Engaging with a Thermostat: Using Seasonal and Connectivity-Based Differences in Residential Thermostat Use to Maximize Savings

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Engaging with a Thermostat: Using Seasonal and Connectivity-Based Differences in Residential Thermostat Use to Maximize Savings

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Executive Summary

WECC and the Michigan Electric Cooperative Association (MECA) partnered in implementing a pilot to test the impacts of a variety of aspects of residential, Wi-Fi-connected thermostats. WECC was formed as a 501(c)(3) nonprofit corporation in 1980, with the mission to champion innovative energy efficiency initiatives that deliver short- and long-term economic and environmental benefits to consumers, businesses, and policy makers. MECA is a collaborative of 12 rural energy cooperatives and municipal utilities throughout Michigan.

The purpose of the pilot was to inform the design of energy efficiency and demand response programs targeting rural homeowners with connected thermostats. The pilot tested elements related to four utility program types.

- Energy savings associated with installation of a connected thermostat (prescriptive or direct-install energy efficiency program)
- Energy savings associated with participant interaction with the connected thermostat (behavior program)
- Potential to reduce system peak demand (demand response program)
- Opportunity for customer communication and engagement (customer satisfaction)

Targeting a customer base of 30,000 residential accounts served by one municipal and two cooperative utilities in Michigan, WECC conducted a direct-contact marketing campaign (mail/email) that generated a 3.2 percent response rate (968 customers enrolled). Wi-Fi enabled thermostats were installed in 334 households with compatible heating, ventilation, and air conditioning (HVAC) systems. Participant, utility meter, and thermostat data was collected and analyzed to assess opportunities to incorporate the connected thermostat into demand response, energy efficiency, efficiency behavior, and utility communication programs.

Energy savings were found in specific sub-groups of the pilot participants, namely those with electric heat and in geothermal systems. Participants with electric heat were found to save 1,248 kWh (0.5kW) and geothermal heating systems with electric backup were found to save 448kWh (0.2kW). No energy savings were found in the summer months for participants with air conditioning (AC). Non-electric energy consumption data was unavailable, thus total energy savings for non-electric and geothermal HVAC systems could not be calculated. Energy savings estimates for non-electric or geothermal HVAC systems was estimated by converting kWh to therms (assuming typical furnace efficiency) and found a value of 50 therms. Energy savings from decreased fan usage was not found, however, this could be attributed to the greater control participants had on the fan settings of their HVAC systems.

The behavioral findings of the pilot show that thermostat usage is weather-dependent. Interesting trends emerged around how the users interacted with their thermostats, with a strong first degree relationship between usage and seasonality. The use of the scheduling function changed drastically between the heating and cooling period, with a significant number of participants only programming their thermostats for the heating season. Due to the mild weather during the 2014 cooling season, participants may have been comfortable without running their AC. Based upon participant feedback, manual thermostat controls were often used to accommodate a highly-variable schedule—users would adjust the settings before they left home and again remotely before returning home.

A demand-response component was included in the pilot to evaluate the electricity savings potential in residential thermostats. No energy savings were found through data analysis. The program's load reduction strategy was developed to guide the curtailment of central space heating and central air conditioning load during the prescribed control periods. Achieving demand reduction is highly dependent upon scheduling curtailment events that coincide with peak demand. A strategy was developed to position the program to maximize the energy savings, shift peak demand, and to minimize participant fatigue. Specific guidelines were developed based upon the larger load reduction strategy that allowed consistent weather monitoring and identification of specific opportunities for calling control events.

WECC's communication strategy for the pilot program consisted of comprehensive marketing and communications efforts. Over 4,000 educational emails were sent to participants over 13 months featuring topical and seasonal energy-related messages. The educational aspect of the program stimulated conversation between participants and program staff about their thermostats. These conversational insights along with more formal findings from two participant surveys provided a rich data set that contributed contextual information for use in the analysis phase of the program.

Thermostats in the Energy Efficiency Industry

Residential thermostats have undergone a substantial evolution in the recent past, transforming from simple HVAC control equipment to complex consumer electronics. The added functionalities open new capabilities to control usage and save energy while providing additional opportunities to interact with homeowners and to influence their behavior.

