Destined to Disappoint: Programmable Thermostat Savings are Only as Good as the Assumptions about Their Operating Characteristics

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ABSTRACT

Programmable thermostats commonly account for a large percentage of energy savings for many residential and small business energy efficiency programs. For some portfolios, because of the limited number of devices that can affect gas savings for these sectors, programmable thermostats are the primary equipment aimed at attaining gas savings goals. However, evaluations reveal that actual energy savings for these devices often fall short of expected savings. Such discouraging results led ENERGY STAR® to suspend labeling programmable thermostats in 2009, citing that the device itself does not save energy, but instead, actual energy savings depend on user behaviors. This paper discusses the impact of assumptions about customer behaviors on actual savings, using the results of a recent evaluation for illustrative purposes.

Typically, it is assumed that old thermostats were operated with constant settings while new thermostats are operated programmatically. While the results of this evaluation reveal the latter is generally true – most customers did operate their new units programmatically – there is little support for the former. In fact, the evaluation results showed that two-thirds of customers participating in the program already practiced energy conserving behaviors by manually setting-back their old thermostats for non-operating hours. Thus, the vast majority of the expected energy savings never materialized. Overall, the results show that for programmable thermostats to manifest expected realization rates, attention needs to be allocated to defining accurate assumptions about user behaviors. Implications for energy efficiency program design will be discussed, highlighting the need for more focus on understanding customer behaviors.

Introduction

Starting in 1995, ENERGY STAR began promoting programmable thermostats as a means of lowering residential consumers' heating and cooling energy bills by 10-30% (EPA 2003a). Early simulations showed that thermostats could reduce natural gas consumption by roughly one percent for each degree Fahrenheit offset during an eight-hour nighttime setback (Nelson & MacArthur 1978).[1] Primarily as a means of bolstering energy efficiency program gas savings, some utilities began offering programs aimed at replacing customers' older manual thermostats with newer programmable models at low to no cost to the customer.

[1] In the context of thermostats, the *setback* is the difference between the typical operating temperature and the energy saving setting. Thermostats setbacks have two components: (1) temperature, and (2) time. For example, if a thermostat controlling a heating system is set at 68°F during the day (from 9AM to 10PM) and is turned down to 64°F at night (from 10PM to 9AM), the temperature setback is 4°F, or the difference between the higher and lower temperature settings and the time setback is 11 hours, or the total amount of time the thermostat is in the energy saving mode.

However, by 2006, evidence was amassing suggesting the expected savings for programmable thermostats were not materializing (EPA 2006). Ultimately, on December 31, 2009, ENERGY STAR suspended the certification of programmable thermostats, instead transitioning to an educational program for customers. ENERGY STAR explained that this policy shift centered on the fact that installing a programmable thermostat, in itself, does not *de facto* result in energy savings. Rather, the manner in which the customer uses the programmable thermostat – or their behavior – actually drives the potential for savings (Shiller 2006). Nevertheless, several state energy efficiency programs continue to include programmable thermostats as viable and acceptable energy saving equipment, and some utilities have even designed and implemented programs aimed solely at replacing older, non-programmable thermostats with programmable units. This is especially prevalent in the small business sector where building shell upgrades for energy efficiency purposes (i.e., added insulation, window replacement) or other larger-scale energy-saving equipment installations are less common than in the residential sector.

Program theory aimed at programmable thermostats, in addition to the calculations used to compute their expected per-unit energy savings values, is typically premised on two basic assumptions (BuildingMetrics, Inc. 2011, Haiad et al. 2004, Nextant 2007, Pigg and Nevius 2000, RLW 2007). The first is that all customers maintained old thermostats at a single constant temperature; the second is that all customers operate their new programmable units programmatically. The second assumption has come into question both within the energy efficiency community (Boait & Rylatt 2010, EPA 2003a, Haiad et al. 2004, Meier et al. 2010, Meier 2011, Pigg and Nevius 2000, Rathouse & Young 2004) and in the press (McCracken 2011), and a new wave of programmable thermostats led by the Nest Thermostat claim to provide better usability and greater energy savings than older models (Manjoo 2011). However, this paper shows that the first assumption may be equally if not more problematic. A general finding is that while the operating characteristics of the new thermostats surely have the potential to impact actual energy savings from programmable thermostats, the way in which customers used their old thermostats likely has a much greater influence.

