"Smart" Residential Thermostats:
Capabilities, Operability and Potential Energy Savings

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Overview

A study by Pike Research indicates that the home energy management sector is struggling.[1] In part, this may be because smart thermostats and the smart grid have been over-hyped. Other studies state that no "killer application" has yet been found.[2]

Utilities (and regulators) are unsure of the magnitude and persistence of potential energy savings promised with the use of smart thermostats and may view them as being a poor value proposition. To make smart thermostats work, homeowners need to invest in additional tools – home energy displays, software and sensors – and properly install them (or hire a contractor to install them) to obtain real-time feedback on their energy consumption.[3] Yet, some estimate that approximately 6 million U.S. households (5 percent of the total) will use some type of home energy management device by 2015.[3]

Following is a brief discussion of the baseline and potential for increased use of smart thermostats in the Northwest. The discussion contains a summary of smart thermostat capabilities, addresses the energy savings potential of utility-sponsored residential behavior change approaches and smart thermostat adoption programs, and provides an overview of the comfort and appliance control features that might be expected in future smart grid programs.

Heating and Cooling System Types

NEEA recently sponsored a "Residential Building Stock Assessment." This 2012 study, conducted by Ecotope, consisted of 1,406 field surveys of single-family homes throughout the Northwest region (Washington, Oregon, Idaho and western Montana). Average house size was 2,006 square feet. Ecotope examined the HVAC system in each home and found that electricity is the primary source of space heating for 34.2 percent of all homes, or approximately 1.37 million of the region's 4,023,937 single-family residences.[4] The distribution of primary heating sources by heating system type is given in Table 1.[4]

Ecotope found that 465 homes, or 33.1 percent of the total population surveyed, listed wood or pellet heating stoves as their primary or secondary heating system. An additional 88 homes listed fireplaces as their secondary heating source.[4] This suggests that approximately 39.4 percent of the region's homes are wholly or partially reliant on wood or pellet stoves and fireplaces. Electrical energy savings from improved space heating comfort control (smart thermostats) are greatest in the 245,460 homes that use forced-air electric furnaces as their primary heat source. Zone control strategies are typically used in the other homes with electric-resistance heat (mostly baseboard and some wall heaters). Electrical energy savings potential from smart thermostats are diminished in homes with heat pumps unless the savings are from smart heat pump controls, and in homes where backup wood or pellet stoves have significant use.

Table 1. Heating System Types in the Northwest

Heating System Type	Percentage	Count
Forced Air Furnace, non-electric	48.0	702
Forced Air Furnace, electric	6.1	
Ductless Heat Pump	1.4	25
Baseboard Heater	12.3	209
Boiler	5.1	83
Fireplace	0.1	2
Ground Source Heat Pump	0.8	14
Air Source Heat Pump	11.4	166
Dual Fuel Heat Pump	1.2	17
Heating Stove	12.8	201
Plug-In Heater	1.0	14
Totals:	100.2	1,433
Note: 46 of the 1,406 homes in the survey listed two primary heating systems, usually heating separate zones.		

Source: NEEA Residential Building Stock Assessment, 2012

The Ecotope study found that about 42.3 percent of all residences region-wide have cooling equipment. The percentage varies widely by cooling zone (as defined in the Northwest cooling zone map by the Northwest Power and Conservation Council, http://www.nwcouncil.org/energy/rtf/zones/regional_cool.pdf). About 31.6 percent of homes in Zone 1 have cooling equipment and 85.4 percent of the residences in Zone 3 have cooling capability.[4] About 23 percent of all primary cooling systems consist of single zone package terminal air conditioners (PTACs), evaporative coolers, or window air conditioners.[4] Approximately 40 percent of the residences with cooling systems have central air conditioning. This equates to about 679,000 homes. The remaining homes are cooled by ground source, air source, or ductless heat pumps.[4]

Heating and Cooling System Setpoints

The average heating thermostat setpoint was 68.7°F, with little variation by state.[4] About 69 percent of homes adjusted the thermostat setpoint down during sleeping hours (night setback), with the average setback being 6.5°F.[4] This setback is automatic when entered into programmable thermostats. In other cases, the occupant manually adjusts the thermostat on a nightly basis.[4]

The average cooling thermostat setpoint was 73.5°F, with an average thermostat “setup” of 9.6°F,[4] which refers to the temperature adjustment during the day when the house is unoccupied. Only 10 percent of the households with cooling made or programmed adjustments to their cooling patterns.[4] Ecotope states that their survey questions may not have captured the percentage of homes that turned the air conditioning *off* during working hours.

