National Consumer Law Center

SMART THERMOSTATS:

Assessing Their Value in Low-Income Weatherization Programs

January 2020

By

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ACKNOWLEDGEMENTS

The author thanks NCLC colleagues Senior Attorney Charlie Harak, Deputy Director Carolyn Carter, Director of Communications Jan Kruse, and Research Assistant Anna Kowanko for their valued comments and assistance. The author also thanks Brian Beote and Brendan Delaney of Action, Inc., The Low-Income Energy Affordability Network (LEAN) attorney Jerrold Oppenheim, and John Wells of Action for Boston Community Development, Inc. (ABCD) for their review of and comments on the draft of the report. NCLC also thanks the members of LEAN, whose support of our work made this report and much more possible. The views expressed in the report are solely those of NCLC and the author.

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EXECUTIVE SUMMARY

Smart thermostats – also referred to as wifi thermostats – are promoted as a measure that can produce substantial household energy savings and increased comfort and convenience for residential utility customers, beyond less costly traditional programmable and non-programmable thermostats. Interest in smart thermostats as a promising energy savings measure has increased in recent years as energy efficiency program administrators seek to identify new products and programs to make up for sharply reduced energy savings in the residential lighting sector, and to enable demand response programs that seek to reduce seasonal peak energy usage.

The perceived promise of smart thermostats is rooted in the two-way, internet-enabled functions that give rise to its "smart" moniker. Smart thermostats allow the homeowner to configure a range of home temperature settings (like a programmable thermostat), but can also automatically alter preset temperatures based on occupancy sensors and remote changes to temperature settings made through smart devices. The "smart" technology, for example, "learns" the householder's schedule to program itself. It can turn the temperature control down (or up) when the customer is away, relying upon a motion detector/occupancy sensor or geofencing – an invisible perimeter around the home or the location of the thermostat that, once crossed, allows for automatic adjustments to thermostat setpoints. It also allows the customer to change the temperature from a smart phone or tablet using a web portal or a mobile app, assuming wifi exists in the home. The technology includes an outdoor air temperature algorithm in the control logic to operate heating and cooling systems. When the customer switches from cooling to heating the home, the thermostat "learns" a new temperature schedule. Smart thermostats have also been incorporated in utility demand response programs that offer customers financial incentives in exchange for permitting the utility to modify a household's thermostat settings during peak energy usage periods.

These advanced features, however, come at a price. Smart thermostats offered in Massachusetts' Mass Save energy efficiency program, for example, vary in retail price from $125 to $249 depending on the brand and technical specifications, excluding installation costs. Manual programmable thermostats offered through the program, by comparison, are priced at $32.95 retail. Even though Mass Save customers can purchase smart thermostats at substantial savings, given the $100 rebates available to utility customers, or potentially receive them at no cost if they are income eligible customers, the incremental costs to the energy efficiency programs of the higher-priced technologies are nevertheless incurred. Beyond the cost of the measure itself, smart thermostats, which enable utilities to connect with a customer's home through demand response programs and the thermostat vendor to collect an individual home's energy usage data, raise both data security and privacy concerns.

Accordingly, those who administer low-income qualified energy efficiency programs advise that the measure's cost and technical functions must be carefully weighed against anticipated benefits. Whether smart thermostats are appropriate, cost-effective measures for installation in a residence for achieving maximum potential energy savings depends on a myriad of factors. They include customer access to wifi internet service and a smart phone or tablet, ease of installation, and customer interest (or lack thereof) in interacting with heating and cooling system controls. Smart thermostat evaluations provide a range of potential gas and electric energy savings estimates, but the most significant savings estimates presume access to wifi in the home as well as to smart phones or tablets to enable remote interaction with the thermostat. Moreover, savings from automatic temperature setback depend on the customer being frequently and predictably out of the home. Many of these assumptions frequently do not apply to low-income households. For example, according to the most recent American Community Survey data, among those households with an annual income below $20,000, a full 40% – more than double the national average and representing 7 million households – have no internet subscription through any mechanism.

A review of evaluations from a sampling of states reveals significant variances in energy savings (both positive and negative) tied to occupant behavior, temperature setpoint baselines, thermostat brand and model, the type of HVAC system being controlled by the smart thermostat, accompanying customer education, overall customer energy usage levels and customer demographics. Smart thermostat evaluations consistently point to the fact that customer behavior can sharply limit energy savings. For example, customers who alter thermostat default settings to increase comfort, for health reasons, or who lack interest in following recommended product controls can diminish expected energy savings. Likewise, if a customer is at home all day due to age, disability or an unpredictable schedule, the daytime thermostat setbacks that drive energy savings can be non-existent. To that end, customer interest in and commitment to appropriately engaging with smart thermostat capabilities (for example, not overriding a preset energy-saving home temperature) is critical to the decision as to whether to install a smart thermostat.

Selecting the most appropriate and cost-effective energy efficiency measures for inclusion in energy efficiency programs is of particular importance for low-income weatherization administrators, who must balance maximizing energy savings in client homes with the need to efficiently invest the state, federal and ratepayer dollars that fund the programs. The Low-Income Energy Affordability Network (LEAN), an association of nonprofit agencies (mostly Community Action Agencies, or CAAs) that coordinate the delivery of government and utility-funded energy efficiency services to low-income utility customers throughout Massachusetts, has led the way in adopting such technological advances as LED lights and air source heat pumps. LEAN considers a variety of factors when deciding which measures work best for a particular client and building. LEAN program administrators consider these relevant factors when deciding whether to install the smart thermostat technology: (1) thermostat cost; (2) whether wifi exists in the home; (3) whether technical issues prevent quick and inexpensive installation; (4) the need for detailed customer product education about both functionality and data collection; (5) home occupancy patterns and health requirements; and (6) customer access to prompt, effective thermostat manufacturers' trouble-shooting assistance. Midwestern weatherization administrators concur on the need to establish an assessment protocol for field specialists who are assessing which thermostat to install based on client needs and potential energy savings.

Although the installation of a smart thermostat can be a cost-effective option for residential utility customers, installation of smart thermostats is neither cost-efficient nor appropriate in many weatherization client residences due to occupancy, energy usage, and behavioral patterns. In the end, the decision whether to install smart thermostats in a particular low-income home is best resolved by on-the-ground, weatherization field specialists, in consultation with the clients they serve.

ASSESSING THE VALUE OF SMART THERMOSTATS

Smart Thermostats – Cost and Potential Benefits

Smart thermostats[1] are promoted by energy efficiency program administrators and product vendors as a measure that can produce significant household energy savings, and increased comfort[2] and convenience for residential customers, over and above less costly, manual programmable and non-programmable thermostats.[3] According to the American Council for an Energy-Efficient Environment (ACEEE),[4] the market for smart thermostats is experiencing significant growth, with projections that by 2021, more than 43 million US homes, or 40% of the total, will have a smart thermostat installed.[5] The majority of current installations are in single-family homes.[6]

According to the American Council for an Energy-Efficient Environment (ACEEE), the market for smart thermostats is experiencing significant growth, with projections that by 2021, more than 43 million US homes, or 40% of the total, will have a smart thermostat installed.

Smart thermostat incentives and rebates are a regular feature of energy efficiency programs across the country. The full retail price of smart thermostats offered in Massachusetts' Mass Save energy efficiency program vary from $125 to $249 depending on the brand and technical specifications.[7] The ratepayer-funded Massachusetts gas and electric energy efficiency programs that operate under the Mass Save brand offer $100 rebates for the smart thermostats.[8] In comparison, manual programmable thermostats offered in the program are priced at $32.95, with a $25 rebate offered.[9]

Smart thermostats offer a configurable range of temperature settings (like a programmable thermostat) and automatically alter preset temperatures based on occupancy sensors and remote changes to temperature settings made through smart devices. Nest's third generation Learning Thermostat, for example, "learns" the householder's schedule to program itself, turns itself down when it determines, through a motion detector, that the customer is away, and lets the customer change the temperature from a smart phone or tablet.[10] The configurable temperature schedules may be default settings, established through user interaction and occupancy sensors, and can be changed manually at the device or remotely through a web portal or mobile app. When the customer switches from cooling to heating the home, the thermostat "learns" a new temperature schedule.[11] In order to aid a customer in tracking energy use in the home, some models offer the customer reports of how much energy was used in a day, and on a monthly basis.[12]

Generally speaking, smart thermostat products and services are characterized as "new, diverse and rapidly changing"[13] in regard to their capability, usability, and sophistication. In order to be labeled as "smart," the thermostat, at a minimum, must be capable of two-way communication and exceed the typical energy savings performance of manual and conventional programmable thermostats through automatic or default capabilities.[14] The equipment baseline for measuring advanced thermostat savings is either the actual type (manual or programmable) if it is known, or an assumed mix of these two types based upon information available from evaluations or surveys that represent the population of program participants.[15] Whether and to what extent smart thermostats achieve significant energy savings for residential customers depends on several factors, including the compatibility of a smart thermostat to a home's HVAC wiring, the default temperature settings selected, and customer overrides of default temperature settings due to anticipated comfort and health needs.