In recent years, an intense focus has developed around connected thermostats, both in the consumer-electronics market and in the energy industry. Manufacturers and industry research have shown that connected thermostats are capable of generating energy savings, but the savings are largely the result of how the thermostat is controlled, either by its software or the end-user. Manufacturers, with the consumer market in mind, have driven the trend toward high-tech thermostats with an emphasis on usability, features, and aesthetic. Utilities and regulatory bodies are still exploring how to successfully incorporate these new products into energy efficiency programs. Thermostat technology has rapidly expanded, opening the door to several data collection and analysis platforms, each with different functionalities and possibilities.
Utilities can justify inclusion of connected thermostats in energy efficiency programs by documenting energy efficiency savings as well as positive customer experiences. Customer education combined with direct feedback on thermostat use can also influence energy and demand savings. The wide variety of functionalities in the thermostat market raises the question of how each feature affects the energy savings from thermostat use.

Research Approach and Methodology

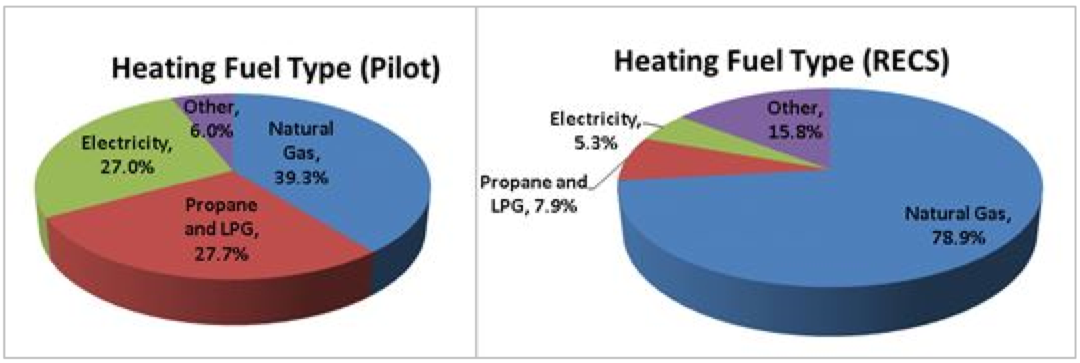
Approach

WECC designed and implemented a pilot program that installed Honeywell's VisionPRO 8000 in 334 residential homes located in three of the MECA member utilities: Great Lakes Energy, HomeWorks Tri-County, and Marquette Board of Light and Power. At the time of selection, the Honeywell VisionPRO 8000 was considered a mid-range thermostat that had comparable features to other connected thermostats in the market without being a large departure from previous thermostat models. The model for the pilot was selected in early 2012, when "smart" thermostats still held virtually zero percent of the market share. The VisionPRO 8000 is a Wi-Fi enabled, programmable thermostat with remote access and control from three User Interfaces (UIs): the thermostat panel, a smartphone or tablet app, and an online web portal.