Benefits of Using Programmable Thermostats

Programmable thermostats are the baseline technology for residential temperature control. They are in widespread use and are required for new construction by the energy codes. Programmable thermostats allow users to enter a heating or cooling temperature setpoint and a night setback or setup temperature for each day of the week. Most devices contain an "override" and also allow the user to specify a vacation – or "away" – setting. Comfort control is thus automatic, unless the user elects to change the settings.

Programmable thermostats include a warm-up feature that starts the HVAC system in advance so the area of the building that is controlled by the thermostat is at the desired temperature at the prescribed time. Some of the more sophisticated thermostats also provide "intelligent recovery" that will pre-heat the home based on the outside air temperature; this is done early enough so the setpoint can be achieved by the time set by the user. In the case of heat pumps, intelligent recovery implies that the setpoint is achieved at the preset time with as little use of the auxiliary heat as possible. The Washington State Energy Code requires seven-day comfort control with four control periods per day (e.g., wake, day, evening, sleep), a minimum 5°F deadband between heating and cooling, vacation setback mode, auto-start with intelligent recovery, and heat pump strip heat lockout capabilities.

The U.S. Department of Energy has estimated that the average homeowner can save between 5 and 20 percent of their heating and cooling costs by using a programmable thermostat.[5] Some field studies have shown no significant savings in households using programmable versus non-programmable thermostats. These studies point out that programmable thermostats are only used successfully by about 50 percent of home occupants,[3] although estimates vary among the different studies. The programmable thermostat itself does not guarantee energy savings; savings depend on how the device is programmed and used in each household versus how a manual thermostat would be used in that household.[5]

Barriers to energy savings occur when devices are not used as designed due to programming and design issues, such as buttons and fonts that are too small, abbreviations that are hard to understand, and difficulty with details involved in programming. Most people do not have an interest in tinkering with their thermostats to optimize performance.[5] Other studies indicate that only about 50 percent of programmable thermostat users actively use programmed schedules.[6]

Large-scale billing analysis studies from 2007 that surveyed 7,000 households concluded that savings of about 6 percent in energy consumption are attributable to programmable thermostat use.[5] A survey conducted in Seattle of 2,300 respondents indicated that thermostats that were programmed correctly reduced electrical energy consumption by an average 9 percent when contrasted with manual thermostat control.[5]

Approaches to Influence Consumer Behavior

Some utilities attempt to change consumer behavior by providing whole-house energy consumption feedback to homeowners based on an analysis of monthly billing data. The feedback can estimate appliance use and include historical and social comparisons (e.g., comparisons with neighbors). Processed feedback can be delivered in billing statements, or on a customer's computer or smartphone. Approaches to change consumer behavior can include energy tips, tailored energy efficiency suggestions, goal setting, and incentives such as rewards or entry into a prize drawing for those who demonstrate energy use reductions.[7]

Behavior science-based approaches to saving energy must be designed to reflect how people are motivated, take into account issues that may act as barriers, and recognize that customer attitudes and preferences are not consistent.[7] Some claim that purely behavior-based programs can produce energy savings of 2 to 10 percent, with some suggesting even greater savings.[7] Bi-monthly Home Energy Reports to customers (provided by OPower, which offers a low-cost behavior-based approach to saving energy, http://opower.com/what-is-opower) enabled the Sacramento Municipal Utility District (SMUD) to achieve a 1.9 percent reduction in energy use and Seattle City Light to achieve 2 percent savings. With a similar approach, PSE reports 1.7 to 2.0 percent savings – about 200 kWh/year per household.[7]

