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How people use thermostats in homes: A review

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ABSTRACT

Residential thermostats control a substantial portion of both fuel and electrical energy—9% of the total energy consumption in the U.S. Consumers install programmable thermostats to save energy, yet numerous recent studies found that homes with programmable thermostats can use more energy than those controlled manually depending on how—or if—they are used. At the same time, thermostats are undergoing a dramatic increase in capability and features, including control of ventilation, responding to electricity price signals, and interacting with a home area network. These issues warrant a review of the current state of thermostats, evaluating their effectiveness in providing thermal comfort and energy savings, and identifying areas for further improvement or research.

This review covers the evolution in technologies of residential thermostats; we found few standards and many features. We discuss studies of how people currently use thermostats, finding that nearly half do not use the programming features. The review covers the complications associated with using a thermostat. Finally, we suggest research needed to design—and especially test with users—thermostats that can provide more comfortable and economical indoor environments.

1. Introduction

Heating and cooling homes consumes a substantial portion of energy. Most households in the U.S.[1] use thermostats to control the heating and/or cooling system in their home; in 2005, approximately 97% of households in the U.S. had a heating system and over 75% had air conditioning (Table 2.6 in [1]). In 2008, about a quarter (28% or 6.04 quadrillion BTUs) of the total residential source energy consumed was for heating and 14% (3.07 quadrillion BTUs) for cooling [2]. Most (65%) of the energy supplied by fuels (primarily natural gas, also fuel oil and propane) was for heating [3], but the use of electricity for heating nearly doubled from 1985 to 2005. While approximately 20% of total residential electrical energy was used for cooling, air conditioning constitutes the largest single contributor to peak electricity demand (which can lead to brownouts and wildly variable wholesale prices) [4]. Moreover, electricity use for air conditioning is rapidly increasing, due to population growth in hot climates and greater demand for comfort. In 2009, nearly 90% of newly constructed single family homes included air conditioning [5]. In 2008, energy for heating and cooling homes comprised approximately 42% of the total source residential energy and about 9% of the total source energy in the U.S. [2,6].

The basic function of the typical residential thermostat—to set a target temperature, see the current temperature, and control the equipment accordingly—has remained constant over the past sixty years. A second—and expanding—role is to save energy. Many new features and functions have emerged in the past twenty years to facilitate the energy-saving role. While the thermostats' capabilities to control temperature are well understood, less is known about the effectiveness of the technologies devised to enable savings. The uncertainty in these savings is increasingly important because manufacturers are adding many new features and functions that affect the ability and ease of saving energy. The most advanced thermostats control multiple zones and humidity levels. Still other features include one-touch energy-savings, access to weather, display of energy consumption, alerts for maintenance (e.g., battery, filter), and diagnostics [7]. Remote control is becoming a popular feature as smart phones and Internet access become ubiquitous. Some changes are dictated by regulations or utilities. Since 1978, California building codes have required thermostats with night setback capabilities and many other regions followed. The Environmental Protection Agency (EPA) established

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[1] The thermostats described in this paper mostly control forced-air systems found in North Amercian homes. However, many of the same issues apply to other heating and cooling systems found in Europe, Australia, and East Asia.

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