Participant Description

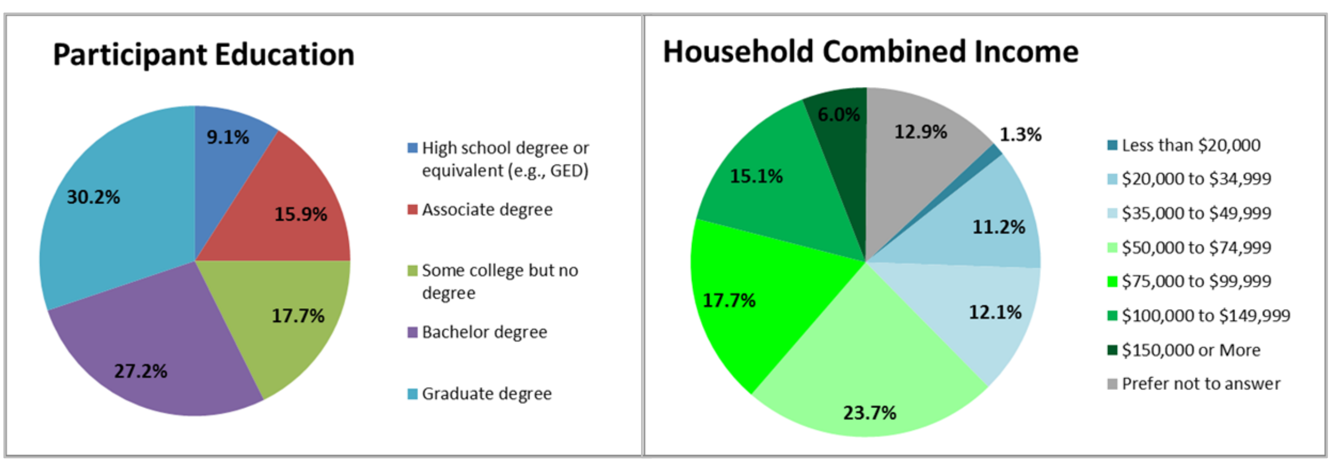
The pilot program installed 376 thermostats (some homes with zoned systems received more than one unit) in residential homes that were previously enrolled in the demand-response programs of the three participating utilities[1]. MECA is a collaborative of utilities that deliver electricity in areas where residents predominantly use combustion heating. As such, the pilot was open to participants that used any fuel type for heating, with the expectation that electric savings for cooling could still be gained. While the mix of fuel types of the participants was not surprising from an operational design perspective, the mix was quite different from Michigan residental HVAC systems when comparing against the 2009 Residential Energy Consumption Survey (RECS) data. The pilot participants were more heavily rural than the general population of Michigan, which resulted in a much larger percentage of propane and liquid propane gas (LPG) users. The proportion of electric-heat participants was high compared to the general public: 27 percent of pilot participants compared to the 5.3 percent of the general public. This disparity was the result of targetting the members currently in Demand Response (DR) programs, which included high numbers of participants with electric and geothermal heating by design. The differences in the fuel type of participants and what is stated in the RECS data can be found in Chart 1.

Chart 1: Heat Fuel Type (pilot participants vs. regional RECS data)

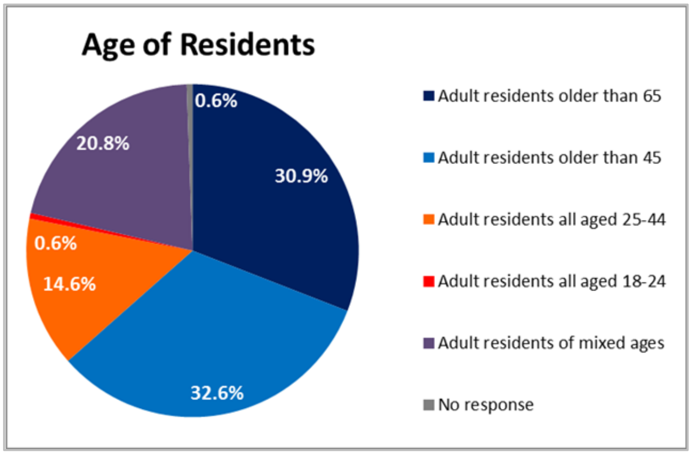


Homeowner demographics were consistent with national median values. The median homeowner participating in the pilot was 45-64 years old, had earned a bachelor's degree as their highest level of educational attainment, and had a combined household income between $50,000 and $75,000. The median homeowner for the entire US is 45-54 years old, with a combined household income of $65,514, according to the 2012 American Community Survey. Of note is the substantial proportion (approximately 30%) of homes inhabited exclusively by residents older than 65. The participant demographics are summarized in Chart 2.

Chart 2: Age, income, and educational demographics of pilot participants



[1] Marquette Board of Light and Power did not have a demand-response program and marketed the program to their entire residential customer base.



There were three (3) levels of participation in the pilot design, assigned randomly prior to enrollment. These groupings facilitated independent analysis of various aspects of engagement with the thermostat functionality. The thermostat features available to each level of participants can be found in Table 1 with participant allocation summarized in Chart 3.