Snohomish County PUD established a program in which participants commit to using 10 percent less electricity. Motivators include feedback, social norms, tips, email contacts and entry into a quarterly prize drawing. In a similar approach, BC Hydro's Power Smart program asks participants for a commitment to save 10 percent while providing constant feedback, support and encouragement. Participants receive a $75 reward when their 10 percent savings goal is achieved.[7]

Other programs adopted by utilities include community competitions and reward points for kWh savings that can be redeemed at local merchants.[7] OPower has recently partnered with Honeywell to offer a "customer engagement platform" for electric utilities. While questions remain about the persistence of program-induced savings, smart thermostats may play a significant role in keeping customers engaged in behavior-based programs.

Smart Thermostat Capabilities

Home energy management systems differ from traditional programmable thermostats in the type of control device (monitoring or managing use at a central or remote point), degree of automation, user interface (home energy display, dashboard or portal, smartphone application, type of raw and processed information displayed), and enabling approach.[3] The enabling approach consists of information gathered by sensors and other data acquisition devices and communications. This time-based information undergoes outside analysis and is delivered to the consumer via periodic reports to influence them to adopt energy-saving behaviors.

Smart thermostats come with layers of features, ranging from dashboard home energy displays, interview-based programming, remote access for comfort and/or appliance control and adaptive learning to full home energy automation with interconnection to the smart grid. Smart thermostats generally must have two specific capabilities:

- The ability to run programs for each day of the week that use temperature setbacks or setups during unoccupied periods or at night, and
- External communications that may include Internet connectivity or access through mobile applications to a web portal.[6] Portals often offer remote viewing and setpoint control, energy use information, energy tips and energy efficiency case studies.

Surveys indicate that users of smart thermostats desire automation features, weather information and goal-setting assistance.[10] A smart thermostat can control a single device (central forced-air furnace or heat pump). Some can communicate with multiple control devices within the home, allowing the user to manage them from a single central or remote location.[2]

The majority of smart thermostats can be connected with two low-voltage wires, making do-it-yourself installation relatively easy. Suppliers of smart thermostats include Honeywell, the Radio Thermostat (also marketed as Filtrete or Homewerks), ecobee, Emerson, Venstar, Proliphix, Aprilaire, Lux, Robert Shaw, Lennox, Carrier, Bay Controls, Evolve, Hunter, Jackson Systems, ICM Controls, Net/X, Intwine Energy, Schlage Nexia, Enphase Energy, Energate, Trane and LockState.

We focus here on smart thermostats that "do the thinking for their owners"; in particular, thermostats with self-programming and adaptive learning capabilities that may help achieve additional energy savings.[6] A brief discussion of smart thermostat features and capabilities follows.

Dashboard Home Energy Displays (HEDs)

Many smart thermostats can provide direct or indirect feedback, including near-real-time whole-house energy consumption, historical comparisons, plus trends and weather-corrected trends that assist in goal setting. The HEDs can also provide personalized and targeted recommendations for energy saving, and provide assistance on how to act on savings recommendations (such as links to utility incentive programs).[2] Other approaches include social comparisons to help consumers gauge their own consumption patterns against those of their neighbors.[8]

How much additional energy can be saved by engaging homeowners with real-time energy usage and cost information?[9] Product effectiveness and savings persistence vary widely and depend on consumer experience. Continued interaction between the occupants and technology dictates how effective home energy management approaches are likely to be.[2]

The Fraunhofer Center for Sustainable Energy Systems completed a study of consumer adoption and response to use of Home Energy Displays (HEDs).[10] These displays make energy use visible and are designed to encourage energy savings through feedback and provision of energy savings tips. The goal is to modify and, hopefully, permanently change occupant behavior. The Center found that energy savings were compromised because the available HEDs fail to engage consumers and maintain interest in energy use and savings over the longer term.[10]

Some studies indicate that even simple HEDs can produce temporary energy savings of up to 10 percent, and more complex displays result in higher savings. Many HED studies are of limited duration, and longer-term evaluation suggests that savings are not sustained after a 15-month interval.[10] Research is needed on feedback designs that sustain engagement and provide long-term energy savings.[10]

A significant survey finding is that consumers are likely to spend little time using their HED systems, and that HEDs need to be more engaging to compete with other media. Simply showing how much energy is being used or has been used is not actionable information.[1] Users also desire multi-media access to energy use information, including a display mounted on a counter or wall, a web portal, and smartphone access to energy use data.[10] Incorporating HED functions into smart thermostats or web portals is a natural fit.

