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Ownership and Use of Programmable Thermostats in Canada in 2003

David L. Ryan and Jevan Cherniwchan

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Executive Summary

Programmable Thermostats (PT) are relatively inexpensive devices that can reduce energy consumption for space heating by automatically adjusting a dwelling's temperature setting during certain periods of the day. Based on the 2003 Survey of Household Energy Use (SHEU03), their penetration in Canadian households is still less than 30%, although this rate has grown substantially since Canadian households were previously surveyed in 1997.

Based on SHEU03, PT ownership varies quite distinctly across provinces, and according to the type, age, and size of dwelling as well as the size of the household. Ownership of a PT is most likely in houses that heat with forced air furnaces, and within these houses, those that heat with natural gas, or electricity and natural gas, or propane. Ownership of a PT is more common with those that have central air conditioning, and increases with higher levels of household income.

Almost 27% of houses with a PT maintained the same temperature through all three periods of the day – daytime, evening, and nighttime. Except in households that set different internal house temperatures in all three periods, households that have a PT on average set higher average temperatures than corresponding households that did not have a PT. Over 70% of houses that maintain the same daytime and evening temperatures are occupied during the daytime hours, while 75% of those that set the same (on average lower) daytime and nighttime temperatures are not occupied during the day.

For all fuels except propane – where the relatively small sample size might explain the anomalous result – households with a PT were found to have lower energy intensities than those houses that did not have a PT. Except for heating oil, even those who don't program their PT have, on average, lower energy intensities than those who do not have a PT. In addition, those households that have a PT and actually program it (do not set the same temperature in all three periods), have lower energy intensities for all fuels except propane than those who do not have a PT, or those who have a PT but don't program it. In most cases those households with a PT that set different temperatures in all three periods do not have the lowest energy intensities. Ongoing research focuses on estimating a model of household energy intensities that controls for the effects of various other factors while assessing the significance and effect of having/using a PT.

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1. Introduction

Per-capita residential end-use energy consumption in Canada, influenced by such factors as climate, efficiencies of space and hot water heating equipment, and housing characteristics, is primarily (57%) required for space heating purposes.[1] Thus, the largest potential gains in residential energy efficiency in Canada appear to be in the space heating of homes. While the most commonly adopted residential energy saving measures include replacing single-pane with double- or triple-pane windows, installing more insulation, and using higher efficiency furnaces, many of these investments are expensive, and often the capital cost would not be recovered for many years. One of the cheapest – yet potentially very effective – measures that can be made by households to reduce energy requirements for space heating involves installing and utilizing the features of a programmable thermostat.

A programmable thermostat (PT) is a temperature sensitive switch that controls a furnace (and/or air-conditioner) by adjusting the temperature setting to preset levels for prescribed periods, such as when the home is unoccupied during working hours, or when a lower (higher) ambient temperature is less of a comfort concern, such as during the night (day). Estimates of the savings that can be obtained by using the features of a PT vary, but are generally quite large. Claims of estimated savings using such a device range from as much as 2% of the home heating bill for each degree Celsius (1.8 degrees Fahrenheit) that the thermostat is set lower at night[2] to approximately $150 (US) of annual energy costs assuming a typical, single-family home with an 8 hour daytime setback and a 10 hour nighttime setback of 8°F in winter and 4°F in summer.[3] Further, these savings are achieved quite inexpensively. According to cost and savings information provided on the US home energy saver website, an Energy Star PT has an incremental cost of $107 and generates annual bill savings of $29, so that the simple payback period is just 3.7 years.[4] In fact, on this site the annual rate of return after-tax for such a device

[1] Natural Resources Canada, "Energy Efficiency Trends in Canada, 1990 to 2004", http://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/tablesanalysis2/res_00_1_e_1_4.cfm?attr=0
[2] Natural Resources Canada, "Heating with Electricity", http://www.oee.nrcan.gc.ca/publications/infosource/pub/home/Heating_With_Electricity_Chapter2.cfm?attr=4#improved
[3] U.S. Department of Energy, "Programmable Thermostats – Proper Use Guidelines", http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines
[4] http://hes.lbl.gov/hes/profitable_dat.html.

is calculated at 30%, rating it 4th best out of 10 energy efficiency measures that were considered, and well in excess of the 16% average rate of return on investment for all 10 measures.

Despite the low purchase and retrofit cost of these devices, and the apparently large energy savings that they are claimed to be able to generate, programmable thermostats do not appear to have been widely adopted in the Canadian residential sector. One possible explanation is that the claimed energy savings for a PT are typically not realized. The purpose of this paper is to use data from the 2003 Canadian Survey of Household Energy Use to examine which households have, and which appear to use, a programmable thermostat, and to assess whether there is empirical evidence that installing and using a programmable thermostat actually reduces energy consumption.

