Advanced Thermostats for Small- to Medium-Sized Commercial Buildings

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ABSTRACT

Large commercial buildings typically incorporate building management systems (BMSs) that facilitate the control of multiple HVAC systems. Such BMSs are not as prevalent in smaller commercial buildings due to cost and complexity levels. The recent introduction of advanced thermostats that communicate through the Internet enable the visibility and control of HVAC systems needed to reach higher levels of efficient operation. Communication capabilities create opportunities for energy and demand savings through smarter controls and enhanced HVAC performance management by facility staff. Additionally, the advanced thermostats can integrate with and control other energy-consuming systems, such as lighting and/or plug loads. The combination of these features suggests that advanced thermostats have the potential to fulfill the original savings promised by programmable thermostats, greatly increase the available data on HVAC performance, change the relationship between the HVAC unit and facility staff, and become the central building block of modular and more cost-effective BMSs that better fit the needs and budgets of smaller buildings. Significant knowledge gaps must be addressed before this potential can be fulfilled, particularly regarding the communications architecture that underlies advanced thermostats. The status of a $3 million DOE-funded effort supporting the development of an open-source communications architecture will be discussed. This paper will present the current state of the technology as well as identify the knowledge and performance gaps still to be closed before program administrators can fully support the measure.

Introduction

In the spring of 2012, the New York State Energy Research & Development Authority (NYSERDA) commissioned an assessment, undertaken by and in partnership with ERS, of the technical and market potential of advanced thermostats. The research was limited to nonresidential applications with an emphasis on energy management. The findings were based on extensive secondary research and interviews with more than twenty industry experts, including advanced thermostat vendors, HVAC contractors, and related industry participants. This paper builds on that research and summarizes key findings on advanced thermostats including technical features, their value-added components, their potential for market transformation, and the challenges and barriers inhibiting that potential.

In order to understand the state of the market today, consider briefly the following estimates: interview responses suggested that advanced thermostats – residential and nonresidential combined – represent less than 10% of all thermostat sales in the U.S. today. Total thermostat sales are commonly estimated to be around 10 million units per year, and the vast majority of sales (>90%) are residential. As such, the current market for advanced thermostats in nonresidential settings can be estimated to be at most 100,000 units per year and is much more likely to be fewer than 50,000 units per year. While the market is small, it is growing; nearly every vendor interviewed indicated that they were experiencing year-after-year sales growth in the range of 20%–50%.

On the building side of the equation, consider just one segment: office buildings. The 2003

Commercial Buildings Energy Consumption Survey (CBECS) reported that 61% of all office buildings in the U.S. are less than 5,000 square feet and 95% are less than 50,000 square feet. Combined, this single segment represents over 750,000 buildings. The vast majority of these buildings will never require a full BMS, yet could still benefit from features offered by advanced thermostats, which could enhance controls for over 80% of their typical energy consumption (U.S. DOE *Buildings Energy Data Book*). If we expand out to all buildings covered in the CBECS data, over 4 million buildings fall into the sub-50,000 square foot category, promising a potential far greater than the sales estimates noted.

In the medium term (<5 years), advanced thermostats will likely come to represent a meaningful part of the energy landscape in nonresidential settings. This paper attempts to provide a sketch of what role nonresidential advanced thermostats will play. Though this paper is primarily forward-looking, the features and value-added components described exist today and have been deployed in the marketplace, albeit in small numbers. The market transformation outcomes, while speculative, are derived from installed examples that are used in a way that is consistent with the market transformation opportunities identified in this paper. By articulating a plausible vision for the role advanced thermostats can play in the market and identifying impediments to that vision, we hope to show how program administrators can help this technology achieve its full potential.

Technical Features

An advanced thermostat is a programmable thermostat that can communicate to the Internet or an intranet (i.e., an internal corporate network) via a wireless or wired network. It controls an HVAC unit via existing wires in the same way that a standard programmable thermostat does. Other names for advanced thermostats are web-enabled programmable thermostats, connected thermostats, and smart thermostats. There are three key components of an advanced thermostat system: hardware, communications, and software. The following subsections describe the most common technical configurations available and deployed today.