Interview-Based Programming

Some equipment manufacturers attempt to eliminate thermostat programming difficulties by offering voice-controlled thermostats. This feature, which simplifies thermostat interactions involving initial setup and out-of-schedule requests, is particularly desirable for elderly or people with physical disabilities.[5] Automated systems that limit human interaction reduce or eliminate the requirement for user programming.[5] One example is the interview-based programming provided by the Honeywell Prestige 2.0 Comfort System, available for about $250 (http://yourhome.honeywell.com/home/Products/Thermostats/7-Day-Programmable/Prestige+HD+7-Day+Programmable+Comfort+System.htm). The thermostat asks questions of the homeowner and then programs itself based upon responses. The on-screen display may also be set for English, Spanish, or French languages. For those unable to install their newly purchased thermostats, Honeywell offers a link to local installers plus a link to utilities that offer rebates. Many homeowners may prefer this “set and forget” approach to home energy management.[3]

Built-In Energy Optimization or Adaptive Learning Capabilities of Available Products

Several smart thermostats are equipped with an intelligent controller that is used to recognize patterns and take into account variables involving weather, house and HVAC characteristics. Manufacturers of these devices claim additional energy and cost savings, although the magnitude of the savings is not science-based. A brief discussion of the features associated with the advanced smart thermostats follows.

ecobee

The award-winning ecobee smart thermostat was introduced in 2007 and has been upgraded multiple times. It was the first Wi-Fi-enabled thermostat and may be controlled remotely through iPhone, iPod and Android applications. A web portal potentially offers complete control over all aspects of a homeowner’s systems. ecobee’s Home IQ™ provides information on energy savings, equipment performance details, weather updates and alerts. ecobee’s DataRhythm™ technology can use HVAC equipment type, historical run times and weather data to make automated, personalized and optimized heating and cooling decisions that result in additional energy and cost savings. (When you register the thermostat, ecobee uses your address to find the closest weather station to your home). E-mail reminders or alerts are posted when periodic HVAC maintenance or furnace filter changeouts are due. ecobee offers customers an energy usage portal that stores up to 15 months of data, allowing for year-to-year comparisons.[6] ecobee cites a study that estimates that the average homeowner saves 26% on their heating and cooling costs when using ecobee compared to a benchmark of leaving their thermostat on hold at 72°F. The cost for the ecobee Smart Si wireless thermostat is about $170. The unit can be self-installed. (See http://www.ecobee.com/solutions/home/smart/.)

Emme (Energy Management Made Easy)

The Energy and Environmental Management System (E2MS) Emme smart thermostat provides advanced controls along with detailed energy monitoring, and allows users to control their HVAC system from a PC, smartphone or tablet. The E2MS claims the Advanced Thermal Model (ATM) can provide up to 30 percent savings on annual heating and cooling costs by analyzing weather conditions, forecasts, remote temperature sensors and historical performance for an individual home. Emme Room-by-Room provides SmartZoning™ so users can separately control comfort within each room in a dwelling and monitor heating and cooling costs with a room-by-room display. (See http://www.getemme.com/.)

Nest

The Nest was introduced in the fall of 2011 and was heavily marketed as *the* killer application. Nest is an Apple-like product (it was developed by ex-Apple executives) touted as a "next generation" thermostat. It is designed to be visually attractive with a user-friendly interface. Like its competitors, Nest is web-enabled, so it allows users to remotely observe occupied or away temperature setpoints, change schedules or setpoints, or turn comfort systems off using a smartphone, tablet, or PC. Users can program Nest directly or rely on a self-programming or schedule-builder mode. Nest has the ability to program itself based on occupancy sensor information and by remembering manual adjustments. New owners use the Nest as a manual thermostat for the first week, setting comfort setpoints and employing setbacks when they leave for work or go to sleep.[6] The Nest then builds a programmed schedule based on user preferences.

