White Paper

Nest Learning Thermostat Efficiency Simulation for France

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September 2014

Introduction

This white paper gives an overview of potential energy savings using the Nest Learning Thermostat in France. 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 France. 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 estimates 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 13% to 31%. This can result in annual savings ranging from €20 to €560.

As data from customers in France 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 France, 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 in five different cities across France -- Lille, Lyon, Paris, Strasbourg, and Toulouse. The simulation uses typical-year hourly weather data files for these five cities 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.

Model parameters

We ran the full set of simulations for five cities which were chosen to represent various climate regions in France:

• Lille

• Lyon

• Paris

• Strasbourg

• Toulouse

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**
125 m^2 detached home	19m^2	715cm^2
106 m^2 semi-detached / end-terrace home	15m2	531cm^2
106 m^2 semi-detached / mid-terrace home	13m^2	491cm^2
72 m^2 two bedroom flat home	7m^2	124cm^2
50 m^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. 20°C baseline temperature with a setback to 15°C for seven hours per night (22:00 - 5:00)

2. 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. 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. 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 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 €.073 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

City	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)
Lille	detached 125m^2	24552 kWh €1792	3515 kWh €257 14%	4757 kWh €347 19%	6408 kWh €468 26%	7371 kWh €538 30%
	end-terrace 106m^2	18675 kWh €1363	2650 kWh €193	3630 kWh €265	4411 kWh €322	5215 kWh €381

			14%	19%	24%	28%
	mid-terrace 106m^2	16931 kWh €1236	2357 kWh €172 € 14%	3269 kWh €239 19%	3864 kWh €282 23%	4623 kWh €337 27%
	flat 2BR 72m^2	3778 kWh €276	533 kWh €39 14%	805 kWh €59 21%	819 kWh €60 22%	1060 kWh €77 28%
	flat 1BR 50m^2	2852 kWh €208	412 kWh €30 14%	616 kWh €45 22%	639 kWh €47 22%	819 kWh €60 29%
Lyon	detached 125m^2	20817 kWh €1520	2955 kWh €216 14%	4196 kWh €306 20%	5544 kWh €405 27%	6448 kWh €471 31%
	end-terrace 106m^2	15879 kWh €1159	2215 kWh v162 14%	3198 kWh €233 20%	3808 kWh €278 24%	4577 kWh €334 29%
	mid-terrace 106m^2	14422 kWh €1053	1967 kWh €144 14%	2884 kWh €211 20%	3337 kWh €244 23%	4068kWh €297 28%
	flat 2BR 72m^2	3334 kWh €243	447 kWh €33 13%	736 kWh €54 22%	745 kWh €54 22%	990 kWh €72 30%
	flat 1BR 50m^2	2518 kWh €184	363 kWh €26 14%	577 kWh €42 23%	580 kWh €42 23%	761kWh €56 30%
Paris	detached 125m^2	22200 kWh €1621	3204 kWh €234 14%	4427 kWh €323 20%	5751 kWh €420 26%	6716 kWh €490 30%
	end-terrace 106m^2	16871 kWh €1231	2397 kWh €175 14%	3366 kWh €246 20%	3923 kWh €286 23%	4743 kWh €346 28%
	mid-terrace 106m^2	15302 kWh €1117	2155 kWh €157 14%	3057 kWh €223 20%	3438 kWh €251 22%	4214 kWh €308 28%
	flat 2BR 72m^2	3391 kWh €247	494 kWh €36 15%	766 kWh €56 23%	748 kWh €55 22%	995 kWh €73 29%
	flat 1BR 50m^2	2562 kWh €187	394 kWh €29 15%	598 kWh €44 23%	580 kWh €42 23%	767 kWh €56 30%
Strasbourg	detached 125m^2	25424 kWh €1856	3752 kWh €274 15%	4867 kWh €355 19%	6868 kWh €501 27%	7673 kWh €560 30%
	end-terrace 106m^2	19476 kWh €1421	2823 kWh €206 14%	3709 kWh €271 19%	4779 kWh €349 25%	5444 kWh €397 28%

	mid-terrace 106m^2	17737 kWh €1295	2535 kWh €185 14%	3360 kWh €245 19%	4206 kWh €307 24%	4834 kWh €353 27%
	flat 2BR 72m^2	4253 kWh €310	608 kWh €44 14%	866 kWh €63 20%	942 kWh € 69 22%	1158 kWh €85 27%
	flat 1BR 50m^2	3198 kWh €23	472 kWh €34 15%	665 kWh €49 21%	725 kWh €53 23%	885 kWh €65 28%
Toulouse	detached 125m^2	16967 kWh €1239	2490 kWh €182 15%	3444 kWh €251 20%	4103 kWh €300 24%	4914 kWh €359 29%
	end-terrace 106m^2	12860 kWh €939	1860 kWh €136 14%	2598 kWh €190 20%	2846 kWh €208 22%	3491 kWh €255 27%
	mid-terrace 106m^2	11637 kWh €849	1660 kWh €121 14%	2342 kWh €171 20%	2495 kWh €182 21%	3099 kWh €226 27%
	flat 2BR 72m^2	2417 kWh €176	347 kWh €25 14%	519 kWh €38 21%	514 kWh €38 21%	665 kWh €49 28%
	flat 1BR 50m^2	1821 kWh €133	271 kWh €20 15%	396 kWh €29 22%	400 kWh €29 22%	515 kWh €38 28%

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 13% to 31%, resulting in annual savings from €20 to €560.