Hardware

The core hardware element of an advanced thermostat system is the actual thermostatic unit, which controls the HVAC system. Advanced thermostatic units operate identically to standard programmable thermostats and replace them one-to-one. Like standard programmable thermostats, they are not designed to control multizone or variable-air-volume (VAV) systems. The vast majority of advanced thermostats use ordinary relays or "pins" to communicate via the existing control wires behind the wall, though a small number can also communicate wirelessly to the HVAC unit.

Unlike standard programmable thermostats, advanced thermostats often include supplementary relays that can be used to collect data from peripheral devices, such as occupancy or temperature sensors, or to control other equipment, such as lighting. Input and output channels are capable of delivering and receiving continuous (e.g., temperature) and discrete (e.g., occupied/unoccupied) signals to and from the thermostatic unit. These expanded control and data collection capabilities are foundational elements of the expanded value proposition and market transformation potential offered by advanced thermostats; these elements will be discussed in depth later in the paper.

Power requirements for advanced thermostats differ from those for standard programmable thermostats. Advanced thermostats can, in most cases, draw enough power from the low-voltage "common" wire that runs from the HVAC unit to charge a battery that discharges when needed, such as when the unit is communicating wirelessly. Certain units offer alternative power sources, such as replaceable batteries or the ability to draw power from an Ethernet cable when that is the preferred method of communication. Each of these power methods is useful in different situations, with many vendors offering more than one option in order to accommodate those situations.

Communications

Advanced thermostats communicate, either wired or wirelessly, to the Internet or an intranet. These thermostats use communications to enable remote control through a web-based interface and also to send data back to a server where it can be analyzed and reported. Communications capabilities are essential to the definition of advanced thermostats; without communications, these thermostats would not be considered “advanced.” In this context, “communications” does not refer to communications between the thermostat and the HVAC unit, but rather between the thermostat and the Internet or “cloud.” Some end users prefer to have their thermostat connect only to a company-internal intranet; this is effectively the same as connecting to the Internet.

The most common methods of communication are wired Ethernet, Wi-Fi, and wireless mesh networks such as ZigBee. Each method has advantages and disadvantages. Understanding the relative value of each method is beyond the scope of this paper and is not critical to understanding the value of advanced thermostats in general. The most important thing to understand is that the differences between methods make them suitable to buildings, customers, and situations with different characteristics; there is no “best” communications method.

Software

Software is the element of the advanced thermostat system to which information is being communicated. Typically, it resides on the Internet or an intranet. Most commonly, the advanced thermostat is communicating to a web-based software platform that enables remote, account-based access to all the thermostats in the system. This access gives authorized users the ability to remotely view and control the thermostats’ schedules and setpoints, overriding local controls. These abilities have important consequences:

1. The act of programming thermostats is made substantially easier by using the relatively intuitive and easy-to-manipulate interface of the computer rather than the often challenging interfaces of standard programmable thermostats.
2. Maintaining setpoints and schedules is made substantially easier by consolidating the controls of many disparately placed thermostats into one web-based interface that is accessible everywhere. Also, most software allows one-click resets of all thermostats in the fleet to predefined defaults. The combination of these features allows maintenance staff to avoid the time-consuming effort of walking around to each thermostat and physically resetting them.
3. By offering an alternative access point, web-based software that controls a thermostat allows maintenance staff the option of limiting or disabling local controls. This helps maintain setpoints and schedules by limiting or eliminating local tampering.

In addition to remote visibility and control, the software supports the processing and storage of data. This data can be leveraged in multiple ways. In real time, it can be used to provide automated alerts via email or text when trends are identified, such as when a unit is slow or unable to reach setpoint. It can also be used to operate a unit more efficiently, such as when historical usage patterns and outside air temperature are analyzed as part of “smart recovery” to minimize the time a unit runs while recovering from setback periods. Finally, over the long haul, this data can be stored and analyzed on regular intervals. The software typically stores 6 months of data or more and is capable of producing reports and graphs that demonstrate system performance. Data storage can be extended indefinitely, either as an add-on to the contract or by downloading the data from the host server and storing it locally.

