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## **EMERGING REQUIREMENTS FOR RESIDENTIAL THERMOSTATS IN NORTH AMERICA**

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### **ABSTRACT**

The requirements for thermostats are increasing in the U.S. for a combination of reasons. Firstly, energy conservation and Demand Response programs are requiring thermostats to have more complex controls that can communicate with electric utilities. Other pressures are caused by the increasing sophistication in U.S. homes such as systems for mechanical ventilation, economizers and ventilation cooling that interact with operation of heating and cooling systems via thermostat controls. In order to meet these challenges, U.S. thermostat manufacturers and regulators are focusing on improving user interfaces, developing standardized communication protocols and meeting the requirements of pending legislation

### **KEYWORDS**

Thermostats, energy conservation, California, regulations

### **INTRODUCTION**

The thermostat converts occupant thermal comfort preferences into operations by heating and cooling systems in modern homes. Thermostats have gradually evolved to match the increasing sophistication of the heating and cooling systems that they control. Early models in North America were simple electromechanical devices matched to forced-air systems (which are the most common systems in North America). Modern thermostats often contain microprocessors and allow the occupant to set desired maximum and minimum temperatures according to a pre-arranged schedule. Other features include operating in a ventilation mode (as opposed to heating or cooling), de-humidification, and controlling multi-stage operation of heat pumps. These options allow consumers to minimize heating and cooling costs while maintaining acceptable thermal comfort.<sup>1</sup> Figure 1 shows a typical programmable thermostat designed to control a forced-air heating and cooling system.

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<sup>1</sup> Nevertheless, few American thermostats match the complexity or sophistication of thermostats used today in Japanese-style mini-split heat pumps. One explanation is that fewer options are feasible when heating and cooling centrally.



Figure 1. A typical programmable thermostat

Recent changes in building codes and elsewhere will require thermostats with more capabilities. This paper outlines these developments and speculates about the long-run implications.

## **CHANGES IN ENERGY STAR SPECIFICATIONS FOR PROGRAMMABLE THERMOSTATS**

In 1995, the Energy Star program (Energy Star 2007) established specifications for programmable thermostats. (A Programmable Thermostat enables the user to establish a schedule with different temperatures. Energy Star recognized that a programmable thermostat could greatly reduce heating and cooling costs by lowering (or, during the summer, raising) indoor temperatures when occupants were away or slept. Computer simulations and actual measurements demonstrated that a correctly programmed thermostat could often save 15% or more from heating and cooling bills. Manufacturers and retailers offering thermostats meeting the Energy Star specifications were allowed to use Energy Star endorsement materials and benefited from an aggressive public relations campaign run by the Energy Star program.

In 2006, however, Energy Star terminated the original program endorsement program and replaced it with a much weaker consumer information program (Energy Star 2007). Its decision was based on a growing body of evidence that programmable thermostats did not deliver the expected energy savings and possibly increased use of heating and cooling energy in many homes. In some studies, homes equipped with programmable thermostats consumed more energy than those homes relying on manual thermostats. Energy Star (and the authors of the individual studies) offered several explanations for these counterintuitive results. One key reason is that many people were already using manual thermostat schedules that mimicked the automatic schedules used in the Energy Star thermostats. It was also speculated that many occupants never learned to correctly program the thermostats in the first place. Other consumers over-rode the thermostat's automatic features and operated them like a switch (e.g., off and on) and in other cases, the programmable thermostat was simply less effective than constant vigilance by the occupants. These studies as a group strongly suggested that programmable thermostats increased energy use but they were not designed to determine how much energy would have been used without the programmable thermostats or that self-selection had occurred. A recent study (RLW Analytics 2007) that focused on a heating dominated climate (New Jersey) and included a much larger sample of several thousand homes concluded that programmable thermostats saved about 6%. This final study suggested that climatic variability was responsible for the different results. It further suggested that the Energy Star thermostat savings estimates could be valid in more extreme climates, but overestimate the savings for mild climates.

After terminating the program, Energy Star left open the possibility of restoring the endorsement program for programmable thermostats. However, the manufacturers would still need to offer improved technologies, interfaces, and field verification that the improved thermostats will reliably save energy compared to manual operation. A new Energy Star thermostat (if approved) would almost

certainly need to conform to new requirements imposed by building codes and electric utilities. These requirements are discussed below.

## **NEW VENTILATION REQUIREMENTS IN CALIFORNIA'S BUILDING CODE**

In 2008, California's building energy code—often referred to as Title 24 (CEC 2007)—will require mechanical ventilation systems in all new homes. This measure was taken to ensure that adequate indoor air quality would be maintained without reliance on natural air infiltration. Sweden, Canada, and Japan, already require mechanical ventilation but systems in U.S. do not. This is mostly because historically homes in the U.S. were very leaky and it was considered that natural infiltration provided sufficient ventilation. However, new construction in the U.S. is becoming tighter and the need for mechanical (or reliable passive) ventilation is increasing - particularly in energy efficient housing (Sherman and McWilliams 2005).

Several ventilation technologies will be used in California. The first uses continuously operating exhaust fans in bathrooms. This approach is already widely used in Europe. The second technology operates the exhaust fan on a timer so as to avoid operation at times of peak heating or cooling ventilation load. This timed operation system could be controlled by the clock in the thermostat. A third technology intermittently supplies fresh air through the forced-air heating and cooling system. The latter system is controlled by, or be coordinated with, the thermostat through a fan cycling control and motorized damper.