The outline of the remainder of this paper is as follows. The following section contains an empirical examination of the types of households that have a PT, while Section 3 examines the extent to which households that do have a PT effectively utilize its features. The focus of Section 4 is on whether, and to what extent, owning and/or effectively using a PT significantly affects energy use. The final section provides a summary and conclusions.

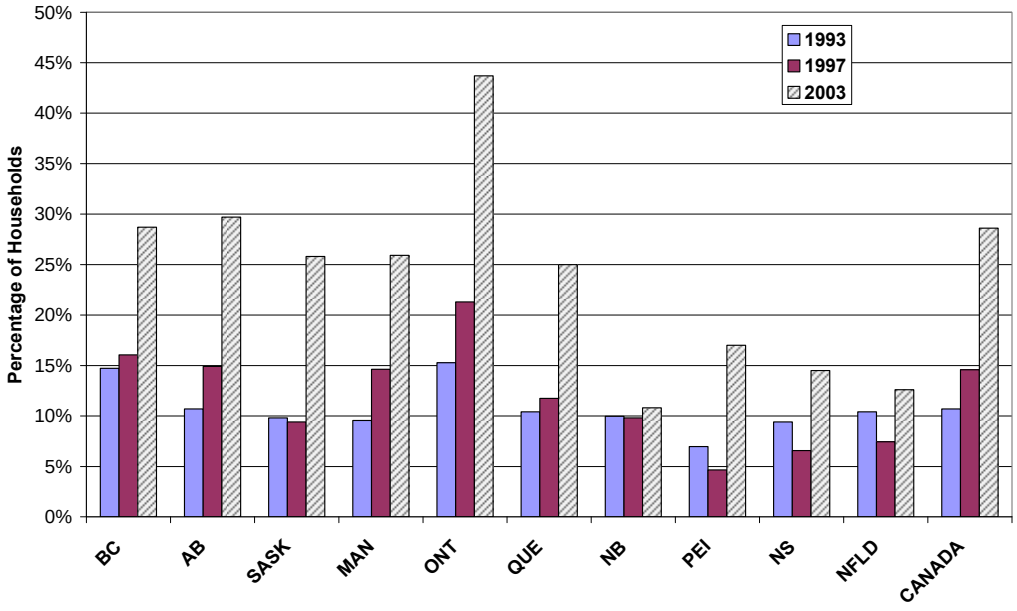
2. Who has Programmable Thermostats in Canada?

Information about whether households have various energy-savings devices such as programmable thermostats (PT) is collected by Statistics Canada in the Survey of Household Energy Use (SHEU), which is conducted periodically. The most recent of these surveys (SHEU03) collected data pertaining to 2003. This survey included responses from 4551 households from various parts of Canada. Along with questions pertaining to energy use, house characteristics, and various demographic and socio-economic variables, survey respondents were asked whether their household equipment included a programmable thermostat. This question was also asked in previous surveys conducted in 1997 (SHEU97) and 1993 (SHEU03).

A comparison of responses from the three surveys, as shown in Figure 1, indicates that across Canada, the proportion of surveyed households that has a PT grew from 10.7% in 1993 to 14.6% in 1997 to 28.6% in 2003. However, PT ownership in 2003 varies quite noticeably across

different regions, with the highest usage occurring in Ontario (almost 44%), followed by Alberta and B.C. (28% to 30%), and then Manitoba, Saskatchewan and Quebec (between 25% and 26%). In the most easterly provinces the proportion of surveyed households with a PT is below 18%, and below 11% in New Brunswick. In fact, apart from New Brunswick, all provinces show growth in ownership of PTs between SHEU97 and SHEU03 exceeding 69% (Newfoundland), with five provinces exhibiting growth during this six-year period exceeding 100%.

Figure 1: Percentage of Canadian Households with Programmable Thermostats, by Province



The sample collected in SHEU03 does not include households living in apartment dwellings located in buildings of more than 5 stories, so that there is no representation of those individuals living in high-rise apartments or condominiums. In contrast, the sample of households included in SHEU97 excluded those living in communal dwellings of two or more units, so that part of the growth in ownership of PTs between 1997 and 2003, as displayed in Figure 1, may reflect the increased coverage in SHEU03. The ownership of programmable thermostats in 2003 by dwelling type is displayed in Table 1. Households living in a single detached dwelling (which comprise over two-thirds of the SHEU03 sample), a double dwelling, or a row or terrace dwelling are more likely to own a programmable thermostat than are those households that live

in a duplex, while those in a low-rise apartment, or a mobile-home have the lowest rate of ownership of a PT (approximately 13.5%).