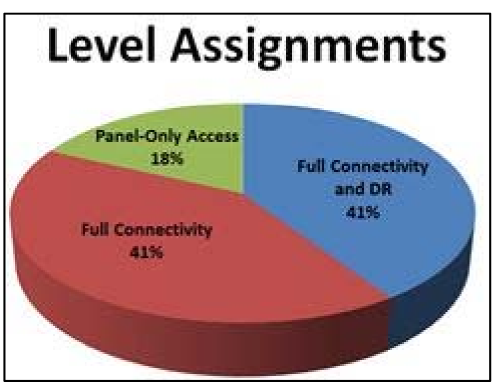
Participation levels:

1. Full Connectivity and Load Management Participation: Wi-Fi thermostat, remote access for controlling and monitoring thermostat, educational messaging, and demand response control
2. Full Connectivity: Wi-Fi thermostat, remote access for controlling and monitoring thermostat, and educational messaging
3. Panel-Only Access: (control group) Wi-Fi thermostat with remote access disabled and educational messaging

Table 1: Summary of Pilot Levels by Features

Pilot Group	Programmable Wi-Fi Thermostat	User Interfaces (UIs)			Load Management Participation	Energy Savings Tips
		Tstat Panel	Web Portal (Online)	Smartphone App (Online)		
Full Connectivity and DR	X	X	X	X	X	X
Full Connectivity	X	X	X	X		X
Panel-Only Access	X	X				X

Chart 3: Pilot Feature Allocation



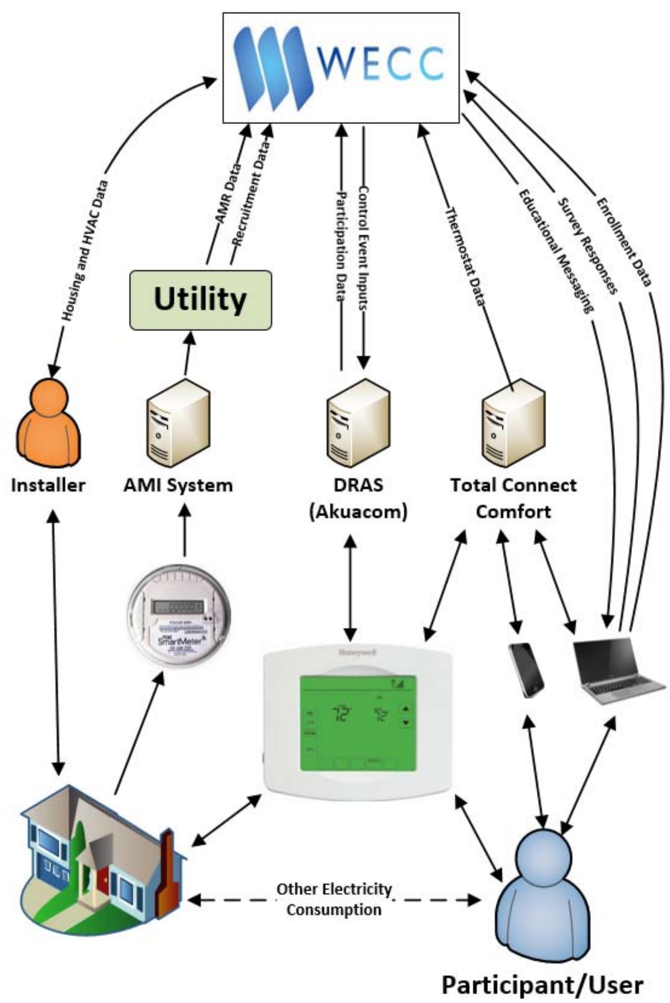
Data Collection

Data was collected from eight sources to capture a variety of information (illustrated in Graphic 1): on-site collection of HVAC system data, meter data, outdoor temperature, demand-response event data, thermostat variables and participant data collected from enrollment forms, three surveys, and responses to educational messaging.

Due to the large number and variety of data collected, data collection and verification was crucial during every aspect of the program. Specific participant attribute data was collected during recruitment, enrollment, and installation phases, with more targeted information being collected at each successive phase of the program, along with usage and local weather data. Quality participant attribute data was required to filter the participants during the analysis phase into subsets of the larger participant group. This ability to filter subgroups allowed analysis to be performed by subset as needed.

Once the thermostats were installed, data was collected periodically from utility advanced metering infrastructure (AMI) systems (fixed interval data) and the thermostat Total Connect Comfort (TCC) platform (time stamped data). Demand event data was collected through the utility demand management infrastructure (Honeywell Akuacom Demand Response Automation Server [DRAS]).

Graphic 1: Data Sources



Methodology

Hourly usage data (historical and pilot period) was gathered for participants and utility customers in order to perform a large-scale consumption data analysis. In addition, a broad set of customer attributes were gathered from utility customer information, pilot enrollment applications, and contractor installation reporting. Time-stamped thermostat data stored in the TCC database was gathered for each installed thermostat. Weather data was also collected from weather stations throughout Michigan.

