WHITE PAPER

Nest Learning Thermostat Summer 2012 Savings

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1. Introduction

The summer of 2012 was the first cooling season that Nest was available to customers. We wanted to test the savings people achieved from changing their schedule and using Nest's Auto-Away feature. This data was captured by Nest thermostats in a field trial and from the larger population of users.

One of the critical things we learned was that people use their thermostat very differently in the summer versus the winter. When it's cold out, most people want a warm house when they get out of bed and when they're home in the evenings. On cold winter nights people prefer to maintain cooler temperatures since they can stay comfortable under blankets and quilts. So in winter, homeowners often save energy with a schedule that turns the temperature down (called a setback) at night and in the afternoon.

However, in summer people care most about staying cool in the evenings and at night. People rarely turn up the temperature at night, so midday provides the best opportunity to save energy.

Heating systems are sized for incredibly cold nights, but cooling systems are sized for a moderate heat wave and to maintain a relatively even temperature. That means they're usually small and not very good at cooling down a home quickly if it's already hot inside. Larger air conditioners are discouraged because, while they could get you to your target temperature faster, air conditioners are designed to run for longer periods of time in order to de-humidify the air.

Cooling is one of the main drivers of peak electricity demand for utility systems, so there's considerable interest in ways to reduce consumption and the large peaks in energy use that come as thousands of air conditioners struggle to cool homes in hot weather. These peaks can cause brownouts and, consequently, an increase in infrastructure to prevent them. The record breaking heat waves this past summer have challenged many systems to keep up with the demand.

All the issues above prompted research and analysis to better understand how Nest users and features behave in the summer.

2. Outline of this paper

We conducted an efficiency trial with Nests that had already been distributed to field trial participants to understand how people change the temperature during the summer.

Using the numbers established in the trial, the entire field of homeowners who

used air conditioning users were evaluated to understand how much savings they were having compared to a non-programmed thermostat. The savings is evaluated only for Auto-Schedule and Auto-Away. The Airwave function was disabled in these homes in order to get clear data for Auto-Schedule and Auto-Away.

3. Summer trial for schedule adjustment analysis

3.1. Experimental setup

A field trial was conducted during the summer to better understand the performance of Nest features and the impact of different setpoint strategies. The study involved:

- A six week trial running from mid-July through the end of August.
- Trial participants were recruited from among the Nest beta test community who used AC frequently.
- A total of 45 households and 59 devices were included.
- The trial required participants to make adjustments to their thermostat on a weekly basis – activating and deactivating features through a special field trial software release following emailed instructions.
- Participants were instructed to use a single temperature schedule for weeks 1 and 6, use their normal schedule for weeks 2 to 5, and turn off Auto-Away for weeks 2 and 4.
- Participants were geographically dispersed in 23 different states, but the majority of the data came from hot humid climates. The most common locations were the humid areas of Texas (26% of data), Florida (18%), and Georgia (12%). About 10% of the data was from the hot dry climates of Arizona (7%) and New Mexico (4%).

3.2. Methods

The analysis of the field trial data relied on logging data from Nest thermostats. This data was summarized into daily values that included:

- Indoor and outdoor temperatures and humidity levels – daily averages and minimums and maximums.
- Actual temperatures set on the thermostat (called setpoints), including setpoints that were simply on the schedule and setpoints that came from

people adjusting the temperature manually. These numbers included daily average temperatures and daily minimums and maximums.

- The fraction of the setpoints each day set by schedule, by manual adjustments, by manual Away and by Auto-Away.
- The status of the activation of Auto-Away.

The analysis focused on days with warm weather (average outside temperature >70°F/21.1°C) and where air conditioning was used for at least one hour. The analysis approach employed regression modeling to assess how cooling runtime and indoor temperatures were affected by schedules and device features. The regression models were designed to control for other factors that affect cooling run times, such as outdoor temperature.

Nest's Airwave feature was enabled for all customers and conditions, therefore any additional savings from Airwave was in both the control and test trials. Its effect was negligible as this test focused only on indoor target temperature changes for the same outdoor temperature and humidity conditions.