Installation of smart thermostats can be either straightforward or time-consuming and costly, depending on the wiring of a home. Nest's self-installation "Compatibility Checker" advises users that Nest is not compatible with a system if the existing thermostat:

- has stranded wires.
- has thick, stranded wires connected by wire nuts.
- is labeled 110V or 120V.[16]

According to Brian Beote, director of Energy Efficiency Operations for Massachusetts' Action Inc.'s Energy Services division, the installation of many of the smart thermostat brands have required what is known as a common wire, a dedicated line that powers the thermostat.[17] For those brands that require a common wire, the weatherization specialist has to install one if not present in the home. That, Beote explains, requires the specialist to snake a line through existing walls, which can be difficult, time consuming and expensive. The existence of a common wire or lack thereof is a critical sticking point in the decision to install a smart thermostat, Beote states.[18] This concern may disappear, however, assuming certain next-generation smart thermostats now available, which do not require the common wire according to product specifications, are selected for inclusion in weatherization programs.[19]

Smart thermostats have also been incorporated in utility demand response programs that offer customers financial incentives in exchange for permitting the utility to modify a household's thermostat temperature settings during summer peak energy usage occurrences.[20] Active energy demand response management through smart thermostats is a part of the energy optimization and strategic electrification push, Beote notes. Strategic electrification involves the growing movement to switch from non-renewable energy sourced appliances, such as heating oil, propane and natural gas-fueled units, to electric air-source heat pumps (ASHPs). The current Massachusetts electric and gas utility energy efficiency plan, for example, includes specific demand response programs designed to reduce summer peak usage, with smart thermostats playing an essential role in utility activation of temperature adjustments.[21] Eversource Gas Company, which serves 1.4 million electric customers and 296,000 natural gas customers in Massachusetts, filed in November 2019 for approval by the Massachusetts Public Service Commission of a demand response program marketed to smart thermostat users.[22]

Amy Vavak, National Grid's income-eligible customer strategy principal for New England, acknowledges that electric utilities are increasingly interested in promoting demand response programs. Vavak says that "every electric utility is trying to think about how their customers will interact with them" as the grid evolves and more distributed resources are used by customers. "You have to pay attention to that for planning purposes."

While two-way communication is not necessary in utility demand response programs,[23] this capability of smart thermostats offers the potential for peak load reductions. Summer peak-time savings programs can then reward utility customers with bill credits for permitting the utility to directly control the customer's thermostat.[24] A California analysis of two Southern California Edison thermostat incentive programs describes the role smart thermostats can play in encouraging shifts in peak demand customer energy usage:

> During demand response events, thermostats can modulate energy via direct load control or remote set-point adjustments for peak time load shifts. Adjustment of set points can also be used during off-peak hours and seasons to encourage energy efficiency programs. As smart thermostat data can also be matched with data from smart energy meters, these devices are a unique way to obtain real-time information on energy use as well as provide insights into customer behavior.[25]

Due to sharply decreasing savings that utility programs can claim in their lighting programs, experts are looking for other program options and efficiency measures to glean savings in the efficiency programs, Beote states.[26] Consultants, vendors, and energy efficiency and demand response program administrators see smart thermostats as one of a handful of "connected" technologies that could play a role in making up for the loss of lighting savings. Vavak of National Grid confirms that the hunt for promising new energy efficiency measures exists. "Customer behavior is changing," she says. "Customers are buying more LEDS. Less (lighting) sockets are available. As we look toward the future, our portfolio mix is transitioning over time."

Beote notes that consultants to the Massachusetts' Energy Efficiency Advisory Council (EEAC)[27] have encouraged low-income agencies like his to embrace smart thermostats as a scalable way to achieve the state's rigorous energy efficiency and decarbonization goals. The Massachusetts' Green Communities Act requires that at least 25%of the state's electric load, including both capacity and energy, be met with "demand side resources including: energy efficiency, load management, demand response and generation that is located behind a customer's meter" by 2020.[28] The Act also calls for the reduction in the use of fossil fuel in buildings by 10 percent from 2007 levels by the year 2020 "through the increased efficiency of both equipment and the building envelope."[29]

Whether smart thermostats are a good bet for program administrators hoping to move beyond the low-hanging fruit of lighting is uncertain. Vavak acknowledges that weatherization managers are being asked to install "a modest increase" of smart thermostats over the next few years in weatherized homes where conditions are right.

In 2018, NMR Group, Inc. prepared a study for the Massachusetts gas and electric utilities and the EEAC to assist the energy efficiency program managers in identifying new products and programs that might replace the diminishing energy savings tied to the eventual exit of LED lighting from programs "given significant market changes and increasing federal standards."[30] While the authors noted that smart thermostats were frequently mentioned by program administrators as a promising measure for potential energy savings, along with non-residential lighting, the authors highlighted the uncertainties associated with the technology:

> While leveraging the ENERGY STAR specification was recommended by several respondents to help with smart thermostat programs, some also noted that certain thermostats – even those that have reached the specification – may not perform as well as others or may not have the same capabilities (e.g., learning capabilities, two-way wifi connectivity). Additionally, electric savings could be limited due to the fairly low penetration of electric heating. Therefore, respondents concluded that careful planning is critical before rolling out a smart thermostat rebate, especially if there will be efforts to use them as both an energy efficiency and demand response tool.[31]

The authors included smart thermostats and connected home technologies as measures having technical energy savings potential due to the fact that program administrator "respondents frequently identified these products as having potential."[32] The authors noted, however, "there were relatively few discussions of the incremental costs associated with these products." Moreover, the study noted that "most measures discussed achieve roughly the same level of savings as – or a lower level of savings than – 10 LED light bulbs would, despite substantially higher costs for many of these products," highlighting "the challenges of replacing the savings produced from lighting."[33]

Symantec reported that the number of Internet of Things attacks increased from about 6,000 in 2016 to 50,000 in 2017—a 600% rise in one year.

Other issues that arise when recognizing the potential of smart thermostats and demand response programs include cyber terrorism and privacy concerns. According to a 2018 report from security firm Symantec,[34] the Internet of Things -- the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data -- continues to grow as a prime target for cybercriminals. Symantec reported that the number of Internet of Things attacks increased from about 6,000 in 2016 to 50,000 in 2017—a 600% rise in one year.[35]

The idea of creating a record of when a homeowner or tenant is present within the building based on thermostat temperature controls raises documented privacy concerns as well.[36] The fact that smart thermostats enable both the collection of personal energy usage data and third-party control of the thermostat is not referenced in online product messaging. These are issues that "should be watched," according to Riley Hastings, senior analyst, Energy Efficiency at Massachusetts-based electric utility Eversource Energy. But, she adds, to the extent these concerns with smart thermostats exist, "it's not something that's impeding our desire to move forward with them as an energy efficiency measure." National Grid's Vavak likewise does not see cyber security issues slowing utilities' interest in demand response programs.

Smart thermostats also provide energy efficiency program administrators, evaluators, and contractors "real-time insight into a home's energy performance and can assist them in post retrofit measurement and verification."[37] Notwithstanding these two-way communication capabilities, the question of whether a smart thermostat is the right, cost-effective measure for installation in low-income homes is a question requiring careful analysis by weatherization program experts.

Low-Income Weatherization and Smart Thermostats – Client Demographics Matter

The demographics and behavior of the residents of a particular household matter when it comes to choosing the right thermostat, Massachusetts-based and other state weatherization experts agree. ACEEE ranked Massachusetts as the best state for energy efficiency (or tied for the best) over the past nine years (2011-2019).[38] One reason for that standing is the results produced by its highly successful, low-income energy efficiency programs overseen by the Massachusetts Low-Income Energy Affordability Network (LEAN), an association of nonprofit agencies (mostly Community Action Agencies, or CAAs) that coordinate the delivery of government and utility ratepayer-funded energy efficiency services to low-income utility customers throughout Massachusetts.[39] LEAN leverages multiple funding sources and aligns different program rules to comprehensively serve low-income households. Since its inception in 1997 through 2018, LEAN's member agencies have delivered more than $1.3 billion in energy efficiency upgrades to more than 200,000 low-income Massachusetts households at no cost to the client.[40]

According to John Wells, vice president for Property and Energy Services at Action for Boston Community Development, Inc. (ABCD), the cost of smart thermostats and the particular demographics of LEAN clients do not support the widespread installation of smart thermostats in programs that LEAN administers.

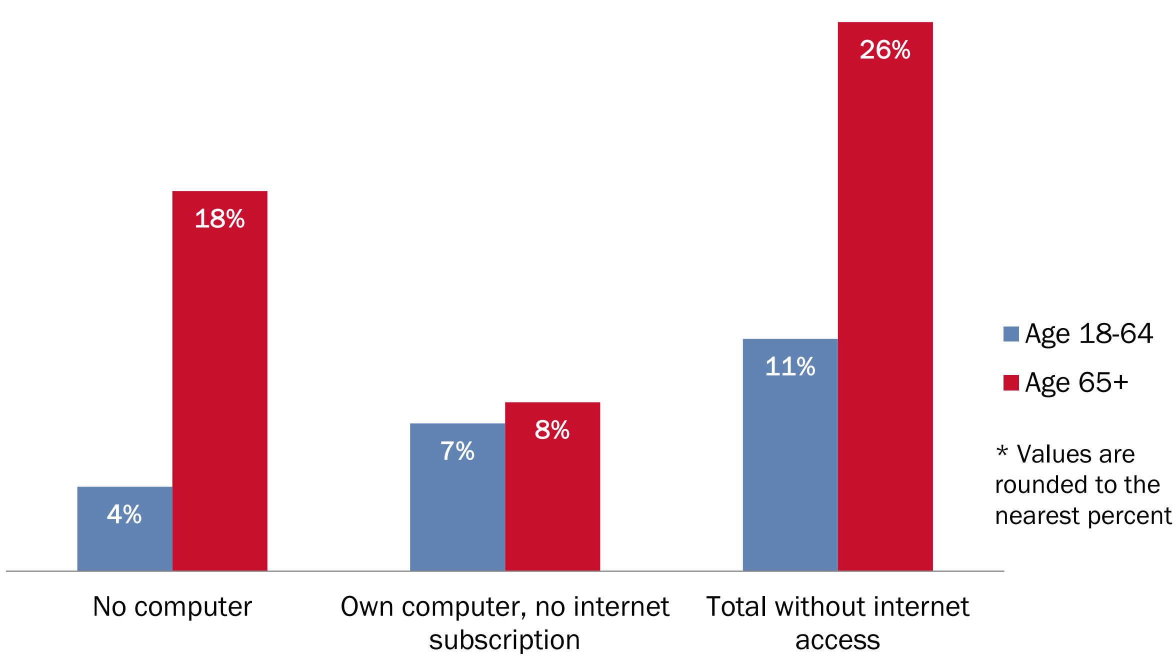
Notwithstanding the generally positive assessment of the potential for energy savings that smart thermostats offer consumers, LEAN member agencies report that they have yet to see significant interest in smart thermostats from their clients. According to John Wells, vice president for Property and Energy Services at Action for Boston Community Development, Inc. (ABCD),[41] the cost of smart thermostats and the particular demographics of LEAN clients do not support the widespread installation of smart thermostats in programs that LEAN administers.