A large-scale data consumption analysis method was used to analyze program impacts. Participant data, along with a matched control group, was associated hour-by-hour with local weather data following similar methodology to the heating/cooling degree hour method. Pre-installation and post-installation regressions correlated consumption with weather, after which the correlation was used to calculate estimated savings for a model year. Inapplicable contributions to datasets, such as customers with fuel oil for heat in the heating season analysis, were filtered out using participant attributes.

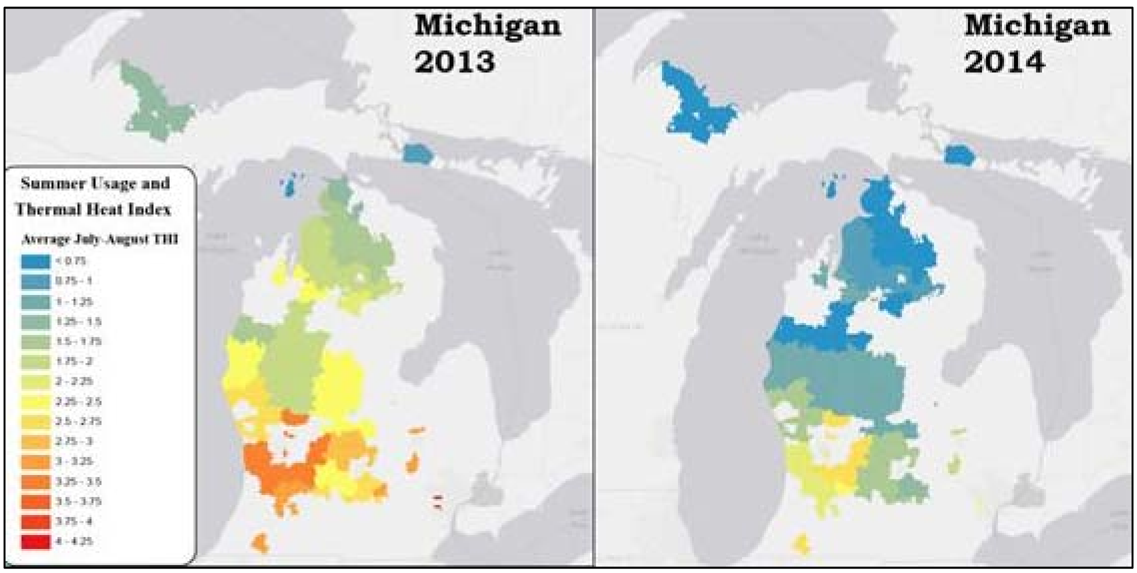
For the behavioral analysis, data were cross-compared to draw conclusions about device impacts, device usage patterns, and participant characteristics.

Weather Impacts

2014: A Very Mild Summer in Michigan

The summer of 2014 was significantly cooler than the summer of 2013, which was a fairly average summer for Michigan. Weather corrections and matched controls drastically reduce the effects of this discrepancy on the final impact analysis, but ultimately the analysis relies on the assumption that the strongest time-dependent impact on energy use is from weather. If the weather is uniformly mild, other small factors may become dominant. These factors include the coincidence between the overall holiday season and weather, or the coincidence of school closings and weather, and the increase in their relative importance detracts from the predictive power of the analysis. Finally, mild weather has a significant impact on other aspects of the analysis. During a mild summer, there is both no need to call load management events, and little expected savings from them. From a behavioral standpoint, participants likely engage with their thermostat differently during a hot summer versus a mild one, so summer behavioral observations may not be fully applicable in future (or past) years.

Graphic 2: Summer Thermal Heat Index in Michigan, 2013 and 2014



Results

Energy and Demand Savings

Significant heating savings were found, reducing heating energy consumption by approximately six percent. From the energy reduction for electric customers, therm savings for non-electric customers were calculated assuming an 85 percent AFUE furnace. Due to the abnormally cool summer, energy savings from cooling systems were inconclusive. With only electricity consumption data, the energy savings for heating could only be analyzed for those with electrical heating systems (electric furnace, strip heat, geothermal).