Value-Added Components

The capabilities described above provide for a range of value-added features in the categories of controls integration, performance management, energy savings, and demand management. The following subsections describe the most common and useful value-added features available and deployed today.

Controls Integration

Integration and interoperability with other control and data collection devices is a major value-added component of advanced thermostats. Advanced thermostats achieve this connectivity to other devices through three main methods:

1. Built-in connectivity – Integration is most commonly achieved through auxiliary relays or supplementary, system-enabled hardware that includes relays. Auxiliary relays are attached to the thermostat itself, while the system-enabled hardware that includes relays links to the software system, but does not control an HVAC unit (e.g., a Wi-Fi enabled relay). These two components – auxiliary relays and system-enabled hardware that includes relays – can be used to collect input from or control sensors, diagnostic probes, and basically anything that can be controlled by a switch (e.g., lighting or plug loads) or which can emit a discrete (i.e., on/off) or continuous (e.g., a value between 0–100) voltage signal. An example of system enabled hardware is offered by BAYWeb.[1]
2. Open-source interoperability – Hardware control units, such as wireless plug-load controllers, that are manufactured by companies other than the advanced thermostat vendor can be made to communicate wirelessly with the advanced thermostat and its back-end software. This connectivity is often enabled by open-source communications protocols like ZigBee and Z-wave.
3. API (custom and partnerships) – Most advanced thermostat software suites include an application programming interface (API), which can be customized for specific applications or specific end users to meet their needs. Many product developers can use their API for demand-response applications or cross-communication to other software systems, such as a BMS.

The first advantage afforded by controls integration is the ability to leverage additional data by connecting to sensors such as discharge air temperature or occupancy sensors. These can be used to monitor or control the performance of the HVAC unit. The addition of such sensors can have diagnostic and energy saving impacts; this is discussed further in the following subsections. These sensors are most typically included through built-in connectivity.

The second and more transformative advantage of controls integration is the ability of an advanced thermostat to act as a hub for an “internet of systems” in the building. Linking up with other energy-consuming systems such as lighting, electric water heaters, plug loads, or basically any electric-powered device, these systems can then be monitored and controlled in the same way that the HVAC unit is controlled: in response to outdoor temperature, occupancy, or schedules. Acting as a network accessible hub, the advanced thermostat goes far beyond its original purpose as a device used to control the output of an HVAC unit and instead becomes the central element of a modular, simplified, or “light” BMS that can be scaled incrementally to include essentially any simple energy-consuming system that

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[1] http://www.bayweb.com/mktg/webintegrator.php

can be controlled through an electric relay. These systems include lighting, electric water heaters, commercial equipment (e.g., coffee maker at a café), refrigeration, and other generic plug loads (e.g., office equipment). It's worth emphasizing that these systems can then access the same monitoring and controls capabilities offered to the HVAC unit. For example, a refrigeration system could have a temperature probe installed to monitor and report on system performance, and a door-contact sensor could be installed to alert facility staff when a walk-in refrigerator door has been left open. The possibilities are profound and will be discussed further in section on Market Transformation Potential.

Performance Management

The data monitored and collected by the advanced thermostat system enables basic performance management functions that improve the ability of HVAC contractors and facility staff to remotely identify and characterize problems. These functions improve the ability of those who manage the HVAC equipment – either building staff or HVAC contractors – to do their jobs effectively and efficiently. Automated alerts, remote visibility of real-time system performance, and regular, long-term data logging support the day-to-day efforts of building staff and HVAC contractors:

- Comfort complaints can be investigated and, if necessary, rectified remotely using the web-based interface. A quick review of the temperature and performance data will reveal in many cases if the complaint is legitimate, what may be causing it, and how it might be fixed – often without ever traveling to the facility or the space.
- Automatic emails and text messages can alert the managing staff to problems before they result in complaints or before the equipment suffers permanent damage from malfunction. For example, most advanced thermostat software systems can be set up to monitor for symptoms of HVAC malfunction, such as failure/slow to reach setpoint, short-cycling, and extended run times.
- Regular (e.g., monthly) reviewing of performance reports can alert the management staff to problems before they devolve into crisis. Performance degradation over time is often overlooked, as it happens slowly and thus goes unobserved by those in the space until it has gotten dramatically worse. For example, a discharge air temperature sensor can be monitored to ensure that it is reaching the specified output temperature.