Nest is equipped with an occupancy sensor and has an auto-off feature that turns the heating or cooling down when it registers inactivity for two hours. (This feature can be disabled if the thermostat is in a poor location). An "Airwave" feature turns the air conditioner off but operates the fan for a few minutes to circulate residual cool air. (Note: duty-cycle controllers have used this strategy in commercial applications with small, if any, savings.)[6]

At present, Nest only makes a ten-day energy history available to customers. In the latest release of software in October 2012 (which was pushed out to all the existing thermostats in the field), Nest now has intelligent recovery and offers what may be a unique strategy for auxiliary electric resistance strip heating lockout control capability when used with heat pumps. The strip heat lockout control is based on a sophisticated algorithm that takes into account the outdoor and indoor temperature, local forecast and building heating history. When the Nest determines that by morning the system will have to use strip heat to achieve the setpoint, but does not need strip heat to maintain the temperature during the evening, it will override the setback and keep the home up to temperature as long as practical with the compressor in order to minimize strip heat usage. The Nest website claims that a correctly programmed thermostat can save about 20 percent on the user's heating and cooling bill and claims to have documentation that 99 percent of the their customers are using some kind of setback program. The retail purchase price is currently $199 with the thermostat designed to allow user installation. (See http://www.nest.com/.)

Venstar

The Venstar ColorTouch T5800 smart thermostat is designed to reduce cooling loads. First, the thermostat only allows "fan on" control during occupied periods. Through use of its "Free Cooling Capability," the thermostat can act as a control system for a residential economizer. When cooling with outside air, a fresh air louver opens and hot exhaust air is purged through the attic. When in cooling mode, outside air is used whenever possible. Mechanical cooling is used when cool outside air is not available. Venstar claims that cooling savings can amount to 30 percent. The cost of the thermostat is about $165; installation of the thermostat with outside air damper, barometric pressure control, and return air damper is about $500.

Mountain Logic

The MountainWise adaptive processing system, like Nest, uses integrated sensors to learn the occupants' needs and habits over time and by zone, and then uses this information to predict when energy use is required. The manufacturer states that "core energy use can be reduced by over 40 percent by only producing energy where it benefits the occupants." (See http://www.mountainlogic.com/.)

EcoFactor

EcoFactor does not manufacture its own smart thermostats; it is a subscription service that operates with hardware from various manufacturers. EcoFactor operates an energy management platform that takes information from thermostats in a home area network and uses it to determine the thermal characteristics of a home and the preferences of its occupants. It then automatically implements energy-efficient programs for each thermostat, optimizes energy use, and document savings on a house-by-house and day-by-day basis. EcoFactor thus does not place any demands on the homeowner.

EcoFactor can provide energy-saving recommendations and HVAC equipment diagnostics to users.[6] EcoFactor's centralized information can also be used by utilities to target energy-intensive households or homes with poorly performing HVAC equipment.[6] EcoFactor claims that their service can save up to 36 percent of the cost to heat and cool homes. The cost is $8 to $10 per month. (See http://www.ecofactor.com/.)

Home Energy Automation with Interconnection to the Smart Grid

Having a smart thermostat does not equate with interconnection to the smart grid.[9] However, smart meters and thermostats may complement each other to help consumers take advantage of the smart grid approach. The ultimate smart grid approach involves two-way communication between the home energy management device and the utility to improve the efficiency of comfort heating and appliance control. Homes can be integrated into the smart grid to minimize energy costs and maximize comfort through developing interconnection standards and deploying smart plugs, smart outlets, smart power strips and smart thermostats that:

- Respond to real-time energy pricing,
- Accommodate distributed generation (i.e., keep track of how much energy photovoltaics, wind or solar hot water systems are producing),
- Effectively utilize energy storage, and
- Monitor the state of charge of electric vehicle batteries and control when charging and discharging occur. [1,11]