Table 1: Programmable Thermostat Ownership in 2003 by Dwelling Type

Dwelling Type	% of Sample	% HH with a PT
Single detached	70.1%	32.6%
Double	5.0%	27.5%
Row or terrace	5.0%	29.0%
Duplex	3.2%	20.1%
Low-rise apartment of fewer than 5 stories or a flat	13.7%	13.4%
Mobile home	3.0%	13.5%
ALL Dwellings	100.0%	28.6%

Since it is more likely that newer homes would come equipped with a programmable thermostat whereas these devices would have to be retrofitted in older houses, it might be expected that the proportion of new housing with a PT would be higher. The SHEU03 data clearly support this contention, as shown in Table 2. In particular, the proportion of houses having a PT is highest for houses built from 2000-2003 (50.4%), and from 1990-1999 (33.4%). For older houses, the percentage owning a PT generally ranges between 25% and 30%, except for houses built between 1920 and 1929 where only 18.6% have PTs.

Table 2: Percentage of Households with a PT according to Year of Dwelling Construction

Year of Building Construction	% of HH with a PT
1900-1909	23.3%
1910-1919	27.2%
1920-1929	18.6%
1930-1939	25.3%
1940-1949	24.9%
1950-1959	29.5%
1960-1969	27.2%
1970-1979	25.2%
1980-1989	29.9%
1990-1999	33.4%
2000-2003	50.4%
Total	28.6%

Tables 3 and 4 summarize programmable thermostat ownership by dwelling and household size. It appears on average that households with a PT are larger (1487.6 square feet) than those that do not have a PT (1281.7 square feet), and contain more people (2.89 people per household on average) than those without a PT (2.56 people per household on average). These findings might reflect the greater awareness of the additional heating costs and the increased need to adopt cost saving measures by people with larger houses and/or households. Alternatively it may mean that with more space to heat, the benefits of having a programmable thermostat are greater.

Table 3: Ownership of PTs by Dwelling Size

	Dwelling Size (sq ft)				
	Mean	Minimum	Median	Maximum	Standard Deviation
HH without a PT	1281.69	120	1150	7500	658.84
HH with a PT	1487.61	112	1300	6480	689.00

HH refers to Households with or without a PT.

Table 4: Ownership of PTs by Household Size

	Household Size				
	Mean	Minimum	Median	Maximum	Standard Deviation
HH without a PT	2.56	1	2.00	9	1.38
HH with a PT	2.89	1	3.00	10	1.37

HH refers to Households with or without a PT.

It is possible that the type of heating system used, as well as its fuel, has an effect on whether a household will have a PT, since the effectiveness of these devices may differ in different circumstances. As shown in Table 5, across Canada almost 55% of the houses in the sample use a forced-air furnace as their main source of heating, while a further 27% use electric baseboards. Forced air furnaces are the primary heating source in Ontario (78.91% of households employ it as the primary source), the Prairie Provinces (83.97%) and BC (51.34%). Electric baseboards are the most common form of equipment used for space heating in Quebec (65.73%), and are used by many households in BC (24.34%) and in the Maritime Provinces (33.60%). In contrast to the rest of Canada, in which it is common to find most residents of an area employing a common heating source, residents of the Maritimes usually employ one of three different heating

sources in their dwelling. Aside from electric baseboards, they also use forced air furnaces (30.93%) or boiler furnaces (21.26%) for heating.

Table 5: Space Heating Equipment Used in Canada

Heating Equipment	Maritimes	Quebec	Ontario	Prairies	BC	Canada	% with PT (Canada)
Forced Air Furnace	30.93%	12.92%	78.91%	83.97%	51.34%	54.95%	37.9%
Electric Baseboards	33.60%	65.73%	8.52%	4.60%	24.34%	26.90%	14.6%
Heating Stove (wood, coal, etc.)	8.68%	6.41%	1.01%	.63%	6.24%	3.69%	11.9%
Boiler Furnace with Hot Water or Steam Radiators	21.26%	11.21%	8.33%	9.87%	12.04%	10.92%	22.7%
Electric Radiant Heating	1.48%	1.30%	.44%	.00%	1.44%	.81%	10.0%
Other Heating Equipment	4.05%	2.43%	2.80%	.92%	4.61%	2.73%	15.0%

As the last column of Table 5 shows, houses that use forced air furnaces are much more likely to have a PT (38%) than are houses with any other type of space heating system. Almost 23% of houses using a boiler furnace have a PT, but less than 15% of households using electric baseboard heating have a PT.

Focusing on households in which space heating is by furnace, the primary energy sources used are displayed in Table 6. Of those households that used a furnace with one heating source, the majority (74.29%) used natural gas, with heating oil being the second most common fuel (14.1%) for furnace-based heating. For those households with two-source furnaces, electricity and natural gas was the most common combination of fuel sources that were used.