Today, in LEAN's single-family and multifamily energy efficiency programs, manual, programmable and smart thermostat technologies are all available for installation. However, non-programmable thermostats are typically installed when HVAC replacements are made, according to Wells. While the programmable and smart thermostats that are on the market have great potential, in his experience, "the practical day-to-day is that customers don't get engaged with controlling their heat and active programming," he says. Even the installation of a manual (non-wifi) programmable thermostat in client homes has not been popular with many of his clients, 35% of whom are 65 years of age or older. "Our experience is people don't know how to use smart thermostats effectively." While acknowledging the significant potential smart thermostat capabilities present, his view is that "the technology is sort of ahead of the customer's desire to use it." Access to quality and readily available trouble-shooting information for smart thermostats, too, remains a concern with Wells.

The U.S. Census Bureau's American Community Survey (ACS) Reports document that nearly half of all U.S. households (48%) have "high connectivity"—a term used to refer to households with a laptop or desktop computer, a smartphone, a tablet, and a broadband Internet connection.[42] However, this connectivity rate varies significantly based on household income and age. According to the ACS data, among those households with an annual income below $20,000, a full 40%—more than double the national average and representing 7 million households -- have no internet subscription through any mechanism.[43] In comparison, only 5% of families earning more than $75,000 are without internet subscriptions.[44]

Older consumers and people of color are also more likely to have limited or no internet access. Eight and a half million people over age 65—almost 18% of all elders—have no computer in their households, compared with only 4% of working people ages 18-64.[45] Almost 4 million older consumers (8%) have a computer without an internet subscription. This means that 12.4 million older consumers, more than 25% of all older consumers, are without internet access.[46] About 10% each of Black and Hispanic Americans, more than 10 million people, have no internet subscription. Among white families, only 6% lack internet.[47]

CHART: PERCENT OF ADULTS WITHOUT BROADBAND INTERNET ACCESS BY AGE GROUP



Source: U.S. Census Bureau American Community Survey by Type of Internet Subscription by Selected Characteristics (2017)

In addition, a clear majority of adults ages 65 and older do not own a smartphone. According to the Pew Research Center, ownership rates of smartphones varies even within this population: 59% of those ages 65 to 74 are smartphone owners, but that share falls to 40% among those 75 or older.[48] The Pew study reported similar double-digit gaps between broadband wifi access based on income level. For example, 92% of adults from households earning $75,000 or more a year say they have broadband internet at home, but that share falls to 56% among those whose annual household income falls below $30,000.[49] Overall, 17% of Americans are now "smartphone only" internet users—meaning they own a smartphone but do not subscribe to broadband internet service at home. This share has roughly doubled since 2013. Ownership of smart phones alone does not enable connection to smart thermostats without home wifi access.[50]

Overall, 17% of Americans are "smartphone only" users, which, without home wifi access, does not enable connection to smart thermostats.

Massachusetts data on households with a broadband internet subscription support Wells' hesitation in incorporating smart thermostats as a standard LEAN energy efficiency program measure. Only 62.6% of customers whose income falls at or below $20,000 had a broadband internet subscription.[51]

Nest emphasizes that wifi connection is not needed for a home to experience heating or cooling energy savings. But Nest notes that "you won't have access to all your thermostat's features, and some of the energy saving features on your thermostat won't work as well."[52] It includes in the list of examples of features that require wifi as:

1. the ability to get local weather data;
2. the download of thermostat software updates; and
3. the ability to control the thermostat with a phone or tablet.[53]

How a smart thermostat "learns" a person's temperature-setting needs and senses when a customer is at home is important in understanding who are and are not good candidates for a smart thermostat, and whether the additional cost, as compared to manual and programmable models, is worth the investment. Smart thermostats' algorithm-based function, for example, "learns" when the customer is home or away by how often the temperature is adjusted or whether the customer walks in front of the thermostat.[54]

Nest also notes that the Home/Away Assist is activated depending on where people's phones are, and whether the thermostat is noticing any activity in the home.[55] Knowing when the thermostat will automatically switch to Home or Away depends on several things, according to Nest. They include the location of everyone who shares access to the home, a customer's phone's cell signal strength, nearby wifi signals, and the phone's hardware and software versions, which can impact the accuracy of the person's location.[56] It also matters where the smart thermostat is installed in the home so it can sense motion.[57] For instance, the manufacturer notes, if the thermostat is installed in an alcove that is away from normal daily traffic, it may not be able to notice when people arrive.[58]

When utility-funded energy efficiency funding is braided with federal Weatherization Assistance Program (WAP) funding, services to households must be prioritized in accordance with the U.S. Department of Energy (DOE) WAP rules. For example, residences with elderly and disabled clients are considered "priority" households, along with households with children.[59] Clients remaining home during the day as a result of age, disability, or presence of pre-school-age children impacts whether energy savings due to thermostat temperature setbacks can be achieved.

Brendan Delaney, technical manager of energy services for Action, Inc., which oversees Massachusetts weatherization efforts for electric and gas utility National Grid, states that while smart thermostats should be made available to a client, "the actual installations will be few and far between." What is critical, according to Delaney, is communication between the field (installation) specialist and the customer to ensure that a smart thermostat installation is appropriate. "The conversations by the field specialist with the client are key to determine whether a smart thermostat is both right for the residence and to ensure that savings are achieved."

Delaney notes that, consistent with the ACS and Pew data findings regarding internet connectivity, the age of the client is important in assessing a client's thermostat needs, particularly when the clients are low-income. "A lot of our clients are elderly and don't use wifi." He notes that smart thermostats are "just a fancy (more expensive) programmable thermostat if you don't have wifi."

Information gathered in a 2015 Cadmus Group, Inc. evaluation of the 2013–2014 Programmable and Smart Thermostat Program for Indiana-based Vectren Corporation supports Delaney's and Wells' concerns. In the report, evaluators specifically examined the impact of demographics on energy savings performance of thermostats. Cadmus collected space temperatures and air conditioner run times from approximately half the Nest and programmable thermostat homes.[60]

The study noted that participants over the age of 65 are more likely to be retired and home on weekdays. The evaluators noted that, assuming that this is true for the sample, "the potential for energy savings from weekday daytime setbacks is lower in homes with participants over age 65 compared to under age 65."[61] They found that the loss of potential for weekday daytime savings for this demographic is greater in homes with the Nest smart thermostat than a programmable thermostat because Nest's Auto-Away and Auto-Schedule features have the largest impact on savings during this period, based on temperature data analysis. While evaluators concluded that, overall, participants with the Nest thermostat reduced their heating gas consumption by approximately 12.5%, compared to only 5.0% for those who used a standard programmable thermostat, the findings indicated that the gas savings are higher in the Nest thermostat homes *due to a reduction in indoor temperature during the daytime on weekdays*.[62] That level of energy savings will not occur if a weatherization client is at home during the day. In addition, assuming participants over age 65 are less likely to use smartphone, tablet, and computer technologies, this demographic is less likely to control a smart thermostat remotely and view monthly energy report e-mails designed to educate the consumer about additional energy savings opportunities.

How participants used their programmable thermostats directly impacted savings results, the study showed. Cadmus evaluators estimated that 51-78% of programmable thermostat users overrode their programmed schedule.[63] The evaluators noted that the smart thermostat Auto-Away feature significantly reduces the impact on such overrides by automatically reinstating temperature setbacks through algorithms that determine when the home is unoccupied, and an Auto-Schedule feature that learns users' behaviors based on how they set the thermostat and automatically programs a setback schedule. Programmable thermostats cannot reinstate a temperature setback until the next setback period[64] which is one possible explanation for the higher Nest heating energy savings numbers.

Art Wilcox, a technical consultant for the Massachusetts LEAN program, makes clear that demographics and building type matter when it comes to deciding what kind of thermostat to install in any structure. He says, the lifestyle or occupancy habits of the building's occupant "is probably the biggest" of all of factors impacting achievement of forecasted energy savings.

Wilcox notes that the age of the occupant is especially relevant to the thermostat installation decision because elderly customers "are often living in an increasingly smaller world. Physical space is smaller. Things that make you happy are comfort. They're not going to see the value."

