RESEARCH HIGHLIGHT

June 2005 Technical Series 05-100

Effects of Thermostat Setting on Energy Consumption

INTRODUCTION

House temperatures are typically set by the occupants to ensure their personal comfort. When occupants are not at home, or are asleep, the house temperature requirements are different. For this reason, many homeowners "set back" the thermostat (reducing the set temperature) during nights as well as during the work day by means of a conventional thermostat or with the aid of a programmable model. This is intended as a simple way to reduce overall household energy consumption during the winter heating season while still ensuring occupant comfort. In summer, a similar strategy can be employed by "setting forward" (increasing the set temperature) during the work day, reducing the load on the air conditioning system during peak hours.

The purpose of this set of experiments was to determine the effects of thermostat setting on household energy performance, and to also examine the overall effect on the house.

METHODOLOGY

The evaluation of thermostat setback and set forward strategies was carried out at the Canadian Centre for Housing Technology (CCHT)[1] in Ottawa in 2003. The CCHT Twin-House Research facility, with its multiple sensors and continuous data recording, is ideal for this type of experiment.

To determine the effect of a given technology, the CCHT houses are first benchmarked under identical conditions, and then a single element is changed in the "Test" house. In benchmark conditions, thermostats were set to 22°C (71.6°F), a mid-efficiency gas furnace provides the heat and its fan provided low- and high-speed continuous circulation during heating and cooling seasons. A high efficiency 12 SEER AC units provided cooling. A total of 28 winter and 27 summer benchmarking days were collected.

The Test House was set to the following winter setback settings (from 22°C):

- 18°C (64.4°F) night setback (11 p.m.-6 a.m.) for 13 days
- 18°C (64.4°F) night and day setback (11 p.m.-6 a.m., 9 a.m.-4 p.m.) for 16 days
- 16°C (60.8°F) night and day setback (11 p.m.-6 a.m., 9 a.m.-4 p.m.) for seven days

Two summer thermostat settings were examined:

- 24°C (75.2°F) higher temperature setting, 24 hours a day for 14 days
- 25°C (77°F) day set forward (9 a.m.-4 p.m.) for 20 days

Data collected throughout the experiments and benchmarking included: AC electrical consumption, furnace gas and electricity consumption, furnace-on time in heating and cooling mode, drywall surface temperatures, window surface temperatures, house temperature and humidity, and solar radiation.

[1] The Canadian Centre for Housing Technology is jointly operated by the National Research Council, Natural Resources Canada and Canada Mortgage and Housing Corporation. This research and demonstration facility features two highly instrumented, identical R-2000 homes with simulated occupancy to evaluate the whole-house performance of new technologies in side-by-side testing. For more information about the CCHT facilities, please visit http://www.ccht-cctr.gc.ca.

FINDINGS

Energy savings

The winter experiments demonstrated that as the setback temperature is decreased, energy savings increase. Higher savings are achieved (as a percentage) on colder days with longer furnace-on times. The greatest savings occurred on the coldest—cloudiest day (minimum -26.2°C [-15.16°F] to maximum -15.4°C [4.28°F] outdoor temperature) of the 16°C (60.8°F) night and day setback.

The setback reduced furnace-on time by 228 minutes, saving 163 MJ of gas and 0.98 kWh of electricity over the benchmark condition. It was also noted that in warmer conditions; for example, outdoor temperatures above 0°C (32°F), the net benefits were not detectable.

These R-2000 houses don't have time to cool down significantly overnight to show an appreciable saving.

During the summer thermostat set forward, electrical savings increased with higher outdoor temperature and larger solar gains. The highest savings occurred on the hottest day, when the minimum outdoor temperature was 20.4°C (68.72°F) and the maximum 30.2°C (86.36°F). The set forward resulted in a reduced on-time of 236 minutes; 6.39 kWh savings in AC compressor consumption, and 1.18 kWh savings in furnace fan consumption.

The higher temperature setting produced consistently high savings independent of temperature or solar radiation, resulting in an estimated 23 per cent savings in AC and furnace electrical consumption for the entire cooling season.

The predicted seasonal savings, shown in Tables 1, 2 and 3, were calculated using the experimental results of this project combined with one year of monitored data for the CCHT reference house and using a method described in the CCHT report *Analysis of Annual Energy Consumption for the CCHT Research Houses.*

Effects of solar radiation

The amount of sun each day had a major effect on both daytime setback and set forward experiments. Thermostat setback proved most effective on cloudy days. In winter, the added energy from solar radiation sometimes kept the Test House from dropping to the setback temperature, reducing the savings from daytime setback.