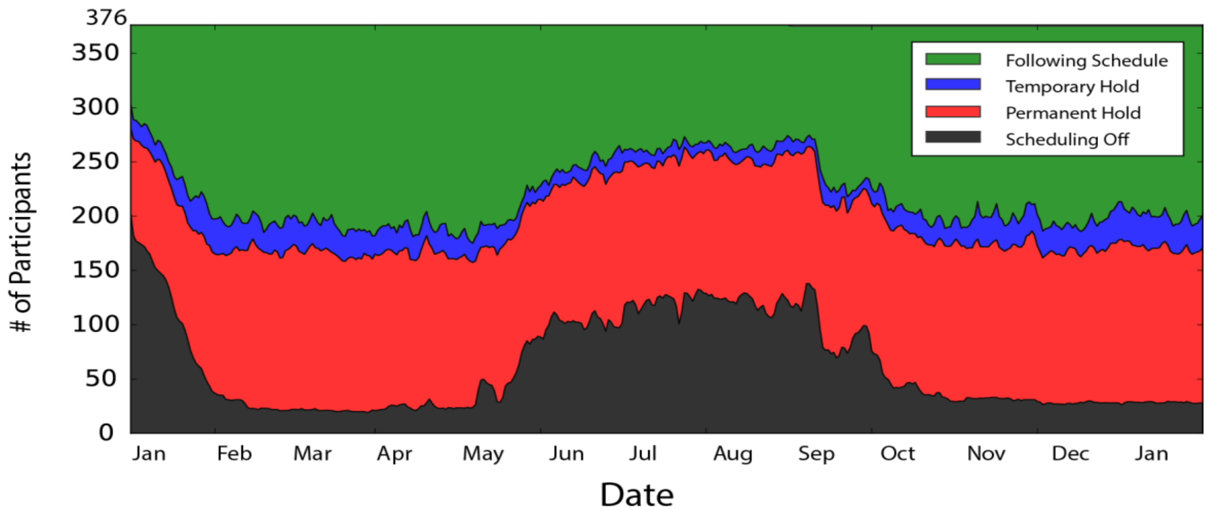
The DR component of the pilot program was designed to determine load reduction and energy-saving capabilities associated with utility control of load management technology in customer/members' homes or small business. While the capacity to predict peak load in response to the weather was achieved, the analysis did not conclusively show electricity savings. Several factors could have contributed to this lack of observed savings. The interaction between mild weather and the 50 percent cycling algorithm for load reduction was thought to be the main barrier to detecting demand-response savings.

Heating Systems (winter only)	Annual Energy Saved	Demand Reduced
Electric Furnace	1,248 kWh	0.5 kW
Geothermal Heat (with electric backup)	488 kWh	0.2 kW
Gas/Oil/Propane Heat	50 therms (Estimated)	-

Usage Observations

Because weather affects the necessity and usage of HVAC systems, it is reasonable to assume it will also affect thermostat usage. This was evident in the thermostat usage data gathered from Honeywell's remote access platform, TCC. After the initial period where installation was still underway, the number of users with programmed thermostats remained fairly constant. However, the first hot day in May was followed by several users turning off their programming function (Graphic 3). After several hot days, 80 participants (approximately 25 percent) turned off their programming functions, and by the end of June nearly a third of participants had switched them off, which represents almost one third of all participants. This group kept their thermostats off until mid-September, when they returned to following a programmed schedule. By contrast, 35 percent of participants disabled their scheduling by switching to "Permanent Hold" mode, and the size of that group remained constant throughout the pilot period. This implies that a substantial portion (60 percent) of the users either accidentally or purposefully kept their thermostats from running on a programmed schedule.

Graphic 3: Aggregate Thermostat Scheduling



Scheduled Participants: This plot shows the number of pilot participants with thermostats currently in each of the four program modes of the VisionPRO 8000. The participants following schedule (green) have their thermostat programming enabled and active. The participants on temporary hold (blue) have placed the thermostat on a hold that will automatically end. The participants on permanent hold (red) have suspended the programming indefinitely, and the participants with scheduling off (black) have disabled the schedule function altogether. As this accounts for all participants, the total is always 376.