He confirms Beote's observation that there is pressure within energy efficiency programs to find measures that will replace the lost energy savings in the lighting sector. Wilcox is no fan of programs that automatically deem a measure's energy savings if that measure's ability to deliver savings is impacted by several factors, such as customer behavior. "No building is a static entity," Wilcox notes. He views the future of smart thermostats overall as "a relatively small niche measure at best" in terms of replacing energy savings lost to the transition away from lighting as a program measure. Wilcox believes, however, that as long as there are clear protocols as to when a smart thermostat should be installed, it should be on the list as an available measure in weatherization programs. "But," he notes, "there's going to be a lot of properties where it's not going to be wise to do it."

Beote of Action, Inc. understands the general interest among program managers and vendors to promote smart thermostats as one of the new measures to make up for the savings lost to the eventual elimination of LED lighting as a cost-effective measure. "They see (thermostats) as low hanging fruit," Beote states. "I think it's because they're so many of them around. There are a couple million thermostats that could be replaced." While Beote believes that weatherization clients should have access to all technologies available in energy efficiency programs, including smart thermostats, he said, "The general pushback from our program is they're not a great fit for everybody."

Beote adds that client education is a critical component of weatherization services. "We always want to make them aware of all their options so they're well-informed." He explains, "It's a conversation with each client. We always let everyone know what's available, what's out there, what we can provide. We don't want to make that choice for them. We want them to be informed." By the time a weatherization project is complete, he says, "we like to think that we leave a client much better informed than when we walk in the door. Not just how much they're going to save on their heating bill, but the science behind why they're going to save it." Beote believes there are "diminishing returns" in the energy savings of a smart thermostat compared to a properly installed and used manual programmable thermostat. "It's not that much larger if it's larger (at all)," Beote states.

Mick Prince, manager of the Illinois Weatherization Assistance Program, which, like the LEAN network, now leverages millions of utility program dollars in its delivery of single- and multi-family weatherization program delivery, shares the LEAN administrators' skepticism over widespread introduction of smart thermostats. Prince believes savings between a manual programmable used properly and a smart thermostat would be negligible. Moreover, he concurs with Wells that even a manual programmable thermostat's setback function, which changes a home's temperature setting based on manual programming, is not appropriate for most elderly, low-income clients who remain at home during the day and are more vulnerable to temperature changes than the general population.

Prince notes, too, that installation of a smart thermostat makes no sense if the client does not have a broadband internet subscription. While the Illinois program permits a smart thermostat installation, Prince argues those circumstances are very limited in number. "You've got to have a tech-savvy client," he observed. Given lower internet and smart phone access rates within low-income communities, and particularly within the over-65 age group, any broad installation of smart thermostats is not cost-effective, according to Prince.

Prince also points out that the DOE WAP rules require that weatherization priority be given to elderly clients, most of whom are at home during the day or homebound, according to Prince. About 27.5% of the Illinois WAP units served are occupied by disabled persons and about 54% of units served are occupied by elderly persons, according to Prince. If clients are remaining at home during the day, the installation of even a manual programmable thermostat makes little sense, he states.

Prince remains skeptical of smart thermostat savings estimates he has heard vendors and some evaluators claim. He points out that unlike the replacement of an antiquated, inefficient furnace with a 95% highly efficient furnace, which delivers verifiable energy savings based on equivalent run times, savings from thermostats depend on customer behavior, which makes assessing energy savings difficult. "There are too many variables," Prince says.

He also notes that the assumed cost-effectiveness of a measure can be undermined if a client requires a callback for trouble-shooting issues, and WAP implementers have to return to a client's home to provide additional client information. "Those costs have to be considered," Prince notes, when assessing the cost-effectiveness of smart thermostats. In the meantime, while manual programmable thermostats and smart thermostats are made available for installation in the Illinois program, the default measure remains a non-programmable, digital thermostat.

Ohio Partnership for Affordable Energy (OPAE) Executive Director Dave Rinebolt agrees that smart thermostats have limited applicability to income-qualified weatherization efforts. As the managing director for this not-for-profit energy agency, Rinebolt states that smart thermostats are installed in weatherized low-income homes only on a very selective basis.

Rinebolt agrees that access to a broadband internet connection and a smart phone or tablet is a prerequisite for achieving assumed energy savings. In addition to lower broadband internet connection rates among low-income customers, as compared to the U.S. population as a whole, Rinebolt notes that geography matters, too. He states that OPAE clients in rural areas have significantly less access to broadband internet service than clients living in urban areas.

Setting aside income disparities in broadband internet access, the Federal Communications Commission (FCC) reported in 2019 that "the gap in rural and Tribal America remains notable" with over 26% of Americans in rural areas and 32% of Americans in Tribal lands lacking broadband internet coverage, as compared to only 1.7% of Americans in urban areas.[65]

A 2018 ACEEE report points to the reason for the broadband access disparity:

> Telecommunication companies have been slow to move into the rural broadband market, finding it cost prohibitive to serve sparsely populated areas. The lack of rural broadband not only impedes efficiency program marketing but also hampers advanced energy management and other energy savings strategies across the residential, commercial, and industrial sectors.[66]

Beote of Action Inc. concurs, noting that geographic impacts matter when assessing the question of which thermostat to install. For example, he notes that the central and western portions of Massachusetts are rural, and can lack broadband internet and cell phone towers.

Rinebolt of Ohio echoes the belief that demographics and assessing client behavior patterns are critical in determining what kind of thermostat to install in a home. "The family needs to have the right profile in terms of occupancy," Rinebolt concludes. That means, that the family needs to be out of the home for a reliable period of time to achieve the savings that smart thermostats enable and to justify the additional cost relative to programmable and manual models. That requirement often does not apply to OPAE clients, according to Rinebolt. Many, he points out, are working one or more part-time jobs, and as a result are not in control of their schedules. The location of the thermostat matters, too, Rinebolt notes. "If the thermostat is in the dining room or in the upstairs hallway, they don't do you any good, unless you're using remote sensors, which we're not (installing)."

Demographics and assessing client behavior patterns are critical in determining what kind of thermostat to install in a home.

At the end of the day, Beote says, deciding whether to install a smart thermostat is a matter best addressed by the weatherization implementers on the ground after a conversation with the client, based on all of the particular circumstances that matter in terms of potential energy savings and client preferences. "We want to do what's best for the client to keep them safe, keep them comfortable, and reduce their energy consumption. That's our mission."

Smart Thermostat Energy Savings – Potential vs. Verified Savings

Energy savings estimates vary widely in published wifi evaluations and research. Gas and electric savings from smart thermostats are calculated separately.[67] In a December 2016 report examining the existing and future residential use cases for smart thermostats, the U.S. Department of Energy highlighted the significant disparity and uncertainty in energy savings estimates for smart devices it referred to as "connected thermostats" (CT):

> The CT market has experienced tremendous growth over the last 5 years—both in terms of the number of units sold and the number of firms offering competing products -- and can be characterized by its rapid pace of technological innovation. However, despite many assuming CTs would become powerful tools for increasing comfort while saving energy, there remains a great deal of uncertainty about the actual energy and cost savings that are likely to be realized from deployment of CTs, particularly under different conditions.[68]

A 2018 ACEEE paper that examined smart technologies and their impact on energy savings took what might be characterized as a more optimistic view of the verifiable energy savings associated with smart thermostats. The Executive Summary of that report states, "Smart thermostats have proved to reduce HVAC energy consumption; average savings of 8% in heating costs and 10% in cooling costs can be expected."[69]

That same ACEEE study also notes that a review of smart thermostat program evaluations from various states shows a wide variance in reported energy savings estimates.[70] It comes as no surprise that a variety of factors and assumptions impact energy savings findings.

A Sampling of Smart Thermostat Energy Savings Results

Energy savings estimates for smart thermostats are literally all over the map. A review of evaluations from a sampling of states reveals significant variances in energy savings (both positive and negative) tied to occupant behavior, temperature setpoint baselines, the type of HVAC system being controlled by the smart thermostat, accompanying customer education, overall customer energy usage levels and customer demographics. The Northeast Energy Efficiency Partnership (NEEP) produced a guidance document in April of 2017 on measuring energy savings from smart thermostats that emphasized the savings *potential* of smart thermostats, while recognizing the uncertainty in the measure because of several variables. The author noted:

> Efficiency programs, pilots, evaluations, and whitepapers throughout the country have documented the savings *potential* of smart thermostats, ranging from lows of zero or even negative savings to upwards of 20 percent savings… While as a category, smart thermostats has shown a yield of significant savings in many cases, the expected savings of an individual home depends on individual factors, such as:
>
> - type, age, and configuration of the HVAC system;
> - details of the specific house, such as floor plan and envelope thermal efficiency;
> - climate and seasonal impacts; and/or
> - occupant behavior and preferences, including occupancy schedule.[71]

The NEEP guidance points out that unlike products like efficient furnaces or light bulbs, smart thermostats involve a more nuanced analysis of energy savings because of the many variables, such as occupant behavior, that impact the savings achieved by these products:

> While any efficiency measure faces a degree of uncertainty when calculating savings (e.g. realized savings from a newly-purchased light bulb depends on what type of bulb it replaces and how often that light is on), programs and evaluators find ways to manage the uncertainty through statistically rigorous studies. One example is socket saturation and hours of use studies for lighting.

> Smart thermostats, however, have both significant per-unit savings potential as well as a high level of uncertainty when compared to more traditional one-for-one efficient measures.[72]

A survey of studies from around the country confirms that savings estimates vary regionally, pointing to the impact of climate on any thermostat's energy savings potential. Nick Lange, Program Lead for Emerging Strategies at ICF, a global consulting firm, believes smart thermostats hold significant potential for delivering energy savings, but notes that climate matters when it comes to assessing the need or desirability of installing a smart thermostat. For example, he notes that in places like Hawaii that have ideal temperatures year-round and lack temperature extremes, smart thermostats have limited energy savings potential.