Energy Savings

Advanced thermostats can save energy relative to standard programmable thermostats:

- The most commonly experienced savings are likely to result from the improved usability described above, which makes it easier and more convenient to view, set, and maintain schedules. Quantifying the expected savings is challenging and depends on the baseline. If – prior to the installation of the advanced thermostat – the facility staff and building culture vigilantly maintained appropriate setpoints and schedules, then the advanced thermostat would realize no savings. On the flip side, if the facility maintained its thermostats poorly (the most likely situation) or had no thermostats, then the savings could be substantial.
- Advanced control features such as smart recovery or smart staging can glean modest heating and cooling savings in certain circumstances. Smart recovery uses historical data and outside air temperature readings to minimize the time a unit runs while recovering from setback periods. Smart staging uses similar data to achieve a setpoint by prioritizing a unit's more efficient stage (e.g., running the heat pump longer rather than using the electric resistance booster).

- In circumstances where there is intermittent occupancy, additional input from a traditional motion detector, door-contact switch, or key-card sensor can dynamically match conditioning to the times that it is needed. This has been shown to be especially effective in, for example, mobile classrooms and hotel rooms, where savings have been as high as 40% on heating and cooling costs.[2]
- Multisystem controls integration has the potential to yield large savings in cases where large, previously uncontrolled loads, such as lighting, are brought into the control system and put on a schedule or tied to a sensor. These savings will be entirely situational, but they represent a significant opportunity.
- It is also possible in some cases for performance management monitoring to yield energy savings. Having optimally operating units can save energy, because malfunctioning units often operate less efficiently. At the same time, diagnostics can be used to identify nonoperational units more quickly, which could – by bringing those units back online – lead to more energy use. Generally, these capabilities will improve comfort and useful life more than they will save energy, but proper and more regular maintenance should lead to more efficient operation.

Demand Management

Advanced thermostat manufacturers currently include some features that relate to demand management. Overall, most of these features are manual, and automated demand management still has some way to go before the technology is ready for mass consumption. However, the technological capability is there and with it there is potential for the following:

- Phased startup – This feature automatically schedules units to recover from setbacks at staggered intervals to avoid demand spikes. Currently, no manufacturer interviewed offered this feature, but a few mentioned that they were working on developing it.
- Precooling – This feature would predict peak demand periods and automatically shift the cooling load to earlier hours of the day to avoid peak demand charges. Currently, no manufacturer interviewed offered this feature, but a few mentioned that they were working on developing it.
- Cooperative load management – This feature uses communication among multiple HVAC units to avoid coincidental demand by automatically shifting loads. REGEN offers an example of this functionality, though they do not manufacture an advanced thermostat and instead achieve this functionality by directly installing communicating hardware on the HVAC units. This avenue is a potential area of opportunity for the future.
- Automated demand response – Many advanced thermostats were designed specifically for automated demand-response programs, particularly in the residential sector. Nonresidential units with the integration capabilities described above tend not to have automated demand-response capabilities built in, but they can achieve those capabilities by integrating via their API to the software of a demand-response aggregator. As a result, and since most units include APIs, advanced thermostats today are typically capable of facilitating automated demand response.