While the majority of dwellings with a one-source furnace in Canada use natural gas as an energy source for heating, use of natural gas for this purpose is not distributed evenly across the country. It is the most common energy source in the Prairies (93.95%), Ontario (85.06%), and BC (79.90%). In contrast, due to its lack of availability, few (0.52%) dwellings in the Maritimes use natural gas for furnace heating, with most (74.87%) using heating oil instead. Most dwellings in Quebec used one of four energy sources for furnace-based heating: 37.71% used heating oil, 23.62% used wood, 20.97% used natural gas and 15.95% used electricity.

Table 6: Energy Use for Furnace-Based Space Heating in Canada

Type	Fuel(s)	Regions					Canada	% with PT (Canada)
		Maritimes	Quebec	Ontario	Prairies	BC		
Single Energy Source Furnaces	Electricity	3.60%	15.95%	2.98%	3.41%	4.78%	4.64%	28.3%
	Natural gas	0.52%	20.97%	85.06%	93.95%	79.90%	74.29%	40.5%
	Oil	74.87%	37.71%	9.14%	1.12%	5.46%	14.10%	26.3%
	Wood	19.89%	23.62%	1.55%	0.59%	8.07%	5.67%	9.6%
	Propane	0.33%	1.75%	1.27%	0.77%	1.66%	1.19%	38.2%
	Other	0.78%	0.00%	0.00%	0.15%	0.13%	0.11%	14.3%
Dual Energy Source Furnaces	Electricity and oil	20.38%	62.09%	10.50%	3.43%	21.06%	25.10%	28.1%
	Electricity and natural gas	0.00%	21.05%	68.13%	84.83%	68.09%	52.08%	46.7%
	Wood and oil	65.01%	2.39%	13.52%	1.42%	0.00%	11.54%	11.9%
	Wood and electricity	12.77%	14.47%	5.78%	3.96%	6.06%	8.51%	25.8%
	Other	1.85%	0.00%	2.07%	6.37%	4.78%	2.77%	9.1%

A similar pattern of use occurs for two-source furnaces. Most dwellings with two source furnaces in the Prairies (84.83%), Ontario (68.13%) and BC (68.09%) utilize electricity and natural gas; this combination of energy sources is not employed at all in the Maritime Provinces. Instead, most (65.01%) households in the Maritimes with two-source furnaces use wood and oil. In Quebec, dwellings with two-source furnaces commonly employ electricity and oil (62.09%).

In terms of PT ownership, those households using natural gas for their furnace, either as a single fuel or in combination (with electricity), or those using propane, are much more likely to have a PT than are those using any other fuel or fuel combination. Households that use wood as a single fuel for their furnace, or who use wood in combination with oil, have very low ownership rates of PTs, although approximately one-quarter of those who use wood in conjunction with electricity as furnace fuels have a PT.

Interestingly, the average age of the main heating equipment (among those who provided this information), is 13.1 years for households with a PT versus 16.0 years for households without a PT. This may reflect the increased use of programmable thermostats with heating equipment that is more energy efficient, which generally would be newer. The presence of central air conditioning in a dwelling also seems to be a strong indicator for having a programmable thermostat, possibly because the thermostat can be used year round in these circumstances. Of

the 994 households (21.8% of the sample) that have central air conditioning, 51.4% have a PT, while only 21.4% of households without central air conditioning have a PT.

Apart from characteristics of the house itself, characteristics of the household residents may also affect whether a PT is installed. For example, some three-quarters of the programmable thermostats in the SHEU03 database are located in households that have incomes exceeding $40,000 per year. In general, the proportion of households having a PT increases with the level of income – while only 13.2% of households with annual incomes less than $20,000 have a PT, this percentage increases to 20.2% for households with annual incomes between $20,000 and $40,000, to 25.6% for households with annual incomes between $40,000 and $60,000, to 35.1% for households with annual incomes between $60,000 and $80,000, and to 41.8% for those households with annual income in excess of $80,000 (Table 7). Since programmable thermostats are relatively inexpensive, this may reflect greater awareness of energy use among households with higher incomes. Unfortunately, information on education levels was not collected in SHEU03. In SHEU97 where such data were collected, a similar finding was found to apply to education levels. Specifically, in SHEU97, between 8.4% and 10.1 % of households in which the survey respondent did not graduate from high school, had a PT. However, this percentage increased to between 15% and 17.4% in households where the respondent was a high school graduate, or had some post-secondary or community college education. Also, in SHEU97, a PT was found to be present in over 23% of households in which the respondent had a bachelor's or graduate degree.

