up and post tune-up portions of the program period.

**Table 2-2. Summary of Exploratory Analysis: Massachusetts**

| Period | Group | Jun 1 – Jul 17 Pre-Period | Jul 18 – Sep 30 Program Period | Δ* | SS Impact** |
|---|---|---|---|---|---|
| **Avg Daily Outdoor Temp (°F)** | | 70.3 | 68.8 | -1.5 | N/A |
| **Avg Daily Scheduled Cooling Setpoints (°F)** | Control | 74.6 | 74.8 | 0.21 | **N/A** |
| | ITT | 74.4 | 75.0 | 0.61 | **0.40** |
| | *Treated* | *74.5* | *75.3* | *0.80* | ***0.59*** |
| | *Untreated* | *74.2* | *74.4* | *0.22* | **N/A** |
| **Avg Daily Cooling Runtime (min)** | Control | 189 | 153 | -36.3 | **N/A** |
| | ITT | 190 | 150 | -40.0 | **-3.66** |
| | *Treated* | *202* | *157* | *-44.6* | ***-8.35*** |
| | *Untreated* | *176* | *141* | *-34.5* | **N/A** |

*The Δ is the difference between the program period and the pre-period.
**The SS impact is the difference between the Δ for the ITT or treated group and the control group.
*Source: Navigant analysis of Nest thermostat telemetry data and National Oceanic and Atmospheric Administration (NOAA) temperature data*

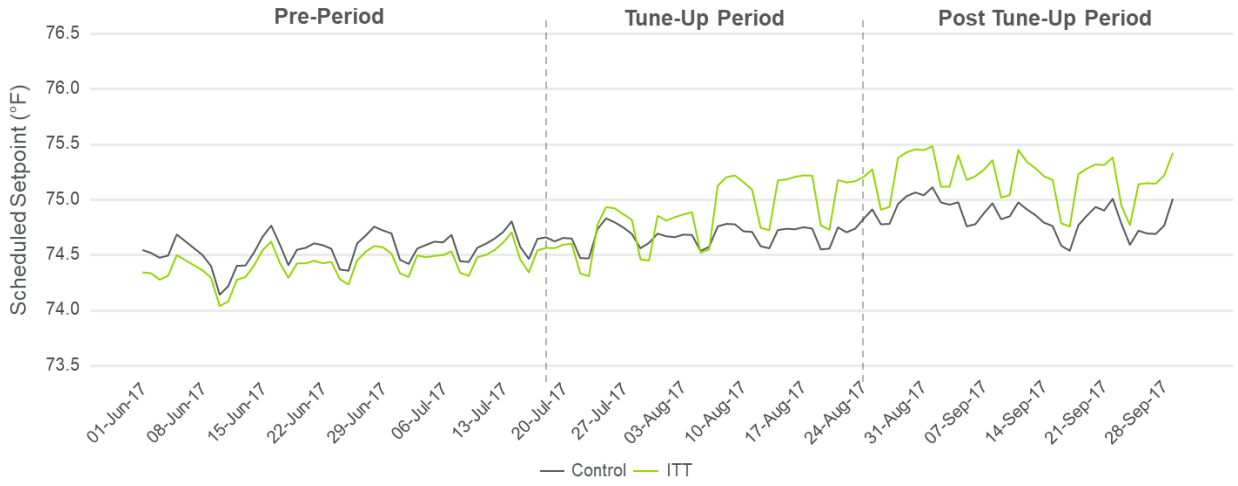
### *2.2.1 Setpoint Comparisons*

Figure 2-3 presents the average daily scheduled setpoints for the ITT and control groups. Figure 2-4 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 centerline.

- **Pre-program period:** Average daily scheduled setpoints during the pre-period were similar across the ITT and control groups, with differences of 0.1°F, on average.[11] This is expected, as customers were randomly assigned into the ITT and control groups; as a result, they are expected to have average daily runtimes that are practically and statistically similar.
- **Program period:** The difference in average daily scheduled setpoints increased for both the ITT and control groups during the program period (tune-up and post tune-up periods), but the increase was larger for the ITT group. Average daily scheduled setpoints increased by 0.4°F for the ITT group relative to the control group. The average adjustments to scheduled setpoints during the tune-up period were slightly lower at 0.32°F due to devices enrolling in the program over a period of 2 weeks and the 3-week tune-up period of making incremental adjustments to scheduled setpoints. During the post tune-up period, average daily scheduled setpoints increased by 0.48°F for the ITT group relative to the control group. This result provides evidence that the program had the intended effect of adjusting scheduled setpoints.

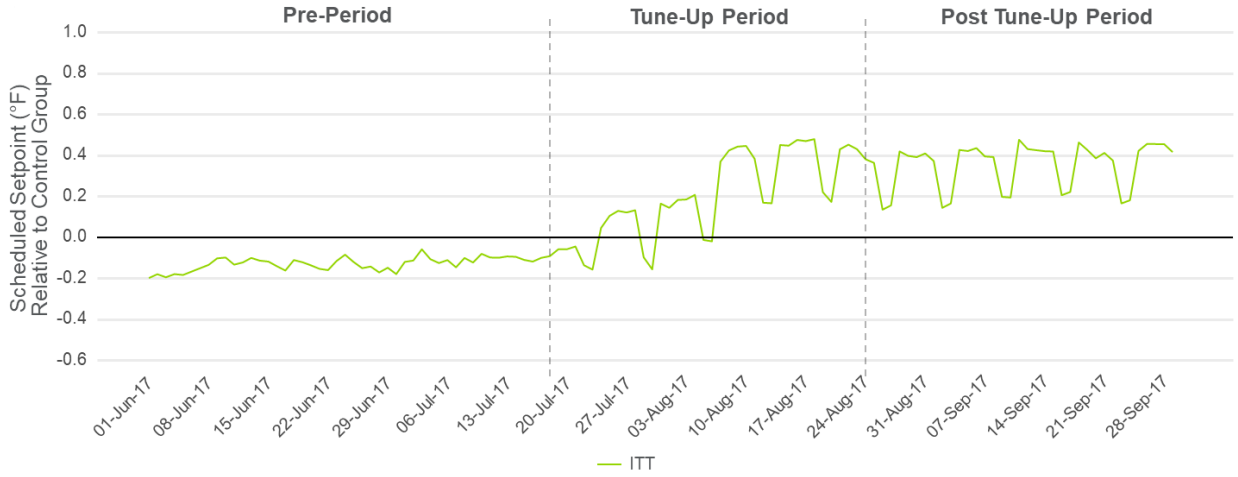
[11] This difference is not statistically significant.

**Figure 2-3. Average Daily Scheduled Setpoints: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

**Figure 2-4. Average Daily Scheduled Setpoint Comparison, ITT vs. Control: Massachusetts**

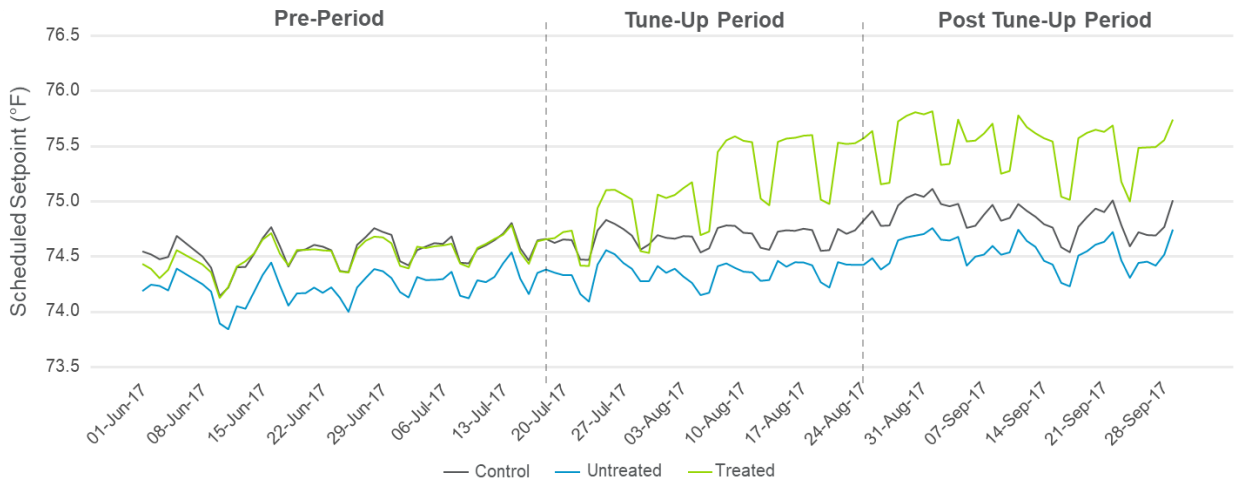



*Source: Navigant analysis of Nest thermostat telemetry data*

Figure 2-5 and Figure 2-6 present a similar comparison as above but show the average daily scheduled setpoints for the ITT group split out by treated and untreated, in addition to the control group. Figure 2-5 presents average daily scheduled setpoints, while Figure 2-6 presents this information relative to the control group, where the control group is represented by the centerline.

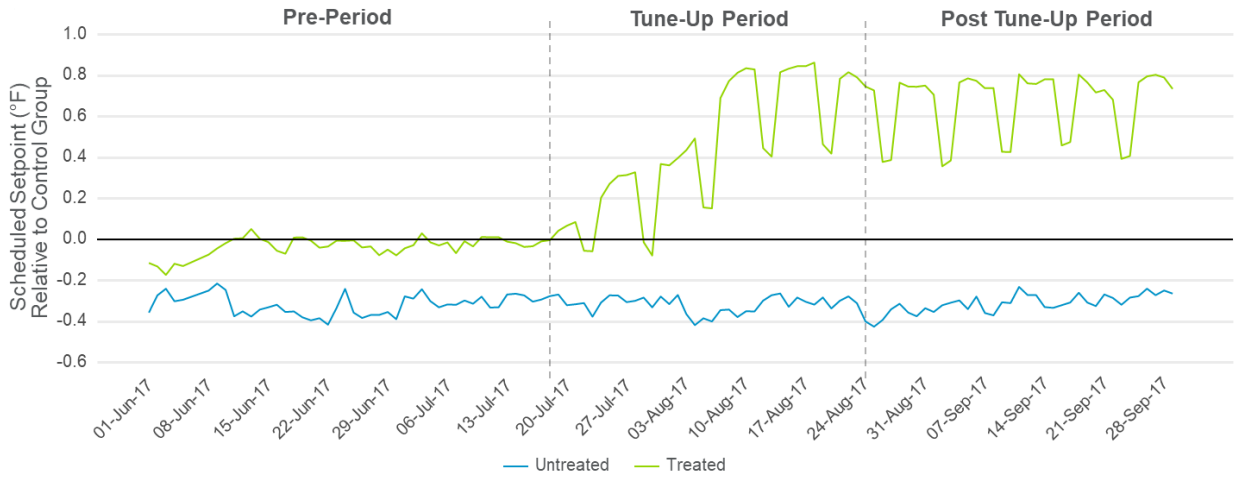
- **Pre-program period:** While the treated and control groups have similar average daily scheduled setpoints during the pre-period, the untreated group's average daily scheduled setpoint was 0.32°F lower, on average. Differences between the treated and untreated groups are expected, as the untreated group includes customers that did not opt in and those who were not eligible to participate in the program.
- **Program period:** Average daily scheduled setpoints increased for all three groups, particularly during the post tune-up period, but the increase was largest for the treated group. Average daily scheduled setpoints increased by 0.59°F for the treated group relative to the control group during the program period, whereas it remained relatively unchanged for devices that were untreated.

**Figure 2-5. Average Daily Scheduled Setpoints, All Groups: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

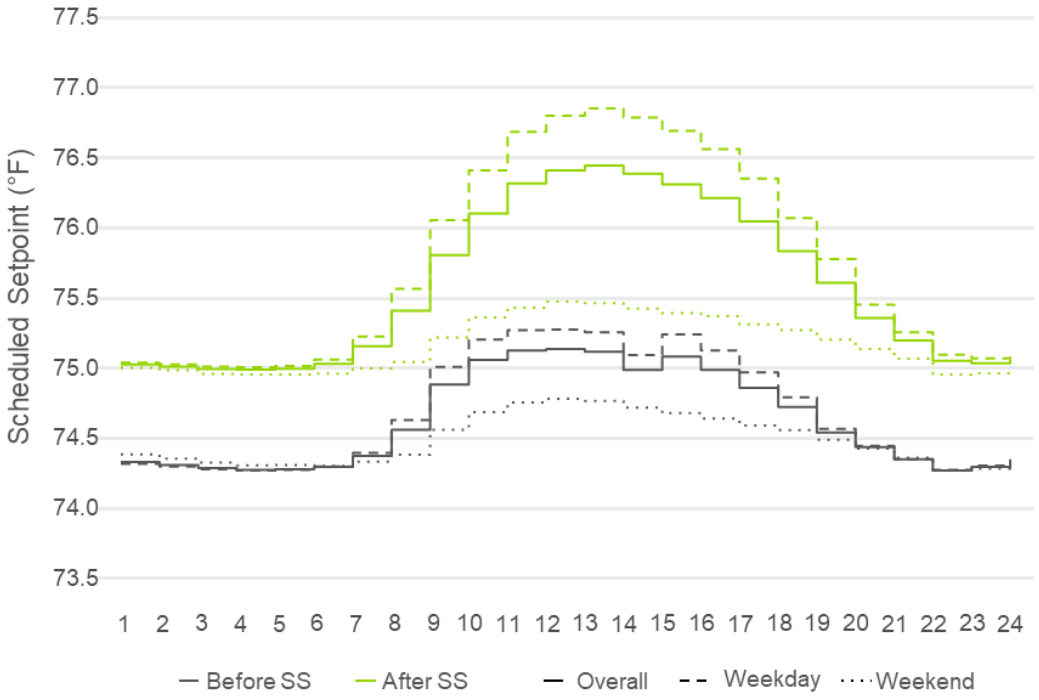
**Figure 2-6. Average Daily Scheduled Setpoint Comparison, Treated and Untreated vs. Control: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