Summer Switch-off Group: The likely explanation for participants switching off their scheduling is the mild weather. Of those who switched off their programming, the number of participants with central air was nearly equal to the number without. This suggests that the action was an intentional disabling of features—the participants did not want the thermostat to automatically heat or cool their home. It is unclear whether this was due to unfamiliarity with the thermostat functions, as properly programmed set points would prevent the system from turning on except when needed. Alternately, users may have wished to save the maximum amount of energy possible by disabling the schedule, thereby resisting the temptation to use cooling even when uncomfortable. The average set point for cooling in this group was the same as the average set point for the group following a schedule, suggesting that the thermostat programming was not switched off to maintain greater control over comfort. In light of this finding, education on thermostat use appears needed; however, marketing campaigns would need to be careful in constructing messaging as users might waste energy by re-enabling this feature.

Permanent Hold Group: There are several possible explanations for the group who placed their thermostats on permanent hold. The first explanation stems from the thermostat user interface itself—the permanent hold button is prominently displayed as an option when a set point is adjusted from its scheduled value. It is possible users set it that way and never remembered to re-schedule. Switching the thermostat completely off disables the "scheduling" tab for the smartphone app and web browser application, so it is possible that this group did not wish to use the programming function, but wanted full functionality available to them. Many users reported that they did not use the scheduling, and solely employed the connectivity functions of the thermostat. In a practical sense, the look-and-feel as well as the true functionality of thermostat features had impacts on how people used them, and future programs with this thermostat should message based on those specifics.

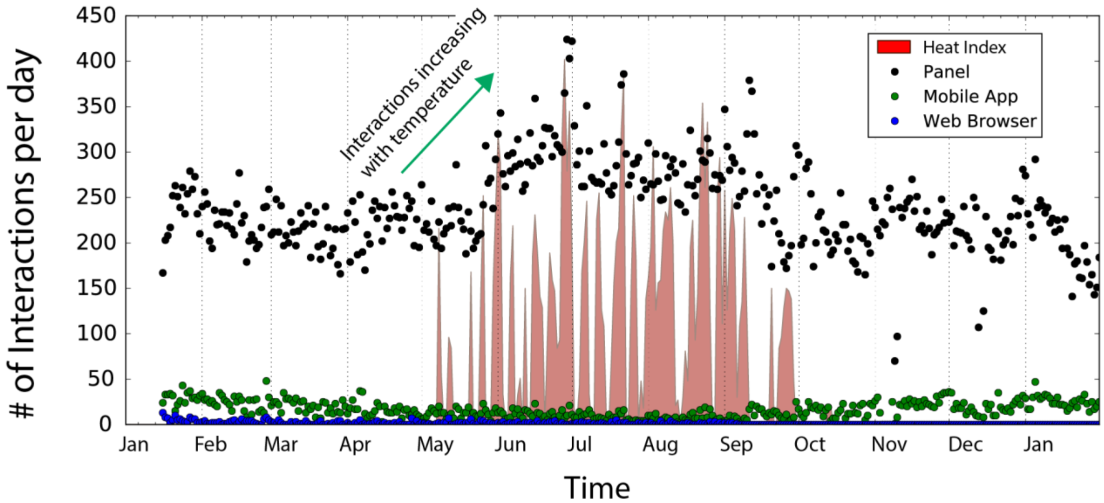
Web and Panel Interactions

Participants interacted with their VisionPRO 8000 through several means. Users changed settings from the panel most often, nearly 10 times as much as through the other interfaces. Mobile interactions came in second, with 10-40 interactions per day across all 334 participants. Finally, the web browser interface was rarely used, and many days had zero web browser interactions with the thermostat.

Summer Interaction Changes: Mobile interactions and web interactions decreased in the summer, while panel interactions increased (Graphic 4). This change in interaction is coincident with the "summer switch-off" mentioned previously. It is also notable that when the heat index peaks, panel interactions also peak. What causes this shift? In this case, the answer is tied directly to turning off the thermostat. The group who kept their thermostats programmed or on permanent hold interacted with the thermostat on average 18 fewer times across the summer months than in the previous three months, while the switch-off group interacted with their thermostats 83 more times each. The switch-off group was likely only adjusting the thermostat when they were uncomfortable (and possibly adjusting it back later). Because they would be at home when this happened, they could easily adjust the thermostat at the panel. Both groups used their mobile devices and web browsers less frequently across the summer compared to the winter heating season.

