White Paper

Nest Learning Thermostat Efficiency Simulation for the Netherlands

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Introduction

This white paper gives an overview of potential energy savings from using the Nest Learning Thermostat in the Netherlands. 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 for homes located in the Netherlands. The Nest Learning Thermostat balances energy savings and comfort for the simulations discussed in this paper. These estimates don't guarantee specific energy savings. 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 13% to 29%. This can result in annual savings ranging from €35 to €618.

As data from customers in the Netherlands 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 by 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 because increasing the set temperature also increases heating time. 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 select energy efficient temperatures by displaying a green Nest Leaf icon whenever they set an efficient temperature. Efficient temperatures are specific to each household, based on the home, the habits of the family and the resulting temperature schedule that the Nest Thermostat has learned.

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 heating 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 the Netherlands, 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. The simulation uses typical-year hourly weather data files for Amsterdam from IWEC2 (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.

Prototypical home configurations

Simulations were performed for five prototypical house 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 air leakage area**
125m^2 detached home	19m^2	715cm^2
106m^2 semi-detached / end-terrace home	15m^2	531cm^2
106m^2 semi-detached / mid-terrace home	13m^2	491cm^2
72m^2 two bedroom flat home	7m^2	124cm^2
50m^2 one bedroom flat home	5m^2	86cm^2

Definition of baseline

In this white paper, energy savings from the Nest Thermostat are calculated relative to a baseline schedule that has a constant setpoint temperature of 20°C throughout the week.

Pathways to energy savings

To show the Nest Thermostat's energy efficiency, four possible schedules were simulated, taking advantage of Nest'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 15°C for seven hours per night (22:00 - 5:00)

2. **Night setback + vacation savings:** 20°C baseline temperature with a setback to 15°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 15°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 15°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 winter vacation. The third schedule uses Auto-Schedule and Auto-Away 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 €0.085 per 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 setback + vacation savings (per year)	Night + day setbacks savings (per year)	Night + day setbacks + vacation savings (per year)
detached 125m²	25616 kWh €2075	3485 kWh €296 14%	4620 kWh €393 18%	6548 kWh €557 26%	7272 kWh €618 28%
end-terrace 106m²	19494 kWh €1579	2616 kWh €222 13%	3538 kWh €301 18%	4579 kWh €389 23%	5217 kWh €443 27%
mid-terrace 106m²	17675 kWh €1432	2345 kWh €199 13%	3208 kWh €273 18%	4042 kWh €344 23%	4659 kWh €396 26%
flat2BR 72m²	3991 kWh €323	536 kWh €46 13%	847 kWh €72 21%	876 kWh €74 22%	1130 kWh €96 28%
flat1BR 50m²	3007 kWh €244	412 kWh €35 14%	646 kWh €55 21%	676 kWh €57 22%	868 kWh €74 29%

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 may be made by the Nest Thermostat's energy saving features such as Auto-Schedule. For the scenarios simulated in this white paper, heating bill savings ranged from 13% to 29%, resulting in annual savings from €35 to €618.