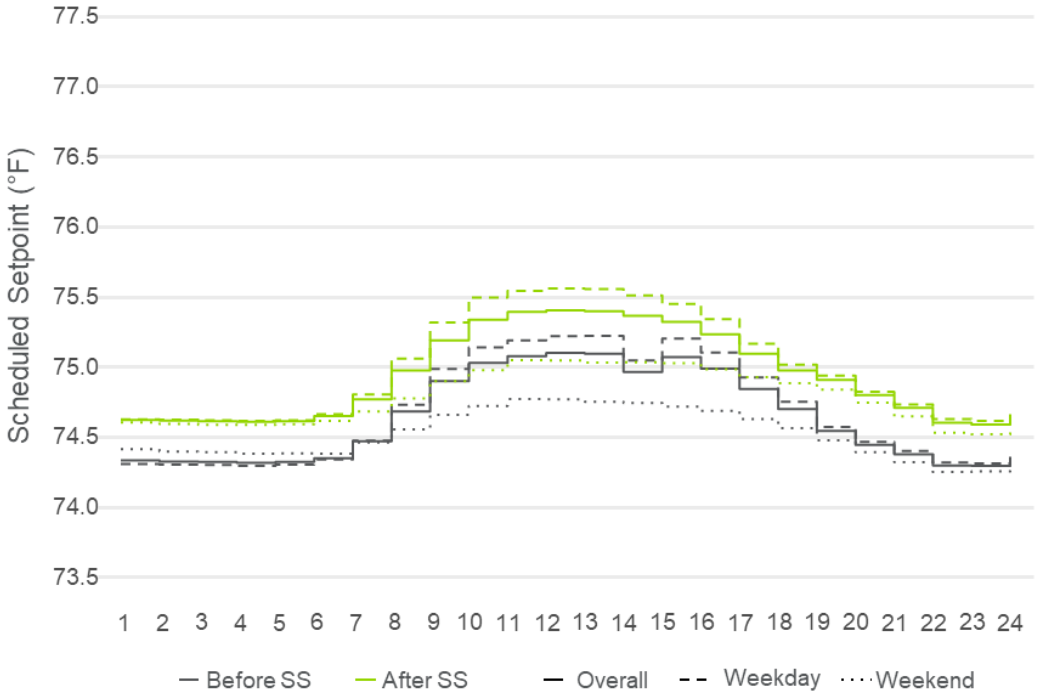
Figure 2-7 and Figure 2-8 present a comparison of average hourly scheduled setpoints based on the weeks of July 11-17, 2017 (before the tune-up period) and August 25-31, 2017 (after the tune-up period) for the treated and control groups, respectively, with values separated out by weekday, weekend, and all days (i.e., overall). This comparison further illustrates that while scheduled setpoints increased for the control group pre- and post-tune-up, the increase for the treated group was larger. Furthermore, the program is designed to make the largest adjustments during times when customers are away from home (e.g., weekday daytime) and smaller adjustments during times when customers are at home (e.g., weekday evenings and weekends), and this is evident in the data. Overall average scheduled setpoints increased by 1.2°F between 10 a.m. and 6 p.m. and 0.8°F during all other hours pre- and post-tune-up for the treated group, while the control group's overall average scheduled setpoints increased by 0.3°F across all hours.

**Figure 2-7. Mean Hourly Setpoint Comparison, Treated, Before and After SS: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

**Figure 2-8. Mean Hourly Setpoint Comparison, Control, Before and After SS: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

Table 2-3 summarizes the change in scheduled setpoints pre- and post-tune-up for the treated and control groups across different day types and times of day.

**Table 2-3. Change in Scheduled Setpoints, Before and After Tune-Up: Massachusetts**

| Day Type | Period | Treated | Control | Δ |
|---|---|---|---|---|
| Weekday | 10 a.m. to 6 p.m. | 1.5°F | 0.3°F | 1.2°F |
| | Other Hours | 0.9°F | 0.3°F | 0.6°F |
| Weekend | 10 a.m. to 6 p.m. | 0.7°F | 0.3°F | 0.4°F |
| | Other Hours | 0.7°F | 0.2°F | 0.5°F |
| Overall | 10 a.m. to 6 p.m. | 1.2°F | 0.3°F | 0.9°F |
| | Other Hours | 0.8°F | 0.3°F | 0.5°F |

*Source: Navigant analysis of Nest thermostat telemetry data*

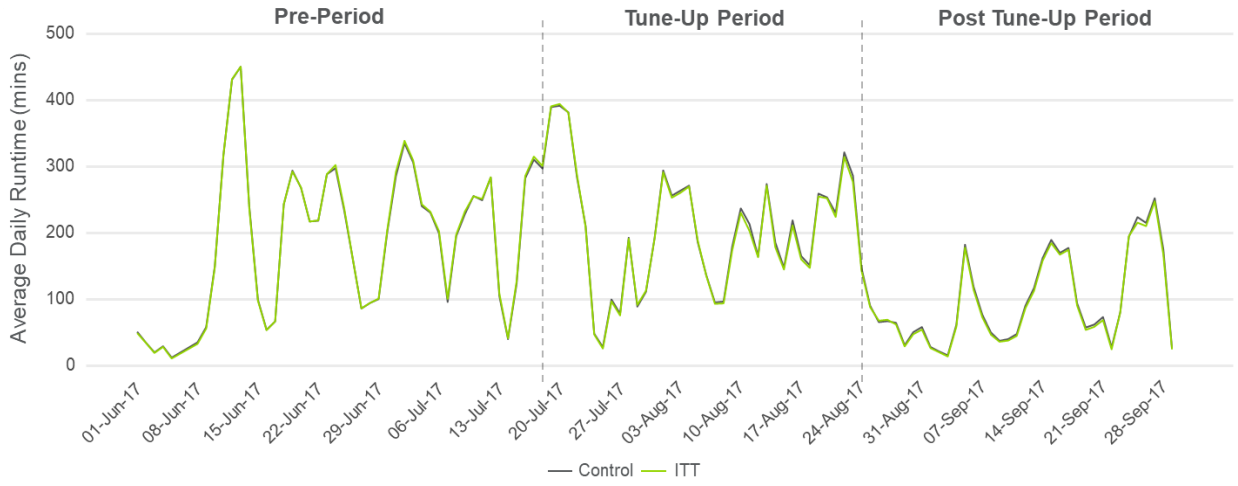
### *2.2.2 Thermostat Runtime Comparisons*

Similar to the exploratory analysis of average scheduled setpoints, this section presents findings from the exploratory analysis of average daily thermostat cooling runtime. Unlike scheduled cooling setpoint, the cooling runtime is correlated with temperature. The average outdoor temperatures during the pre-program and program periods were 70.3°F and 68.8°F, respectively. Within the program period, the tune-up period was somewhat warmer with an average outdoor temperature of 71.4°F, compared to 66.1°F in the post tune-up period. Figure 2-9 shows average daily runtime over the course of the 2017 summer season for the ITT and control groups. Figure 2-10 presents this information as a comparison of average daily runtime for the ITT group relative to the control group, where the control group is represented by the centerline.

- **Pre-program period:** There were small differences in average daily runtime during the pre-period across the ITT and control groups (differences of just 0.9 mins, on average).[12] Again, this is expected, as customers were randomly assigned into the ITT and control groups; as a result, they are expected to have average daily runtimes that are practically and statistically similar.
- **Program period:** During the program period, average daily runtime decreased for both the ITT and control groups, but the decrease was slightly larger for the ITT group. Average daily runtime decreased by an average of 3.66 mins during the program period for the ITT group relative to the control group. This result provides evidence there was less cooling taking place for the ITT group relative to the control group as a result of the program. The decrease in average daily runtime was slightly lower during the tune-up period than the post tune-up period due to devices enrolling in the program over a period of 2 weeks. Average daily runtime decreased by 3.55 mins during the tune-up period for the ITT group relative to the control group, and 3.77 mins during the post tune-up period relative to the control group.

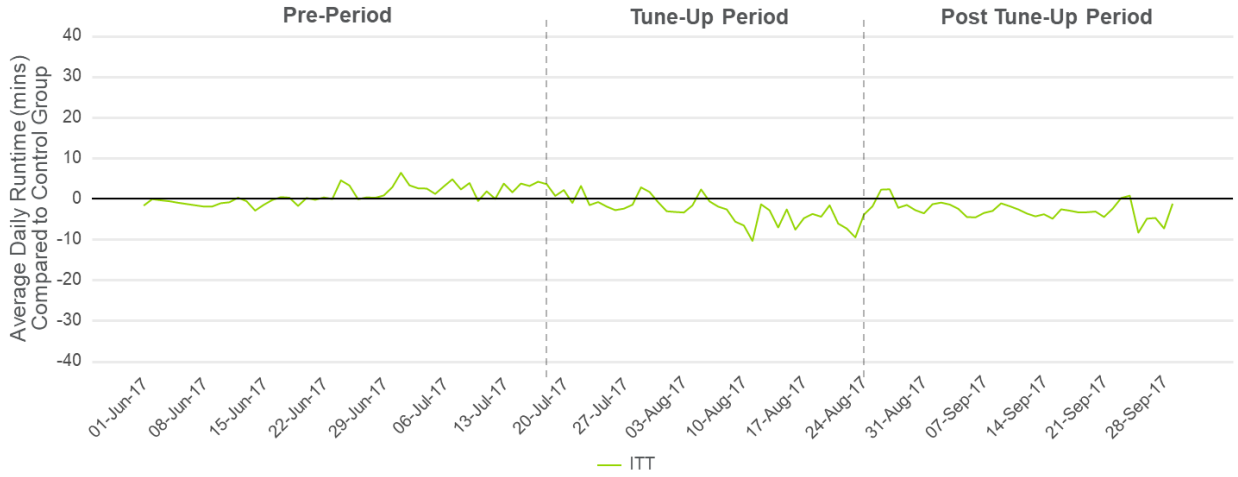
[12] This difference is not statistically significant.

**Figure 2-9. Average Daily Runtime, ITT and Control: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

**Figure 2-10. Average Daily Runtime Comparison, ITT vs. Control: Massachusetts**



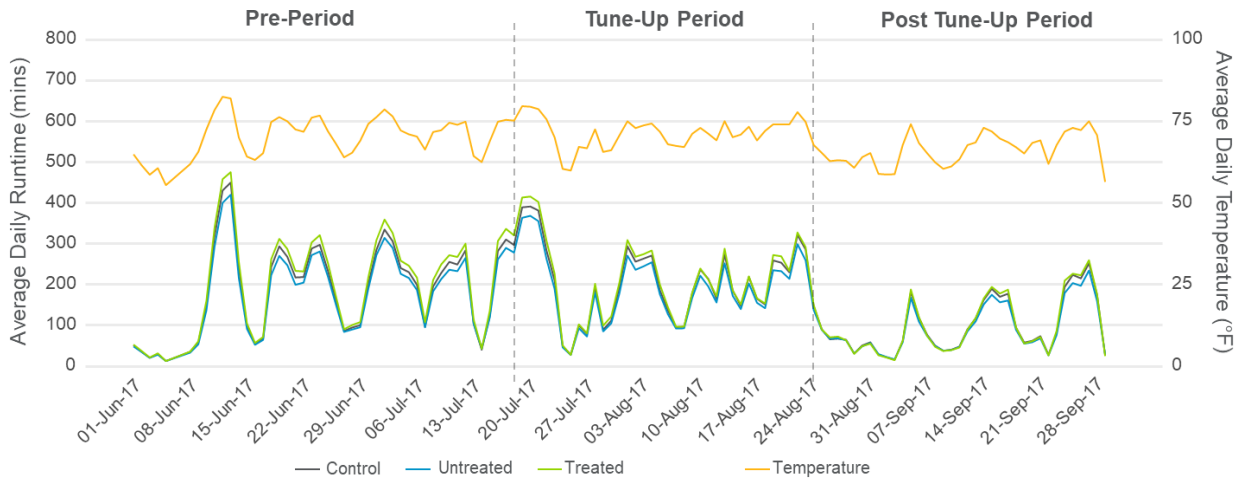

*Source: Navigant analysis of Nest thermostat telemetry data*

Figure 2-11 and Figure 2-12 present a similar comparison as above but show the average daily runtimes for the ITT group split out by treated and untreated, in addition to the control group. Figure 2-11 presents average daily scheduled setpoints with the addition of average daily cross-group temperature, while Figure 2-12 presents the runtime information relative to the control group, where the control group is represented by the centerline.

- **Pre-program period:** There was a small difference in average daily runtime during the pre-period between the treated and untreated sub-groups and the control group. The treated group had 13 minutes more runtime than the control, whereas the untreated group had 13 minutes less than the control.
- **Program period:** During the program period, average daily runtime decreased for all groups, but the decrease was largest for the treated group. Average daily runtime decreased by an average of 8.4 mins during the program period for the treated group relative to the control group. This result provides evidence there was less cooling taking place for the treated group relative to the

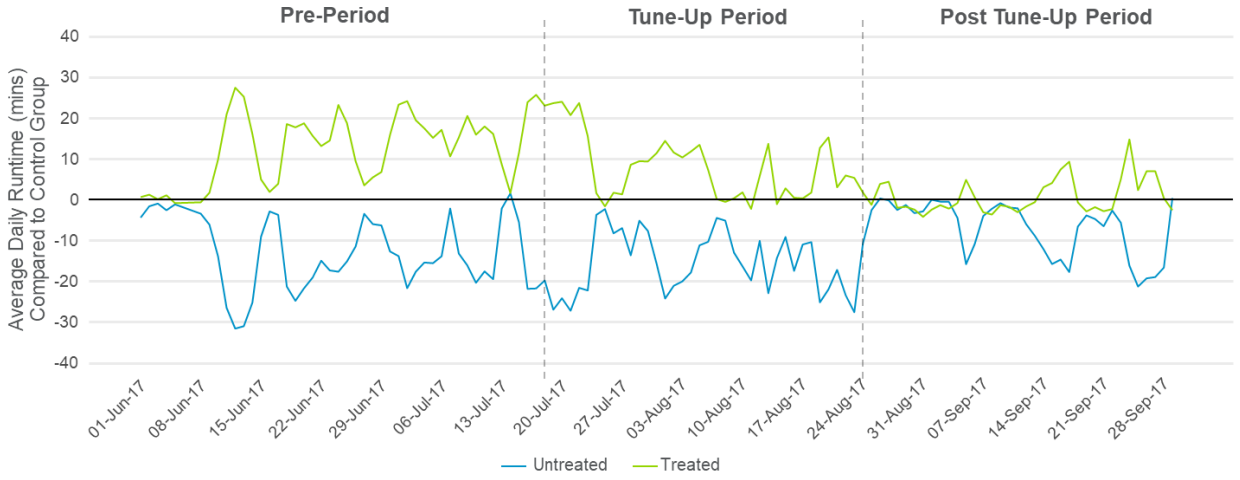
control group as a result of the program. The decrease in average daily runtime relative to the control was slightly lower during the tune-up period than the post tune-up period. These values are 4.6 and 12.1 minutes more reduction in runtime than the control group, respectively.

**Figure 2-11. Average Daily Runtime and Temperature, All Groups: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data*

**Figure 2-12. Average Daily Runtime Comparison, Treated and Untreated vs. Control: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

## 2.3 Impact Analysis

This section presents the findings from the energy and peak demand impact analysis, summarized in Table 2-4. The SS program resulted in total energy savings of 189 MWh from July 18 to September 30, 2017, and total peak demand savings of 366 kW between July 18 to August 31, 2017.