This paper is unique for two reasons. First, while a number of evaluations have covered programmable thermostats, almost all have been conducted in the residential sector (e.g. see Haiad et al. 2004, Pigg and Nevius 2000, RLW 2007). This paper focuses on the evaluation of a programmable thermostat program for small businesses. Thermostats in a commercial facility serve large groups of people – guests/customers, employees, and administrators – who may have varying privileges or abilities to set the thermostat. Second, this paper is differentiated by its emphasis on assessing the basic assumptions as they relate to actual thermostat operating behavior. An overview of ENRGY STAR's experience with programmable thermostats follows, before moving on to a more detailed discussion of these assumptions.

ENERGY STAR and Programmable Thermostats

Labeling for programmable thermostats that met ENERGY STAR specifications began in 1995 and continued until 2009. Plans to "sunset" the label for thermostats began to take shape in 2007, based on the general finding that programmable thermostats were simply not delivering the expected energy savings. This finding centered on two main issues: (1) many customers found that using the new technology was a challenge preventing them from using the units programmatically, essentially causing them to operate the thermostats with constant settings, and

(2) the operating characteristics of both the old and new thermostats mattered. Prior to de-certifying programmable thermostats, particular attention was placed on the former issue. The last official programmable thermostat specification (v. 1.2, approved in 2008) contained a requirement that the customer "be able to change the settings on the programmable thermostat with little difficulty" (EPA 2008). Usability continued to be the focus of drafts of the v. 2.0 specification, which ultimately was abandoned in favor of phasing out the certification.

However, the decision to indefinitely suspend ENERGY STAR certification for programmable thermostats rested on more than usability concerns. EPA also reviewed five studies that showed no statistically significant savings for households with programmable thermostats over those with non-programmable models. ENERGY STAR summarized this finding as primarily the result of two groups of users that produced no savings: (1) households that did not set back their manual thermostat and continued to not set back their programmable thermostat, undergoing no behavior change, and (2) households that previously set back manual thermostats and continued to set back their programmable thermostat (Shiller 2006). They concluded that the introduction of the technology was insufficient to induce a behavior change for this former group of users, concluding "only the behavior saves, not the box."

Even though ENERGY STAR's analysis suggested that customers' behavior with their new programmable thermostat is not the only factor that determines energy savings, little attention has been allocated to better understanding the role that the operational characteristics of the old thermostats plays in the difference between expected and actual energy savings. This is potentially problematic given that the installation of even the most intuitive, user-friendly programmable thermostat will likely result in negligible savings if the thermostat it replaced was diligently adjusted manually.

In the following we explore this issue in the context of examining the assumptions underlying the logic of how programmable thermostats accrue energy savings.

Programmable Thermostat Assumptions

In general, there are two primary assumptions that are foundational to programs aimed at affecting gas an/or electricity energy savings with programmable thermostats:

> **Assumption 1**: All older, replaced thermostats were operated with constant settings.[2]
>
> **Assumption 2**: All new thermostats are operated programmatically, using appropriate degree and hour setbacks.

These assumptions arise in two distinct aspects of typical energy efficiency program design. First, assumptions of how customers use their old and new thermostats are part of the basic program theory. Here, the predominant view is that replacing older, manual thermostats with newer, programmable models allows the customers to use time and temperature setbacks to reduce the amount of time their heating and/or cooling system needs to run, thus resulting in energy savings. Second, the assumptions play a part in the calculations used to compute expected per-unit energy savings estimates for programmable thermostats.

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[2] Embedded within the statement "constant settings," are the assumptions that: (1) the settings of old units – both temperature and time – were consistent across all days of the week, and (2) the customers reliably set back their units each day, never missing any days.