Table 7: Programmable Thermostat Ownership in 2003 by Income Group

Income Group	% of Sample	% HH with a PT
Less than $20,000	13.4%	13.2%
$20,000 to $40,000	23.4%	20.2%
$40,000 to $60,000	18.8%	25.6%
$60,000 to $80,000	14.5%	35.1%
Over $80,000	22.9%	41.8%

3. Who Actually Uses Programmable Thermostats in Canada?

Almost all houses in Canada utilize a thermostat to regulate temperature during the space heating season, and most houses utilize only a single thermostat. Therefore, knowing that a household possesses a PT might simply mean that the thermostat that is present in the household *could* be programmed, but that it is simply being used in place of a regular thermostat in exactly the same way – as an on/off switch that maintains the internal temperature of the house at a specified level throughout each day. In such cases, little – if any – energy savings would be expected to be attributable to the household having a PT. Therefore, in determining the energy savings attributable to a PT, if such households are treated in the same way as households that actually utilize the features of a PT, the results that are obtained are likely to offer very little insight into the effectiveness of this energy savings device if it is used for the purpose for which it was intended.

In contrast to SHEU97, which only asked survey respondents if they had a PT, but not whether they utilized its features, in SHEU03, respondents who had a PT were also asked if they programmed it. Of those with PTs, 26.8% stated that they did not program it. On this basis, although 28.6% of survey respondents possessed PTs, only 21% actually possessed a PT and claimed to utilize its features by actually programming it.

Of course, claiming to program a thermostat is not actually the same as programming it effectively, in the sense of having different settings on the thermostat at different times of the day. To elicit this information, SHEU03 respondents were also asked what temperature setting they use for different periods – day (D), evening (E), and night (N) – during the heating season. In many cases, the settings are the same in two or even three of these periods. The average temperature set by households is displayed in Table 8 according to whether the household's temperature settings are the same in the day and the evening (D=E), during the day and at night (D=N), during the evening and at night (E=N), throughout the day (D=E=N), or if the temperature is varied in all three periods ($D \neq E \neq N$). In addition, the average temperatures for these groupings are provided separately for those with a PT (denoted PT) and those without a PT (no designation).

Table 8: Average Internal Temperatures in Degrees Celsius during the Heating Season for Dwellings According to Time-Varying Temperature Settings

Temperature Settings	Percent with PT	Percent of Households	Average Internal Temperature(°C)		
			Day	Evening	Night
D=E	30.1%	20.6%	20.69	20.69	17.69
D=E (PT)		8.9%	20.82	20.82	18.14
D=N	41.6%	7.1%	17.58	20.34	17.58
D=N (PT)		5.1%	17.96	20.90	17.96
E=N	28.7%	6.5%	19.60	19.32	19.32
E=N (PT)		2.6%	20.47	19.53	19.53
D=E=N	20.2%	30.1%	20.06	20.06	20.06
D=E=N (PT)		7.6%	20.77	20.77	20.77
D,E,N Not Equal	39.3%	6.9%	19.65	21.09	17.89
D,E,N Not Equal (PT)		4.5%	19.11	20.84	17.82

D, E and N refer to the temperature during the Daytime, Evening and Night respectively.
PT refers to those dwellings that own one or more programmable thermostats.

Perhaps counter intuitively, it appears from Table 8 that those households that own a programmable thermostat generally maintain *higher* internal temperatures in all three daily periods during the heating season than do those households without a programmable thermostat, with the exception of households that vary the dwelling temperature in each period throughout the day. Within this latter group of households, those that had a programmable thermostat maintained lower temperatures in all three periods of the day. In general, to use a PT effectively, the temperature setting should vary in all three periods. However, of PT owners, only 15.6% fall in this category. Indeed, a larger percentage of PT owners – almost 27% – do not vary the temperature at all throughout the day (compared to 42.3% of non-PT owners, indicating that almost 58% of these non-PT owners make some manual temperature setting adjustments to their thermostat during each day). Interestingly, the lowest average daytime temperature, and the second lowest nighttime temperature, is achieved by those with PTs who set the daytime and nighttime temperatures to be the same. Combining this group with those who set the three temperatures to be different – to form a group that might be referred to as "effective PT users", we see that almost one-third of PT owners are included in this category, representing less than 10% of all households in the survey.

Returning to the SHEU03 responses to the question concerning whether PT owners actually programmed their device, it is instructive to cross-tabulate these responses with the temperature setting information in Table 8. The data show that all those who have a PT and maintain a constant (D=E=N) temperature setting responded that they did not program their thermostats. This accounts for 99.4% of all those with a PT who claimed not to program it (possibly with the other 0.6% simply using the preset factory settings on their PT). This is an interesting finding insofar as many PTs are purchased with preset factory settings, so that to maintain a constant temperature in these circumstances requires a deliberate act of removing the preset programming from the device. In any event, responses to this question about whether the survey participant programmed their device are largely redundant in the sense that they just reinforce the temperature setting information displayed in Table 8.