A 2016 study assessing the potential energy savings potential of five home automation technologies prepared for the Consumer Technology Association (CTA) further highlighted the reasons energy savings results can vary among evaluations:

> Different baseline scenarios, especially, can greatly influence the results of a study, making direct comparisons difficult or impossible. Results may also pertain only to specific climate regions, demographics, thermostat products, or have other restrictions, limiting how the results can be interpreted or generalized. Because not every home has the same kind of thermostat or the same setpoints to begin with, replacing an existing thermostat with a connected thermostat could yield appreciably different changes in performance from one home to the next.[73]

The variances present among studies are highlighted in the ACEEE paper, which notes that the CTA study reports 15% heating savings for homes in very cold climates and 20% cooling savings in mixed-humid climates.[74] The CTA report authors, however, specifically noted that "absolute savings" were calculated based on climate "using typical regional household energy consumption," not specific customer usage analysis.[75] In comparison, second-year results of a Pacific Gas &Electric study found 1–5% electric savings and 0–4% gas savings on average for three different smart thermostats installed in 2,207 homes in PG&E's California service territory.[76] Meanwhile, the 2019 version of the Mid-Atlantic Technical Reference Manual projected average heating and cooling savings projections at 6% for electric heating, 7% for cooling and 6% for fuel heating.[77]

California

In a California study that analyzed both the energy efficiency and demand response results tied to a Southern California smart thermostat incentive/demand response program, evaluators "found statistically significant increases in the average daily kWh after installation of the smart thermostats."[78] These statistically significant increases in energy usage (i.e., negative savings) occurred in both cooling and heating seasons, according to the evaluators, but the magnitude of the increase varied. The report stated that the "analysis was replicated across climate zones and connected HVAC types, which yielded similar results."[79]

The California study noted that while the customers in this study participated in demand response events and demonstrated successful shifting of energy load during peak periods, "on non-event days, some of these households may not have felt the need to employ energy saving features of their thermostats."[80] The evaluators surmised that "[i]t is also possible that having sacrificed some personal comfort on event days for demand savings, participants were less willing to trade personal comfort for energy efficiency on the non-event days."[81] The evaluators reported that customers with lower, pre-installation energy usage patterns showed lower and even negative energy savings which offset greater relative energy savings realized by customers with higher pre-period energy usage.[82]

The California study suggested that future program design look at tiered incentive designs to investigate whether behavior can be further modified using smart technologies. Past findings suggest that "when provided with relevant energy saving information, customers are more likely to engage in energy efficient behaviors."[83] But, while noting that the estimated savings varied substantially across climate zones and weather conditions, the evaluators' findings "suggest that smart thermostat energy savings are limited to certain customers. Results reiterate that not all customers are willing and/or able to modify their energy usage with the assistance of a smart thermostat."[84] The evaluators concluded that "From a behavioral design perspective, targeting customers with moderate to high energy usage appear to have greater potential for consistent energy savings with the installation of a smart thermostat."[85]

Colorado

Three years ago, Nest launched its first "Nest Power Project" pilot with the Colorado Energy Office Weatherization Assistance Program to test the incremental heating energy savings potential from the installation of Nest Learning Thermostats. Nest provided a local WAP agency, Arapahoe County Weatherization, with Nest thermostats at no cost and installed them in approximately half of the homes they weatherized from May 2016 through December 2017. A Nest summary of the pilot noted that a home was considered a candidate for thermostat installation if (1) it was a single-family, owner-occupied residence, including manufactured/mobile homes; (2) heated with natural gas provided by Xcel Energy; (3) had only one thermostat in the home; and (4) the customer was willing to have a Nest thermostat installed. The study author noted that wifi in the home was not required. Importantly, in addition to the stated eligibility criteria, implementers "also used their judgment about the likelihood of a successful installation based on discussions with the client and a desire to not push the technology onto clients that might not be a good use case."[86]

A total of 74 WAP+Nest jobs and 43 standard WAP jobs were included in the analysis.[87] The additional, incremental savings from the Nest thermostat were estimated at 58 therms/year, equal to 7.3% of total gas use and 9.4% of heating use.[88] While the authors noted that "the samples were too small for any strong or statistically significant conclusions," the report asserts that the absence of wifi "did not appear to have any significant impact on the incremental savings," although there were only 15 WAP+Nest homes that did not have wifi.[89]

Steve Elliott, weatherization division manager for Arapahoe County Community Resources, noted that the County assisted the evaluation by providing data but did not participate in developing any final conclusions regarding the pilot. He stated that, in his opinion, the energy savings in the Nest evaluation summary attributed to "just weatherization" (that is, measures such as insulation and air sealing without a smart thermostat) was "low," noting that the energy savings associated with these measures were typically much higher than the report surmised. “Maybe a larger sample would be better,” Elliott stated.

The data assessed was also compared to data from other Nest customers in the same area of Colorado, excluding vacation homes. The analysis highlighted notable differences in resident occupancy patterns, as evidenced by the amount of time the thermostats spent in “Eco” mode, which is triggered either by the occupancy detector on the thermostat or by a manual change by the homeowner:

> WAP client homes spent only about half as much time in Eco mode as the typical Nest customer homes -- an average of 1.7 hours per day vs. 3.2 hours per day. This difference isn't very surprising when one considers expected demographic differences such as more elderly occupants, people with disabilities, extended families, and families with young children.[90]

The Nest report authors concluded that “[o]verall, the analysis of thermostat data indicates that WAP clients are generally using the Nest thermostat effectively but that the lower frequency of times when the home is unoccupied limits the savings slightly.”[91] In all, the report concludes that “about half of WAP clients may be good candidates for having a Nest thermostat added to their WAP treatments.” A yet-to-be released follow up study that includes utility data through the winter of 2017-2018 is expected to increase the sample available for analysis and provide more precise and detailed findings.

The “Nest Power Project” continues, with its stated goal of distributing one million Nest thermostats in low- and moderate-income homes by 2023, in part by offering the thermostats “at cost” to state and local weatherization providers, fair housing agencies and other organizations, according to Serj Berelson, manager of Energy Regulatory Affairs for Home/Nest Products.

Illinois

Illinois energy efficiency experts are currently wrestling with establishing the deemed energy savings to be assigned to smart thermostats. Navigant Consulting Corporation, Inc. (Navigant), the independent evaluator for the Northern Illinois gas and electric utilities, conducted three impact analyses in Illinois. Based on a review of early smart thermostat evaluations, the Illinois Technical Resource Manual (TRM) technical consultants set cooling savings at 8%.[92] Heating savings are currently deemed at 8.8% over manual thermostats and 5.6% for manual programmable thermostats.[93]

But these numbers will likely change with time and future evaluations, which are now being planned by Illinois independent evaluators through the state’s Technical Advisory Committee (TAC). “Eight percent (cooling savings) seemed like a reasonable number” based on those early studies, explained Pace Goodman, who worked for Navigant at the time and was actively involved in the Illinois TAC. But once Chicago-area electric utility Commonwealth Edison Company (ComEd) launched a smart thermostat pilot and evaluations began, that savings figure was put in doubt, Goodman says.

The November 2018 report analyzed the savings achieved by smart thermostats incentivized through Chicago-area electric utility ComEd's rebate program for the 2015-2016 program year. As part of the analysis, the evaluators examined electric cooling savings, and included an examination of how if at all a customer's receipt of a Home Energy Report (a behavioral program that provides a comparison of the customer's usage with neighbors in similar nearby housing stock) impacted savings. The evaluation revealed markedly different results than the 8% cooling energy savings that had been assumed in the state's TRM. Navigant evaluators found 2% cooling savings for smart thermostat participants who did not receive Home Energy Reports, "and about 0, or even perhaps slightly negative cooling savings for participants who did receive HERs (internal citation omitted)."[94] The Navigant evaluation recommended that the Illinois TRM administrator and the Illinois TAC consider updating the cooling reduction factor in the next version of the Illinois TRM, to revise the assumed 8% electric savings to 2%.[95] When consensus could not be reached among TAC participants, participants agreed that the electric savings figure would remain at 8% pending new evaluation results expected in 2020.

Indiana

In a 2015 evaluation of a programmable and smart thermostat program run by Indiana utility Vectren Corporation, evaluators found that participants with the Nest thermostat reduced their heating gas consumption by approximately 12.5%, compared to only 5.0% for those who used a standard programmable thermostat.[96] The evaluators noted findings indicating that the gas savings were higher in the Nest thermostat homes due to a reduction in indoor temperature during the daytime on weekdays. The Nest and programmable thermostat groups reduced cooling electric consumption, however, by approximately the same amount—13.9% (Nest) and 13.1% (programmable). The evaluators concluded Nest has greater potential than the programmable thermostat to capture savings during the daytime on weekdays, when many participants might leave home without turning down their thermostats. Evaluators highlighted the impact the age of study participants and their behavior had on energy savings results.