Typically, energy efficiency programs claim expected per-unit energy savings for programmable thermostats based on engineering calculations that rely on these assumptions in addition to information on estimated operating hours, building shell and HVAC system characteristics, and estimated temperature settings for typical operating hours and the energy-saving mode (BuildingMetrics, Inc 2011, Nextant 2007, RLW 2007). Inherent in the second assumption is that for thermostats controlling heating systems, the energy-saving mode temperature is set lower than the standard operating temperature, and for thermostats controlling cooling systems, the energy-saving mode temperature is set higher than the standard operating temperature. For example, one engineering study assumes that for residential applications, for heating systems, the temperature settings are 70°F and 60°F, respectively, while for a cooling system they are 75°F and 80°F, respectively (BuildingMetrics, Inc. 2011). In both cases the setback time is from 11PM to 6AM. For commercial applications, the assumed temperature settings and operating hours typically vary by building or business type to account for the significant variability across types (e.g., offices, small industry, retail, restaurants, etc.), and then results are weighted and aggregated to derive a single per-unit savings value that is claimed for each unit installed under the program.

A better understanding of the role the basic assumptions play in both of these aspects is critical for effective program design, and the attribution of device energy savings, gas or electric. **Figure 1** demonstrates the implications of these assumptions for energy savings, by classifying potential savings according to the two assumptions.

Figure 1. Classification of Potential Savings by Assumptions

		New Thermostats	
		Constant	**Setback**
Old Thermostats	**Constant**	**Zero savings**	**Positive Savings**
	Setback	**Negative savings**	**Zero, negative, or positive Savings**

Notable from **Figure 1** is that only one of the four outcomes results in energy savings. Namely, if participants operated their old thermostats with constant settings and operate their new units with programmed setbacks – affirming both assumptions – savings from the program will likely materialize.[3] The other three potential outcomes represent less desirable impacts. For participants that habitually set back their manual thermostat, even if they did not do so 100% of the time, the net result is a movement from certain positive savings towards uncertain or zero savings regardless of how they use the programmable thermostat.

If participants operated their old thermostats with constant settings and continue to operate the new units with constant settings, no energy use changes occur and program savings will not accrue. In contrast, if participants operated their old thermostats with manual setbacks and new units are operated with constant settings, greater energy consumption would occur and negative savings will result. Lastly, if participants operated old thermostats with manual setbacks

[3] It is worth emphasizing that even though energy savings would theoretically accrue for these customers, the amount of energy savings would not necessarily result in the expected savings due to differences between the actual setbacks and the specific assumed setbacks. The net effect of this could increase or decrease energy consumption depending on the actual temperature settings.

and new thermostats are also operated with setbacks, either no change in energy consumption occurs, or energy consumption could even increase or decrease based on the actual time and temperature setbacks. With this last case, it is important to note that customers that adjusted their old thermostats manually would have done so when physically present in a facility (i.e. when they arrive in the morning and when they depart at night). With new programmable thermostats, customers could program their unit to go on *before* staff arrive and off *after* staff depart. In this situation, the result could be a decrease in the total setback hours, producing *negative* energy savings attributable to the devices.

For the remainder of this paper we use data from a recent programmable thermostat evaluation of a program aimed at small businesses to assess actual energy savings in terms of engineering adjustments and to classify program participants based on the schema discussed above. However, before moving on to the analysis, the following section briefly describes the data and methods.

Data and Methods

The data discussed in this paper come from 194 telephone surveys conducted over a one-month period (late April to late May, 2011) by Energy Market Innovations, Inc. with small business customers that participated in a 2010 program where their utility replaced older manual thermostats controlling heating or cooling systems with programmable models.[4] This program was designed primarily to attain gas savings goals, though electricity savings were also reported when applicable. The sample plan for this particular program was designed with the goal of attaining 90 percent level of confidence at the 10 level of precision at the program level. The program consisted of direct installation of thermostats by the program implementer. Installers went door-to-door, offering to install the programmable thermostats on the spot, at no cost to the customer. After installing the thermostats, the installers would program the thermostats setbacks based on customers preferences.

The population was stratified by total project expected savings to ensure adequate representation of larger and smaller projects.

Table 1 shows the distribution of completed surveys by stratum.

