WHITE PAPER

Energy Savings from Nest

The impact of Nest Learning Thermostat

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1. Introduction

Nest has quantified the energy savings of Nest Learning thermostat by combining Nest usage data with smart meter data. From May 2012 to September 2013, we analyzed the energy usage of hundreds of Southern California Edison (SCE) customers, with their approval. While these results represent data from actual Nest devices, savings may vary based on a number of factors, including a customer's energy use, utility rates and plan. Savings numbers are not a guarantee.

To determine savings, we compared their 2012 summer energy usage without Nest to their summer 2013 usage with a Nest Thermostat. We applied a degree-day model to normalize for the weather variations across the two summers.

Highlights:

- Results show that customers in southern California saved an average of 1.16 kWh per day or 11.3% of AC-related energy usage after installing a Nest Thermostat.
- These savings result in an average peak demand reduction of 0.10 kW during 2-6 pm on weekdays.
- The results also show that AC-related electricity accounted for 25.9% of whole home electricity usage for users.

2. Methodology

With customer approval, we received meter data from SCE for hundred of Nest Rush Hour Rewards customers. All meter data dates back to May 2012, although many of the customers got their Nests after May 2012. Several hundreds of these customers got their Nests between September 2012 and April 2013. We are able to compare their usage from 2012 summer and 2013 summer to determine Nest Learning Thermostat's impact.

Comparing energy usage between summers, data was normalized to account for weather differences. The standard way of doing this is called degree-day fitting [Fels 1986]. Degree-day fitting is an outdoor temperature threshold above which we expect to see a house start to use its AC. This threshold varies depending on thermostat setpoints and insulation efficiency of the house.

A degree-day is the number of degrees the outdoor temperature is above the threshold, averaged across days. For example, if the threshold is 65 ˚F, and it was 70 ˚F every day for

a month, then the average degree-days for that month is 5, as it was 5 ˚F above the threshold each day. If it was 60 ˚F outside, then the degree-days would be 0.

Figure 1 shows energy usage versus degree-days for a typical house. As the degree-days increase, the energy usage also increases. A simple linear model is fit to these points to estimate the effects of outdoor temperature on AC usage. The y-intercept of the fit is the baseline daily kWh usage when there is no AC. The slope of the line indicates how much AC-related kWh are used each day for every one degree-day increase.

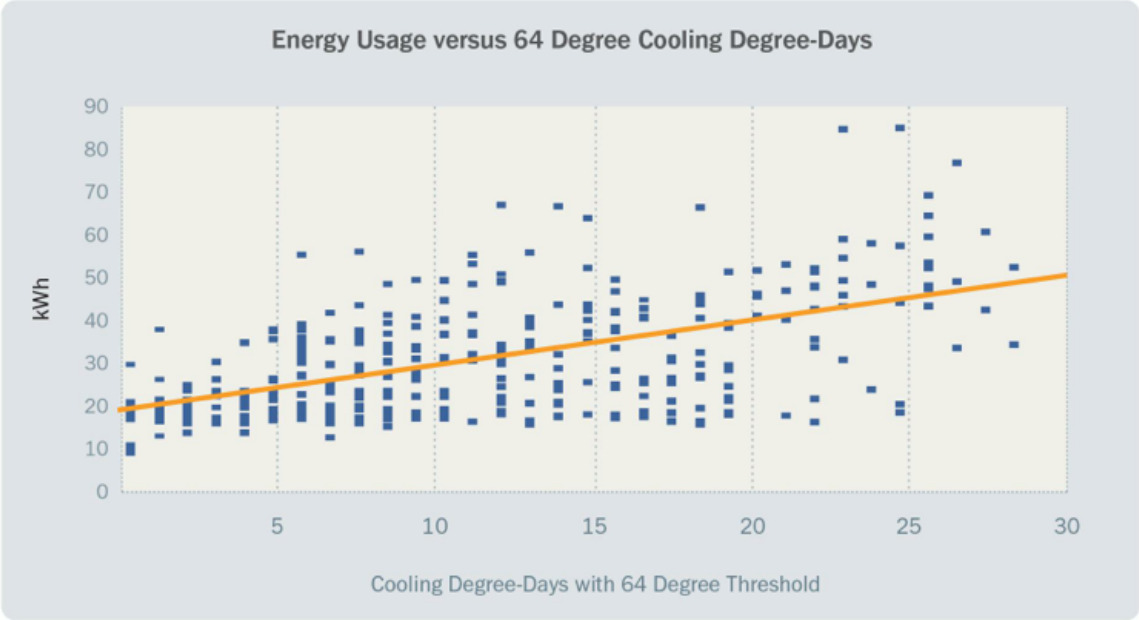

Figure 1: Daily kWh usage versus 64 ˚F baseline cooling degree-days for a typical house.