While the homeowner may override the system at any time, it is expected that most would "set and forget" the system, allowing the home energy management system to optimize household energy use.[8] Energy savings to the homeowner would occur from enhanced insight and operational efficiency, including reducing runtimes whenever possible, dimming lights in occupied areas, and setting back the HVAC system during sleep, away and vacation times.[9, 12]

Some thermostat designs with appliance control features allow the homeowner to turn appliances on and off to gain insight into their electrical demand. For instance, the ecobee is capable of accepting wireless inputs and providing remote on/off control for up to 32 devices. Whole-house energy consumption can be viewed through installation of a current clamp at the utility meter. Savings to the utility occur when load profiles can be modified to minimize peak demands.[3] Smart thermostats with demand-reduction capabilities are currently available, such as the EnergyHub Mercury line and ecobee's smart thermostat. The EnergyHub software allows utilities to see how much load is available for a demand response event in real time.[6] (See http://www.energyhub.com/.) When a demand-reduction event is triggered, the software can tell the utility which homes are participating and how much load is being shed, again in real time.[6] Available load-reduction techniques include cycling air conditioners during peak periods, delaying water heating and curtailment of discretionary loads.

New Features of Advanced Metering

Advanced systems might also include activity detection using occupancy sensors and door and motion sensors for light dimming and comfort control. Energy management functions naturally integrate with other automated systems, such as controls for home security systems; fire alarms; audio-visual equipment; landscape sprinklers; pool and spa heating; and drapery, shutter and electrochromic window control.[12]

Advanced systems may also monitor and control for humidity and volatile organic compounds (VOCs, which can cause odors). Some manufacturers are developing advanced diagnostic equipment that can monitor heat pump operation and detect efficiency problems before they can be detected by humans, such as refrigerant over- or under-charge and reduced airflows (due to plugged filters) on the condenser or evaporator.[12] Messages or alerts could be sent to the owner, utility or equipment maintenance contractor when the equipment operates outside of specifications.[12] It is said that "the residential sector represents the most untapped potential for demand response."[9]

Disadvantages of Advanced Metering

A disadvantage of advanced metering and automation systems is cost. Consumers must invest in additional sensors, energy displays, and/or software to achieve near real-time feedback.[8] To increase the ability of homeowners (and small businesses) to participate in future utility demand response programs and/or smart grid initiatives,[13] California building codes will likely be changed to require upgradeable setback thermostats with a communications module as a mandatory measure.[13]

Strong interactive effects exist between the potential savings obtainable through home energy management systems and use of efficiency-enhancing technologies such as LED lighting, high-efficiency heat pumps, heat pump water heaters, efficient clothes dryers, super efficiency window and window film technologies, use of electrically commutated permanent magnet motors, and technologies designed to reduce plug loads.

Conclusions

Manufacturers of smart thermostats with self-programming capability claim significant – 20 to 40 percent – energy savings, but demonstration projects have not been conducted to provide a scientific basis for these claims. Literature from manufacturers often cites testimonials, and it is unclear whether their stated savings refer to total energy use, space heating energy use or space heating plus cooling energy use. Manufacturers also do not cite a baseline or comparison technology or operating pattern.

Smart thermostat energy saving performance would vary considerably due to thermostat use patterns previously established by the occupant (the baseline), weather zones and year-to-year variations, and intermittent occupancy patterns (often the norm for homes). Another variable is that backup heating systems are often used. Finally, it is difficult to distinguish savings from proper programming and use of a smart thermostat (which should have long persistence) from temporary savings due to increased energy awareness or the provision of information designed to promote behavior change.

It is difficult to claim energy savings beyond those obtainable with a conventional programmable thermostat (that has been properly programmed) combined with the provision of energy use information. When self-programming features of smart thermostats are employed, they mimic existing manual or programmable thermostat control. Increased energy savings would occur if a higher percentage of homeowners properly programmed their conventional programmable thermostats to achieve appropriate setbacks or setups.

Perhaps the most promising energy-savings features of smart thermostats involve the use of monitoring weather forecasts to help optimize intelligent recovery and to help minimize the use of supplemental strip heat with heat pumps.