Winter Interactions: Winter interactions increased with extreme cold, as well as over the holiday season. These effects were small compared to the summer increases, and in general winter interactions held constant at 200-250 per day.

Graphic 4: Thermostat Interactions



Thermostat interactions: The number of interactions per day across all participants is plotted. Panel interactions (black) increase as the Thermal Heat Index (THI) (red) becomes substantial, while mobile (green) and web browser (blue) interactions decrease. Panel interactions drop off when the weather cools, while mobile and web interactions ramp up again.

Effects of Connectivity: The group with panel-only access interacted with their thermostats 31 percent less in total than the group with full connectivity. Surprisingly, ¾ of the additional interactions by the connected users were made up of interactions at the panel. In other words, users without a smartphone app interacted less frequently with their thermostat at the panel. This suggests that the presence of a smartphone app may have enticed users to interact with their thermostat more, both on their phones and at the panel. Overall, average set points between the two groups were within 0.02°, indicating little difference in ultimate comfort or energy use outcomes. There is one particularly relevant takeaway from this comparison: a fully-featured thermostat is a more compelling device than one with fewer features, and it has little to do with saving energy.

Likes and Dislikes of Connected Thermostats

Throughout the pilot program, the wide variety and high volume of interactions with participants yielded insights into what users liked and disliked about the connected thermostat. Overall, the participants found the connected thermostat to be easy to use and felt it helped them conserve energy.

A number of participants mentioned that they enjoyed the connectivity functionality of the thermostat because it not only allowed them to control their thermostat remotely but also to monitor their homes while they were away. This was largely found in the winter months when possibilities such as freezing pipes are a real danger to homeowners in Michigan. The remote monitoring ability provided ease of mind that is not present in non-connected thermostats.

Problems with establishing and maintaining connectivity did occur for some participants. Changes to their internet provider or router caused many to struggle with reconnecting the thermostat to Honeywell's Total Connect Comfort system. This apparent challenge, coupled with the reliability of internet service in rural Michigan, proved to be a problem for some users.

Conclusions

Energy savings in the pilot program were dependent upon the participants' heating fuel type. Electric heating systems saved 1,248 kilowatt hours (kWh) on average, while thermostat usage was found to be weather-dependent based on behavioral data from participants. Interestingly, trends in how the users interacted with their thermostats emerged with a strong relationship to the change of the seasons. The use of the scheduling function changed drastically between the heating and cooling period, with a significant number of participants only programming their thermostats for the heating season. The large number of participants that turned off the scheduling function at the beginning of the summer could be attributed to a migration away from heating without a shift to cooling. Due to the mild weather during the 2014 cooling season, participants may have been comfortable without running their AC. While there were different levels of usage of the scheduling function of the thermostat, the average set point was the same across the program users and the non-program users, suggesting the non-program users were manually changing the set point to emulate the program function. Based upon participant feedback, manual thermostats control was often used to accommodate a highly variable schedule—users would adjust the settings before they left and again remotely before returning home.

The connected-thermostat pilot provided a wealth of knowledge for future program design. Since the beginning of the pilot, smart thermostats have gained and continue to gain substantial market share. This rapid adoption, and the arrival of smart lighting and other smart home features, suggests a future where most energy-consuming devices have a digital interface. While these devices will enable energy efficiency, they may not be intuitively set up to encourage efficiency right out of the box. Programs that ignore the savings potential in the packaged features of those devices are foregoing an opportunity to access cheap energy savings. While the manufacturers are not creating an energy efficiency product, the ability to claim saving energy as a selling point is enticing enough that many will add or modify software to enable it, in the form of standby modes, usage sensing, and optimization to minimize unnecessary or unwanted energy use.

From a program-delivery standpoint, the various connected or smart technologies offer expanding channels for saving energy. Pilots, as well as manufacturer or vendor information, help programs understand how consumers use these devices. By understanding the selling points and features of these devices, low-cost energy savings can be achieved through both the device installation and behavioral messaging. With a working knowledge of what energy efficiency-enabling settings are possible, either through downloadable additions or packaged (but disabled out of the box) software, implementers can effectively encourage actions on the part of users. Doing so keeps energy efficiency messaging fresh and relevant, and activates the digital efficiency infrastructure that consumers have built through the purchase of modern electronics.

About WECC

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