Threshold is calculated separately for each house. A fit is done for every possible integer threshold between 55 and 85 ˚F and the one with the least error is used.

We compared the average AC runtime of all Nest thermostats in an area with the cooling degree-days for that area. Both are plotted in Figure 2, which shows that the degree-day model accurately predicts aggregate AC usage.

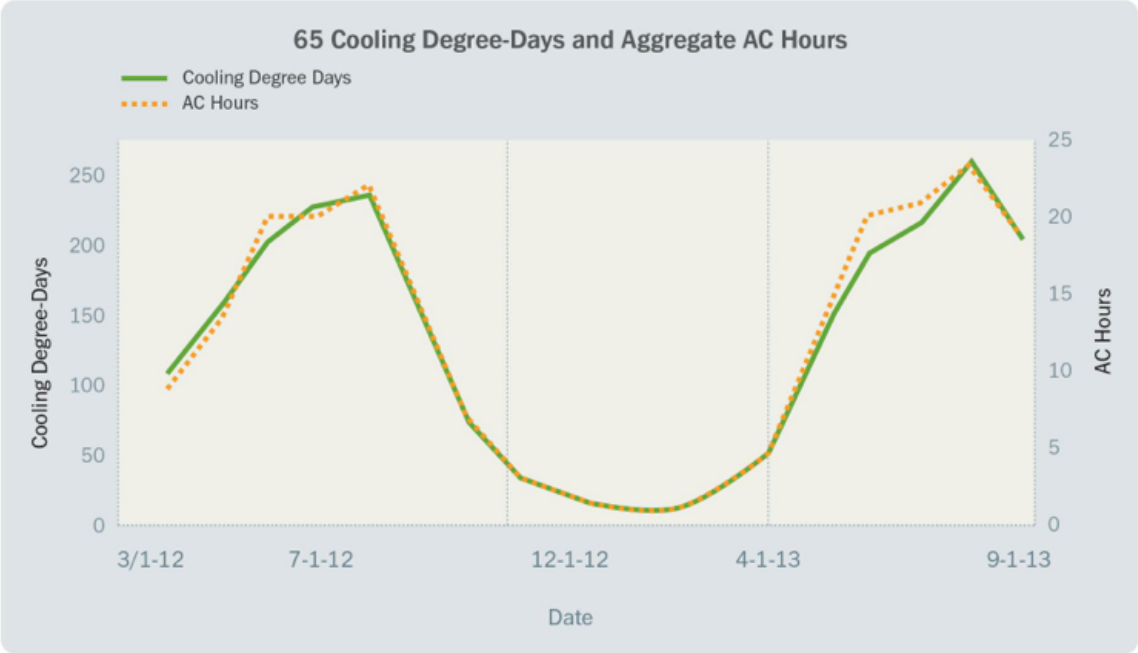

Figure 2: Cooling Degree-Days vs Aggregate AC Runtime for devices in one area

To compare savings, a degree-day model was built for the period before customers installed their Nest Thermostat. The model can predict the energy usage of their previous thermostat on this day with how much energy was actually used with their Nest Thermostat.

3. Results

Nest received meter data for hundreds of SCE households for all customers who signed up for Rush Hour Rewards and Seasonal Savings and agreed to share their data. After filtering for active Nest devices matching our database, a sample set of thousands of devices remained. To compare usage, customers with 180 days of meter data both before and after installing Nest was needed. 434 devices fit the profile.

91% of the customers had hourly meter data and 9% of them had 15 minute meter data. However, degree-day fitting works on entire days or months, so data was combined into daily totals.

To calculate the savings accurately, outliers that overwhelm the results, were removed. These outliers are customers who likely did some other home remodeling at the same time as installing Nest. For example going from having no central AC before to having central AC

after installing Nest. Figure 3 shows an example user who likely installed AC with Nest or did other home remodeling at the time they installed their Nest. Their energy usage increased dramatically after the Nest was installed.