**Table 2-4. SS Summary from July 18 to September 30, 2017[1]: Massachusetts**

| Statistic | ITT[2] | Treated (Subset of ITT)[2] |
|---|---|---|
| Number of Nest thermostats in control group | 6,742 | |
| Number of Nest thermostats | 15,708 | 8,336 |
| Average energy savings (% of cooling load) | 2.6% ± 1.0% | 5.4% ± 2.1% |
| Average daily energy savings per device (kWh) | 0.17 ± 0.06 *** | 0.34 ± 0.13 *** |
| Average total energy savings per device (kWh)[3] | 12.4 | 22.7 |
| Total energy savings (MWh)[4] | 196 | 189 |
| Average demand savings (% of cooling load) | 4.0% ± 1.0% | 9.0% ± 2.2% |
| Average demand savings per device (kW)[5] | 0.020 ± 0.005 *** | 0.044 ± 0.011 *** |
| Total demand savings (kW)[6] | 306 | 366 |

*Source: Navigant analysis*

[1] The first offer date for the SS program occurred on July 18, 2017. The SS program persists as long as air conditioning systems are in cooling mode. This evaluation relies on data through September 30, 2017.

[2] ITT includes all devices randomly assigned to receive the SS program offering. Treated is a subset of ITT and includes those devices that qualified and opted into the program.

[3] Total savings per device is calculated as average daily savings per device *x* the number of days post tune-up start date.

[4] Total savings is calculated as total energy savings per device *x* the number of treated/ITT devices.

[5] Average demand savings on weekdays, non-holidays, 1 p.m.-5 p.m., June through August.

[6] Total savings is calculated as average demand savings per device *x* the number of treated/ITT devices.

*** p<0.01, ** p<0.05, * p<0.10, range indicates 90% confidence interval.

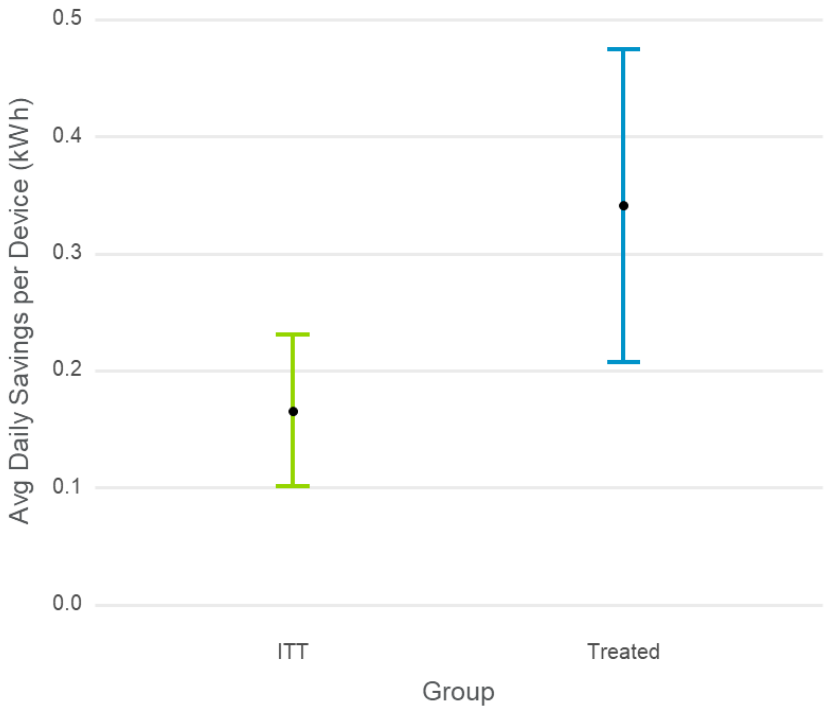
### *2.3.1 Energy Impacts*

Figure 2-13 presents the estimate of average daily energy savings for the ITT group (including devices that opt in, do not opt in, and do not qualify) and the treated group (including only devices that opt in). Average daily energy savings is estimated to be 0.17 kWh[13] per device for the ITT group and 0.34 kWh[14] per device for the treated group. Figure 2-14 presents these results as a percentage of cooling load. Average daily energy savings are 2.6% of cooling load for the ITT group and 5.4% for the treated group.

[13] The 90% confidence interval is (0.10 kWh, 0.23 kWh).

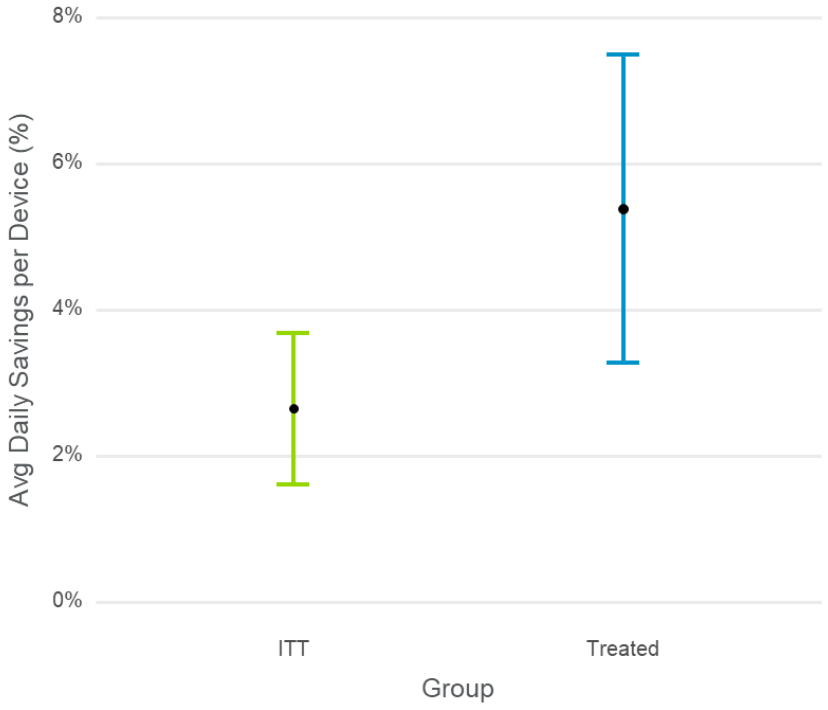
[14] The 90% confidence interval is (0.21 kWh, 0.48 kWh).

**Figure 2-13. Average Daily Savings: Massachusetts**




*Source: Navigant analysis*

**Figure 2-14. Average Daily Savings (as a Percentage of Cooling Load): Massachusetts**

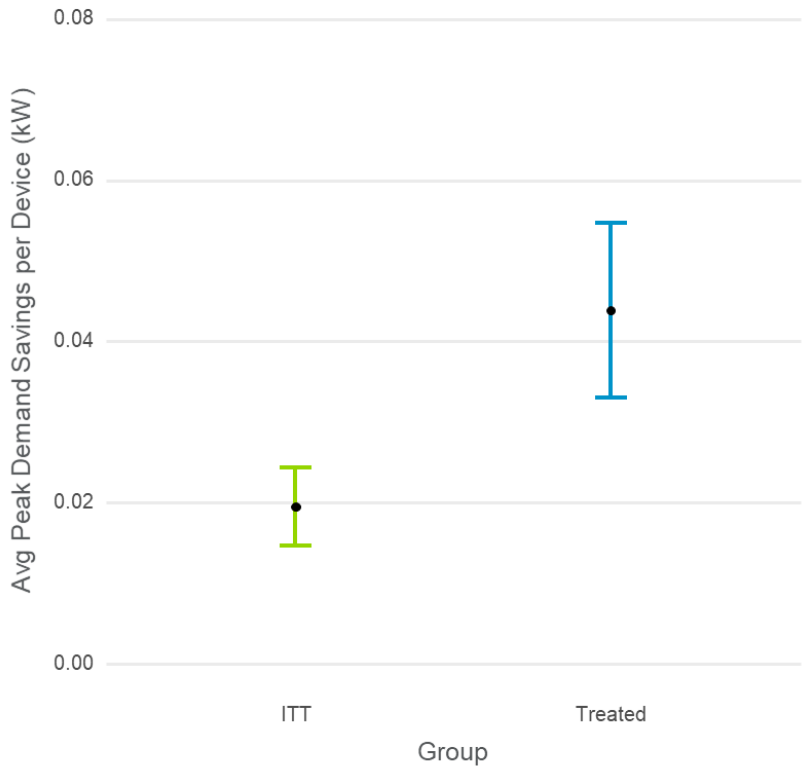



*Source: Navigant analysis*

### *2.3.2 Peak Demand Impacts*

Navigant estimated peak demand impacts from 1 p.m. to 5 p.m. on program period non-holiday weekdays in July and August. Figure 2-15 presents the estimate of average peak demand savings for the ITT group (including devices that opt in, do not opt in, and do not qualify) and the treated group (including only devices that opt in). Average peak demand savings is estimated to be 0.020 kW[15] per device for the ITT group and 0.044 kW[16] per device for the treated group. Figure 2-16 presents these results as a percentage of cooling load. Average peak demand savings are 4.0% of cooling load for the ITT group and 9.0% for the treated group.

**Figure 2-15. Average Peak Demand Savings: Massachusetts**

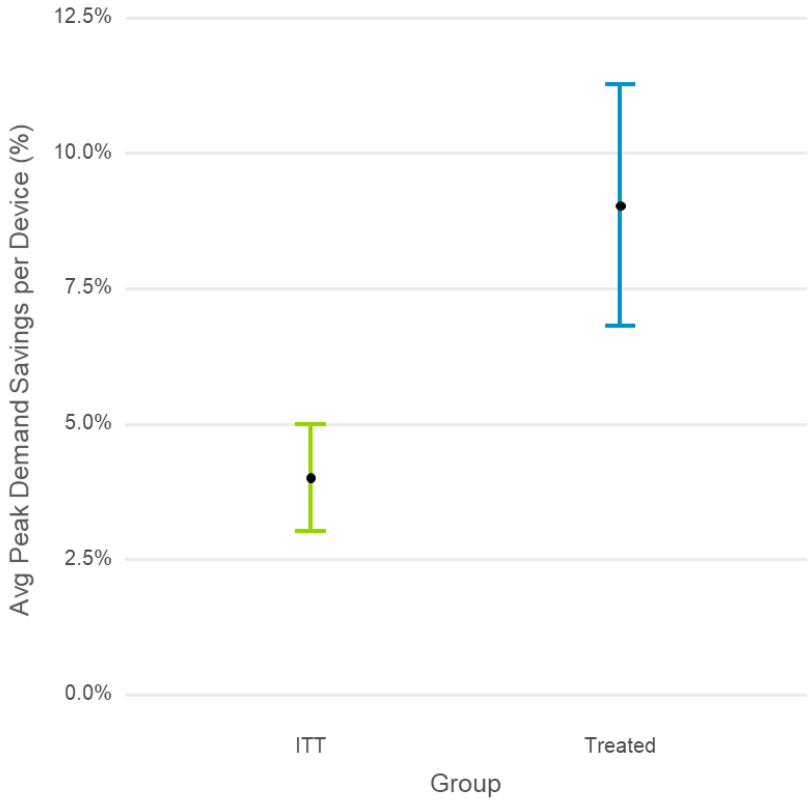



*Source: Navigant analysis*

[15] The 90% confidence interval is (0.015 kW, 0.024 kW).

[16] The 90% confidence interval is (0.030 kW, 0.055 kW).

**Figure 2-16. Average Peak Demand Savings (as a Percentage of Cooling Load): Massachusetts**




*Source: Navigant analysis*

# 3. RHODE ISLAND PROGRAM

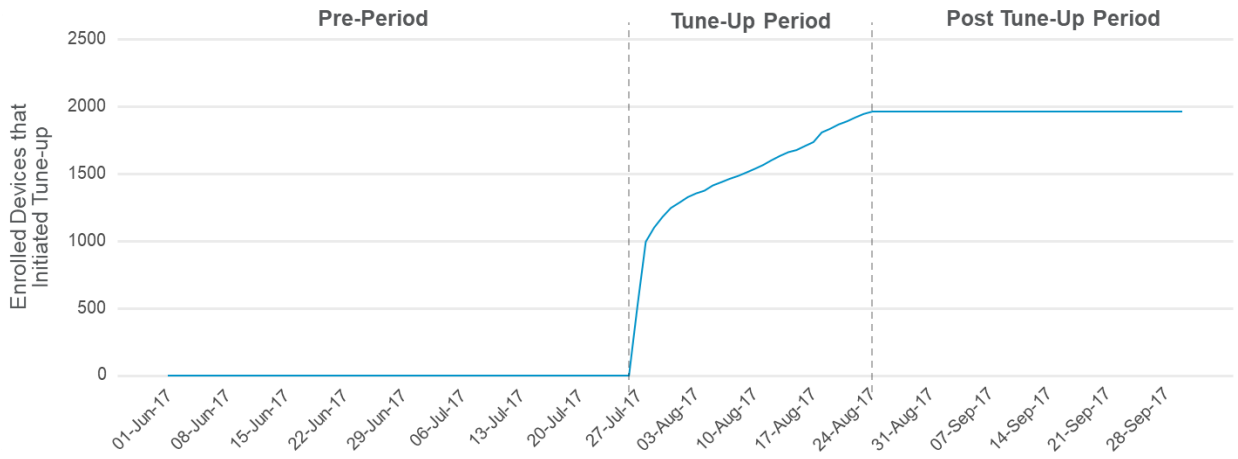
This section presents the findings from Navigant's evaluation of the SS program in 2017 in Rhode Island. The remainder of this section is organized as follows:

- Section 3.1: Program Enrollment
- Section 3.2: Exploratory Analysis
- Section 3.3: Impact Analysis

## 3.1 Program Enrollment

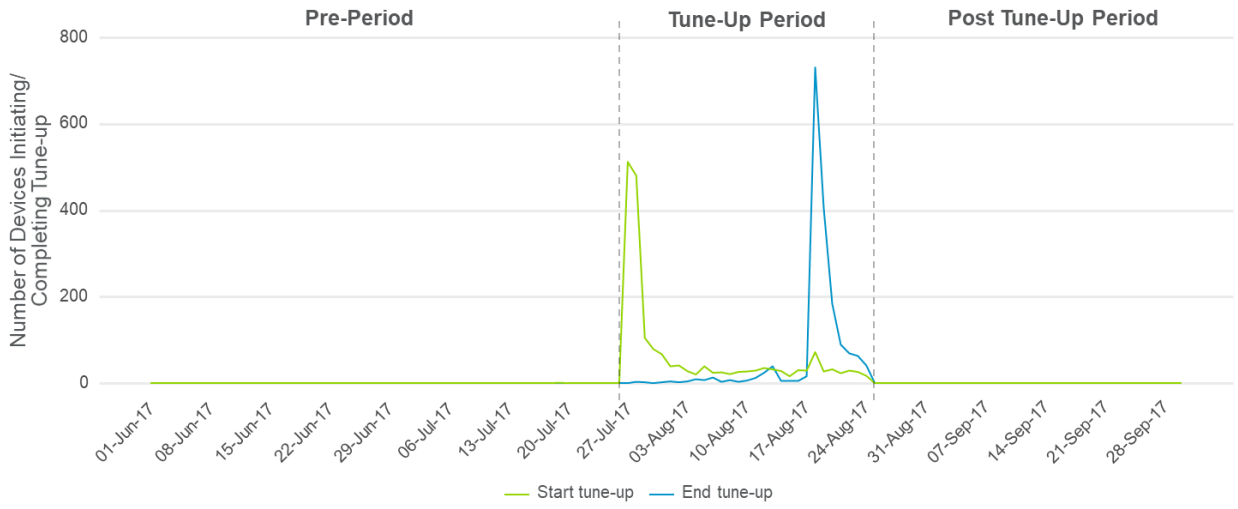
As of August 24, 2017—the end of the tune-up period—there were 1,966 thermostats enrolled in the SS program in Rhode Island. Figure 3-1 shows the number of thermostats enrolled in the program, with a steady increase throughout the 4-week tune-up period. Figure 3-2 presents the number of devices entering and exiting the tune-up phase. Customers were quick to enroll in the program, with 68% of devices (1,326) enrolling in the first week of the program offering.