> Participants over the age of 65 are more likely to be retired and home on weekdays. Assuming this is true for the sample, the potential for energy savings from weekday daytime setbacks is lower in homes with participants over age 65 compared to under age 65. The loss of potential for weekday daytime savings for this demographic is greater in homes with the Nest than programmable thermostat because Nest's Auto-Away and Auto-Schedule features have the largest impact on savings during this period (as shown in temperature data analysis). In addition, assuming participants over age 65 are less likely to use smartphone, tablet, and computer technologies, this demographic is less likely to control Nest remotely and view monthly energy report e-mails.[97]

Study participants receiving the Nest were required to have Internet in their home so that they could use the wifi features.[98]

Massachusetts

In a 2012 Cadmus Group evaluation of a Massachusetts wifi thermostat pilot, evaluators concluded that the electric savings for non-programmable thermostat replacements are effectively equal to those for programmable thermostat replacements.[99] The evaluators noted that "Not all occupants use the full functionality of their programmable thermostats. In cases where an occupant has a programmable thermostat but declines to use the schedule and set point functionality the thermostat is effectively a non-programmable thermostat."[100]

The Massachusetts study further concluded that electric savings associated with wifi-enabled thermostats vary significantly from one house to another, with the occurrence of energy savings "very dependent on occupant behavior and baseline set point information."[101] The evaluators noted, too, that for some participants, the energy savings benefits of a wifi-enabled thermostat are similar to those of a standard programmable thermostat. Cadmus evaluators found that "Whether a participant saves more energy with a wifi thermostat than they would with a programmable thermostat is difficult to quantitatively predict as the savings are reliant on participant behavior."[102]

The study further noted that wifi-enabled thermostat gas savings for non-programmable thermostat replacements (10% per thermostat) are larger than for programmable thermostat replacements (8% per thermostat).[103] Eversource analyst Hastings notes that more information will be forthcoming about actual energy savings achieved in residential smart thermostat installations through a two-year Massachusetts statewide evaluation, projected to be completed in 2021. If savings are to occur, she notes, the settings on the thermostat are very important. "You need to make sure the temperature settings are being optimized," Hastings states. That means that during the summer, the thermostat has to be set at a temperature that is achieving savings – not colder than the customer would have otherwise set it at, and vice versa for the heating season.

New York

The New York State Energy Research and Development Authority (NYSERDA) undertook a study of the potential of home energy management systems (HEMS) that included the installation of smart thermostats. The stated objectives of the study, performed by the National Renewable Energy Laboratory (NREL) for NYSERDA and published in March of 2019, were "to implement simple HEMS solutions for lighting, space conditioning, and plug loads in single-family homes and multifamily units in Con Edison's service territory—and to develop technology transfer strategies based on datasets and insights gained during the implementation process."[104] The authors noted that the demonstration was designed with a particular focus on stakeholder education, "to help promote the benefits and savings of HEMS technologies across New York State and achieve wide-scale adoption of proven products and strategies."[105] While the authors characterized the energy savings conclusions as "anecdotal at best" given the small size of the study, the most impactful results, the study stated, "are derived from observations and challenges… encountered during the actual site visits and subsequent homeowner interactions."[106]

They noted:

> Smart thermostats are often not as do-it-yourself or DIY friendly as they may seem. Many homes have legacy wiring or newer air conditioners with proprietary thermostat systems. Future programs may wish to include installation credit as an option, and in addition, work with local trades to have a list of approved and recommended installers.[107]

And even though the pilot eligibility requirements sought single-family home customers with a central ducted AC system that was compatible with the ecobee4 thermostat and a preference for customers with a central heating system as well (so that thermostat will control both heating and cooling systems), installation complications arose:

> A major unexpected complication for both program administrators and evaluators was that, for the majority of the single-family home participants, upgrading their thermostat to the ecobee4 smart thermostat was either complicated or not possible. Of the nine SFHs in the demonstration, only three homes had both air-conditioning and heating systems that were compatible with the ecobee. Many of the homes had separate thermostats for heating and cooling, and in many of these cases only the heating system was compatible with the ecobee. In addition, five of the homes had legacy wiring systems and/or lacked a common wire, and it was necessary to schedule a follow-up visit with an HVAC technician to complete the installation. In the end, a total of 11 ecobee thermostats were installed in eight homes (seven SFHs and one MFU), with only three ecobee thermostats controlling a central AC.[108]

As previously noted, however, the next generation of some smart thermostats do not require a common wire. This development may solve some installation issues.

Oregon

Energy savings results, too, may depend on the HVAC system being controlled by the wifi thermostat. A 2015 Energy Trust of Oregon evaluation involving smart thermostats and air source heat pumps found 12% average electric heating savings tied to smart thermostats both in the initial study and in the follow-up evaluation a year later.[109] But another evaluation of an Energy Trust of Oregon Pilot comparing two smart thermostat brands involving gas furnaces reported about 6% heating load savings, on average, in gas-heated homes with one brand and about 5% *increases* in energy use with another brand.[110]

The brand comparison pilot, according to the Apex Analytics, LLC (Apex) evaluation report, focused on the Honeywell Lyric and the Nest Thermostat, two smart thermostats in the market, both of which claimed to offer simple user interfaces with advanced features to save energy.[111]

Features included automated and occupancy-based temperature management and various remote-control options. Among the primary goals of the evaluation were to:

1. quantify the annual natural gas savings that result from installing smart thermostats in single-family homes heated with a gas furnace;
2. identify variations in savings between participants based on demographic and household characteristics and any differences in savings between the two thermostats; and
3. determine whether smart thermostats are a viable technology for achieving cost-effective gas savings in homes heated with gas furnaces, and whether they should be incented by Energy Trust.

The study produced mixed results. The Nest thermostat produced about 6% heating load savings, on average, in gas-heated homes, according to Apex evaluators. On the other hand, the Honeywell Lyric thermostat was associated with significant *increases* in energy use, with the Lyric adding 4-5% to heating loads, on average, in gas-heated homes.[112] Homes where the previous thermostat was manual or not programmed appeared to have substantially higher savings among Nest participants, although there was no difference among Lyric homes. For both thermostat groups, there appeared to be lower savings in homes where the occupancy detection features had been disabled, not surprisingly.[113] The report further stated that "it is worth noting that the Lyric was at a much earlier phase in product development during the Pilot, and feedback from the program has allowed Honeywell to make improvements to the next generation of thermostats. Further testing of future versions of the Lyric and other smart thermostats may reveal energy savings for additional products."[114]

Evaluation Take-Aways

All of the studies make clear that understanding the role of human behavior is perhaps *the* key factor in forecasting and realizing a thermostat's energy savings potential and when designing energy efficiency and demand response programs. ACEEE highlights human behavior as key to achieving reduced energy usage:

> Understanding human behavior is critical for achieving the goals of energy efficiency. Whether we are purchasing goods, using energy to service our homes and workplaces, or responding to the constraints placed upon us by technology and systems that surround us, human behavior is the key.[115]

Understanding the role of human behavior is perhaps the key factor in forecasting and realizing a thermostat's energy savings potential and when designing energy efficiency and demand response programs.

That observation underscores the importance of understanding the unique demographics of low-income client households. The level of client interest in and opportunity to engage with temperature controls (or not) is paramount in the decision of whether to install an advanced thermostat. In addition, the California study's observation that "targeting customers with moderate to high energy usage appear to have greater potential for consistent energy savings with the installation of a smart thermostat" has relevance for weatherization implementers whose clients tend to have lower usage patterns due to the relatively smaller size of their residences. Indeed, a substantial portion of America's low-income population lives in multifamily rental housing.[116]

Glenn Reed of Energy Futures Group and a consultant for the Massachusetts EEAC, cautions against painting low-income customers "with a broad brush" when it comes to predicting energy efficiency measure applicability. But Reed acknowledges demographic characteristics, such as lower wifi-connection rates than the general population, as important factors in assessing the energy savings potential of smart thermostats in the income-qualified energy efficiency programs. While Massachusetts program administrators noted exceptional energy savings results from smart thermostats in recent energy savings reports provided to the Massachusetts Energy Efficiency Advisory Council,[117] Reed explained that recent reported increases in energy savings by Massachusetts program administrators tied to smart thermostats resulted primarily from increases in the number of *purchases* of the devices through the smart thermostat rebate program over utility-forecasted totals. Purchased thermostats are assumed installed and savings deemed, based on the Massachusetts TRM protocols. Amy Vavak of National Grid says that the Mass Save Marketplace,[118] an online product purchase portal, has been the primary avenue for getting smart thermostats in the hands of customers.

While Vavak states that smart thermostats are a vital ingredient to electric utilities' increasing interest in and deployment of demand response programs, she also concurs with weatherization managers that they are not a principal measure to offset the energy savings reductions tied to any diminished emphasis on lighting programs. Riley Hastings of Eversource predicts that the installation of air sealing, insulation, and heating systems will remain primary energy efficiency measures going forward. "I still view weatherization as the core of our business," Hastings states. "And I don't see that going away." Hastings believes that the decision as to whether to install smart thermostats should be left to those on the ground who interact with low-income customers due to the particular demographic and building characteristics that exist within this customer group.

What actual savings can be cost-effectively achieved with smart thermostats – particularly in low-income homes – remains an open question that will likely evolve based on changes in the measure's cost, technical specifications and customer interest. Jerrold Oppenheim,[119] a Massachusetts LEAN attorney who has advocated for the interests of low-income utility customers over his 40-plus-year legal career, questions whether the projected low-income energy savings benefits of advanced thermostats are worth the cost to the program. "Whatever the advantage in savings is," Oppenheim asks, "does it justify the extra cost?"

The aforementioned 2016 report prepared for the CTA on smart technologies' potential included one conclusion about the energy savings performance of smart thermostats that highlights the uncertainty accompanying smart thermostat energy savings forecasts: "We emphasize the need for continued study."[120] In the meantime, weatherization program administrators must assess the value of smart thermostats within the context of program goals, the measure's relatively significant higher cost, and the on-the-ground realities of income-qualified households.