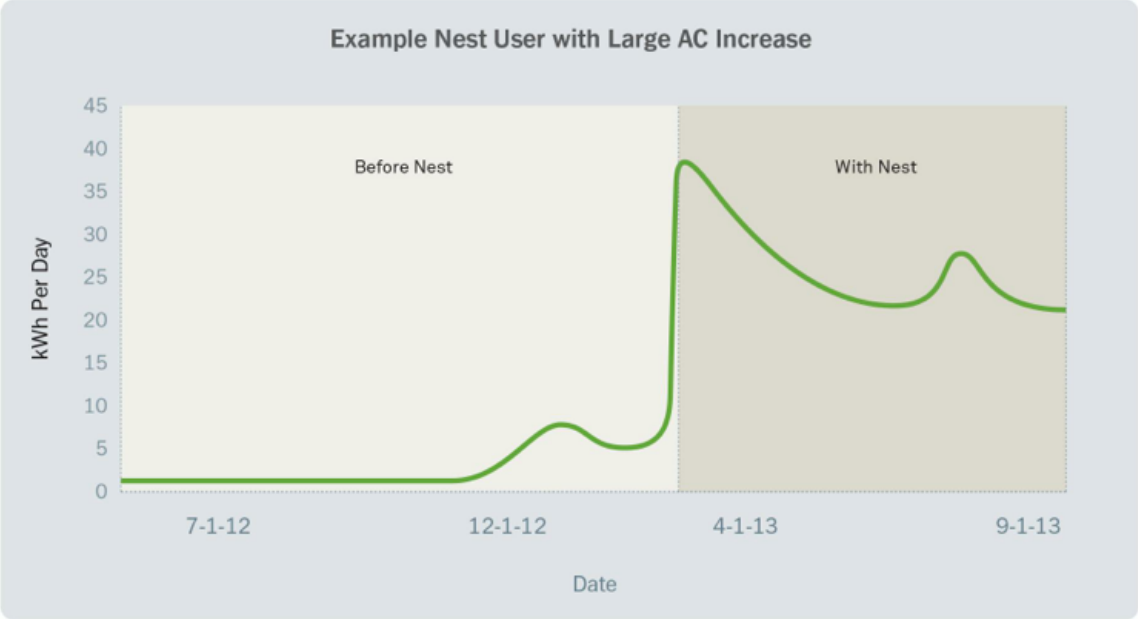

Figure 3: Example user who likely installed AC or did other major home improvements when they installed Nest.

To remove customers who bought AC with Nest or did major home improvement renovation, as indicated by the meter data, we excluded devices that had savings greater than +/- 100% of their energy bill. This filter removed eight of the 434 devices. Figures 4 and 5 show the average kWh saved per day and % of kWh bill saved across these 426 customers with reasonable savings percentages. Customers saved an average of 1.16 kWh per day after installing Nest, for an average of 1.87% of their total kWh bill.