Table 1. Evaluation Sample Design and Survey Completes

Strata	**Gas Savings (MCF)**	**Electricity Savings (MWh)**	**Customers in Sample Frame**	**Total Completed Surveys[5]**
1	≥200	≥6.2	39	20
2	≥100 and <200	≥3.1 and <6.2	160	62
3	≥50 and <100	≥1.5 and <3.1	494	58
4	<50	<1.5	792	54
TOTAL			**1,485**	**194**

[4] For the purposes of this evaluation, a "customer" translates to a unique facility address.

[5] In the end, 180 valid survey respondents are discussed in this paper. Several cases were eliminated because they did not have adequate data with which to conduct the analyses.

The telephone survey instrument was designed to collect the data needed to support an impact evaluation of this programmable thermostat program. In the state in which this program operates, expected savings from programmable thermostats were deemed, and thus the state regulatory structure only required installation rates be used to adjust expected savings when certifying program savings. However, in order to conduct a more comprehensive analysis we collected a significant amount of additional information (i.e., temperature and usage characteristics of the old thermostats as well as temperature and usage characteristics of the new thermostat, business operating hours, days of week variability, etc.).

Findings

Engineering Adjustment Factors

Even though the primary objective of the impact evaluation was to verify installation, the evaluation team collected specific information on customers' usage characteristics allowing us to compute engineering adjustment factors and assess the assumptions underlying the program. In short, the *engineering adjustment factor* represents the percent of the assumption-based expected degree hours ($Expected_{DegreeHours}$) that were actually verified through the evaluation ($Actual_{DegreeHours}$). Our approach to computing the engineering adjustment factors involved plugging the actual data from our evaluation into the following:

$$SB_{Hours} = (Time_2 - Time_1) * 7$$
$$SB_{Degrees} = ABS(Temp_1 - Temp_2)$$
$$New.SB_{DegreeHours} = New.SB_{Degrees} * New.SB_{Hours}$$
$$Old.SB_{DegreeHours} = Old.SB_{Degrees} * Old.SB_{Hours}$$
$$Actual_{DegreeHours} = New.SB_{DegreeHours} - Old.SB_{DegreeHours}$$

$$Engineering\ Adjustment\ Factor = \frac{Actual_{DegreeHours}}{Expected_{DegreeHours}}$$

- $Time_1$ = Time the setback ended (in 24 hour-time, e.g. 8AM = 8)
- $Temp_1$ = The temperature setting for operational hours (in °F)
- $Time_2$ = Time the setback started (in 24 hour-time, e.g. 9PM = 21)
- $Temp_2$ = The temperature setting for non-operational hours (in °F)
- New = New programmable thermostats settings
- Old = Old manual thermostat settings

Table 2 shows the final engineering adjustment factors by energy type.

Table 2. Estimated Engineering Adjustment Factors by Energy Type

Thermostat Type	Sample Size	Engineering Adjustment Factor [a]
MCF (heat)	98	0.374
kWh (A/C)	83	0.266

a. Values shown are unweighted means of the phone survey samples.

Since these adjustment factors represent the percent of expected degree hours verified through the evaluation, if the assumptions about operation of new and old thermostats are correct, they should be very close to 1.000. However, the estimated values presented in **Table 2** suggest that only about one-third (37.4 %) of expected gas savings and just over one-quarter (26.6%) of expected electricity savings are actually being realized. Though rather low, these values are similar to other studies (Cross & Judd 1996, Haiad et al. 2004, KEMA 2006, Shipworth et al. 2010), even though most have been conducted in the residential sector. Overall, these results suggest the expected per-unit savings values for programmable thermostats are potentially too high.

To clarify the significance of the assumptions and provide a better understanding of how deviances from them might affect actual program savings, in the next section participants in the program are classified according to the schema presented in **Figure 1**.