CONCLUSION

Whether smart thermostats are an appropriate and cost-effective measure for installation in income-qualified weatherization client homes is a question requiring nuanced analysis, tailored to the unique circumstances presented in each client residence. Evaluations to date of advanced thermostat energy savings, too, make clear that client behavior is key to realizing energy savings.

The unique demographic characteristics of low-income clients, including lower broadband internet and smartphone or tablet access rates compared to the U.S.-at-large, coupled with higher cost of smart thermostats compared to non-programmable and manual programmable thermostats, do not support widespread installation of smart thermostats in low-income homes.

Given that thermostat energy savings are tied to "learned" behavior and client-initiated temperature setbacks, residences occupied by those who are homebound due to age or infirmity represent inappropriate candidates for smart thermostat installations. Likewise, in order to justify the additional expense of this installation, protocols should include an assessment of whether the customer will be outside of the home a reliably significant period of time in order to achieve the savings that smart thermostats enable. Other factors, including generally lower-than-average energy usage due to the relatively smaller low-income housing stock, raise questions about the cost-effectiveness of widespread smart thermostat installations in low-income weatherization programs.

Widespread installation of smart thermostats will remain neither cost-efficient nor appropriate in low-income energy efficiency programs unless:

1. broadband wifi exists in the home;
2. clients demonstrate specific interest in advanced thermostat installation;
3. clients spend regular blocks of time outside of the home;
4. no technical issue arises that would significantly increase labor costs associated with thermostat installations as compared to less advanced thermostat models;
5. the client is sufficiently technology savvy; and
6. access to critical product education information and trouble-shooting is promptly and readily available.

Ultimately, the decision whether to install smart thermostats in low-income residences is best resolved by on-the-ground, weatherization field specialists, in consultation with the clients they serve.

ENDNOTES

1. In this paper, the "smart" designation refers to both wifi-enabled thermostats that allow a user to control the thermostat's settings remotely through an-internet connected device, such as a phone or tablet, as well as those that have customer occupancy sensors that enable "learning" features and do not necessarily require a wifi connection.
2. Product information for Nest's Learning E thermostat states, "Nest's DR solutions are specifically designed to optimize participant satisfaction through the use of pre-conditioning (where applicable) and personalized schedule adjustments to ensure occupant comfort by limiting deviations from scheduled setpoints. The algorithms are regularly updated and enhanced based on operational experience and user feedback."
3. *See, e.g.,* https://aceee.org/blog/2015/10/smart-thermostat-initiatives-reveal
4. ACEEE is a nonprofit, 501(c)(3) organization that advances energy efficiency policies, programs, technologies, investments, and behaviors through research.
5. ACEEE, *Energy Impacts of Smart Home Technologies,* Jen King April 2018 Report A1801, p. 17.
6. *Id.*
7. *See* https://www.poweredbyefi.org/masssave/heating-cooling/thermostats.html?product_list_mode=grid
8. *Id.*
9. *See* https://www.poweredbyefi.org/masssave/catalog/product/view/id/11/s/luxpro-5-2-day-incented/category/50/
10. *See* https://www.poweredbyefi.org/masssave/catalog/product/view/id/159/s/nest-learning-thermostat-white/category/50/?x=144&y=14
11. *See, e.g.,* https://nest.com/support/images/000001160/WelcomeGuide.pdf
12. *Id.*
13. 2019 Illinois Technical Resource Manual (TRM) v7.0 Vol. 3_September 28, 2018_Final, p. 159.
14. *Id.*
15. *See,* e.g., the 2019 Illinois Technical Resource Manual (TRM), Vol. 3 at 159-160. The purpose of TRMs is to provide a transparent and consistent basis for calculating energy (electric kilowatt-hours (kWh) and natural gas (therms) and capacity (electric kilowatts (kW)) savings generated by a state's ratepayer-funded energy efficiency programs, as typically administered by a state's largest electric and gas utilities or a third party energy efficiency utility. A TRM is a technical document that is serves as a common reference document for stakeholders, Program Administrators, and regulators to provide transparency regarding savings assumptions and calculations and the underlying sources of those assumptions and calculations. *See, e.g.,* 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 7.0, Volume 1: Overview and User Guide (Effective January 1, 2019), p. 4.
16. *See* https://store.google.com/us/magazine/compare_thermostats?hl=en-US&GoogleNest#works/
17. Nest's latest generation of smart thermostat does not require a common wire. *See, e.g.,* https://support.google.com/googlenest/answer/9230098?hl=en&ref_topic=9361775

18. Beote notes that the LEAN network is currently looking at a smart thermostat brand that the manufacturer states solves the missing common wire by incorporating a HVAC module box in the mechanical room that supplies the power to the thermostat.

19. Product specifications state that “Adding a Common "C" wire is not needed in 99% of installations.”

20. *See, e.g.,* Southern California Energy, Smart Energy Program.

21. Massachusetts Joint Statewide Electric and Gas Three-Year Energy Efficiency Plan, 2019–2021, pp. 47-48.

22. NSTAR Gas Company d/b/a Eversource Energy, Petition for Approval of an Increase in Base Distribution Rates and a Performance-Based Regulatory Plan - D.P.U. 19-120 (“Eversource 2019 rate case”), Petition, pp. 1-2. The proposed pilot project would establish a three-year gas demand response program to test its effectiveness in helping to shave peak demand, alleviate temporary pipeline constraints, reduce the amount of pipeline capacity the Company needs to buy, and lower greenhouse gas emissions by reducing overall gas emissions. The Company will contract for a software platform to enroll customers that have wifi thermostats and gas heating. During gas demand response events, the temperature on the customer’s thermostat will be reduced by a couple of degrees for a few hours. Customers will have the ability to opt-out of an event if necessary. Demand response events will be called 3 to 8 times per season between November and March. *See* Eversource 2019 rate case, testimony of Penelope McLean Conner and Michael Goldman, p.37. Residential customer will be paid $25 to sign up and $20 per heating season if they remain in the program. The Company’s goal is to enroll 3,000 residential customers and 50 commercial and industrial customers. *Id.*, pp. 38, 41.

23. For example, a “Direct Load Control” switch can be installed through programs such as Commonwealth Edison Company’s (ComEd) AC Cycling program. The DLC switch, which ComEd will install on the side of a customer’s home or directly on the air conditioner's compressor panel, allows the utility to turn the compressor off, so it uses less energy during a cycling event.

24. *Id.*

25. 2019 International Energy Program Evaluation Conference, Denver, CO, *When are Smart Thermostats a Smart Investment?* Sarah Monohon, Evergreen Economics, Portland, OR, Prapti Gautam, Southern California Edison, Rosemead, CA, Ross Donaldson, Evergreen Economics, Portland, OR, p. 1.

26. The Mass Save 2019-2021 gas and electric utility statewide energy efficiency plan (Mass Save Plan) notes:
“The Program Administrators, with the support of the (Energy Efficiency Advisory) Council, have been able to accelerate the adoption of efficient lighting and support increased building codes through the successful implementation of the energy efficiency programs. Due to these efforts, the lighting market has been substantially transformed. In addition, new standards have increased lighting baselines, creating enduring economic and environmental benefits for all customers, but the savings associated with standard practice and rising baselines reduce the savings claimable by the Program Administrators.” Mass Save Plan, p. 8.

27. The Massachusetts Energy Efficiency Advisory Council (EEAC) was created by the Green Communities Act of 2008, a comprehensive energy reform law that added new energy efficiency and renewable and alternative energy requirements for the Commonwealth. EEAC members guide the development of state energy efficiency plans by the Commonwealth’s investor-owned gas and electric utilities and energy providers. The Council lists its priorities as developing, implementing, evaluating, and monitoring the implementation of these plans. *See* http://ma-eeac.org/about/

28. Session Laws, Acts of 2008, Ch. 169, § 116(a).

29. *Id.*

30. *RLPNC 16-10: What is Next for Products – Market Scan.* NMR Group, Inc. (February 2018), (Exec.. Summary) p. I.

31. *Id.*, p. 15.

32. *Id.*, p. 10.

33. *Id.*

34. *See* https://www.symantec.com/content/dam/symantec/docs/reports/istr-23-2018-en.pdf

35. *Id.*

36. The Internet of Things Privacy Forum, Dr. Gilad Rosner, Erin Kenneally, "Clearly Opaque: Privacy Risks of the Internet of Things," (UC Berkeley Center for Long-Term Cybersecurity, Internet of Things Privacy Forum, May 2018). The authors note: "As to IoT manufacturers being lax in disclosures, a pattern of poorly informing users is emerging. Prof. Scott Peppet surveyed twenty popular IoT devices in 2014, including the Nest Thermostat, the FitBit, health products, and home monitoring systems, in an attempt to gauge the depth and degree of their privacy disclosures. He found them to be shockingly inadequate: 'None of the twenty devices included privacy- or data-related information in the box. None even referred in the packaging materials or user guides to the existence of a privacy policy on the manufacturer's website… Some policies seem to apply to both website use and sensor-device use. Other policies limit their application to website use, not sensor-device use, but provide no means to locate a device-related privacy policy. This leaves unanswered whether any privacy-related policy applies to the data generated by these devices.'" (Internal footnotes omitted.)