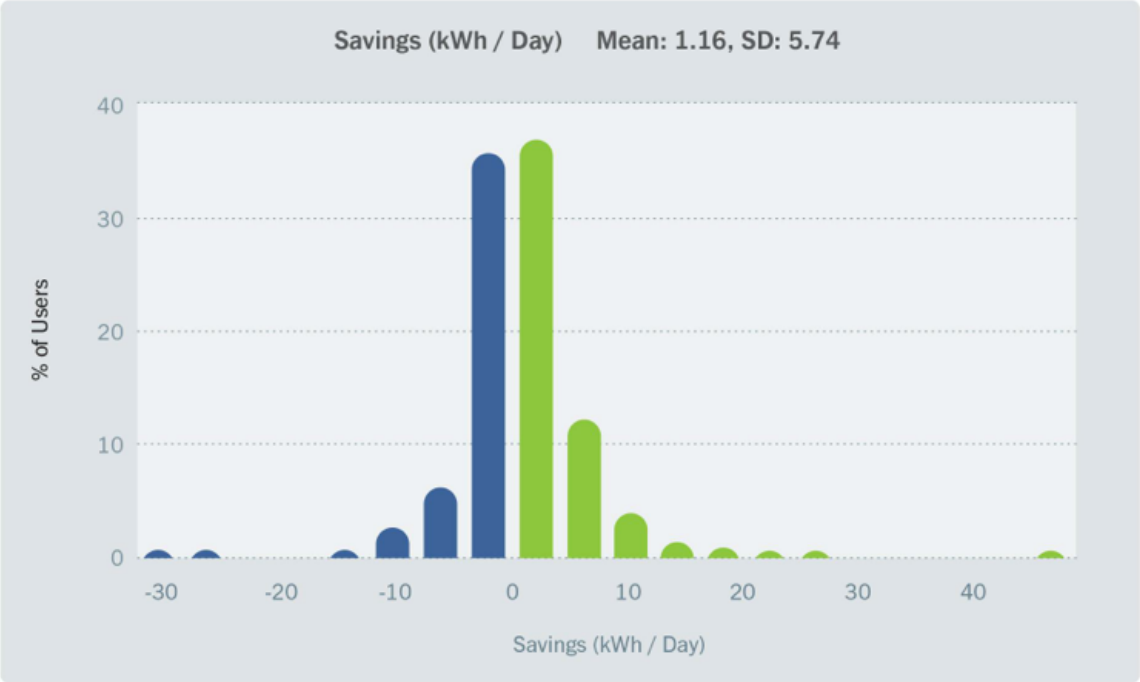

Figure 4: Average kWh / day saved for remaining 426 customers who were not savings % outliers.

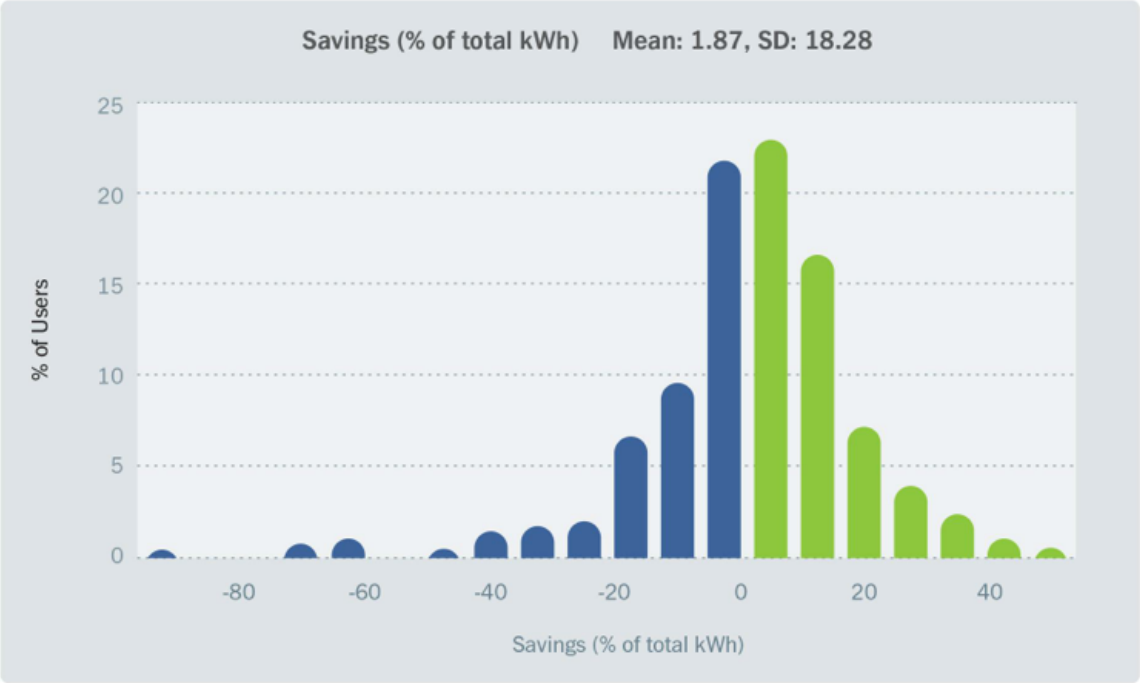

Figure 5: Average savings % of total kWh bill for remaining 426 customers who were not savings % outliers.

Figure 6 shows an example comparison of a typical before and after Nest kWh usage. The blue line shows their daily kWh usage, with the black line on November 1, 2011 indicating when they installed their Nest. The red line is their predicted kWh usage based on their meter data before installing the Nest. After installing a Nest Thermostat, actual usage was less than the predicted usage by an average of 2.02 kWh / day. Usage was reduced after installing the Nest.