Smart thermostats are increasingly being marketed for their non-energy features, such as displaying the outdoor temperature or indoor humidity and for their visual appeal. For example, the Nest changes color when the occupancy sensor detects the user to indicate if the home is in heating or cooling mode. Venstar's ColorTouch Wi-Fi smart thermostat comes with preinstalled display backgrounds and allows users to use the thermostat as a digital picture frame by allowing downloading of screensaver photos directly from an SD card. Venstar can operate in "slide show" mode and has the capability of displaying text messages on-screen. ecobee allows the user to select a thermostat appearance that matches the style of their home décor through the provision of scratch-resistant GelaSkin covers.

Sellers of advanced smart thermostats provide data showing that most users employ setback programs. In addition, these sellers have documented that many users access smart thermostats through mobile applications at least once a week. Nest attempts to engage users and promote energy-efficient behavior changes by displaying a green leaf icon when an economical setpoint is selected. Longer-term behavior change is incentivized by awarding green leaves for days when energy savings occur. A monthly report, sent to users via email, shows days on which green leaves were earned for user performance and contrasts this with the performance of other Nest users. Nest also maintains a website with encouraging stories and videos about how people have successfully used their product. It is both a marketing tool and motivational device. Nest claims that users login to an online portal or mobile application seven to ten times each week.[6]

E Source concludes that there is no clear winner among the currently available smart thermostat solutions.[6] Products are fairly new and still evolving. Some manufacturers promote physical appearance (customized covers, servings as a digital picture frame), while others promote energy savings through providing energy tips at their web portal and displaying heating equipment usage history. Some promote ease of programming (interview-base) while others come with pre-programmed schedules and temperature setpoints. Yet other smart thermostats are designed for demand reduction and responding to real time pricing, while some feature the ability to interconnect with the smart grid and interface with other smart thermostats and wireless energy monitoring devices such as smart plugs, smart outlets, and smart strips. Almost all smart thermostats provide maintenance alerts and show live weather. Smart thermostat capabilities are summarized in Appendix #1.

One advantage of wireless communications is that thermostat programming can be updated remotely, and several of the manufacturers provide auto-updates of their software for existing thermostats via the Internet. Some products offer superior two-way communications, which may be of value to utilities involved with demand reduction or savings verification programs. Manufacturers of smart thermostats are currently negotiating deals with retail stores and on-line outlets to attract consumer interest. Partners include Best Buy, Lowe's, Apple, Amazon, Johnson Controls, Comcast and Home Depot.

E Source concludes that the smart thermostat market looks promising. The market will determine winners and losers, and future research will reveal whether advanced smart thermostats outperform programmable thermostats and if energy savings persist over time.[6] Privacy and security issues will also need to be resolved as more people use smart thermostats and link with the smart grid.

The EPA, which dropped its ENERGY STAR label for programmable thermostats in 2009, is investigating a new labeling program for smart thermostats.[6] A number of utilities are attempting to resolve energy savings claims by conducting smart thermostat demonstration programs.

Ongoing Smart Thermostat Demonstration Programs

Following is a list of known utility or other sponsor smart thermostat demonstration projects:

- The Energy Trust of Oregon (ETO) is testing a number of smart thermostats in heat pump applications to learn how best to control heat pumps. The objective is to evaluate the technology rather than individual products. They started in late 2010, have 100 participants, and are using thermostats from Honeywell, Alerton, Emerson, Carrier and White-Rodgers. Source: Kyle Barton (ETO), 503-307-3710.