Market Transformation Potential

Advanced thermostats offer the potential for substantial market impact. The following discussion highlights four aspects of advanced thermostats that will likely have the most significant impact: fulfilling the promise of programmable thermostats, massively increasing the available data, changing

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[2] http://www.techzone360.com/news/2010/03/16/4675008.htm; http://www.magnumenergysolutions.com/case-study.php

the relationship between maintainer and unit, and supporting a modular, light building management system. The potential market transformations described are based on the capabilities that exist today and anecdotal evidence regarding how installed advanced thermostats are being used.

Fulfilling the Original Promise of Programmable Thermostats

In 2009, the DOE/EPA ENERGY STAR program suspended its labeling of programmable thermostats in residential settings stating that the "EPA has been unable to confirm any improvements in terms of savings delivered by programmable thermostats and has no credible basis for continuing to extend the current ENERGY STAR specification."[3] ENERGY STAR has never had a specific nonresidential thermostat standard, and no plans for such a standard could be found, but the failures of thermostats in residential settings are similar to those in nonresidential settings. Reasons for withdrawing the standards for programmable thermostats were as follows:

- Lack of usability – End users were not making use of programming features to set schedules and setpoints because it was not easy to do so. The thermostat interface was too difficult and complicated to use.
- Difficulty in substantiating savings – There was not enough reliable evidence that programmable thermostats were actually achieving energy savings. Field studies have recorded savings that are substantially lower than the typical savings consumers are advised they will save. In several case studies, it was shown that these products resulted in no savings. This outcome has been attributed to improper use, which partially stems from the usability issue noted above.

ENERGY STAR will be issuing new standards for programmable thermostats in 2013. These new standards will take into account the added features of advanced thermostats for enhanced usability. The new standards will grade thermostats not only based on programming functionality, but also on usability. Communications and connectivity will be an integral part of the new ENERGY STAR standards, and many advanced thermostat features will be required for products seeking the ENERGY STAR label. These features include connectivity, year-round scheduling capabilities, smart recovery algorithms, API availability, and data transmission minimums.[4]

In this way, the new generation of advanced thermostats may be able to fulfill the original promise of programmable thermostats. Advanced thermostats make it easier and more convenient to view, set, and maintain temperature setpoints by replacing at-thermostat controls with web-based, remotely accessible interfaces. It is the opinion of these authors that this improved usability should lead to more appropriate and persistent schedules and setpoints that will yield savings to end users and the grid. While anecdotal claims from manufacturers suggest that this is the case, wider field studies will have to be performed to confirm this outcome.

Massively Increasing the Available Data

Advanced thermostats are collecting, transmitting, and recording data that standard programmable thermostats are unable to capture. This information has never been systematically captured before. Advanced thermostats have the capability of capturing data at highly frequent intervals. The intervals are customizable, but they can typically go as frequently as the data network can tolerate and the server can store. They can capture information that includes, for example, measured indoor air

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[3] http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/thermostats/Spec_Suspension_Memo_May2009.pdf

[4] http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/climate_controls/Residential_Climate_Controls_Draft_3_Version_1_Cover_Memo.pdf

temperature, outdoor air temperature (either measured or pulled from the Internet), and binary output controls (e.g., air handling fan relay engaged/disengaged). Compatible peripheral equipment can similarly capture data relating to occupancy patterns, discharge air temperature, and equipment-level energy consumption. Additionally, at-thermostat control changes can be monitored and recorded to observe trends in consumer behavior.

The result is that a single HVAC unit will provide thousands and thousands of data points mapping its performance over the course of a week, month, or year. This data can be analyzed at both the micro (building) and macro (industry) level:

- At the building level, facility staff members are better able to understand long-term issues and respond in ways that were not possible before. Most available advanced thermostat software systems are capable of producing automated reports and trends that can reveal performance degradation, improperly set schedules/setpoints, and patterns of misuse or underperformance. This visibility is facilitating the improvement of overall performance, including comfort, efficiency, and maintenance.
- At the industry level, performance data will be available at an extraordinary scale. If efforts to gather and aggregate this data are made by program administrators who promote efficiency, it will afford the industry an unprecedented opportunity to gain insight into efforts aimed at reducing HVAC energy use. Program administrators can use this data to observe control and use patterns at a granular level and identify the most effective control mechanisms and features. HVAC manufacturers and the community of HVAC contractors can use the information to identify trends regarding maintenance and unit failure with the hopes of improving efficiency of operation and longevity of equipment. The opportunities are significant.

