White Paper

Nest Learning Thermostat Efficiency Simulation for Ireland

Nest Labs

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Introduction

This white paper gives an overview of potential energy savings using the Nest Learning Thermostat in Ireland. The Nest Thermostat offers easy-to-use, energy efficient features, programs itself and automatically turns down the temperature when users are away or asleep.

This paper presents an estimate of the expected energy savings based on simulations of different house types and user behaviors in Ireland. The Nest Learning Thermostat balances energy savings and comfort for the simulations reflected in this paper, and the simulations make assumptions about households with moderate energy consciousness. These simulations don't guarantee specific energy savings, and actual energy savings will depend on factors beyond the Nest Thermostat's control such as boiler efficiency, home construction and weather.

The simulations compare the estimated annual energy usage of homes operating under a variety of heating schedules, ranging from schedules with a constant 20°C temperature, to schedules with deep temperature setbacks for two significant periods per day (similar to having a programmer or timer) and during holiday periods. Depending on the user's home, the local climate, existing schedule and which thermostat features they use, heating bill savings may range from 5% to 27%. This can result in annual savings ranging from €12 to €306.

As data from customers in Ireland becomes available, this white paper will be revised to reflect the latest findings based on actual usage and temperature schedules.

Energy-saving features

The Nest Learning Thermostat offers several features that help users save energy: Auto-Schedule, Auto-Away, Time-to-Temperature, True Radiant, the Nest Leaf, Energy History and Report, and remote control using the Nest app.

Auto-Schedule

The Nest Thermostat automatically learns customers' schedules and preferences based on their selected temperatures. Through the automatic learning algorithm, the thermostat creates a setback schedule that uses a lower temperature setting when people are away or asleep, providing energy savings without compromising comfort.

Auto-Away and Away mode

Auto-Away detects when users leave the house, whether for several hours or several days. Sensor data is interpreted by algorithms to provide a confidence determination of the home's occupancy. When the Nest Thermostat is confident that nobody is home, Auto-Away overrides the existing schedule to save energy. During Away periods, the heating setpoint (target

temperature) is reduced to a user-selected value where efficiency gains can be realized. Away mode can also be set manually on the thermostat, or remotely using the Nest app. Even if Auto-Away is deactivated, customers can use remote control to save energy while out of the house.

Time-to-Temperature

The Time-to-Temperature feature calculates and displays in real-time an estimated time to reach the set temperature. People often set a very high temperature hoping to hurry their heating, but this behavior is inefficient. By showing the estimated time it will take to reach their desired temperature, Time-to-Temperature reassures the customer that their heating is on and can discourage wasteful behavior.

True Radiant

True Radiant uses Time-to-Temperature to decide when heating should begin, in order to reach desired temperatures according to the Nest Thermostat's schedule. The learning algorithm accurately determines when to turn on heating to reach the right temperature at the right time, based on information about how quickly the home heats and cools. This can reduce unnecessary overheating and potentially save additional energy.

Leaf

The Nest Thermostat encourages users to save energy select energy-efficient temperatures by displaying a green Nest Leaf icon whenever those settings are reached. Efficient temperatures are specific to each household, based on the home, schedule and habits of the family.

Energy History and Report

Energy History displays a comparison of the last ten days of heating usage to a running ten day average, letting users know how much they used and why. By revealing the factors affecting their energy consumption, Energy History helps users understand how they can save even more energy. The Nest Energy Report is a monthly email sent to each customer with an Internet connected Nest Thermostat that summarizes the previous month's heating usage, providing tips on saving energy. It also compares the customer's heating usage to their historical usage, as well as to other customers' energy use. In this way, all Nest customers are encouraged to use the thermostat features to be more efficient.

Methods

In order to analyze the energy savings that a Nest Thermostat might provide a user in Ireland, simulations accounted for different home types and different climate regions. Energy usage for

typical setpoints was simulated for a standard thermostat and for the Nest Learning Thermostat, taking advantage of its energy-saving features. Comparing these two simulations provides an estimate of the savings that different users might achieve.

Simulation model

The thermostat energy simulation is a dynamic model based on the main principles of heat transfer and heating equipment performance, incorporating state-of-the-art research on building and equipment performance. The model simulates the heating requirements of five different types of homes and using typical year hourly weather data for Dublin (from ASHRAE International Weather files for Energy Calculations, version 2.0 see https://www.ashrae.org/resources--publications/bookstore/iwec2).

The model simulates building heat transfer using a standard U*A*dT approach, where U is the heat transfer coefficient; A is the surface area; and dT is the difference between the indoor and outdoor temperatures. The model incorporates the effects of the thermal mass of the building skin and also of the interior contents using a lumped capacitance approach. Solar gain through windows is modeled from hourly solar data. Air infiltration is based on a detailed infiltration model that includes wind and stack effects using hourly wind speeds and indoor and outdoor temperatures. Heating equipment is modeled to include transient start-up effects, distribution system thermal lags (using a time constant approach), distribution losses and interactions between the heating output and building thermal mass. The model employs a 30-second time step and simulates a full year of operation (i.e., more than 1 million time steps per year), which allows for dynamic HVAC effects and provides for direct solution of the thermal model heat balance at each step based on lagged values. This level of detail was employed in the simulation to reflect important system dynamics that could have an impact on the energy savings provided by differing thermostat control strategies.

Prototype home configurations

Simulations were performed for four prototype home and apartment configurations. The homes all have insulated walls (assembly U= 0.55m^2 K/W) and some loft insulation (also U-0.55). The windows are assumed to be double pane (U-2.84). The heating source for all homes is also assumed to be a boiler with an 80% efficiency.