**Figure 3-1. Number of Enrolled Thermostats: Rhode Island**




*Source: Navigant analysis of customer enrollment data*

**Figure 3-2. Number of Thermostats Entering and Leaving Tune-Up: Rhode Island**




*Source: Navigant analysis of customer enrollment data*

Table 3-1 summarizes the number of devices assigned to the ITT and control groups, as well as the number of devices that did not qualify or did/did not opt in. The initial randomization assigned 70% of devices into the ITT group. Of these, approximately 24% did not qualify and another 23% did not opt in, resulting in approximately 53% of devices that were randomly assigned to receive the program offering actually receiving thermostat optimization.

**Table 3-1. Implementation of SS in Rhode Island**

| Category | Number | Percentage |
|---|---|---|
| Nests in electric service area | 5,281 | - |
| Nests in control group | 1,580 | 30% of Nests |
| Nests in ITT group | 3,701 | 70% of Nests |
| Nests enrolled in SS (treated group) | 1,966 | 53% of ITT |
| Nests in untreated group | 1,735 | 47% of ITT |
| Nests that did not qualify | 899 | 24% of ITT |
| Nests that did not opt in | 836 | 23% of ITT |

*Source: Navigant analysis of customer enrollment data*

## 3.2 Exploratory Analysis

This section presents the findings from the exploratory analysis of the thermostat telemetry data. Table 3-2 provides the average daily scheduled setpoint and average daily cooling runtime for the control, ITT, and 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 cooling runtime. The tables in in Appendix A.2 provides the same statistics for the tune-up and post tune-up portions of the program period.

**Table 3-2. Summary of Exploratory Analysis: Rhode Island**

| Period | Group | Jun 1 – July 26 Pre-Period | Jul 27 – Sep 30 Program Period | Δ* | SS Impact** |
|---|---|---|---|---|---|
| **Avg Daily Outdoor Temp (°F)** | | 70.4 | 69.2 | -1.2 | N/A |
| **Avg Daily Scheduled Cooling Setpoints (°F)** | Control | 74.2 | 74.4 | 0.15 | **N/A** |
| | Intent-to-Treat | 74.4 | 74.9 | 0.51 | **0.36** |
| | *Treated* | *74.6* | *75.3* | *0.67* | ***0.52*** |
| | *Untreated* | *73.9* | *74.0* | *0.11* | ***N/A*** |
| **Avg Daily Cooling Runtime (min)** | Control | 201 | 158 | -42.4 | **N/A** |
| | Intent-to-Treat | 197 | 149 | -48.4 | **-6.00** |
| | *Treated* | *206* | *152* | *-54.2* | ***-11.8*** |
| | *Untreated* | *188* | *146* | *-41.8* | ***N/A*** |

*The Δ is the difference between the program period and the pre-period.
**The SS impact is the difference between the Δ for the ITT or treated group and the control group.
*Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data*

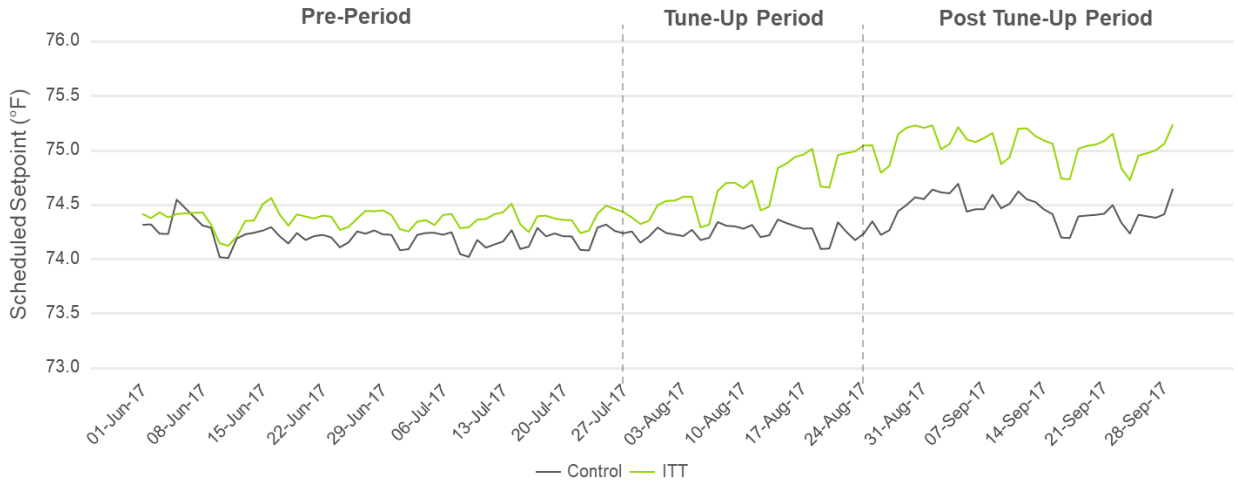
### *3.2.1 Setpoint Comparisons*

Figure 3-3 presents the average daily scheduled setpoints for the ITT and control groups. Figure 3-4 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 centerline.

- **Pre-program period:** Average daily scheduled setpoints during the pre-period were similar across the ITT and control groups with differences of 0.15°F, on average.[17] This is expected, as customers were randomly assigned into the ITT and control groups; as a result, they are expected to have average daily runtimes that are practically and statistically similar.
- **Program period:** The difference in average daily scheduled setpoints increased for both the ITT and control groups during the program period (tune-up and post tune-up periods), but the increase was larger for the ITT group. Average daily scheduled setpoints increased by 0.36°F for the ITT group relative to the control group. The average adjustments to scheduled setpoints during the tune-up period were slightly lower at 0.24°F due to devices enrolling in the program over a period of 1 week and the 3-week tune-up period of making incremental adjustments to scheduled setpoints. During the post tune-up period, average daily scheduled setpoints increased by 0.44°F for the ITT group relative to the control group. This result provides evidence that the program had the intended effect of adjusting scheduled setpoints.

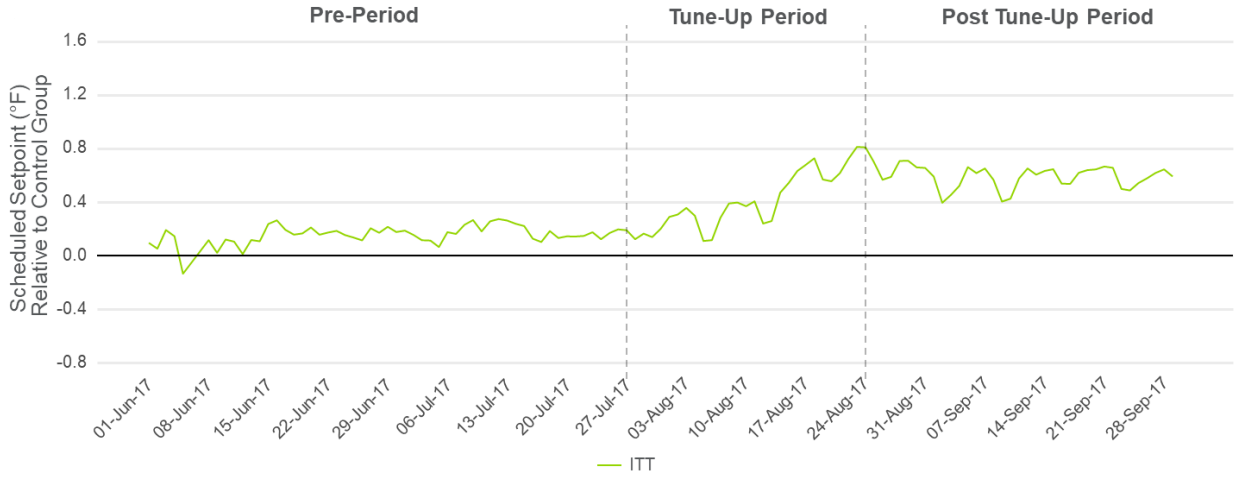
[17] This difference is not statistically significant.

**Figure 3-3. Average Daily Scheduled Setpoints: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data*

**Figure 3-4. Average Daily Scheduled Setpoint Comparison, ITT vs. Control: Rhode Island**



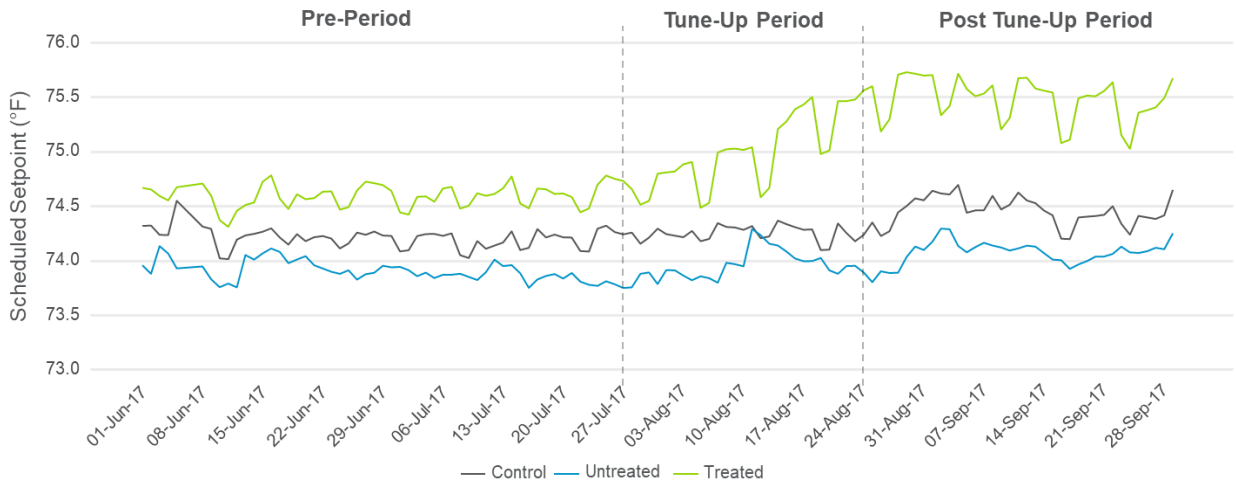

*Source: Navigant analysis of Nest thermostat telemetry data*

Figure 3-5 and Figure 3-6 present a similar comparison as above but show the average daily scheduled setpoints for the ITT group split out by treated and untreated, in addition to the control group. Figure 3-5 presents average daily scheduled setpoints, while Figure 3-6 presents this information relative to the control group, where the control group is represented by the centerline.

- **Pre-program period:** The average daily scheduled setpoints for the treated and untreated groups did differ from the control group by approximately 0.4°F and 0.3°F, respectively. Devices in the treated group had an average daily scheduled setpoint that was 0.7°F higher than the untreated group. Differences between the treated and untreated groups are expected, as the untreated group includes customers that did not opt in and those who were not eligible to participate in the program.
- **Program period:** Average daily scheduled setpoints increased for all three groups, particularly during the post tune-up period, but the increase was largest for the treated group. Average daily scheduled setpoints increased by 0.5°F for the treated group relative to the control group during

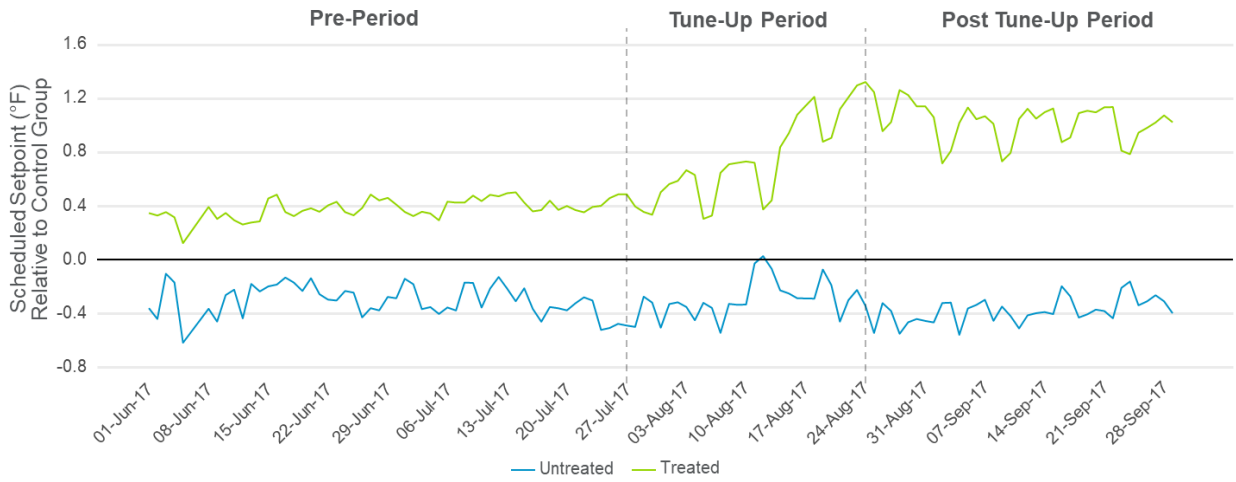
the program period, whereas it remained relatively unchanged for devices that were untreated, decreasing by only 0.04°F, on average, relative to the control group.