The value of the data is predicated on the willingness and ability of someone to analyze it. It is possible – though unlikely, in the opinion of these authors – that this data will prove to be of little or no value. There are also substantial challenges to avoiding "analysis paralysis" in the face of the coming wave of data. That said, the introduction into industry of an enormous volume of data provides an unprecedented opportunity for learning. Already there is anecdotal evidence that HVAC contractors and maintenance staff are leveraging the available data to their advantage at individual buildings; it is up to program administrators to aggregate and parse market-wide data for broader trends.

Changing the Relationship between the HVAC Unit and Maintenance Staff

Remote visibility and control fundamentally change the relationship between the HVAC systems and those that maintain them. The ability to instantly view system setpoints, operational schedules, and status from any Internet browser or mobile phone has important implications for the way two key stakeholders – HVAC contractors and facility staff – do their jobs. Anecdotal evidence suggests that advanced thermostats are already being used to improve outcomes for occupants, management, and facility staff alike by allowing maintenance staff to:

- Anticipate and address comfort issues before they become complaints – The advanced thermostat can alert the maintenance staff via text message or email that the space temperature is diverging from the acceptable setpoint. This is primarily a benefit to facility staff and occupants. For occupants, it effectively improves the experience by avoiding comfort issues before they even happen. For facility staff, it means they don't have to receive as many comfort complaints.
- Triage and respond to comfort complaints remotely when complaints do happen. First, among complaints, many are often the result of personal preferences, that is, the unit and space are

operating at the temperature desired by management. Remote investigation can reveal this to be the case by identifying the indoor air temperature and ensuring that the system is operating properly. This saves facility staff a trip to the offending zone. Second, in the case that there is an issue – for example, if an occupant manipulates the thermostat, raising the temperature dramatically – the facility staff member can rectify the issue remotely. This saves them time and also improves the level of service experienced by the tenant since the issue is resolved more quickly.

- Anticipate and address mechanical and performance issues before they become full-blown catastrophes – Trends and alerts can be set to warn HVAC contractors and facility staff when a unit is acting erratically or in a way that is consistent with a mechanical issue. For instance, discharge air temperature can be measured to identify when a unit, though it is engaged, is unable to perform to spec. By investigating an issue before it becomes a significant problem, management, HVAC contractors, and facility staff can avoid costly mechanical failures that can disrupt service or lead to avoidable unit replacement.
- Triage mechanical and performance issues and respond more appropriately – In cases where systems have malfunctioned, remote visibility can help HVAC contractors and facility staff to understand the problem before arriving on-site. For example, in the case where a facility has multiple units serving the same space, maintenance staff can determine which unit in particular is malfunctioning and bring the appropriate replacement parts, helping to avoid a second trip. The current stock of advanced thermostats do not perform sophisticated unit-level diagnostics, but observing the remotely available data may help maintenance staff isolate the issue to a handful of root causes, thus enabling them to come to the site better prepared. This ability will likely evolve over time in industry as the data becomes better understood. Overall, these capabilities should enable internal or external maintenance staff to save time and provide better and prompter service.

Vendors already report that customers often cite the time and cost savings associated with these abilities as being of the greatest value to them. It is reported that overall service levels improved without increased costs. The benefits are greatest when staff work remotely (e.g., off-site HVAC contractor or energy manager of a chain account) and in big buildings or campus-style settings where the facility staff are often at a distance from units and zones.

These authors speculate that, in some cases and in the long term, management will be able to reduce facility staff numbers or repurpose their time for valuable projects that do not normally get the attention they deserve. There is also an opportunity for HVAC contractors to offer value-added services and play the role historically played by internal facility staff by leveraging the remote visibility and control afforded by advanced thermostats that enable them to be “virtual” facility staff.