Table 9: Average Internal Temperatures in Degrees Celsius during the Heating Season for Dwellings According to whether House is occupied during Daytime

Someone at home during daytime hours	PT	Percent of Households	Average Internal Temperature(°C)		
			Day	Evening	Night
No	All		19.34	20.26	18.71
	No PT	30.9%	19.33	20.09	18.71
	Has PT	12.8%	19.38	20.67	18.70
Yes	All		20.41	20.54	18.98
	No PT	40.4%	20.37	20.47	18.95
	Has PT	15.9%	20.51	20.74	19.04

Of course, one of the reasons that the thermostat may be set the same during different periods of the day is due to occupancy of the house during all these different periods. The general expectation is that the thermostat setting will be lowered at night when occupants are sleeping and during the day when occupants are at work. However, if household members are actually occupying the house during the day, then it would be more likely that the temperature setting during the daytime hours would not be lowered. To investigate this possibility, Table 9 presents information on average temperature and daytime occupancy of the house (whether someone was home all day on an average weekday). As can be seen from the first row of Table 9, when there is no-one at home during the day, average temperatures follow the expected pattern, with the average daytime temperature being almost 1°C less than the average evening temperature, and

with the average nighttime temperature being almost ⅔°C lower again. This pattern is similar for those without PTs (row 2) and for those with PTs (row 3). However, when there is someone at home during the average weekday (4th row of Table 9), then the day and evening average temperatures are quite similar and the average nighttime temperature is around 1.5°C lower. Again, these findings hold for those with and those without a PT.

Table 10 shows the proportion of households in which someone is at home during an average weekday for each of the different temperature settings identified in Table 8. In households that set the daytime and evening temperatures the same, over 70% have the house occupied during daytime hours. Similarly, in 75% of houses with the same daytime and nighttime temperature setting, no-one is at home during the day. Households with different temperature settings in all three periods have someone at home in 50% of the cases, while 58% of houses with the same temperature setting in all three periods have someone at home during the daytime. Among households that set the same evening and night temperature, occupancy during the daytime differs according to whether or not they have a PT; for those with a PT the house is occupied during the daytime in two-thirds of the cases, whereas for those without a PT, the house is only occupied during the day in one-half of the cases.

Table 10: Daytime Household Occupancy and Time-Varying Temperature Settings

Temperature Settings	Percent of Households with Someone at home during daytime hours
D=E	70.4%
D=E (PT)	72.8%
D=N	25.4%
D=N (PT)	24.6%
E=N	50.3%
E=N (PT)	66.4%
D=E=N	57.6%
D=E=N (PT)	57.8%
D,E,N Not Equal	48.9%
D,E,N Not Equal (PT)	44.2%

D, E and N refer to the temperature during the Daytime, Evening and Night respectively.
PT refers to those dwellings that own one or more programmable thermostats.

4. How is Energy Use Affected by Having/Using a Programmable Thermostat?

Presumably, one of the most important reasons for installing a programmable thermostat is to reduce energy use and save on energy costs. This extent to which this occurs can be examined by comparing energy consumption for households that have and that do not have a PT. The values in the first four rows of Table 11 indicate average energy consumption for all households where consumption data for the specified energy source (electricity, natural gas, heating oil, and propane) were both available and positive. For both electricity and natural gas, the quantities refer to consumption during the heating period only. The data for these two fuels reveal that on average households with programmable thermostats use less electricity and less natural gas than do households without these devices. However, this finding is reversed for households that used heating oil or propane, although the sample sizes for these two fuels are small so that average consumption may not be representative.

Unfortunately, energy consumption information was not available for all households in the sample – in such cases missing energy consumption values are imputed by Statistics Canada. The values in the final two four rows of Table 11, which indicate average consumption of each energy type for all households in SHEU03 (provided such consumption is positive), make use of these imputed values wherever actual data are not available. Here, consumption of both electricity and heating oil is lower for houses with a PT, but this finding is reversed for households with natural gas or propane.

A disadvantage of comparisons such as those in Table 11 is that other factors that may affect energy use – apart from the decision to install a PT – such as the size of the house, number of occupants, type of heating system, etc., are not held constant. Here we focus on the size of the house by calculating energy intensities, measured as GJ of each fuel consumed per square foot of heated area in the dwelling. These values, presented in Table 12, show that for all fuels except propane, energy intensities are lower for those households that have a PT. This difference is greatest in percentage terms for electricity and then natural gas. Again, the perverse findings for propane may reflect the very small sample sizes for that fuel (the small number of households with non-zero consumption of propane – as identified in Table 11).