Other parts of the United States and Canada will probably implement similar requirements after California so the demand for effective controls will soon be larger than just California. Modern thermostats capable of reliably controlling ventilation are now becoming available in the U.S., such as the intermittent supply air system described above and residential ventilation cooling and economizer systems that deliberately use outdoor air to provide space conditioning.

## **DEMAND RESPONSE AND COMMUNICATING THERMOSTATS**

After California's 2001 electricity crisis, the state made control and reduction of peak electrical demand a priority. The policies consisted of both mandatory and economic measures. The mandatory measures included revisions of the state building energy code in 2005. The new code required numerous design changes aimed to buildings' reduce peak electricity demand (as opposed to simply conserve energy).

Other measures give consumers economic incentives to avoid consuming electricity during periods of peak demand. This approach is often called "Demand Response". An important element of Demand Response is to adjust the price of electricity based on the cost of providing it. During periods of peak demand the price of electricity will rise sharply, sometimes to over ten times the base rate. Demand Response leaves consumers the option to not respond but they will be required to pay very high electricity California hopes to control about 5% of peak demand through Demand Response (Herter et al. 2002). Note that Demand Response programs differ from Demand *Control* programs. Demand Control programs take over control of the consumers' equipment (typically by periodically switching them off or changing thermostat setpoints) during critical periods.

Air conditioning is the largest contributor to peak power demand in much of the U.S., so most Demand Response programs seek to reduce air conditioning electricity use in residential and commercial buildings. One of California's Demand Response programs will require the installation of thermostats capable of receiving price signals and adjusting the temperature in response (CASE 2006). The "Programmable Communicating Thermostat" (or PCT) specification will be proposed for adoption in January 2008 and, if adopted, will be required in new homes after April 2009.

The PCT is unique in that it will be capable of receiving different kinds of signals from the utility. During normal conditions, the utility will broadcast electricity price signals but, in case of a grid emergency, it can also send control signals. The thermostat will respond to the price signals by raising indoor temperature (if programmed to do so). One important feature of the PCT will be standardized communication protocols which will permit interoperability among systems. These signals may be radio frequency broadcasts, available through the internet, or possibly via the electricity distribution network (the wires connected to the house). The communications protocols for the PCT are still under development and must address important issues related to security and one-way addressing. Nevertheless, manufacturers are already designing thermostats to comply with expected specifications and at least one prototype is available.

## **DISCUSSION**

In addition to the normal pressures to offer new features, the examples above demonstrate that other issues are strongly influencing the design of future thermostats. On one side new responsibilities are being added to thermostats (e.g., ventilation control and Demand Response) which add to the device's complexity. At the same time, Energy Star is retreating from specifications because it found that current levels of complexity may have contributed to lack of savings. Issues of complexity also depend on who is installing and/or programming the thermostat: either the building occupants or a contractor/installer. Incidentally, it is not clear which of these two groups is necessarily more sophisticated and better able to master more complex controls. Energy Star has to date not considered specifications for thermostats that would include capabilities to address ventilation and peak power demand.

These specifications need to be coordinated to so as to ensure that the desired results are achieved. In some cases priorities must be established. For example, should mechanical ventilation be suspended during periods of peak demand? Put another way, should ventilation take precedence over peak power demand? Indoor air quality standards suggest that short term interruptions of ventilation for a few hours are acceptable from a long-term exposure point of view. However, if we want to retain the ability to eliminate chronic short term pollutants then some sort of ventilation override is required. This ability to reduce ventilation load under peak conditions can save energy and, more importantly, have a significant reduction in peak building load (a key concern for Demand Response programs).. In some areas, the air quality during periods of peak electrical afternoon (typically very hot afternoons) may be worse outside than inside (e.g., ozone in Southern California).

The Energy Star experience suggests that the user interface to thermostats needs to be improved. There has been almost no research on user comprehension of existing displays, symbols, controls. Adding new features will further complicated the user interface and the likelihood that users select incorrect settings. Certain aspects may need to be standardized. A standardized user interface for power management of computers and related equipment has already been adopted by IEEE and supported by Energy Star. The standardization requires that manufacturers use certain symbols, terms, and actions identical across all products. A similar standardization of user interface may be needed for thermostats if we want to improve the likelihood of contractors correctly installing controllers. Standardization may also help consumers who install their own thermostats, but this is likely to be less of an effect than for contractors because consumers will very rarely install a thermostat.

The examples above also demonstrate the growing number of products whose operation is either controlled or needs to be monitored by the thermostat. Here, too, standardized protocols for communication will be increasingly important. Some progress has already been made although the protocols are often proprietary and hinder interoperability.

The thermostat has traditionally been a component of the heating and cooling systems. However, advances in consumer electronics, communications, and product design may cause thermostats to become separate from the heating and cooling systems. Future thermostats may reside in PCs, digital picture frames (such as Figure 2), or other kinds of remote controls. This evolutionary step must wait until communication protocols are standardized.



Figure 2. The digital picture frame is a possible new home for the residential thermostat

## CONCLUSIONS

The thermostat plays a key role in assuring thermal comfort and indoor air quality in homes. New codes, incentives, and technologies will stimulate important changes in the residential thermostat in North America. The principal drivers in the U.S. are revised building codes (particularly in California), which require mandatory ventilation and raising temperatures during summer electricity shortages. Response to electricity shortages will require a degree of communication between utilities and homes never before undertaken in the United States.

By withdrawing its endorsement of programmable thermostats, the Energy Star program has challenged manufacturers to develop new thermostat designs that will more reliably save energy. This may require entirely new user interfaces and a greater understanding of how consumers actually select a level of thermal comfort.

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