In summer, the effect was opposite and even more prominent. The sunnier the day (higher solar radiation), the higher the savings from thermostat set forward. For the sunny days the experiment obtained 13 per cent electrical savings from set forward, as opposed to only 2.9 per cent from all cloudy days (see Table 3).

Recovery time

Recovery time is a measure of the time taken for the house air temperature to return to its original setting. Recovery times from thermostat setback were all below two hours—on most occasions taking less than one hour to recover. The lower the temperature the house is allowed to reach (that is, the lower the setback temperature) the longer the recovery time.

Recovery time from summer thermostat set forward were much longer—up to seven hours on the hottest days—the same length of time as the set forward itself. This long recovery time would be expected to affect occupant comfort in the evenings.

Table 1 Predicted winter gas savings from thermostat setback in the CCHT Test House

	22°C benchmark	18°C night setback	18°C night and day setback	16°C night and day setback
Furnace gas consumption (MJ/yr)	66,131	61,854	59,231	57,241
Savings from benchmark (per cent)	---	6.5	10.0	13.0

Table 2 Predicted winter electrical savings from thermostat setback in the CCHT Test House

	22°C benchmark	18°C night setback	18°C night and day setback	16°C night and day setback
Winter furnace fan electrical consumption (kWh/yr)	2,314	2,295	2,270	2,261
Savings from benchmark (per cent)	---	0.8	1.9	2.3

Table 3 Predicted summer electrical savings from thermostat setting in the CCHT Test House

	22°C benchmark	24°C 24 hours	25°C 9:00 AM to 4:00 PM—all	25°C 9:00 AM to 4:00 PM—cloudy	25°C 9:00 AM to 4:00 PM—sunny
Summer circ. fan and AC electrical consumption (kWh)	3,104	2,381	2,771	3,015	2,694
Savings from benchmark (per cent)	---	23.3	10.7	2.9	13.2