Table 11: Average Consumption of Energy with and without a PT

Average Consumption per Household of:	Number of households with positive consumption	Households with a Programmable thermostat	Households without a Programmable Thermostat
Electricity (GJ)	3418 (28.0%)	31.4	34.1
Natural Gas (GJ)	1378 (40.6%)	95.2	97.3
Heating Oil (GJ)	323 (22.6%)	98.4	95.9
Propane (GJ)	52 (28.8%)	58.8	39.2
Electricity (GJ)**	4548 (28.0%)	32.1	34.6
Natural Gas (GJ)**	2279 (36.5%)	96.0	93.4
Heating Oil (GJ)**	705 (24.1%)	110.0	112.3
Propane (GJ)**	150 (28.0%)	58.3	46.4

Notes: For each energy source, average consumption calculations include only those households with positive consumption.
Numbers in parentheses indicate percentage of households with a PT.
Electricity and natural gas consumption refer to during the heating season only.
** indicates that calculations include households with imputed values of energy consumption.

Table 12: Average Energy Intensities with and without a PT

Average Consumption per square foot per Household of:	Households with a Programmable thermostat	Households without a Programmable Thermostat	Percentage Difference
Electricity (GJ/sq ft)	0.0173	0.0243	40.5%
Natural Gas (GJ/sq ft)	0.0456	0.0561	23.0%
Heating Oil (GJ/sq ft)	0.0614	0.0672	9.4%
Propane (GJ/sq ft)	0.0425	0.0305	-28.2%
Electricity (GJ/sq ft)**	0.0176	0.0243	38.1%
Natural Gas (GJ/sq ft)**	0.0470	0.0567	20.6%
Heating Oil (GJ/sq ft)**	0.0644	0.0763	18.5%
Propane (GJ/sq ft)**	0.0310	0.0274	-11.6%

Notes: For each energy source, average energy intensity calculations include only those households with positive consumption.
Energy intensity is calculated as energy consumption per square foot of dwelling heated area.
Electricity and natural gas consumption refer to during the heating season only.
** indicates that calculations include households with imputed values of energy consumption.

As noted in Section 3, one of the problems with the data on PT ownership is that owning a PT is not the same as using it, or using it effectively. To investigate whether there are greater differences in energy intensity for those who program their PT (that is, do not set the temperatures to be the same in different periods of the day), energy intensities were calculated separately for different groups of PT owners. Specifically, separate energy intensities are calculated for those households that have a PT but set D=E=N, or D=E, or D=N, or E=N. In addition, energy intensities are calculated for those households with a PT that set a different temperature in all three periods, as well as for all PT owners except those who set D=E=N. The results are displayed in Table 13.

The energy intensities in Table 13 reveal an interesting picture. First, for all fuels except heating oil, those with a PT who do not program it, that is, who set D=E=N, have lower energy intensities on average than do those who do not have a PT. Thus, the mere act of having a PT – even if it is not programmed – appears to lower energy intensity. This may reflect the possibility that those households that have a PT are likely to be more energy aware and thus act to reduce energy consumption even if they don't actually program their PT. Second, reinforcing the findings from Table 12, those who have a PT and actually program it (do not set D=E=N, as in the last column of Table 13), have lower energy intensities for all fuels except propane than those who do not have a PT, or those who have a PT but don't program it (set D=N=S as in the third column of Table 13). Third, in general (except for heating oil when households with imputed energy consumption values are excluded), those households with a PT that set different temperatures in all three periods do not have the lowest energy intensities. However, of the five groups identified in Table 13 as having PTs, these households that set different temperatures in all three periods are among the three lowest energy intensities for each fuel except for propane. Interestingly, those households with a PT that set D=E or D=N have among the lowest average energy intensities. This may reflect the information in Table 8 that indicates that households setting D=E have a quite low average nighttime temperature, while those setting D=N have relatively low daytime and nighttime average temperatures.

Table 13: Average Energy Intensities with and without a PT by Thermostat Setting

Average Consumption per square foot per Household of:	Households without a Programmable Thermostat	Households with a Programmable Thermostat					
		D=E=N	D=E	D=N	E=N	D≠E≠N	All except D=E=N
Electricity (GJ/sq ft)	0.0243	0.0203	0.0154	0.0165	0.0171	0.0168	0.0162
Natural Gas (GJ/sq ft)	0.0561	0.0496	0.0456	0.0484	0.0414	0.0452	0.0445
Heating Oil (GJ/sq ft)	0.0672	0.0719	0.0438	0.0552	0.1215	0.0369	0.0580
Propane (GJ/sq ft)	0.0305	0.0158	0.0083	0.0702	0.0830	0.0809	0.0492
Electricity (GJ/sq ft)**	0.0243	0.0204	0.0161	0.0163	0.0174	0.0172	0.0165
Natural Gas (GJ/sq ft)**	0.0567	0.0500	0.0482	0.0430	0.0483	0.0445	0.0461
Heating Oil (GJ/sq ft)**	0.0763	0.0812	0.0548	0.0480	0.0869	0.0660	0.0592
Propane (GJ/sq ft)**	0.0274	0.0151	0.0119	0.0301	0.0629	0.0891	0.0360

Notes: For each energy source, average energy intensity calculations include only those households with positive consumption.
Energy intensity is calculated as energy consumption per square foot of dwelling heated area.
Electricity and natural gas consumption refer to during the heating season only.
** indicates that calculations include households with imputed values of energy consumption.