**Figure 3-5. Average Daily Scheduled Setpoints, All Groups: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data*

**Figure 3-6. Average Daily Scheduled Setpoint Comparison, Treated and Untreated vs. Control: Rhode Island**

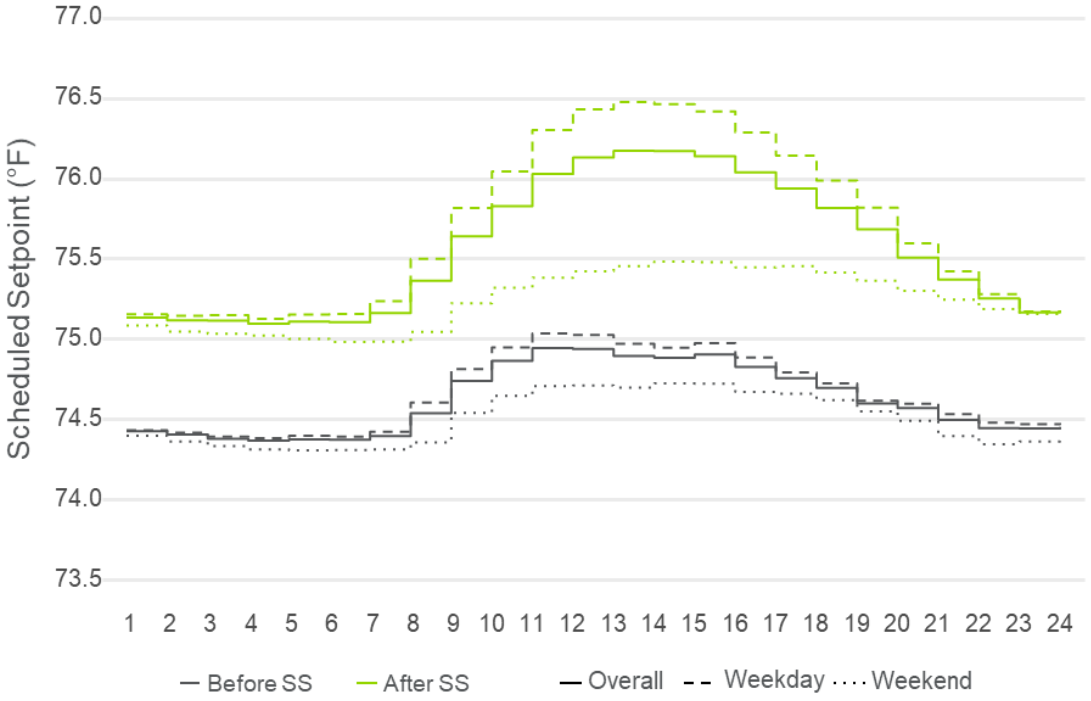



*Source: Navigant analysis of Nest thermostat telemetry data*

Figure 3-7 and Figure 3-8 present a comparison of average hourly scheduled setpoints based on the weeks of July 11-17, 2017 (before the tune-up period) and August 25-31, 2017 (after the tune-up period) for the treated and control groups, respectively, with values separated out by weekday, weekend, and all days (i.e., overall). This comparison further illustrates that while scheduled setpoints increased for the control group pre- and post-tune-up, the increase for the treated group was larger. Furthermore, the program is designed to make the largest adjustments during times when customers are away from home (e.g., weekday daytime) and smaller adjustments during times when customers are at home (e.g., weekday evenings and weekends), and this is evident in the data. Overall average scheduled setpoints increased by 1.2°F between 10 a.m. and 6 p.m. and 0.8°F during all other hours pre- and post-tune-up for

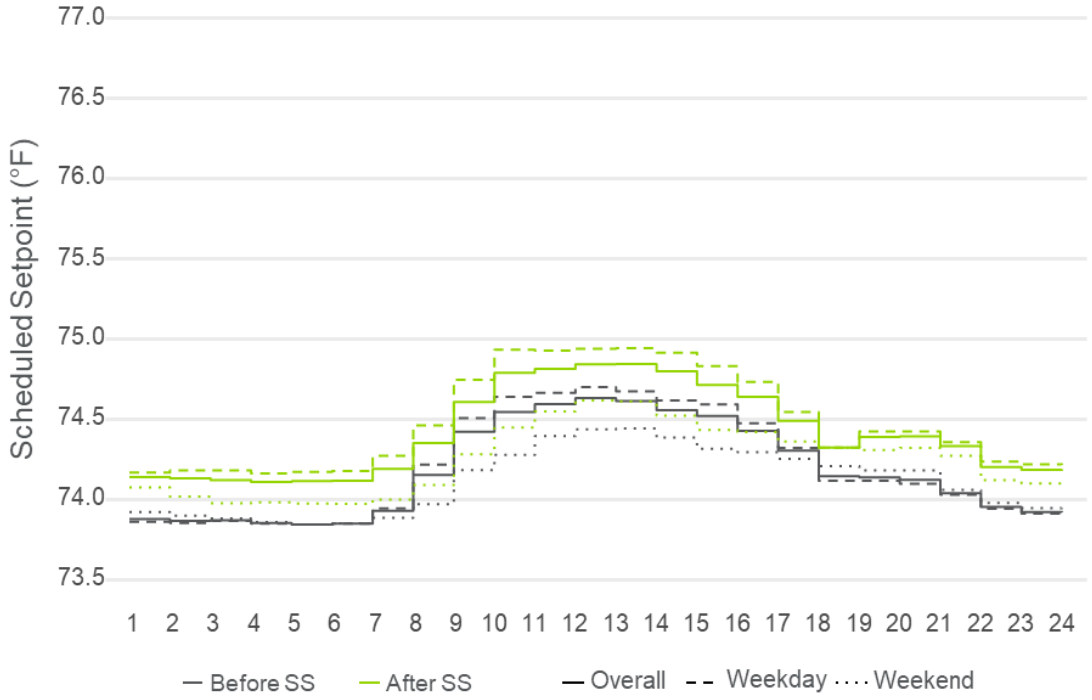
the treated group, while the control group's overall average scheduled setpoints increased by 0.2°F across all hours.

**Figure 3-7. Mean Hourly Setpoint Comparison, Treated, Before and After SS: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data*

**Figure 3-8. Mean Hourly Setpoint Comparison, Control, Before and After SS: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data*

Table 3-3 summarizes the change in scheduled setpoints pre- and post-tune-up for the treated and control groups across different day types and times of day.

**Table 3-3. Change in Scheduled Setpoints, Before and After Tune-Up: Rhode Island**

| Day Type | Period | Treated | Control | Δ |
|---|---|---|---|---|
| Weekday | 10 a.m. to 6 p.m. | 1.4°F | 0.3°F | 1.2°F |
| | Other Hours | 0.8°F | 0.3°F | 0.5°F |
| Weekend | 10 a.m. to 6 p.m. | 0.7°F | 0.1°F | 0.6°F |
| | Other Hours | 0.7°F | 0.1°F | 0.6°F |
| Overall | 10 a.m. to 6 p.m. | 1.2°F | 0.2°F | 1.0°F |
| | Other Hours | 0.8°F | 0.2°F | 0.6°F |

*Source: Navigant analysis of Nest thermostat telemetry data*

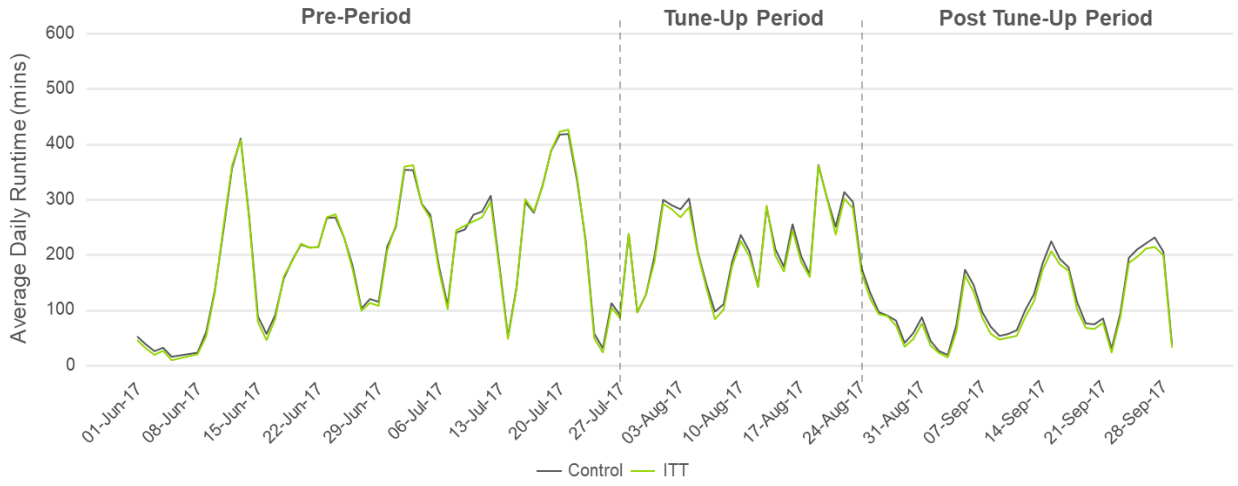
### *3.2.2 Thermostat Runtime Comparisons*

Similar to the exploratory analysis of average scheduled setpoints, this section presents findings from the exploratory analysis of average daily thermostat cooling runtime. Unlike scheduled cooling setpoint, the cooling runtime is correlated with temperature. The average outdoor temperature during the pre-program and program period was 70.4°F and 69.2°F, respectively. Within the program period, the tune-up period

was somewhat warmer with an average outdoor temperature of 71.9°F, compared to 67.2°F in the post tune-up period. Figure 3-9 shows average daily runtime over the course of the 2017 summer season for the ITT and control groups. Figure 3-10 presents this information as a comparison of average daily runtime for the ITT group relative to the control group, where the control group is represented by the centerline.

- **Pre-program period:** There were small differences in average daily runtime during the pre-period across the ITT and control groups (differences of just 3.3 mins, on average).[18] Again, this is expected, as customers were randomly assigned into the ITT and control groups; as a result, they are expected to have average daily runtimes that are practically and statistically similar.
- **Program period:** During the program period, average daily runtime decreased for both the ITT and control groups, but the decrease was slightly larger for the ITT group. Average daily runtime decreased by an average of 6.0 mins during the program period for the ITT group relative to the control group. This result provides evidence there was less cooling taking place for the ITT group relative to the control group as a result of the program. The decrease in average daily runtime was slightly lower during the tune-up period than the post tune-up period due to devices enrolling in the program over a period of 2 weeks. Average daily runtime decreased by 4.8 mins during the tune-up period for the ITT group relative to the control group, and 6.9 mins during the post tune-up period.

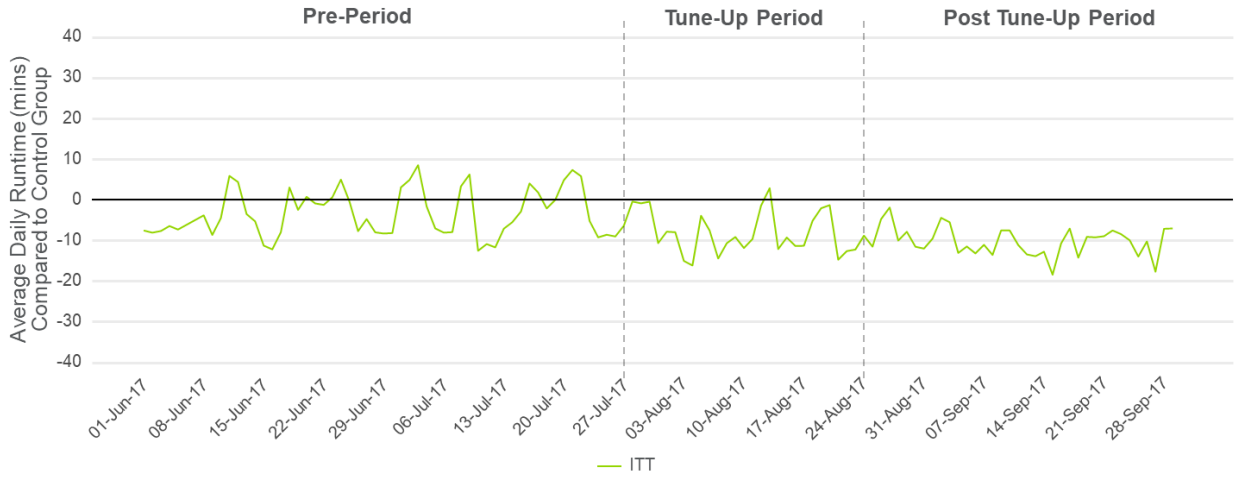
**Figure 3-9. Average Daily Runtime, ITT and Control: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data*

[18] This difference is not statistically significant.

**Figure 3-10. Average Daily Runtime Comparison, ITT vs. Control: Rhode Island**

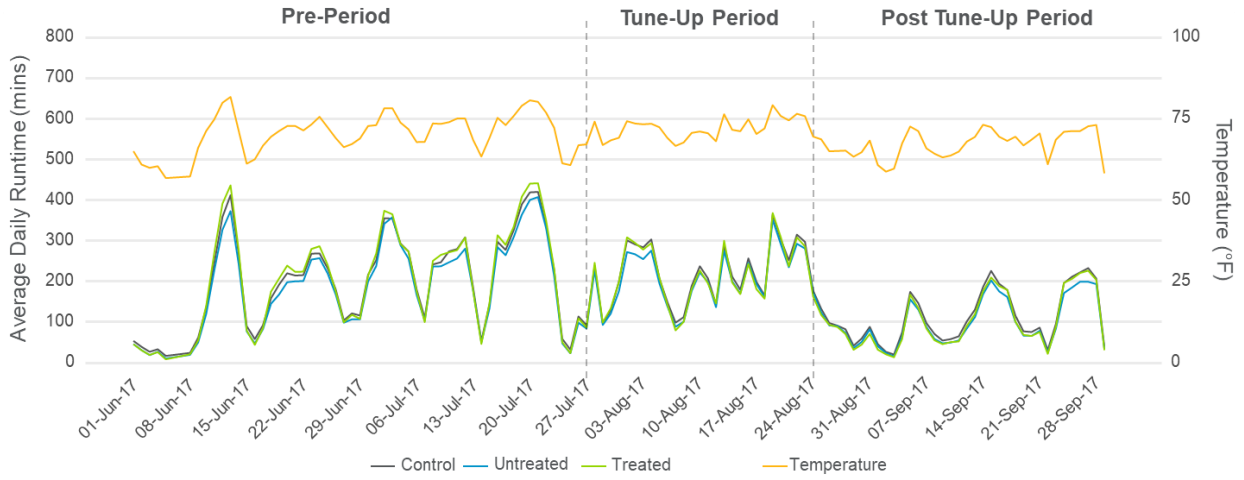



*Source: Navigant analysis of Nest thermostat telemetry data*

Figure 3-11 and Figure 3-12 present a similar comparison as above but show the average daily runtimes for the ITT group split out by treated and untreated, in addition to the control group. Figure 3-11 presents average daily scheduled setpoints with the addition of average daily cross-group temperature, while Figure 3-12 presents the runtime information relative to the control group, where the control group is represented by the centerline.