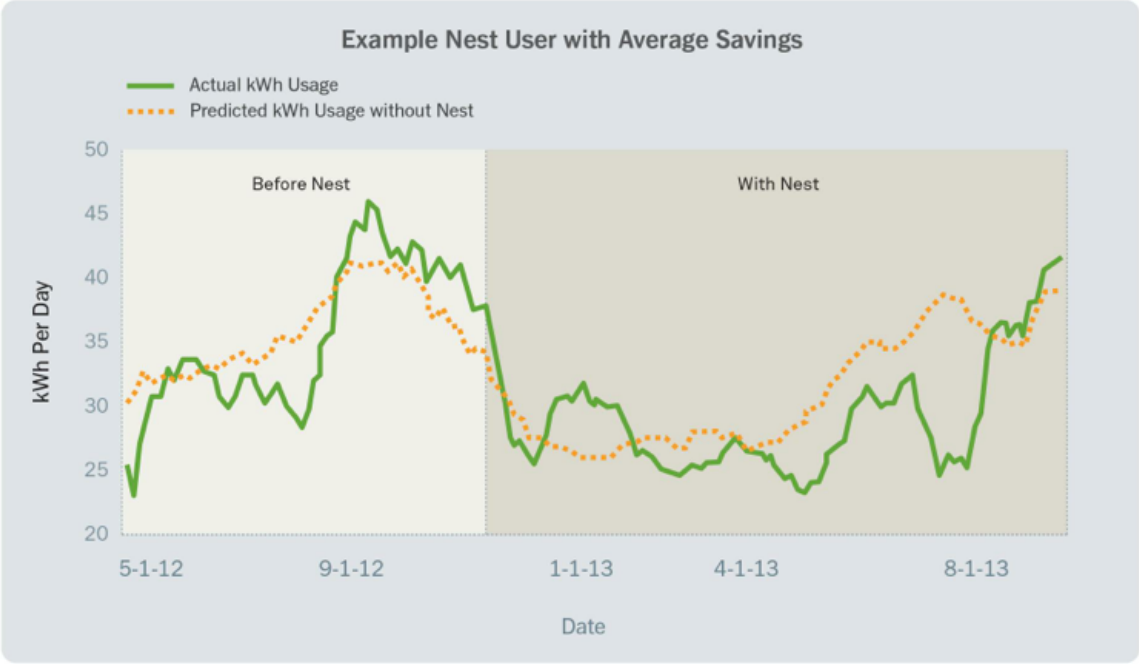

Figure 6: Daily kWh usage (green) compared with the predicted usage from the pre-Nest model (orange)

Looking at the percentage of a user's total electricity bill that is saved can be misleading. Customer AC spending may differ wildly (e.g. customers with different sized homes). The Nest team disaggregated kWh usage due to AC and compared savings reduction relative to that amount. A degree-day fit was utilized to divide the daily kWh usage into baseline and AC portions. AC usage accounted for 25.9% of total electricity usage on average, with a standard deviation of 12.7%. Of the filtered set of 426 customers, those who did not use AC were further filtered, reducing the set to 414 customers.

Outliers were eliminated again by removing customers who had savings of more than +/- 100% of the AC portion of their usage. 283 customers remained. Customers who were

removed had very little estimated AC usage, resulting in disproportionately high savings percentages, with an average savings percentage of 70.6%.

The remaining 283 customers saved an average of 1.16 kWh / day, which was 11.3% (Standard Deviation: 43%) of the AC portion of their usage. Table 1 shows statistics on these users' savings and average energy usage. Figure 7 shows a histogram of the percentage of AC portion of the bill that these customers saved.

Table 1: Savings Results for Filtered Group of Customers

Number of Customers	283 customers
kWh Usage / Day	26.32 kWh
AC-related kWh Usage / Day	7.24 kWh
kWh Savings / Day	1.16 kWh
% of AC portion of bill saved	11.3%
Summer Savings (assuming 16¢ / kWh)	$28
Estimated Peak Demand Reduction	0.10 kW