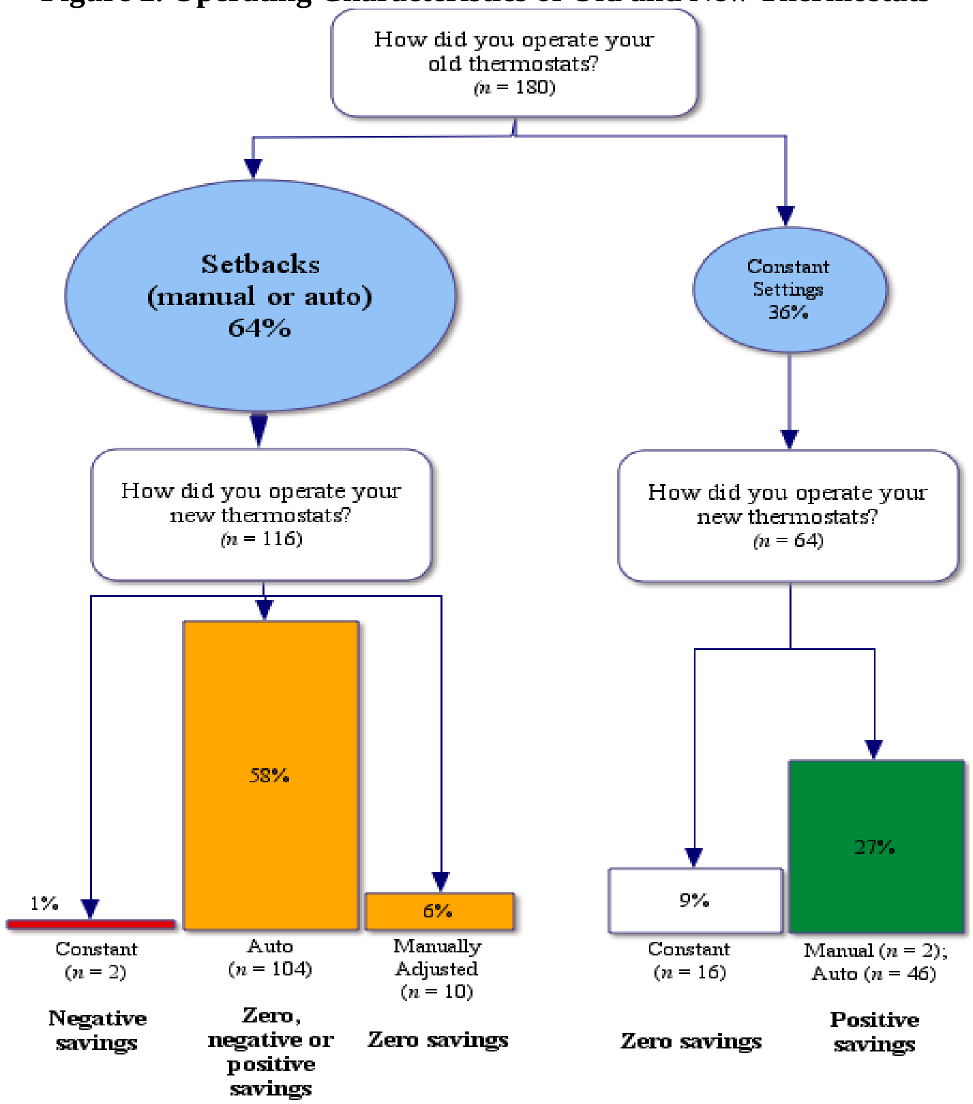
Thermostat Operating Characteristics

Error! Reference source not found. shows the results of the participating customer surveys revealing the operating characteristics of the old, replaced thermostats and the new programmable models. First, and maybe most important, note that only about one-quarter of all respondents (27%) indicated that they operated their old and new thermostats in accordance with the assumptions. More specifically, while about one-third of the respondents (36%) indicated that they operated their old thermostats with constant settings, 75% of these (27% of total) indicated they are using the new thermostat programmatically. These are the only respondents that we can confidently say amassed any energy savings for the program.