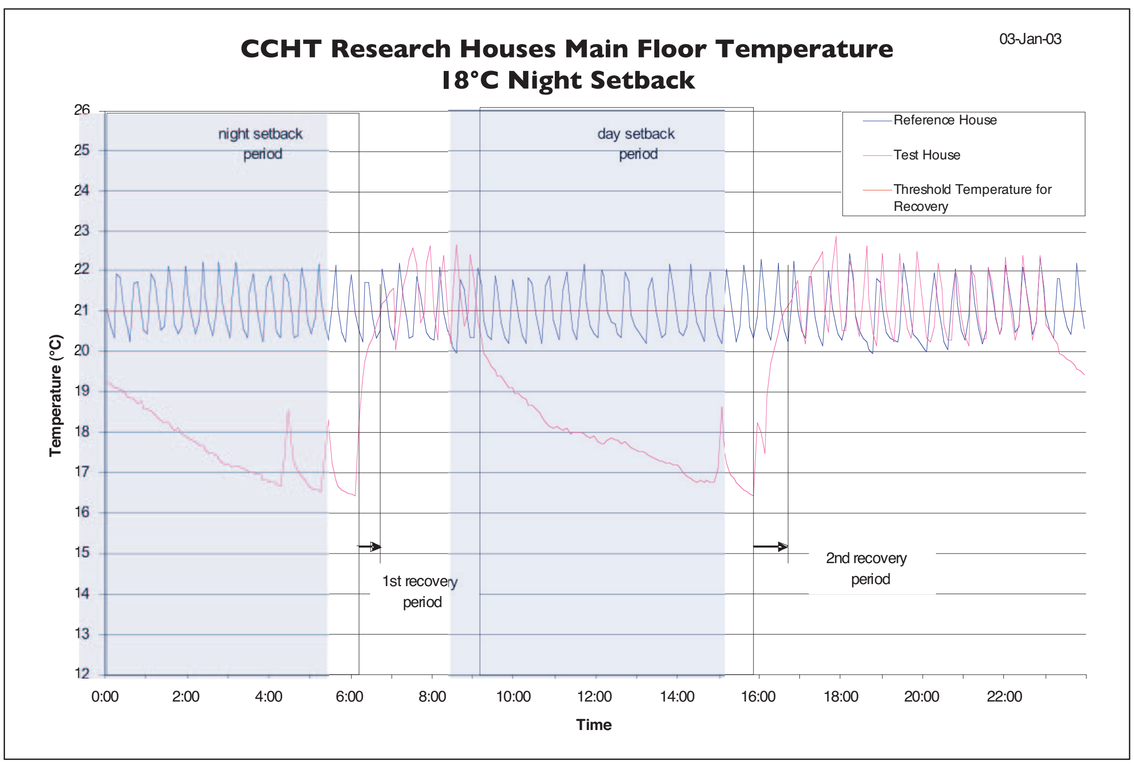

Figure 1 Sample air temperature recovery time for 18°C night and day setback on Jan. 3, 2003—outdoor temperature minimum -8.5°C (16.7°F), maximum -4.7°C (23.54°F)

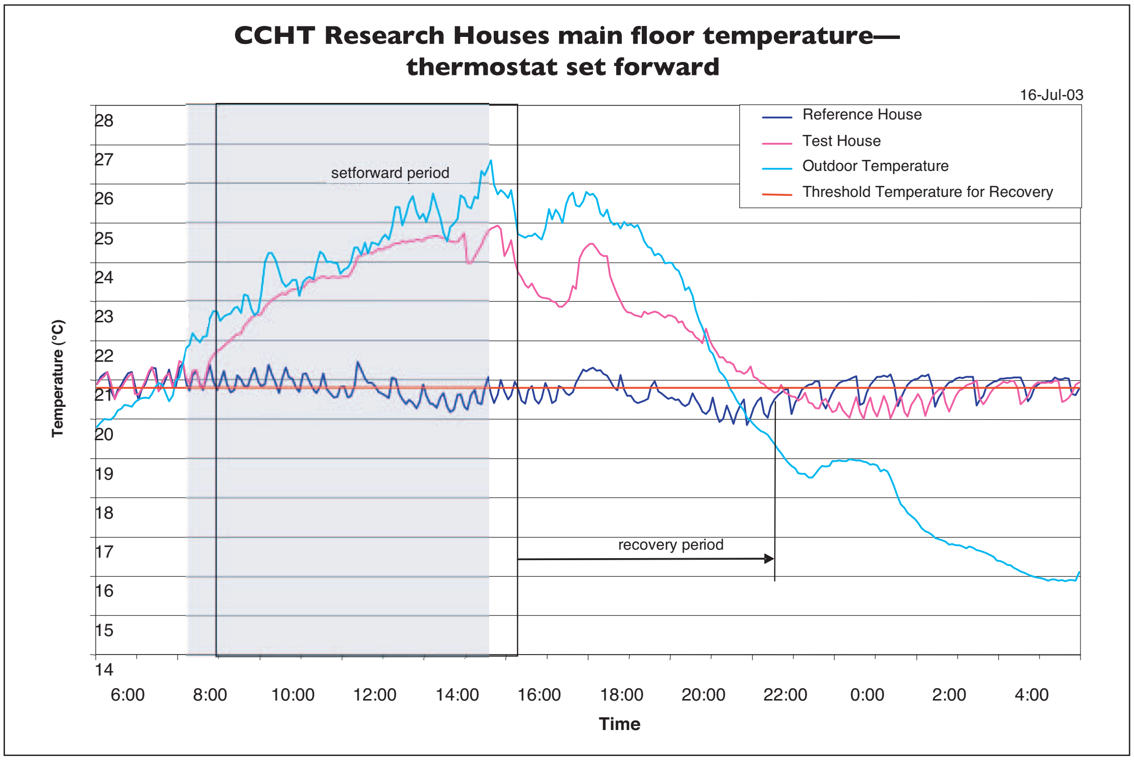

Figure 2 Sample graph showing recovery period from thermostat set forward

Winter surface temperatures

During the setback experiments, drywall surface temperatures on the 1st and 2nd floors remained above 12.7°C (54.86°F) for the 16-degree setback and above 17.8°C (64.04°F) for the 18-degree setback. At the coldest temperature recorded on the drywall, condensation problems would occur with a relative humidity of 55 per cent at 22°C (71.6°F). It should be noted that these drywall surface temperatures were measured at the centre of an insulated wall cavity, and lower surface temperatures could be expected on the wall-stud framing, at the bottom plates, at corners, or in sections with poorer thermal characteristics.

The lowest window surface temperatures were recorded on the frame—reaching as low as -2.6°C (27.32°F) even during benchmarking. Condensation or ice problems would be expected on the frame, unless relative humidity levels were kept below 19 per cent at 22°C (71.6°F). No condensation problems were observed during the experiments, as the houses were not humidified during the winter test period.