Home type	**Window area**	**Effective heat leakage**
86 m^2 detached home	12.9m^2	492cm^2
60 m^2 semi-detached / end-terrace home	8.2m2	300cm^2
60 m^2 semi-detached / mid-terrace home	7.5m^2	278cm^2

60 m^2 two bedroom flat home	6.0m^2	103cm^2
46 m^2 one bedroom flat home	4.6m^2	80cm^2

Definition of baseline

In this white paper, energy savings from the Nest Thermostat are calculated relative to two baseline schedules. The first baseline schedule has a constant setpoint temperature at 20°C throughout the week. The second baseline schedule incorporates the effect of an external timer or programmer that prevents the heater from turning on between 22:00 and 05:00.

Pathways to energy savings

Four possible schedules were simulated which demonstrate potential energy savings by using the Nest Thermostat's features. Each of these alternatives incorporates different combinations of schedule setpoint temperatures held throughout the year, as a result of the energy saving features.

1. **Night setback savings:** 20°C baseline temperature with a setback to 9°C for seven hours per night (22:00 - 5:00)

2. **Night setback + vacation savings:** 20°C baseline temperature with a setback to 9°C for seven hours per night (22:00 - 5:00) and during a two-week away period in mid-winter

3. **Night + day setbacks savings:** 20°C baseline temperature with a setback to 9°C for seven hours per night (22:00 - 5:00) and for nine hours per day (8:00- 17:00)

4. **Night + day setbacks + vacation savings:** 20°C baseline temperature with a setback to 9°C for seven hours per night (22:00 - 5:00), for nine hours per day (8:00 - 17:00) and during a two-week away period in mid-winter

In the first example, Nest assumes the use of Auto-Schedule to add a temperature setback during the night. The second schedule uses Auto-Away to reduce heat during a two week winter vacation. The third schedule uses Auto-Schedule to reduce heating while residents are away during the day. The fourth schedule combines all of these advantages, with nighttime and daytime setbacks and the winter vacation setback.

Energy costs

The analysis used a natural gas price of €.072 per kilowatt hour (kWh) based on the most recent data from Eurostat of the Eurpopean Commission (Source: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Electricity_and_natural_gas_price_statistics - accessed 5-Sep-2014).

Results

This section shows the results of the simulations and related estimates of energy savings. All numerical results are estimates and don't guarantee specific energy savings from using a Nest Thermostat. Actual savings will depend on factors beyond the Nest Thermostat's control such as boiler type, home construction, weather, as well as the price of heating fuel.

Savings

In Table 1, the energy savings (in kWh per year), as well as the cost savings (in euros per year), can be found for the different pathways to energy savings provided in the previous section, compared to a baseline schedule with a constant setpoint temperature at 20°C. As the user adds setbacks and takes advantage of Nest's energy saving features, the savings increase.

Table 1: Energy Savings Compared to Constant 20°C Baseline

Home Type	Baseline Heating Usage (per year)	Night setback savings (per year)	Night + day setbacks savings (per year)	Night setback + vacation savings (per year)	Night + day setbacks + vacation savings (per year)
detached 86m^2	20047 kWh €1443	2700 kWh €194 13%	3617 kWh €260 18%	4256 kWh €306 21%	5031 kWh €362 25%
end-terrace 60m^2	12976 kWh €934	1711 kWh €123 13%	2323 kWh €167 18%	2601 kWh €187 20%	3127 kWh €225 24%
mid-terrace 60m^2	11761 kWh €847	1570 kWh €113 13%	2133 kWh €154 18%	2359 kWh €170 20%	2839 kWh €204 24%
flat2BR 60m^2	3315 kWh €239	493 kWh €35 15%	705 kWh €51 21%	697 kWh €50 21%	881 kWh €63 27%
flat1BR 46m^2	2683 kWh €193	412 kWh €30 15%	584 kWh €42 22%	577 kWh €42 22%	724 kWh €52 27%

Table 2 below shows Nest Thermostat savings compared to a baseline where people already use a programmer that prevents heating from turning on between 22:00 and 05:00. This comparison demonstrates the savings possible for users who already have one setback, but could save further by taking advantage of the Auto-Away and Auto-Schedule features of the Nest Thermostat.

Table 2: Energy Savings Compared to 20°C with Nighttime Setback Baseline

Home Type	Baseline heating with programmer + night setback usage (per year)	Night + day setbacks savings (per year)	Night setback + vacation savings (per year)	Night + day setbacks + vacation savings (per year)
detached 86m²	17347 kWh €1443	1556 kWh €112 9%	917 kWh €66 5%	2331 kWh €168 13%
end-terrace 60m²	11265 kWh €934	890 kWh €64 8%	612 kWh €44 5%	1416 kWh €102 13%
mid-terrace 60m²	10191 kWh €847	789 kWh €57 8%	563 kWh €41 6%	1269 kWh €91 12%
flat2BR 60m²	2822 kWh €239	204 kWh €15 7%	212 kWh €15 8%	388 kWh €28 14%
flat1BR 46m²	2271 kWh €193	165 kWh €12 7%	172 kWh €12 8%	312 kWh €22 14%

Conclusion

The Nest Thermostat comes with a variety of features that can help users reduce unnecessary heating use while staying comfortable. Simulations of energy usage with typical setpoint schedules were compared to those with setpoint schedules that users may receive from the Nest Thermostat's energy-saving features. For the scenarios simulated in this white paper, heating bill savings ranged from 5% to 27%, resulting in annual savings from €12 to €306.