Of the customers that indicated they ran their old thermostats with constant settings, 25% (9% of total) indicated they are doing the same with the new unit. These thermostats account for no program savings. Only two of the 180 surveyed customers (1% of total) indicated that they operated their old thermostat with setbacks, but ran their new unit with constant settings. These are the only customers we can confidently say account for negative savings. It is also worth emphasizing from **Figure 2**, that only 18 out of 180 participants (10%) indicated they were not using any setback – manual or automatic – with their new thermostats. This figure is substantially lower than the percentage found in some residential studies such as EIA's (2005) Residential Energy Consumption Survey, which found that about 35% of U.S. households did not set back their programmable thermostats at night in the heating season.

Maybe most important, of the 180 total customers included in this analysis, almost two-thirds (64%) stated that they were already practicing energy efficient behavior by setting back their old thermostats for non-operating hours. About 98% of these (64% of total) indicated they continued this energy saving behavior with the new thermostat by allowing it run automatically with programmed settings (58% of total) or manually setting back the unit (6% of total). For this 64% of the surveyed customers, the only possibilities for accruing energy savings are if the temperature setback increased, the time setback increased, or they were inconsistent in how often they manually adjusted their old unit. Otherwise, if the setbacks remained the same, there is no savings; if the setbacks actually decreased, there is potential for negative savings. Additional analyses were conducted to see if time and temperature setbacks differed between old and new thermostats, and no statistically significant differences were found. However, statistically significant differences were detected when assessing setback hours. In fact, for heat, the mean weekly setback hours dropped from 100.54 for old units to 99.05 for new units (decrease of 1.49 hours/week; *p*=0.010); for A/C, the mean weekly setback hours also went down from 99.44 to 95.59 (decrease of 3.85 hours/week; *p*=0.013). Thus, even though no significant differences were detected in temperature setbacks, it is very possible for these customers, actual energy consumption with the new thermostats is greater than it was with the old units.

Figure 2. Operating Characteristics of Old and New Thermostats



Discussion

In this paper we present some results from a recent evaluation of a programmable thermostat program tailored to small businesses. In this program, participants received free programmable thermostats as replacement for older manual models. Similar to some residential studies (Cross & Judd 1996, Haiad et al. 2004, KEMA 2006, Shipworth et al. 2010), this study found that actual energy savings for the program likely do not meet the expectations. More specifically, the engineering adjustments factors were found to be quite low – 0.374 for gas and 0.266 for electricity. To better understand this, the evaluation team conducted an assessment of the assumptions underlying programmable thermostat program theory and expected energy savings value calculations for these devices. This small business evaluation, similar to residential studies (Haiad et al. 2004, Nevius & Pigg 2000, Meier et al. 2010), points to customers' operating behavior as the single most important factor affecting the energy savings potential of programmable thermostats.

Overall, the most salient finding from this paper is that approximately two-thirds of the responding small business customers were already practicing energy saving behaviors by manually adjusting their old thermostats. These numbers are in line with residential studies; Tachibana (2010) found 60% of Seattle residential customers to practice nightly setbacks with manual thermostats and Nevius & Pigg (2000) found 67% of Wisconsin households with manual thermostats to practice nightly setbacks.

Setbacks with manual thermostats are of primary importance because regardless of how customers use their new thermostats, if they were already adjusting their old ones, actual energy savings from the program will be quite limited – there is even potential for some *negative* savings. Indeed, our results showed that even though no significant differences were detected between old and new thermostat temperature setbacks for those that were adjusting the old units manually, significant differences were detected for both heat (decrease of 1.49 hours/week; p=0.010) and A/C (decrease of 3.85 hours/week; p=0.013). Reasons for this are not entirely clear from our data, but may be because typical customers had to manually turn off their old thermostats at the end of the day and turn it back on when arriving in the morning, but now can program the thermostat to turn on a little before they get in in the morning and go off a little after leaving. Thus, their setbacks are shorter and they are actually using *more* energy. The relatively small but significant differences detected add support to this interpretation.

One potential limitation to this study is the fact that the data relied upon are participant survey self-report data. Although the results are not presented here, in conducting the evaluation, a small subsample of survey respondents were randomly selected and asked if they would be willing to participate in an onsite inspection, which allowed the evaluation team to inspect the settings of the customers' thermostats and compare the actual settings to the settings they reported for the new thermostats in the telephone survey. Overall, the results were quite consistent and very little variability was found between the phone and onsite data. Other studies such as Nevius & Pigg (2000) have also suggested that self-reported thermostat settings are a good indicator of actual behavior.