5. Summary and Conclusion

Programmable thermostats are relatively cheap devices that can reduce energy consumption for the major energy-using activity in a house, namely space heating. Yet, based on SHEU03, their penetration in Canadian households is still less than 30%, although this rate has grown substantially since Canadian households were surveyed previously on this subject in 1997. PT ownership varies quite distinctly across provinces, with the highest ownership rates occurring in Ontario, Alberta, and B.C., and the lowest rates in the easternmost provinces. Households residing in low-rise apartments or mobile homes are less likely to have PTs than are those in single-detached, double, and row or terrace dwellings. Households located in newer buildings are also more likely to have a PT, as are those in larger dwellings or those having more household members. Ownership of a PT is most likely in houses that heat with forced air furnaces or, to a lesser extent, those whose heating equipment is boiler furnaces with hot water or steam radiators. Within the group of households that use forced-air furnaces, which ranges from about 31% of households in the Maritimes to 84% of households in the Prairies, those that heat with natural gas, or electricity and natural gas, or propane, are most likely to have a PT.

Ownership of a PT is also more common with those that have central air conditioning, and tends to strongly increase with higher levels of household income.

Even among houses that have a PT, not all of them use a PT effectively. In particular, based on the information in SHEU03, almost 27% of those with a PT stated that they did not program it. In fact, not only did they not program it, but almost this entire group of households maintained the same temperature through all three periods of the day – daytime, evening, and nighttime. Unexpectedly, it was found that apart from households that set different internal house temperatures in all three periods, households with a PT on average set higher average temperatures than corresponding households that did not have a PT. Interestingly, the lowest average daytime temperature, and the lowest or second lowest nighttime temperature, is achieved by those who set the daytime and nighttime temperatures to be the same. However, PT owners in this group and in the group who set the temperatures in the three periods to be different represent less than 10% of all households in the survey. Perhaps not surprisingly, over 70% of houses that maintain the same daytime and evening temperatures are occupied during the daytime hours, while 75% of those that set the same (on average lower) daytime and nighttime temperatures are not occupied during the day.

In terms of energy usage, during the heating season, those houses with a PT on average consume less natural gas and electricity, although this result does not hold up for natural gas when imputed values of energy consumption are included for those houses where actual energy consumption data were unavailable. To allow for differences in the heated area of the dwelling, energy intensities, measured as GJ per square foot, were also calculated for all households. These revealed that for all fuels except propane – where the relatively small sample size might explain the anomalous result – households with a PT were found to have lower energy intensities than those houses that did not have a PT. Energy intensities were also evaluated separately for households with a PT according to whether they set the same temperature during various periods of each day. This revealed that except for heating oil, even those who don't program their PT have, on average, lower energy intensities than those who do not have a PT. In addition, those households that have a PT and actually program it (do not set the same temperature in all three periods), have lower energy intensities for all fuels except propane than those who do not have a

PT, or those who have a PT but don't program it. Interestingly, in most cases those households with a PT that set different temperatures in all three periods do not have the lowest energy intensities.

Overall, therefore, there does appear to be some evidence in the SHEU03 data that having a PT, and particularly having and effectively using a PT, can reduce energy intensity. However, a disadvantage of comparisons of energy intensities such as those described here is that other factors that may affect energy use, such as the size of the house, number of occupants, type of heating system, main heating fuel, location, household income, etc., are not held constant. To rectify this it would be necessary to estimate a model of household energy consumption or energy intensities, possibly separately for each type of main heating fuel, and control for these and various other factors while assessing the significance and effect of a variable that reflects whether a household possesses and/or appears to effectively utilize a PT. Since the presence or absence of a PT in a household may not be the result of random choice – the same households that are more aware of energy efficiency and energy saving measures may be more likely both to have a PT and to use it appropriately – the endogeneity of this decision needs to be taken into account in empirical work. For example, if households that are very conscious of energy efficiency are likely to use less energy than an otherwise identical household – whether or not the energy-efficiency conscious household has a PT – then a comparison of such a household that has a PT with a less energy-efficiency conscious household that does not is likely to lead to an overstatement of the energy savings that are attributable to a PT. To rectify this problem, estimates obtained from a discrete choice model of the determinants of the decision to have a PT would have to be used in the estimation of the household energy consumption or energy intensity equations. This approach is currently being utilized in ongoing research concerned with evaluating the effectiveness of programmable thermostats.

CBEEDAC
Department of Economics
University of Alberta
8-14 Tory Building
Edmonton, Alberta
Canada
T6G 2H4
cbeedac@ualberta.ca