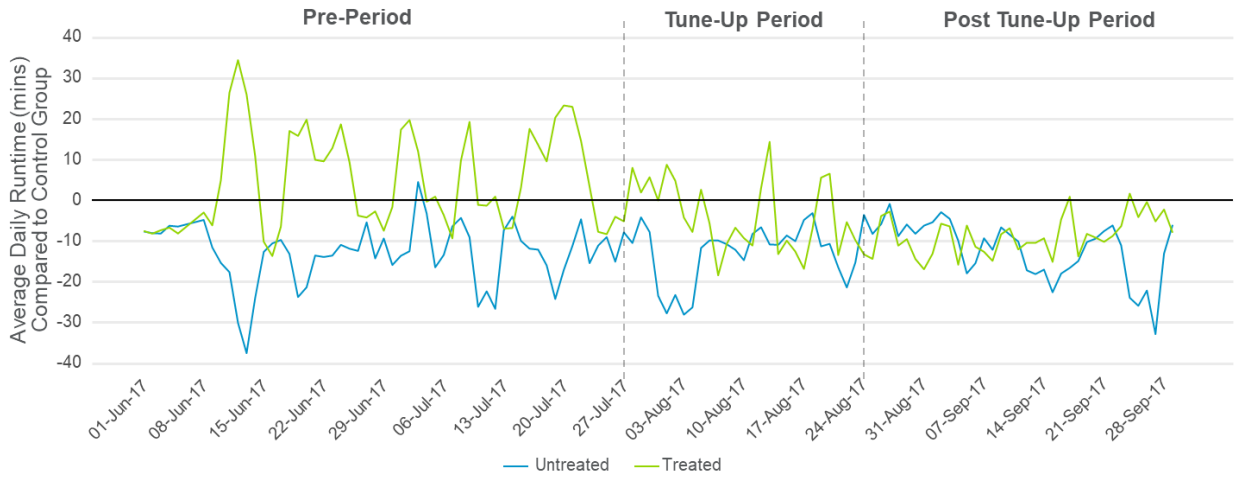
- **Pre-program period:** There was a small difference in average daily runtime during the pre-period between the treated and untreated sub-groups and the control group. The treated group had 5.1 minutes more runtime than the control, whereas the untreated group had 13 minutes less than the control.
- **Program Period:** During the program period, average daily runtime decreased for all groups, but the decrease was largest for the treated group. Average daily runtime decreased by an average of 11.8 mins during the program period for the treated group relative to the control group. This result provides evidence there was less cooling taking place for the treated group relative to the control group as a result of the program. The decrease in average daily runtime relative to the control was slightly lower during the tune-up period than the post tune-up period due to devices enrolling in the program over a period of 2 weeks. These values are 8.95 and 13.9 minutes more reduction in runtime than the control group, respectively.

**Figure 3-11. Average Daily Runtime and Temperature, All Groups: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data*

**Figure 3-12. Average Daily Runtime Comparison, Treated and Untreated vs. Control: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data*

## 3.3 Impact Analysis

This section presents the findings from the energy and peak demand impact analysis summarized in Table 3-4. The SS program resulted in total energy savings of 57 MWh between July 27 and September 30, 2017, and total peak demand savings of 134 kW between July 27 and August 31, 2017.

**Table 3-4. SS Summary from July 27 to September 30, 2017[1]: Rhode Island**

| Statistic | ITT[2] | Treated (Subset of ITT)[2] |
|---|---|---|
| Number of Nest thermostats in control group | 1,580 | |
| Number of Nest thermostats | 3,701 | 1,966 |
| Average energy savings (% of cooling load) | 3.9% ± 2.3% | 7.6% ± 4.6% |
| Average daily energy savings per device (kWh) | 0.24 ± 0.14 *** | 0.49 ± 0.30 *** |
| Average total energy savings per device (kWh)[3] | 15.9 | 29.2 |
| Total energy savings (MWh)[4] | 59 | 57 |
| Average demand savings (% of cooling load) | 5.7% ± 2.0% | 12.4% ± 4.4% |
| Average demand savings per device (kW)[5] | 0.030 ± 0.011 *** | 0.068 ± 0.024 *** |
| Total demand savings device (kW)[6] | 112 | 134 |

*Source: Navigant analysis*
[1] The first offer date for the SS program occurred on July 27, 2017. The SS program persists as long as air conditioning systems are in cooling mode. This evaluation relies on data through September 30, 2017.
[2] ITT includes all devices randomly assigned to receive the SS program offering. Treated is a subset of ITT and includes those devices that qualified and opted into the program.
[3] Total savings per device is calculated as average daily savings per device *x* the number of days post tune-up start date.
[4] Total savings is calculated as total energy savings per device *x* the number of treated/ITT devices.
[5] Average demand savings on weekdays, non-holidays, 1 p.m.-5 p.m., June through August.
[6] Total savings is calculated as average demand savings per device *x* the number of treated/ITT devices.
*** p<0.01, ** p<0.05, * p<0.10, range indicates 90% confidence interval.

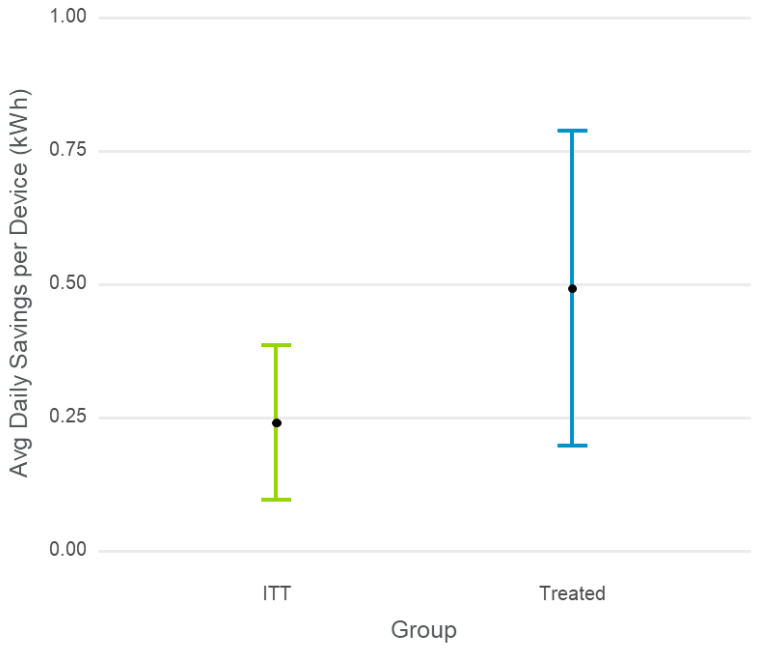
### *3.3.1 Energy Impacts*

Figure 3-13 presents the estimate of average daily energy savings for the ITT group (including devices that opt in, do not opt in, and do not qualify) and the treated group (including only devices that opt in). Average daily energy savings is estimated to be 0.24 kWh[19] per device for the ITT group and 0.49 kWh[20] per device for the treated group. Figure 3-14 presents these results as a percentage of cooling load. Average daily energy savings are 3.9% of cooling load for the ITT group and 7.6% for the treated group.

[19] The 90% confidence interval is (0.10 kWh, 0.39 kWh).

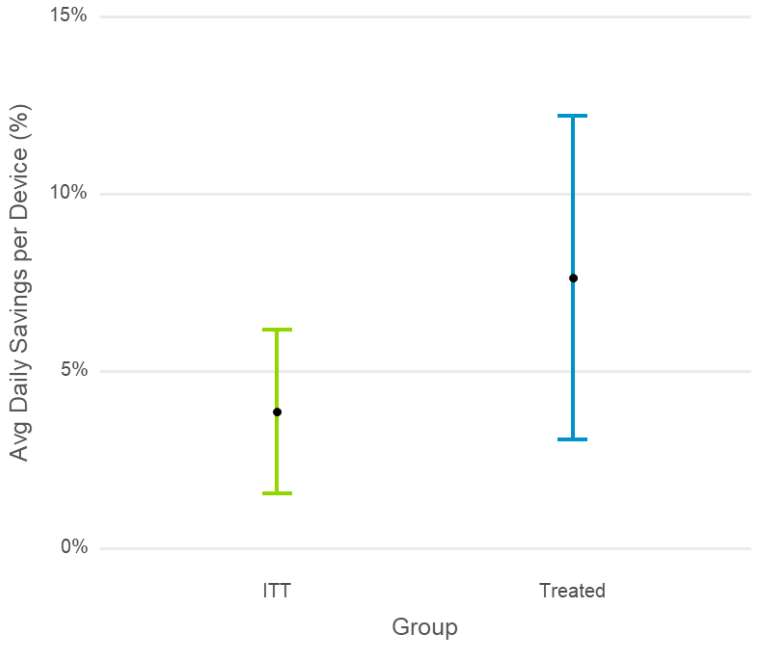
[20] The 90% confidence interval is (0.20 kWh, 0.79 kWh).

**Figure 3-13. Average Daily Savings: Rhode Island**




*Source: Navigant analysis*

**Figure 3-14. Average Daily Savings (as a Percentage of Cooling Load): Rhode Island**

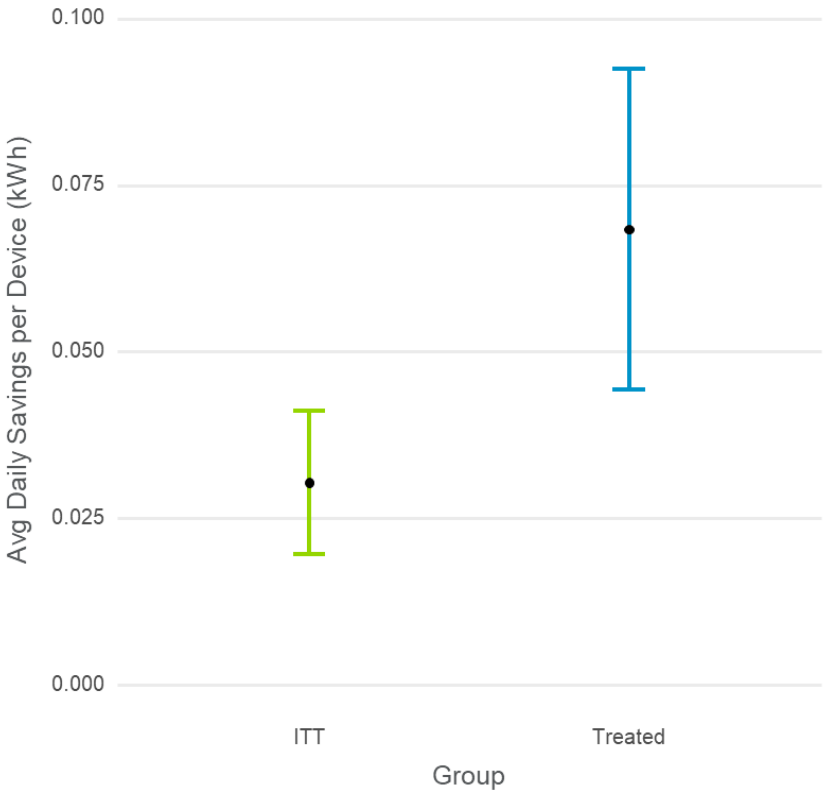



*Source: Navigant analysis*

### *3.3.2 Peak Demand Impacts*

Navigant estimated peak demand impacts from 1 p.m. to 5 p.m. on post-period non-holiday weekdays in July and August. Figure 3-15 presents the estimate of average peak demand savings for the ITT group (including devices that opt in, do not opt in, and do not qualify) and the treated group (including only devices that opt in). Average peak demand savings is estimated to be 0.030 kW[21] per device for the ITT group and 0.068 kW[22] per device for the treated group. Figure 3-16 presents these results as a percentage of cooling load. Average demand peak savings are 5.7% of cooling load for the ITT group and 12.4% for the treated group.

**Figure 3-15. Average Peak Demand Savings: Rhode Island**

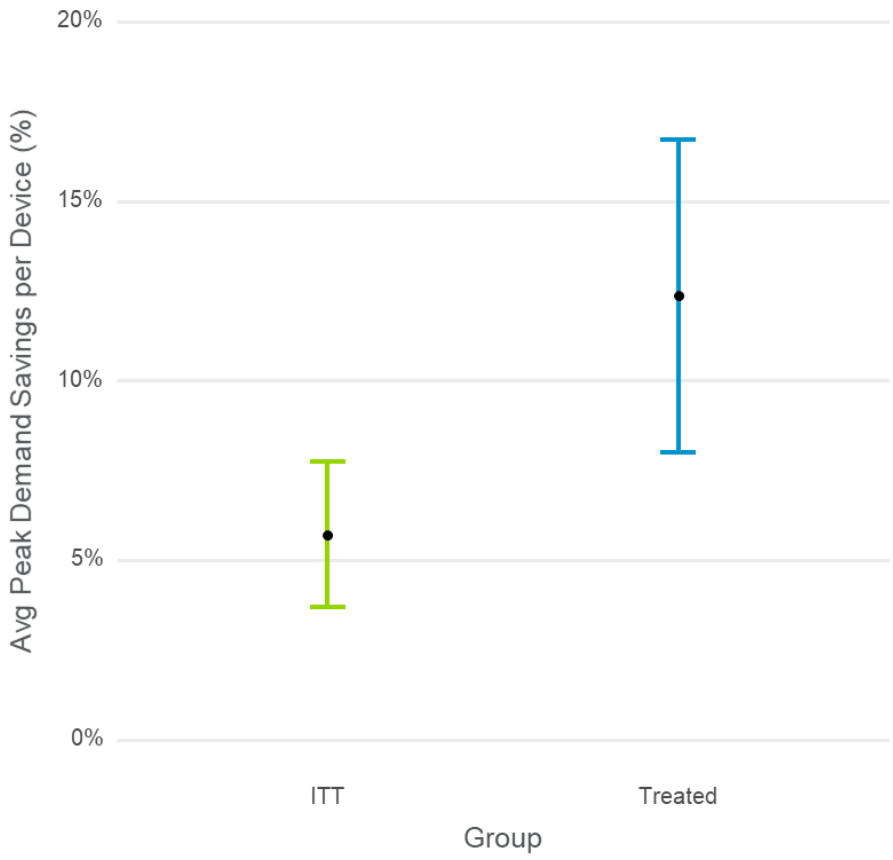



*Source: Navigant analysis*

[21] The 90% confidence interval is (0.020 kW, 0.041 kW).