In a similar vein, some studies have also questioned whether customers can effectively set back their thermostats manually. For example, in 2007, RLW Analytics conducted a billing analysis of the GasNetworks ENERGY STAR Qualified Thermostat Rebate Program for residential customers in the Northeast. As part of their analysis, RLW compared non-participants who said they controlled their manual thermostats to the rest of the control (non-participants who indicated no manual setbacks), and found that the customers who indicated manual control actually *increased* their gas usage by 25 ccf relative to the rest of the control.

In the commercial and industrial sector, due to shear size, a greater number of people typically occupy areas served by a thermostat than in residences. Plourde (2003) speculates that this could lead to "coordination problems" for manual thermostat adjustments. While that may be true for some businesses, in others, a designated employee might manage thermostats. The fact that most businesses are completely unoccupied at night could also increase the likelihood that businesses manually setback thermostats. While it is certain that thermostat behavior differs in some ways between the residential and commercial sectors, few studies have attempted to elucidate what those differences may be.

The results of this study suggest that thermostat operating behaviors in the small business sector may be similar to those in the residential sector. The similar scale of small businesses and households might explain the similar results; many small businesses have a relatively small staff. Motivations – namely economic – may overlap for the two sectors as well. Utility bills can represent substantial costs for "mom-and-pop" stores just like they can for the average household. However, another reason for this similarity may simply be that the small business population is a subset of the residential population and the behaviors they practice at home are similar to those they practice at work. Nevertheless, these explanations remain speculation and more research is needed to answer this question definitively.

Nevertheless, the reality is that the energy efficiency industry has existed for over two decades, and many people have been practicing energy saving behaviors for even longer. During the 1970s, perhaps as an artifact of the energy crisis, one author remembers his parents and grandparents turning the air conditioning down at night or when not home during the hot, muggy Midwest summers, and turning the heat down at night or when not home during the cold winters. So maybe it should not be surprising that today, after years of exposure to the notion of energy efficiency and the current national energy supply concerns, about two-thirds of the program participants surveyed for this evaluation indicated that they were already practicing energy saving behavior prior to receiving the programmable thermostat.

Regardless, the potential for programmable thermostats to provide energy savings is not a closed subject. New energy efficiency programs continue to arise where programmable thermostats are considered viable energy saving devices. Nevertheless, to date, relatively little attention has been allocated to the bigger issue of how the long-accepted assumptions that play such a dominant role in programmable thermostats programs actually manifest during program implementation. In reality, it is likely that most expected per-unit savings values that rely on these assumptions greatly overstate actual savings. This is not necessarily fatal to these programs – some savings almost certainly do accrue as a result of these devices. However, if implementers continue to recruit customers that are manually adjusting their older units, at the program level, some of the installed units will likely result in no actual energy savings. If customers already performing energy conserving behaviors cannot be effectively precluded from participating in these programs, one possible solution could be to allocate effort to accurately estimating the prevalence of these particular participants. These estimates could then be used to adjust expected energy saving values derived through current procedures to more realistically represent actual energy savings.

In conclusion, the results and findings outlined in this paper suggest the need for reconsideration of the assumptions underlying expected per-unit energy savings calculations for programmable thermostats. One dominant finding prevails: if programmable thermostat programs are solely built on the underlying assumption that all old thermostats were operated using constant settings, actual impacts for the program are destined to disappoint.

References

Boait, P. and Rylatt, R. 2010. A method for fully automatic operation of domestic heating. *Energy and Buildings:* 42(1), 11-16.

BuildingMetrics, Inc. 2011. *Michigan Statewide Energy Savings Database: Weather Sensitive Retrofit Measures for Residential and Commercial Buildings*. Boulder Colo.: Morgan Marketing Partners.

Cross, D., and Judd, D. 1997. Automatic Setback Thermostats: Measure Persistence and Customer Behavior. In *Proceedings of 1997 International Energy Evaluation Conference*, Chicago, Ill.