House temperature and humidity

The effects of winter thermostat setback were most noticeable on the main floor—minimum temperatures closely followed the thermostat settings. Despite the basement reaching lower temperatures than the main floor during these trials, Test House and Reference House basement minimum temperatures were less than two degrees Celsius different even during the 16-degree setback. See Table 4 for a list of house temperatures.

During summer thermostat experiments, a two-degree thermostat setting increase translated into a 2.45-degree increase on the 2nd floor and only a 1.47-degree increase in the basement.

While thermostat set forward appeared to have very little effect on household humidity, the higher temperature setting resulted in an overall increase in the moisture content of air by more than 1 g vapor/kg air—equivalent to an increase of ~6 per cent RH at 22°C (71.6°F), ~5 per cent RH at 25°C (77°F).

Limitations of this study

Thermostat setback savings will vary for different houses and mechanical setups. Care should be taken in applying these results to other homes.

Some of the issues that should be kept in mind include:

- The CCHT houses are built to R-2000 standards; therefore, they hold heat better than older houses. During thermostat setback, lower quality windows and insulation could lead to lower surface temperatures and additional condensation problems.
- The furnaces are sidewall-vented, mid-efficiency furnaces and are oversized by about 50 per cent, based on monitored results so far. A smaller furnace would likely take a longer time to recover from thermostat setback and set forward.
- The houses feature a heat recovery ventilator (HRV) that runs in continuous circulation mode to bring fresh air into the house while losing little heat. This is a feature of R-2000 houses due to their high airtightness level, which is uncommon in older, “looser” houses, in which air exchange occurs without mechanical help and without heat recovery.
- The CCHT houses are unfurnished. In a furnished house, the contents could affect the time taken for the house to adapt to changes in the temperature settings and the time required to return to the set temperature.
- The benchmark thermostat setting during the summer testing season was relatively low (22°C): a higher thermostat setting would affect set forward results.
- The furnace fan runs continuously at low speed to circulate air through the house, a practice in only a portion of Canadian households. Increased stratification of house temperatures would be expected when running the fan on “auto.”
- During the winter trials, the humidity levels were unconventionally low in the houses, below 20 per cent RH (no humidifiers were run). Condensation problems can only be predicted quantitatively and were not observed qualitatively.

CONCLUSIONS AND IMPLICATIONS FOR THE HOUSING INDUSTRY

The experiments showed that thermostat setback has significant potential as an effective and inexpensive energy-saving method, even in an energy-efficient house. Savings from thermostat setback and house temperatures will be different for all types of homes and mechanical setups. For this reason, it should be noted that these findings are valid for the CCHT Twin Houses and an energy model should be used when projecting the results to other situations.

The lengthy recovery period from the summer set forward highlights the need for a different approach to thermostat setting during the cooling season. Large savings were produced by simply increasing the thermostat setpoint. However, when it comes to setting this setpoint in the home, occupant comfort will likely be the determining factor.

A full report on this project is available from the Canadian Centre for Housing Technology.

Table 4 Minimum house temperatures during thermostat setback

	Main floor (°C)			2nd floor (°C)			Basement (°C)		
	Test	Reference	Difference	Test	Reference	Difference	Test	Reference	Difference
22°C benchmark	21.69	21.27	0.42	20.01	19.57	0.44	16.68	17.02	- 0.34
18°C setback	18.06	21.10	-3.04	16.93	19.79	- 2.86	14.26	15.72	- 1.46
16°C setback	15.81	21.15	-5.34	14.77	19.41	- 4.64	13.67	15.32	- 1.65

The Canadian Centre for Housing Technology

Canada Mortgage and Housing Corporation (CMHC), The National Research Council (NRC) and Natural Resources Canada (NRCan) jointly operate the Canadian Centre for Housing Technology (CCHT).

CCHT is a unique research, testing and demonstration resource for innovative technology in housing. CCHT's mission is to accelerate the development of new housing technologies and their acceptance in the marketplace.

CCHT operates a Twin-House Research Facility, which offers an intensively monitored, real-world environment. Each of the two identical, two-storey houses has a full basement. The houses, 223 m^2 (2,400 sq. ft.) each, are built to R-2000 standards.

For more information about the CCHT Twin-House Research Facility and other CCHT capabilities, visit http://www.ccht-cctr.gc.ca.

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Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

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