3.3. Results

The field trial provided data for 59 devices and 2,886 device-days that met the criteria of average outdoor temperature warmer than 70°F/21.1°C and air conditioner run time of at least one hour. Some basic observations from the field trial data include:

- The average setpoint during schedule operation was 75.6°F/24.2°F. The daily average minimum setpoint was 73.5°F/23.1°C and an average maximum was 78.0°F/25.6°C.
- The average daily outdoor temperature during the trial was 81.0°F/27.2°F with an average 63.8% relative humidity.
- Air conditioner runtime averaged 8.9 hours per day – a 37% average duty cycle. Runtime averaged 5 hours per day when the average outdoor temperature was 70°F-75°F (21.1°C-23.9C) and increased to 10.6 hours per day when outdoor temperatures averaged 85°F-90°F (29.4°C-32.2°C).

The analysis findings included:

- Regression analysis estimated that a 1°F/0.6°C increase in indoor temperature leads to about an 8% decrease in air conditioner runtime.
- A 1°F/0.6°C increase in outdoor temperature leads to about a 6% increase in air conditioner run time.

4. Auto-Schedule and Auto-Away Savings Estimate from Summer Schedule

4.1. Methods

Auto-Schedule and Auto-Away impacts were studied more broadly by analyzing data collected during August 2012 from the full population of Nest thermostats. The analysis was limited to Nests that used air conditioning and provided a reliable data stream via Wi-Fi (significantly greater than 10,000 units --- specific number is not disclosed).

Device data was further screened to identify days with daily average outdoor temperatures above 70°F/21.1°C and with at least some air conditioner use during the day. These screens led to considerably more than one million device-days of data to use for this analysis.

For analysis purposes, the device log data was summarized into daily values representing:

- Indoor and outdoor temperatures and humidity levels.
- Actual temperatures set on the thermostat, including setpoints that were simply on the schedule, setpoints that came from people adjusting the temperature manually in addition to the scheduled temperatures, and setpoints set by manually turning Nest to Away and by Auto-Away.
- Devices that were OFF are excluded.

To assess the impact of scheduled setpoint changes, we defined a baseline temperature to represent the preferred setting for comfort when the home was occupied. This value was set to the 10th percentile of hourly average setpoints of each device and is an estimate of the temperature a non-programmable thermostat would be set to.

The impact of actual scheduled setpoints on air conditioner runtime was assessed using a regression model of cooling runtime with outdoor temperature as a control variable and a variable indicating the difference between the day's average setpoint and the baseline setpoint.

An analysis of Auto-Away employed a fixed effects regression model that included outdoor temperature and the cooling setpoint without Auto-Away (the scheduled set point plus any manual changes) as control variables. The model also included the fraction of the day when Auto-Away was active to capture the

impact of Auto-Away on air conditioner runtime.

4.2. Results

The estimated cooling savings is 20.1% from all setpoint changes. That includes:

- 4.1% savings from all Away events (including Auto-Away and manually turning Nest to Away). Auto-Away alone saved 2.7%.
- 22.2% savings from scheduled setpoint changes.
- -7.1% from manual setpoint changes, i.e. when people adjusted the temperature manually, they used more energy.

This is compared to homes simply maintaining a single baseline setpoint. The average setpoint temperature was 2.8ºF/1.7ºC higher than the baseline temperature.

To determine Auto-Away savings, we used the Auto-Away regression model to estimate the average cooling runtime with and without Auto-Away. The result was that Auto-Away reduced cooling hours per day from 7.73 to 7.52. This reduction of 0.21 hours per day represents a 2.7% overall cooling savings from Auto-Away. The large sample size led to very narrow confidence interval of +/- 0.02%. New Auto-Away algorithms are being released that may further improve upon this impact.

5. Conclusions

In conclusion, we found that homeowner's behavior in the summer is very different than in winter. In winter, people set a wide range of temperatures and change those temperatures more often. In the cooling months, people make smaller changes to the temperature throughout the day. The average temperature change in the summer is only 2.8ºF/1.7ºC.

However, even though users maintain a small range of temperatures, each 1ºF/0.6ºC they turn the temperature up saves them 8%, on average. That means even small changes to a schedule can result in big savings. This is very different from our heating estimate in a previous white paper, where homeowners used 2-5% less energy when changing the temperature 1ºF/0.6ºC.

On average, homeowners using Nest's Auto-Schedule and Auto-Away features saved 20.1%. Auto-Away and manual Away contributed 4.1% of that number. This is compared to how much energy they'd use if they had a non-programmable thermostat or a programmable thermostat that wasn't programmed.