[EIA] Energy Information Administration. 2005. *Residential Energy Consumption Survey: Space Heating Characteristics by Housing Unit*. Washington, D.C.: U.S. Department of Energy.

[EPA] U.S. Environmental Protection Agency. 2003a. *Summary of Research Findings from the Programmable Thermostat Market*. Memo to Manufacturers on Programmable Thermostat Specification Review. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/thermostats/Summary.pdf. Washington, D.C.: U.S. Environmental Protection Agency.

[EPA] U.S. Environmental Protection Agency. 2003b. *Cover Letter*. Memo to Manufacturers on Programmable Thermostat Specification Review. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/thermostats/Cover_letter.pdf. Washington, D.C.: U.S. Environmental Protection Agency.

[EPA] U.S. Environmental Protection Agency. 2008. *ENERGY STAR Program Requirements for Programmable Thermostats: Version 1.2*. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/thermostats/specv1.2.pdf. Washington, D.C.: U.S. Environmental Protection Agency.

Haiad, C., Peterson, J., Reeves, P., and Hirsch, J. 2004. *Programmable Thermostats Installed into Residential Buildings: Predicting Energy Savings Using Occupant Behavior & Simulation*.

KEMA, Inc. 2006. *Evaluation of the 2004-2005 Partnership in Energy Affordability in Multi-Family Housing Program*. San Francisco, Calif.: California Public Utilities Commission.

Manjoo, F. 2011. “Home Thermostats, Wallflowers No More.” *The New York Times*, 7 Dec. 2011.

McCracken, H. 2011. “Reinventing the Wheel.” *Time Magazine*, 5 Dec. 2011.

Meier, A. 2011. *Thermostat Interface and Usability: A Survey*. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Meier, A., Aragon, C.,Peffer, T., Perry, D., Peffer, T., and Pritoni, M. “How People Actually Use Thermostats.” In *Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency Buildings*. Pacific Grove, Calif.: American Council for an Energy-Efficient Economy.

Nelson, L., & MacArthur, J. 1978. "Energy Savings through Thermostat Setbacks." *ASHRAE Transactions* 83 (1): 319-333.

Nevius, M., and Pigg, S. 2000. "Programmable Thermostats that Go Berserk? Taking a Social Perspective on Space Heating in Wisconsin." In *Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings*. Pacific Grove, Calif.: American Council for an Energy-Efficient Economy.

Nextant. 2007. *Arkansas Deemed Savings Quick Start Program Commercial Measures: Final Report*. Houston, Tex.: Frontier Associates, LLC.

Pigg, S and Nevius M. 2000. *Energy and Housing in Wisconsin: A Study of Single-Family Owner-Occupied Homes*. 2000. Madison, Wisc.: Energy Center of Wisconsin.

Plourde, A. 2003. *Programmable Thermostats as Means of Generating Energy Savings: Some Pros and Cons*. Canadian Building Energy End-Use Data and Analysis Centre, Technical Report CBEEDAC 2003-RP-01.

Rathouse, K. and Young, B. 2004. *RPDH15: Use of Domestic Heating Controls*. Watford: Building Research Establishment (UK).

RLW Analytics. 2007. *Validating the Impact of Programmable Thermostats*. Middletown, Conn.: GasNetworks.

Shiller, D. 2006. *Programmable Thermostat Program Proposal*. ENERGY STAR Programmable Thermostat Industry Meeting. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/thermostats/Proposal_011106.pdf. Washington, D.C.: U.S. Environmental Protection Agency.

Shipworth, M., Firth, S., Gentry, M, Wright, A, Shipworth, D., and Lomas, K. 2010. Central heating thermostat settings and timing: building demographics. *Building Research & Information*: 38(1), 50 - 69.

Tachibana, D. 2010. *Residential Customer Characteristics Survey 2009*. Seattle, Wash.: Seattle City Light.

Vermont Energy Investment Corporation. 2010. *State of Ohio Energy Efficiency Technical Reference Manual*. Burlington, Vt.: Public Utilities Commission of Ohio.