[22] The 90% confidence interval is (0.044 kW, 0.092 kW).

**Figure 3-16. Average Peak Demand Savings (as a Percentage of Cooling Load): Rhode Island**




*Source: Navigant analysis*

# 4. CONCLUSIONS

Navigant's evaluation of the SS program in Massachusetts and Rhode Island found it was successful in testing the technical feasibility of thermostat optimization and in customer acceptance of the offering. The evaluation shows promise for thermostat optimization, though important questions remain regarding incremental savings from future deployments, persistence of savings, and expected savings from a full season deployment under warmer weather conditions. Table 4-1 summarizes the key evaluation findings, and Table 4-2 provides recommendations

**Table 4-1. Key Findings**

| Key Findings |
|---|
| • 70% of devices eligible to participate opted in to programs in both Massachusetts and Rhode Island—70% in Massachusetts and 70% in Rhode Island. |
| • The setpoint point schedules for the treated thermostats were adjusted upward by 0.6°F during the program period, on average—0.6°F in Massachusetts and 0.5°F in Rhode Island. |
| • The largest setpoint adjustments took place during the middle of the weekdays (1.5°F), when customers were least likely to be at home. |
| • The average impact of the SS program on cooling runtime for SS participants was 9.70 minutes—8.35 minutes in Massachusetts and 11.8 minutes in Rhode Island. |
| • The average energy savings per thermostat from mid/late July and September 30 was 22.7 kWh in Massachusetts and 29.2 kWh in Rhode Island. |
| • The program yielded energy savings of approximately 6% of cooling load between mid/late July and September 30—5.4% in Massachusetts and 7.9% in Rhode Island for program participants. |
| • The average demand savings per thermostat from mid/late July to August 31 was 0.044 kW in Massachusetts and 0.068 kW in Rhode Island. |
| • The program yielded average peak demand savings of 9.7%—9.0% in Massachusetts and 12.4% in Rhode Island. |
| • The program achieved energy and demand savings of 189 MWh and 366 kW in Massachusetts, and 57 MWh and 134 kW in Rhode Island. |

**Table 4-2. Recommendations**

| Recommendations |
|---|
| • Recommendation #1: National Grid should claim average energy savings of 22.7 kWh per thermostat in Massachusetts and 29.2 kWh per thermostat in Rhode Island in 2017. |
| • Recommendation #2: National Grid should claim average demand savings of 0.044 kW in Massachusetts and 0.068 kW in Rhode Island in 2017. |
| • Recommendation #3: Continue offering a summer thermostat optimization program to achieve energy and demand savings and consider offering a winter thermostat optimization program to address electric and gas savings. |
| • Recommendation #4: The summer SS program should be evaluated an additional year to:<br>o assess how customers respond to two summers of schedule adjustments<br>o understand whether customers leave SS during hot weather<br>o seek to ascertain a relationship between savings and weather<br>o develop an approach to incorporate SS into the Massachusetts and Rhode Island Technical Reference Manuals |

# APPENDIX A. EXPLORATORY STATISTICS

This appendix presents an exploratory analysis comparing average scheduled setpoints during the pre-period, tune-up period, and post tune-up periods for Massachusetts and Rhode Island.

## A.1 Massachusetts

**Table A-1. Exploratory Analysis Comparing Tune-Up to Pre-Pre-Period: Massachusetts**

| Period | Group | Jun 1 – Jul 17 Pre-Period | Jul 18 – Aug 24 Tune-Up | Δ* | SS Impact** |
|---|---|---|---|---|---|
| **Avg Daily Outdoor Temp (°F)** | | 70.3 | 71.4 | 1.2 | N/A |
| **Avg Daily Scheduled Cooling Setpoints (°F)** | Control | 74.6 | 74.7 | 0.12 | **N/A** |
| | Intent to Treat (ITT) | 74.4 | 74.9 | 0.44 | **0.32** |
| | *Treated* | *74.5* | *75.1* | *0.59* | ***0.47*** |
| | *Untreated* | *74.2* | *74.3* | *0.10* | **N/A** |
| **Avg Daily Cooling Runtime (min)** | Control | 189 | 207 | 18.3 | **N/A** |
| | ITT | 190 | 205 | 14.7 | **-3.55** |
| | *Treated* | *202* | *216* | *13.7* | ***-4.59*** |
| | *Untreated* | *176* | *192* | *16.0* | **N/A** |

*The Δ is the difference between tune-up and the pre-period.
**The SS impact is the difference between the Δ for the ITT or treated group and the control group.
*Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data*

**Table A-2. Exploratory Analysis Comparing Post Tune-Up to Pre-Pre-Period: Massachusetts**

| Period | Group | Jun 1 – Jul 17 Pre-Period | Aug 25 – Sep 30 Post Tune-Up | Δ* | SS Impact** |
|---|---|---|---|---|---|
| **Avg Daily Outdoor Temp (°F)** | | 70.3 | 66.1 | -4.2 | N/A |
| **Avg Daily Scheduled Cooling Setpoints (°F)** | Control | 74.6 | 74.9 | 0.30 | **N/A** |
| | ITT | 74.4 | 75.2 | 0.78 | **0.48** |
| | *Treated* | *74.5* | *75.5* | *1.00* | ***0.70*** |
| | *Untreated* | *74.2* | *74.5* | *0.30* | **N/A** |
| **Avg Daily Cooling Runtime (min)** | Control | 189 | 98.3 | -90.9 | **N/A** |
| | ITT | 190 | 95.4 | -94.6 | **-3.77** |
| | *Treated* | *202* | *99.0* | *-103.0* | ***-12.1*** |
| | *Untreated* | *176* | *91.1* | *-84.9* | **N/A** |

* The Δ is the difference between post tune-up and the pre-period.
** The SS impact is the difference between the Δ for the ITT or treated group and the control group.
*Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data*

## A.2 Rhode Island

**Table A-3. Exploratory Analysis Comparing Tune-Up to Pre-Pre-Period: Rhode Island**

| Period | Group | Jun 1 – Jul 26 Pre-Period | Jul 27 – Aug 24 Tune-Up | Δ* | SS Impact** |
|---|---|---|---|---|---|
| **Avg Daily Outdoor Temp (°F)** | | 70.4 | 71.9 | 1.5 | N/A |
| **Avg Daily Scheduled Cooling Setpoints (°F)** | Control | 74.2 | 74.3 | 0.04 | **N/A** |
| | ITT | 74.4 | 74.6 | 0.28 | **0.24** |
| | *Treated* | *74.6* | *75.0* | *0.38* | ***0.34*** |
| | *Untreated* | *74.2* | *74.0* | *-0.20* | **N/A** |
| **Avg Daily Cooling Runtime (min)** | Control | 201 | 217 | 16.9 | **N/A** |
| | ITT | 197 | 209 | 12.1 | **-4.76** |
| | *Treated* | *206* | *214* | *7.9* | ***-8.95*** |
| | *Untreated* | *188* | *204* | *16.0* | **N/A** |

*The Δ is the difference between tune-up and the pre-period.
**The SS impact is the difference between the Δ for the ITT or treated group and the control group.
*Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data*

**Table A-4. Exploratory Analysis Comparing Post Tune-Up to Pre-Pre-Period: Rhode Island**

| Period | Group | Jun 1 – Jul 26 Pre-Period | Aug 25 – Sep 30 Post Tune-Up | Δ* | SS Impact** |
|---|---|---|---|---|---|
| **Avg Daily Outdoor Temp (°F)** | | 70.4 | 67.2 | -3.3 | N/A |
| **Avg Daily Scheduled Cooling Setpoints (°F)** | Control | 74.2 | 74.5 | 0.24 | **N/A** |
| | ITT | 74.4 | 75.0 | 0.68 | **0.44** |
| | *Treated* | *74.6* | *75.5* | *0.89* | ***0.65*** |
| | *Untreated* | *74.2* | *74.1* | *-0.10* | **N/A** |
| **Avg Daily Cooling Runtime (min)** | Control | 201 | 113 | -87.3 | **N/A** |
| | ITT | 197 | 103 | -94.2 | **-6.94** |
| | *Treated* | *206* | *105* | *-101.2* | ***-13.9*** |
| | *Untreated* | *188* | *101* | *-87.0* | **N/A** |

* The Δ is the difference between post tune-up and the pre-period.
** The SS impact is the difference between the Δ for the ITT or treated group and the control group.
*Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data*

# APPENDIX B. ENERGY CONSUMPTION

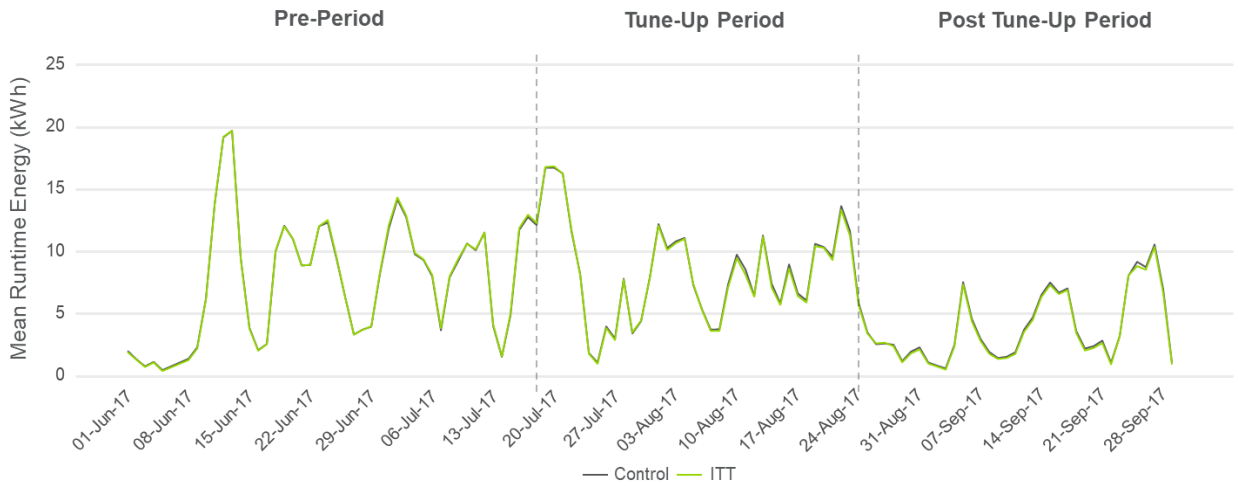
This appendix presents an exploratory analysis of average daily energy consumption for Massachusetts and Rhode Island.

## B.1 Massachusetts

Figure B-1 presents the average daily runtime energy (or energy consumption) for the ITT and control groups. Figure B-2 presents this information as a comparison of the ITT group relative to the control group, where the control group is represented by the centerline.

- **Pre-program period:** Average daily energy consumption during the pre-period was similar across the ITT and control groups, differing by only 0.03 kWh, on average.[23] This is expected, as customers were randomly assigned into the ITT and control groups; as a result, they are expected to have levels of average daily consumption that are practically and statistically similar.
- **Program period:** The difference in average daily energy consumption decreased for both the ITT and control groups during the program period (tune-up and post tune-up periods), but the decrease was larger for the ITT group. Average daily energy consumption decreased by 0.17 kWh for the ITT group relative to the control group during both the tune-up and post tune-up periods. These results provide evidence that the program had the intended effect of reducing seasonal energy consumption via adjustments to scheduled setpoints.

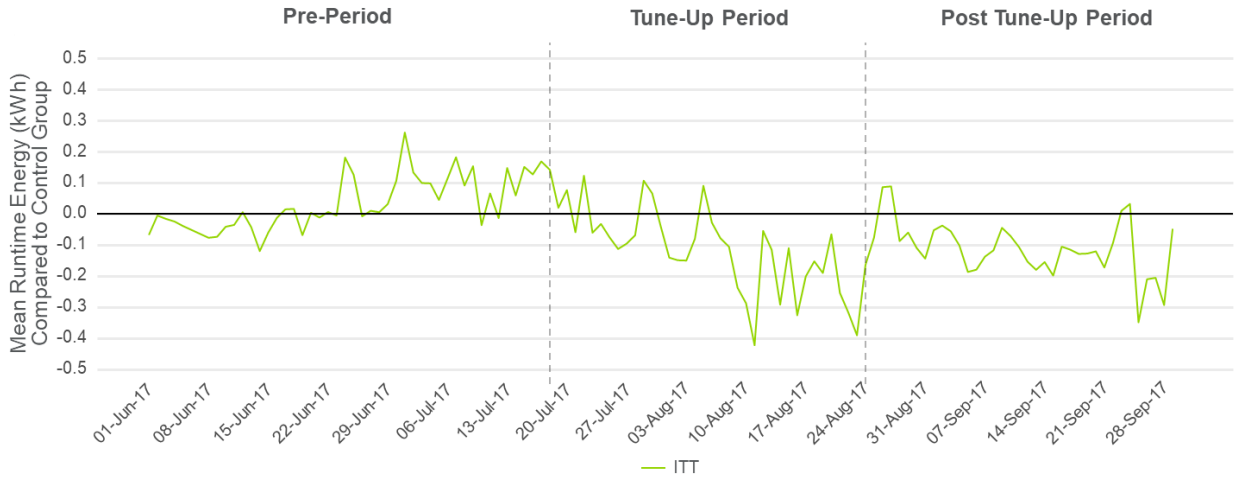
**Figure B-1. Average Daily Energy Consumption, ITT and Control: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

[23] This difference is not statistically significant.