Supporting a Modular, Light Building Management System

The integration capabilities of advanced thermostats are perhaps the features with the potential for the most profound impact on the market. Integration capabilities make it possible for the advanced thermostat to act as the cornerstone of a modular energy management system that can achieve most of the capabilities of a BMS at a fraction of the cost. It is worth noting that very few customers have taken advantage of these capabilities, with most – at least for now – focusing on the benefits described above.

In addition to controlling the HVAC systems, advanced thermostats can be easily configured to control lighting, water heaters, and any other equipment controlled by an electric circuit. In the sub-

50,000 square foot class of buildings, these loads represent 75% of all energy consumed (DOE *Buildings Energy Data Book*). This can be achieved either directly through the thermostat or through supplemental hardware that leverages the same communications and software platforms. In this sense, the advanced thermostat is a stepping stone to something much greater. Upon installation, customers enjoy the benefit of the advanced thermostat's nonintegration features (which are the primary marketing points at this time), but they are also provided robust software connectivity that allows other equipment to be integrated with relatively little marginal cost. The additional equipment can be integrated iteratively and slowly over the course of time, which makes the system modular. Vendors report that most consumers choose not to integrate non-HVAC equipment into the system at the time of original installation; those that do, though, report satisfaction. It remains to be seen whether consumers will recognize the value of monitoring and controlling non-HVAC equipment, but the advanced thermostat is the entry point by which these light BMSs will take hold if they are to do so.

These authors do not believe advanced thermostat systems will replace BMSs. Advanced thermostats are not intended to control more advanced HVAC systems such as VAV systems, which tend to be managed by BMSs. Down market, however, the advanced thermostat system can be used as an effective substitute for a BMS in small- to medium-sized buildings where the costs of a BMS cannot be justified. While all vendors suggested that costs vary substantially by installation, self-reported costs ranged from approximately $750 to $1,250 per thermostat installed. While this is two to five times the cost of a regular thermostat, it is a fraction of the cost of a traditional BMS, offering small- and medium-sized buildings an alternative way to control their energy-consuming systems.

The Learning Curve and Barriers to Adoption

Advanced thermostats offer new challenges to HVAC contractors and end users. Overall, the product is intended to be simple and easy to understand. This is primarily accomplished by making it familiar. Nearly all the vendors indicated that in terms of control issues, an advanced thermostat is "just a regular thermostat" with some bells and whistles – all HVAC contractors should be able to connect the thermostat to an HVAC unit without issue once they realize the control wiring works exactly the same way behind the wall. Power issues are not entirely new either, nor are they especially complicated. According to the vendors, most HVAC contractors require little assistance in this realm. The most popular power mechanism – power by common wire – is a holdover from programmable thermostats with larger power draws. Ethernet and battery power methods are newer, but are relatively intuitive. Issues with control and power tend to be small and easily solved. Most vendors have developed online support forums or FAQs, which vary in quality, to deal with simple issues, and some offer dedicated tech support call-in numbers that operate 24/7.[5]

All vendors agreed that the biggest knowledge gap surrounds the communications technologies. While setting up advanced thermostat networks is by IT standards a fairly simple task, HVAC contractors are unfamiliar with this type of technology. Most vendors see this issue as an industry-wide learning curve that would eventually be overcome. This gap has contributed to a lack of uptake of advanced thermostats in the retail and distributor market channels. In order to overcome this challenge, most vendors have developed HVAC partner networks that include training on such issues as communications as a condition of joining the network.

Additionally on the communications and networking front are the protocols and interoperability between the various controls, sensors, and systems. In an ideal world the controls would be plug-and-

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[5] http://support.nest.com/thermostat/; http://www.ecobee.com/support/resources/; http://www.bayweb.com/mktg/downloads.php

play yet the reality across the entire BMS world has been a tendency toward proprietary control strategies that do not cooperate. In this area, the U.S. DOE has an on-going effort (DE-FOA-0000822) to develop an open source architecture software solution specifically tailored to small- and medium-sized buildings. The goal of this is of course to "support data/information exchange" between devices in the building to permit "enhanced control strategies typically available to highly sophisticated automation systems." At a minimum, this effort will address the following three kinds of devices: thermostats, lighting controllers, and "general purpose" controls. This effort was launched in the summer of 2013 with an expected duration of up to 3 years.