- NV Energy is using EcoFactor's automated energy management services to obtain about 20 MW of demand reduction. They require about 7,500 participating households to achieve this goal.[14] A pilot program in Las Vegas in 2010 reduced cooling costs by 13 percent by providing a peak demand reduction of 3 kW per household.
- Two Tennessee Valley Authority co-ops are testing EnergyHub: Gibson Electric Membership Corporation and Mid-South Energy.
- Ecobee is working with a number of utilities, including National Grid, Just Energy and Wisconsin Public Service.
- PG&E is working on a project with Honeywell.
- Reliant is working with Nest and EcoFactor.
- San Diego Gas & Electric is working with EnergyHub and Alarm.com to leverage two-way thermostat use in their Reduce Your Use program.[14]

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Appendix #1 Smart Thermostat Performance Characteristics

	Ecobee Smart Si	Nest	Honeywell Prestige 2.0	E2MS emme	Venstar Colortouch T5800	Radio Thermo stat	Lux TX90 00RF	Trane ComfortLink II	Lennox iComfort Sense	LockState Connect LS 90i	Energate Pioneer Z100	Aprilaire Model 8800	Emerson Evolve or Inspire
Product Cost	$170	$249	$205		$170	$100	$70		$230	$299		$270	
Wi-Fi Enabled	x	x	x	x	x	x		x	x	x	x	x	x
Mobile Apps	x	x	x	x	`	x		x	x	x	x		
Pre-Programmed							x						
Self-Learning		x	Interview-based programming										
Usage History	13 Months	10 days		2 weeks	7 days			x					By month and cost
Energy Savings Tips	Home IQ	x											
Scheduling	7d		7d	7d	7d	7d	7d	7d		7d	7d	5-1-1/5-2	7d
Custom Appearance	x Skins				Own Photos			x (frames)	Custom skins				
Live Weather	x	x	x	x		x		x	x			Outdoor	x
Humidity Sensing	x	x	x	x		x		Air filtration	x	x		Circulate mode	x
Maintenance Alerts	x	x	x	x	x		x	x	x		x	x	
Energy Optimization	x	O.S.	x	x				x	x	x	x		
Real-time Pricing			x								x		Schedule rates
Remote Sensors	x			x									
Economizer					x								
Zone Control				x				Floor/floor				x	x
Multiple Stats	x		x	x							x		

	Honeywell RTH8580WF	Honeywell RTH6580WF	Enphase Environ	Jackson Systems Wireless Comfort	Bay Controls BayWeb				
Product Cost	$129	$120							
Wi-Fi Enabled	x	x	x	x	x				
Mobile Apps	x	x	x		x				
Pre-Programmed		x							
Self-Learning		x							
Usage History					x				
Energy Savings Tips									
Scheduling	7d	7d	7d	7d					
Custom Appearance	Touchscreen								
Live Weather	x								
Humidity Sensing			x						
Maintenance Alerts	x				x				
Energy Optimization					Occup Sensor				
Real-time Pricing									
Remote Sensors									
Economizer									
Zone Control									
Multiple Stats	x				x				

Appendix #2 Smart Thermostats With Heat Pump Capabilities

	Ecobee Smart Si	Nest	Honeywell Prestige 2.0	Intwine IECT220	Radio Thermo stat	PECO T12000	Trane Comfort Link II	Energate Pioneer Z100	RobertShaw 9920i	Carrier Comfort Choice	LuxPro Pro-Fit PSP722E	Emerson evolve 1.1, Inspire
Product Cost	$170	$249	$205		$100				$125			
Wi-Fi Enabled	x	x	x	x	x	No	x	x	No	x	No	x
Mobile App Connectivity	x		x	x	x		x	x	No			
Pre-Programmed		x	Interview								x	
Self-Learning		x										
Usage History	x	10 days					x					By month and rate
Energy Savings Tips		x										x
Scheduling	7d	7d	7d	7d	7d	Config Recover	7d	7d		7d	7d	7d
Custom Appearance							x			Photos		
Live Weather	x	x	x		x		x			x		
Humidity Sensing	x	x	x	x	x		x					
Maintenance Alerts	x	x	x	x			x					
Auto Optimize for Energy	x	x	x			Occup Sensor	x	x			IAQ, Comp Delay	
Real-time Pricing (TOU Scheduling)			x					x		x (6 tiers)		Schedule rates
Heat/Cool, Lockout of Strip	x	x	4/2	3/2	3/2	3/2		3/2	2/2	3/2 + lockout	3/2	4/2
Smart Grid	x							x		x		