**Figure B-2. Average Daily Energy Consumption Comparison, ITT vs. Control: Massachusetts**

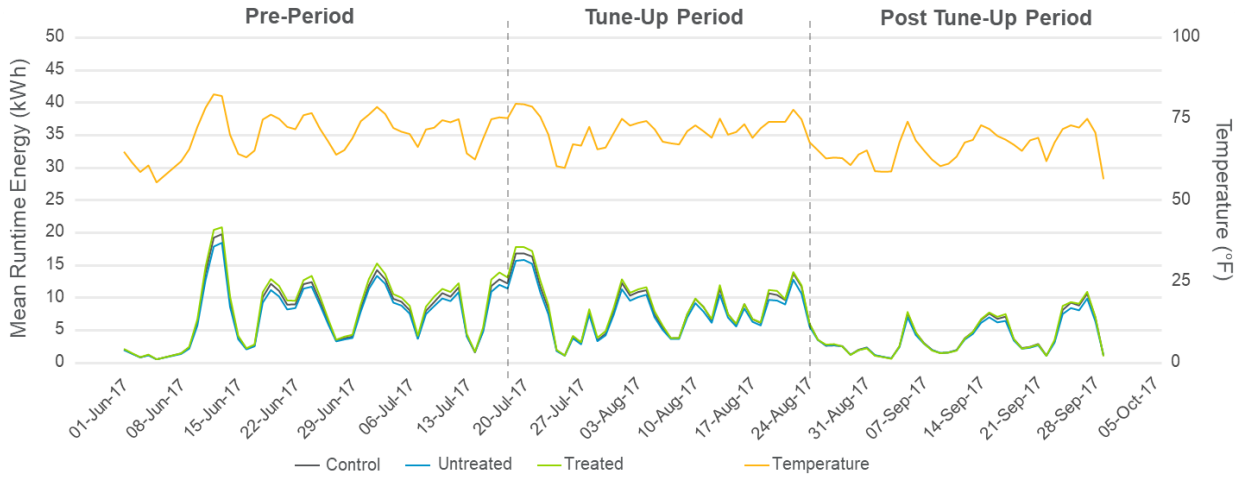



*Source: Navigant analysis of Nest thermostat telemetry data*

Figure B-3 and Figure B-4 present a similar comparison as above but show the average daily runtime energy for the ITT group split out by treated and untreated, in addition to the control group. Figure B-3 presents average daily energy consumption with the addition of average daily cross-group temperature, while Figure B-4 presents this information relative to the control group, where the control group is represented by the centerline.

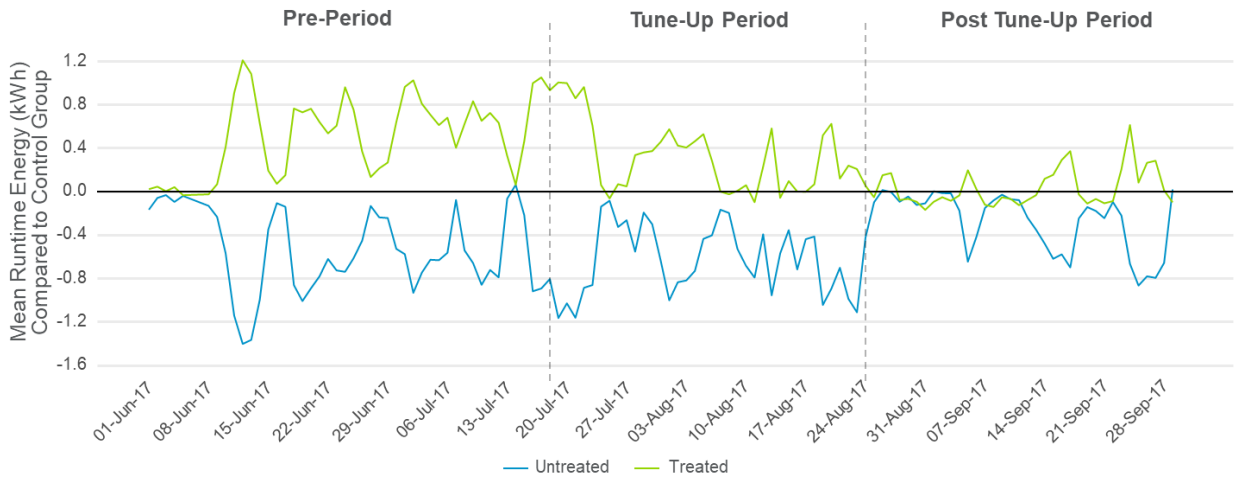
- **Pre-program period:** During the pre-period and compared to the control group, average daily energy consumption was 0.52 kWh greater for the treated group and conversely 0.55 kWh less for the untreated group, on average. This means that the treated group's average daily energy consumption was approximately 1.07 kWh greater than that of the untreated group prior to enrollment.
- **Program period:** Average daily energy consumption decreased for all three groups, particularly during the post tune-up period, but the decrease was largest for the treated group. Average daily energy consumption decreased by 0.34 kWh for the treated group relative to the control group during the program period, whereas it remained relatively unchanged for devices that were untreated—only 0.09 kWh less of a decrease than for the control.

**Figure B-3. Average Daily Energy Consumption and Temperature, All Groups: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

**Figure B-4. Average Daily Energy Consumption Comparison, Treated and Untreated vs. Control: Massachusetts**




*Source: Navigant analysis of Nest thermostat telemetry data*

## B.2 Rhode Island

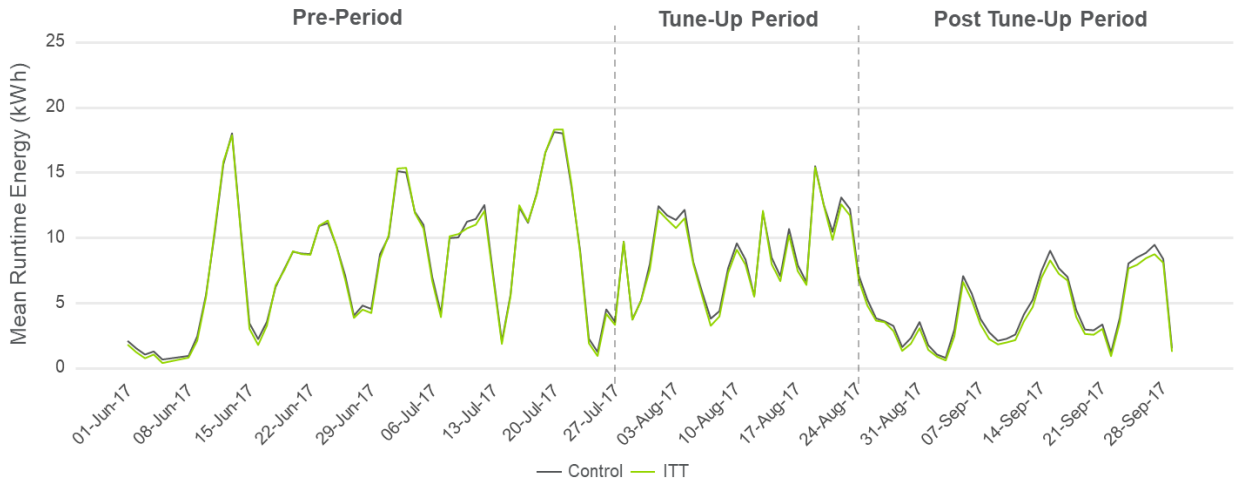
Figure B-5 presents the average daily runtime energy (or energy consumption) for the ITT and control groups. Figure B-6 presents this information as a comparison of the ITT group relative to the control group, where the control group is represented by the centerline.

- **Pre-program period:** Average daily energy consumption during the pre-period was similar across the ITT and control groups, differing by only 0.13 kWh, on average.[24] This is expected, as customers were randomly assigned into the ITT and control groups; as a result, they are expected to have levels of average daily consumption that are practically and statistically similar.

[24] This difference is not statistically significant.

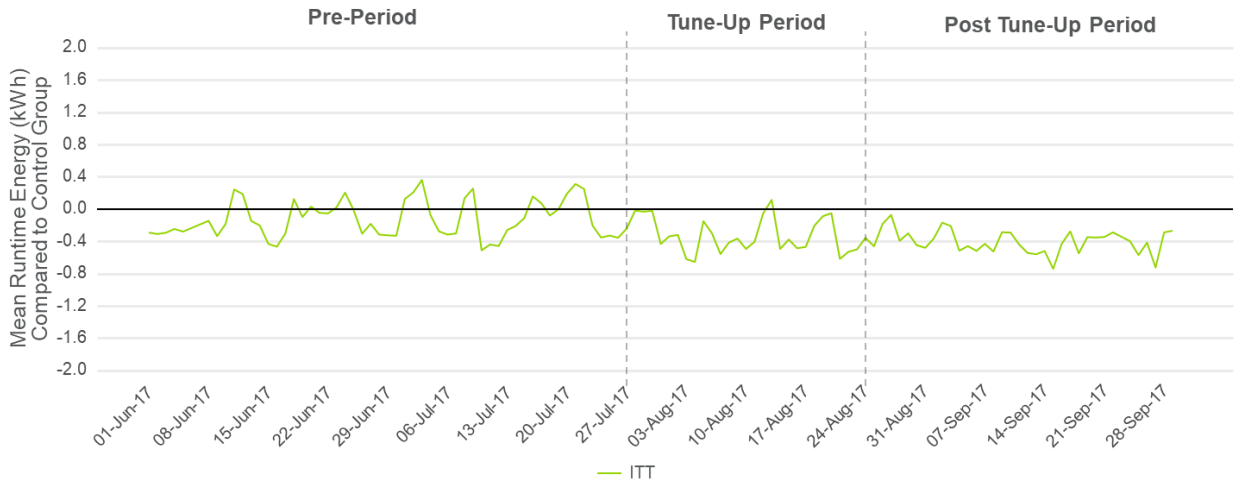
- **Program period:** The difference in average daily energy consumption decreased for both the ITT and control groups during the program period (tune-up and post tune-up periods), but the decrease was larger for the ITT group. Average daily energy consumption decreased by 0.24 kWh for the ITT group relative to the control group. The average change in energy consumption during the tune-up period was 0.19 kWh due to devices enrolling in the program over a period of 2 weeks and the additional 2-week tune-up period of making incremental adjustments to scheduled setpoints. During the post tune-up period, average daily energy consumption increased by 0.28 kWh for the ITT group relative to the control group. These results provide evidence that the program had the intended effect of reducing seasonal energy consumption via adjustments to scheduled setpoints.

**Figure B-5. Average Daily Energy Consumption, ITT and Control, Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data*

**Figure B-6. Average Daily Energy Consumption Comparison, ITT vs. Control: Rhode Island**



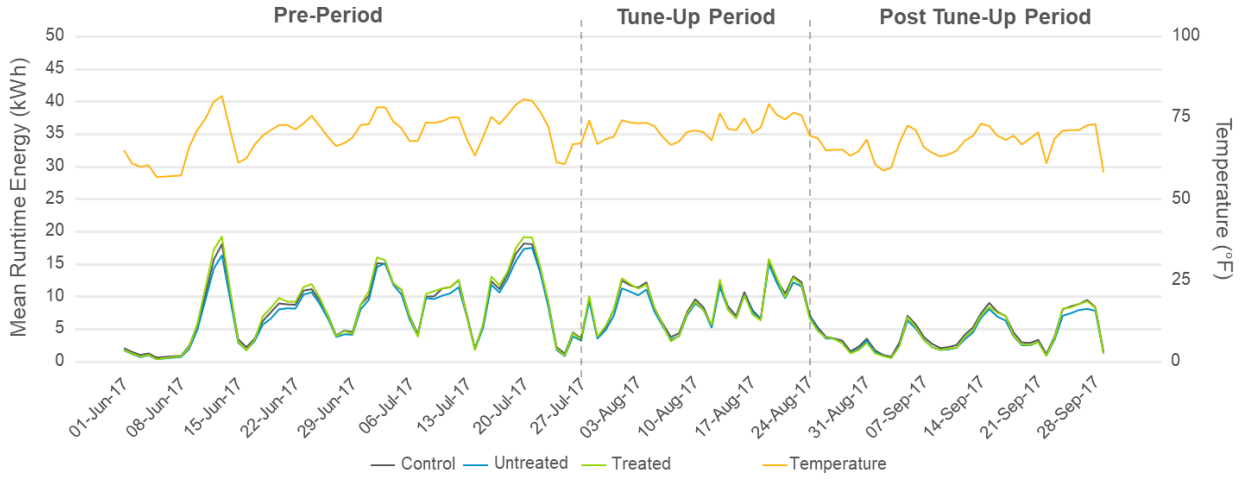

*Source: Navigant analysis of Nest thermostat telemetry data*

Figure B-7 and Figure B-8 present a similar comparison as above but present the average daily runtime energy for the ITT group split out by treated and untreated, in addition to the control group. Figure B-7 presents average daily energy consumption with the addition of average daily cross-group temperature,

while Figure B-8 presents this information relative to the control group, where the control group is represented by the centerline.

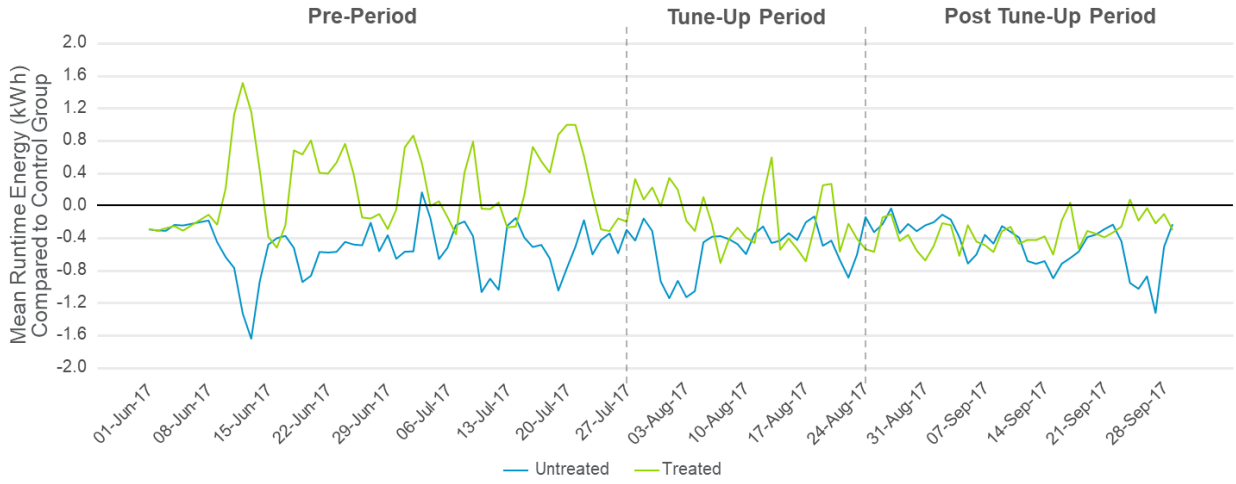
- **Pre-program period:** During the pre-period and compared to the control group, average daily energy consumption was 0.22 kWh greater for the treated group and conversely 0.54 kWh less for the untreated group, on average. This means that the treated group's average daily energy consumption was approximately 0.76 kWh greater than that of the untreated group prior to enrollment.
- **Program period:** Average daily energy consumption decreased for all three groups, particularly during the post tune-up period, but the decrease was largest for the treated group. Average daily energy consumption decreased by 0.49 kWh for the treated group relative to the control group during the program period, whereas it remained relatively unchanged for devices that were untreated—only 0.04 kWh less of a decrease than for the control.

**Figure B-7. Average Daily Energy Consumption and Temperature, All Groups: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data*

**Figure B-8. Average Daily Energy Consumption Comparison, Treated and Untreated vs. Control: Rhode Island**




*Source: Navigant analysis of Nest thermostat telemetry data*