Additionally, understanding how to use the thermostat is another potential gap. Most vendors interviewed suggested that end users rarely if ever requested training. They attributed this to "idiot-proof" design and familiarity. Thermostat settings on an advanced thermostat are broadly similar to those on a standard programmable thermostat, with the key difference being a web-based interface that is simpler to interact with. In order to promote proper operation of the basic functionality, vendors like ecobee offer regular webinars[6] and online video resources[7] for interested parties. Other vendors suggested they were developing the same types of material.

Advanced thermostats offer a suite of more advanced features that are not covered by these resources and that may or may not be used properly, regardless of whether customers and installers request training on them. Connecting vendors to actual feedback from users regarding those features (e.g., smart recovery, parameter-based alerts, and integration) that they are using, not using, or potentially misusing is important to ensure that the product category is reaching its full potential. A misunderstanding of the value of advanced features by users and installers alike is holding back key distribution channels such as retail and distributors and seems also to be inhibiting greater uptake of advanced features such as integration. Training sponsored by vendors or program administrators could improve this situation and contribute to an increase in general industry-wide awareness.

Conclusion

Advanced thermostats hold the potential to transform the market for controls of HVAC and other energy-consuming equipment in nonresidential settings. All of the features described – with the exception of some of the more advanced demand-response features – are available today and have been deployed already. Similarly, the opportunities for market transformation described above are representative of how the units are being used in some installations today.

Overall, though, advanced thermostats are underutilized in two distinct and important ways that we believe program administrators can work to remedy. First, as indicated in the introduction, the market is not yet deploying these units at much scale. Research suggests that installation numbers have been deflated by installers' lack of understanding of advanced thermostats in general and communications technology in particular. Vendors have reacted by shifting their business models to promote trained HVAC-contractor networks and to rely more heavily on direct sales, rather than distributors or retail. This has led to a growth in overall installations, and we suspect that it will continue to expand as knowledge of this technology disseminates and greater numbers of installers recognize that they can increase revenues by installing these more costly units. We also believe this trend can be further encouraged by program administrators. Utility and state government programs can lend their credibility to the technology and put greater resources behind training the broader market of thermostat installers.

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[6] http://www.ecobee.com/contractors/webinars/

[7] http://www.ecobee.com/support/resources/tutorials/

Expanding the number of installations will not, on its own, guarantee that advanced thermostats fulfill the potential described in this paper. Most of those already installed are not being fully leveraged, which is the second way that advanced thermostats are underutilized. On the one hand, interview responses suggest that customers are effectively using the units to better set and maintain their setpoints and schedules, and that one of the greatest value-adds has been the ways that maintenance staff have leveraged remote control to make their jobs easier and more efficient. On the other hand, HVAC contractors have yet to embrace the business model opportunities offered by remote control and visibility. Effective use of the newly available data is still limited at the building level and nonexistent at the industry level, and – most importantly – very few customers have embraced the notion of the advanced thermostat as the central node in a light BMS. While use of peripherals, for example to measure discharge air temperature, is quite common, full-scale controls integration of lighting and other energy-consuming equipment is exceedingly rare. We suspect that these unfulfilled market transformation opportunities will be tapped, if slowly, as customers and installers become more comfortable with the technology. That said, we believe that program administrators can accelerate these market transformation outcomes by, for example, incentivizing expanded installations that include lighting and other energy-consuming equipment, encouraging HVAC contractor business model transformation to include advanced thermostats through training and conferences, or requiring that incentivized installations provide data back to the program so that it can develop an industry-wide database of HVAC performance. These sorts of actions are important not just to ensure that advanced thermostats are installed at a much higher rate, but that those units installed are maximally utilized so that the technology can achieve its full potential.