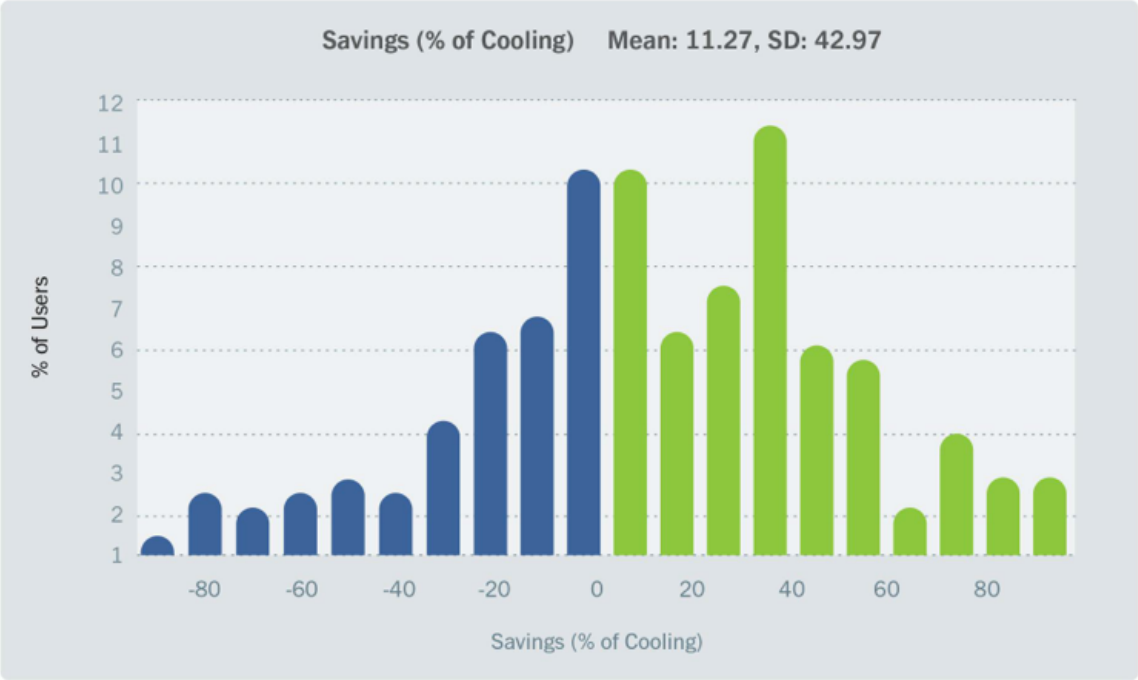

Figure 7: Average savings on AC portion of bill

For the average SCE customer, 33.5% of their daily AC runtime comes between 2-6 pm. Assuming that 33.5% of the daily 1.16 kWh savings also falls between 2-6 pm implies that users save 0.39 kWh during those four hours. This savings results in an average peak demand reduction of 0.10 kW during this period.

These customers span two different climate zones: Marine and Hot-Dry. 25 customers lived in Marine climates and 258 customers in Hot-Dry climates. Customers in Marine climates used more electricity than those in Hot-Dry climates, and saved more energy as well. They saved an average of 2.61 kWh / day, or 14.7% of the AC portion of their usage. The Hot-Dry climate customers saved an average of 1.03 kWh / day, or 10.9% of the AC portion of their usage. While this difference shows that customers in Marine climates used and saved more electricity, the small sample size makes it difficult to attribute these differences to the climate zones alone.

Marketing and Enrollments

For the 2013 summer, 19% of Nest customers in Southern California Edison's territory enrolled in the Rush Hour Rewards (demand response) and Seasonal Savings (bi-annual

Nest schedule 'clean-up') programs. By leveraging Nest's low-lift, inexpensive enrollment web pages, emails, and social activity, SCE succeeding in enrolling a significant portion of the Nest customer population over one summer. Enrollments in the program are done online and do not require a home visit. Within a few weeks of launching the program, Southern California Edison had a load reduction resource in place.

Customer Response

As with any demand response program, utilities and vendors are concerned about customer response to the program. Customers responded very positively to a Nest Support survey about their experiences with Rush Hour Rewards and Seasonal Savings.

Over the season (May-September), only 0.6% of the enrolled SCE customers, assuming a different customer for each placed call, contacted Nest Support about Rush Hour Rewards or Seasonal Savings. Looking at the call categories, the majority of the calls, 38%, were general questions about what their Nest Learning Thermostat would and wouldn't do before, during, and after an energy rush hour. The next categories of questions related to assistance with enrollments, also 38%. Only 8%, or 0.05% of all Rush Hour Rewards related calls, called to un-enroll from the Rush Hour Rewards program.

4. Conclusion

The results were calculated using meter data from hundreds of participating SCE customers for periods both before and after installing a Nest Learning Thermostat. The Nest team applied an industry standard approach of degree-day modeling to normalize for weather differences before and after customers installed their Nest Learning Thermostat.

Our analysis of SCE customers' meter data shows that customers saved an average of 1.16 kWh / day, or 11.3% of their AC-related energy usage after installing the Nest Learning Thermostat. This analysis also showed that peak demand was reduced by an average rate of 0.10 kW per device.

In future papers, the Nest team will analyze heating season savings as well.

References

M. Fels, “PRISM: An Introduction”, Energy and Buildings 9, #1-2, pp. 5-18, 1986.