37. ACEEE, *Energy Impacts of Smart Home Technologies,* Jen King April 2018 Report A1801, p. v.

38. *See* https://aceee.org/state-policy/scorecard

39. LEAN program offerings are provided to income-eligible customers throughout Massachusetts and include ratepayer funding from the state's gas and electric utilities, including Berkshire Gas, Blackstone Gas Company, Cape Light Compact, Columbia Gas of Massachusetts, Eversource, Liberty Utilities, National Grid and Unitil.

40. In order to qualify for the LEAN weatherization program, a single-family resident's household annual income must not exceed 60% of the area median income (AMI) of same-size households in Massachusetts. For multifamily residential buildings (5+ units), at least 50% of the development households have income at or below 60% AMI.[40] Eligible structures include single-family homes (rental and owner-occupied), small multi-families (1-4 units), condominiums, multifamily buildings (5+ units), manufactured housing as well as group homes, single-room occupancy rooming houses (SRO) and shelters.

41. ABCD is the local community action agency that serves the greater Boston area and oversees the low-income energy efficiency programs offered by Eversource, a Massachusetts electric and gas utility.

42. A broadband subscription refers to households who responded "Yes" in American Community Survey questions to possessing one or more of the following categories: broadband (high speed) such as cable, fiber optic, or DSL, cellular data plan, satellite, or fixed wireless. *Computer and Internet Use in the United States: 2016, American Community Survey Reports*, Camille Ryan, U.S. Census Bureau, (August, 2018), p. 8.

43. U.S. Census Bureau American Community Survey, *Types of Computers and Internet Subscriptions* (2017).

44. *Id.*

45. U.S. Census Bureau American Community Survey by Selected Characteristics (2017)

46. *Id.*

47. *Id.*

48. "Mobile Technology and Home Broadband 2019", Pew Research Center (June 2019), p. 4.

49. *Id.*

50. *Id.,* p. 10. Meanwhile, a growing share of non-broadband users credit their smartphone as a reason why they forego a subscription to high-speed home internet service. According to the Pew study, some 45% of non-broadband adopters say they do not have high-speed internet at home because their smartphone lets them do everything online that they need to do. This represents an 18-percentage point increase from 2015, as 45% of non-broadband users now cite their smartphone as a reason for not subscribing to high-speed internet service when only 27% of non-adopters cited their smartphone as a reason for not having home broadband.

51. U.S. Census Bureau, *Types of Computers and Internet Subscriptions* (2017)

52. https://support.google.com/googlenest/answer/9244917?hl=en

53. *Id.*

54. https://support.google.com/googlenest/answer/9247510?hl=en

55. https://support.google.com/googlenest/answer/9257400?co=GENIE.Platform%3DiOS&oco=0

56. *See* https://support.google.com/googlenest/answer/9251759?hl=en#when-switch

57. *Id.*

58. *Id.*

59. 10 CFR §440.16.

60. Cadmus Group, Inc., *Evaluation of the 2013–2014 Programmable and Smart Thermostat Program*, Indiana-based Vectren Corporation (2015), p. 8.

61. *Id.*, p. 37.

62. *Id.*, p. 41.

63. *Id.*, p. 4.

64. *Id.*, pp. 4-5.

65. Federal Communications Commission, 2018 BROADBAND DEPLOYMENT REPORT, p. 23.

66. ACEEE, *Reaching Rural Communities with Energy Efficiency Programs,* Mary Shoemaker, Annie Gilleo, and Jill Ferguson (September 2018), p. 10.

67. *See, e.g.,* IL TRM Version 8.0, Vol. 3, p. 165.

68. U.S. Department of Energy, *Overview of Existing and Future Residential Use Cases for Connected Thermostats,* Energetics Incorporated (Julia Rotondo, Robert Johnson, Nancy Gonzalez, Alexandra Waranowski), Vermont Energy Investment Corporation (VEIC) (Chris Badger, Nick Lange, Ethan Goldman, Rebecca Foster) p. 25 (December 2016)

69. ACEEE, Report A1801, at v.

70. *Id.*

71. *Claiming Savings from Smart Thermostats: Guidance Document,* Northeast Energy Efficiency Partnerships, Claire Miziolek (April 2017) (emphasis in original).

72. *Id.*

73. Fraunhofer USA Center for Sustainable Energy Systems, *Energy Savings from Five Home Automation Technologies: A Scoping Study of Technical Potential, Final Report to the Consumer Technology Association,* Bryan Urban, Kurt Roth, and Chimere (David) Harbor, April 2016, p. 18.

74. *Id.*, p. 24.

75. *Id.*

76. PG&E Smart Thermostat Study: Second Year Findings, Barb Ryan and Kelly Marrin, Applied Energy Group (March 20, 2018), pp. 1, 2, 5.

77. *Id.*

78. *When are Smart Thermostats a Smart Investment?* Sarah Monohon, Evergreen Economics, Portland, OR; Prapti Gautam, Southern California Edison, Rosemead, CA; Ross Donaldson, Evergreen Economics, Portland, OR (2019), p. 13.

79. *Id.*

80. *Id.*

81. *Id.*

82. *Id.*

83. *Id.*

84. *Id.*

85. *Id.*

86. Nest, *Evaluation of Energy Savings from Colorado Weatherization Assistance Program Nest Thermostat Pilot,* p. 2 (August 2018).

87. *Id.*, p. 5.

88. *Id.*, p. 6.

89. *Id.*, p. 7.

90. *Id.*

91. *Id.*, p. 8.

92. 2020 IL Technical Resource Manual v8.0, Vol. 3 (September 20, 2019), p. 170.

93. *Id.*, p. 168.

94. *ComEd Advanced Thermostat Evaluation Research Report,* Navigant Consulting, Inc., Pace Goodman, Will Sierzchula, Carly Olig, p. 6.

95. *Id.*, p. 9.

96. *Evaluation of the 2013–2014 Programmable and Smart Thermostat Program,* January 29, 2015, Prepared for Vectren Corporation, The Cadmus Group, p. 41

97. *Id.*, p. 37.

98. *Id.*, p. 5.

99. The Cadmus Group, Inc., *Wi-Fi Programmable Controllable Thermostat Pilot Program Evaluation*, prepared for the Electric and Gas Program Administrators of Massachusetts (2012), p. 29.

100. *Id.*

101. *Id.*

102. *Id.*, p. 30.

103. *Id.*, p. 12.

104. NYSERDA, *Home Energy Management Systems (HEMS): Demonstrations In New York City and Westchester Residences,* Report Number 19-13, (March 2019), p. ES-1.

105. *Id.*

106. *Id.*

107. *Id.*

108. *Id.*, p. 13.

109. *See* https://www.energytrust.org/wp-content/uploads/2016/12/nest_heat_pump_control_pilot_follow-up_billing_analysis.pdf

110. *Energy Trust of Oregon Smart Thermostat Pilot Evaluation Prepared for Energy Trust of Oregon,* March 1, 2016, prepared by Apex Analytics, LLC, p. 1-1.

111. *Id.*, p. 1-1.

112. *Id.*, p. 6-1. The evaluation report noted that the Nest thermostat was preset with the Auto-Away feature enabled, while the Lyric model used in the pilot required the user to enable the geofencing feature during initial setup. The report also noted that a higher proportion of Lyric users engaged in manual adjustments of the thermostats. *Id.*, pp. 5-13, 5-14. The report further stated that "it is worth noting that the Lyric was at a much earlier phase in product development during the Pilot, and feedback from the program has allowed Honeywell to make improvements to the next generation of thermostats. Further testing of future versions of the Lyric and other smart thermostats may reveal energy savings for additional products." *Id.*, p. 6-1.

113. *Id.*, p. 1-5.

114. *Id.*, p. 6-1.

115. ACEEE, *Behavior and Human Dimensions.*

116. *Partnering for Success: An Action Guide for Advancing Utility Energy Efficiency Funding for Multifamily Rental Housing*, A Report by National Housing Trust, in partnership with ACEEE, D&R International and the National Consumer Law Center (March 2013), p. 6. *See also ACEEE, Affordable Multifamily Housing*, Stefen Samarripas and Dan York, (April 2019), p. 1 ("The multifamily market is composed of many types of buildings, ownership structures, and residents. Low-income residents make up an important segment of this market and live in many types of multifamily buildings that collectively are often termed 'affordable housing.'"). A third quarter, 2019 report from The U.S. Census Bureau further notes that 78.7% of U.S. households with incomes greater than or equal to the median family income own homes, as compared with 50.9% of households with family income below the family median income. QUARTERLY RESIDENTIAL VACANCIES AND HOMEOWNERSHIP, THIRD QUARTER 2019 Release Number: CB19-157 (October 2019), Table 8.

117. 2016-2018 Term Report Review, presented to the Massachusetts Energy Efficiency Advisory Council, August 21, 2019, page 16.

118. Mass Save Marketplace.

119. Over a more than 40-year career, Oppenheim has played a key role in the development of regulatory policy in U.S. states as legal counsel and advisor for state governments, consumer organizations, low-income advocates, labor unions, environmental interests, industrial customers, and utilities. Oppenheim directed energy and utility litigation for the Attorneys General of New York and Massachusetts, as well as consumer and utility legal assistance programs for low-income clients in New York and Chicago for the U.S. government's legal assistance program. He was founding Director of Renewable Energy Technology Analysis at Pace University Law School and directed the energy and telecommunications program at the Boston-based National Consumer Law Center.

120. Fraunhofer USA Center for Sustainable Energy Systems, *Energy Savings from Five Home Automation Technologies: A Scoping Study of Technical Potential, Final Report to the Consumer Technology Association,* Bryan Urban, Kurt Roth, and Chimere (David) Harbor, April 2016, p. 18.

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