BTO Peer Review 2016: Connected Thermostat Side Session

R&D Participant Perspectives Overview

On April 7, 2016, the Building Technologies Office (BTO) of the U.S. Department of Energy (DOE) hosted a Connected Thermostat Side Session in Falls Church, Virginia; the work session was held in conjunction with the 2016 BTO Program Peer Review.

More than 22 researchers and subject matter experts from utilities, national labs, government, industry, and academia participated in this session. The goal of the side session was to get feedback on the necessary research and development (R&D) activities required to enable new end-uses from connected thermostat data. The side session opened with welcoming remarks from Karma Sawyer, BTO Emerging Technologies Tech-to-Market Manager, followed by a plenary presentation from Kurt Roth, Fraunhofer Institute, on R&D opportunities and limitations they see in the field.

After the plenary, participants were asked to identify key capabilities of an ideal connected thermostat. After brainstorming, the group used a two-part voting process to identify those technologies that:

- Reflected ideas that could result in the highest energy savings (yellow)
- Reflected ideas that would not achieve market penetration without government action (blue)

Participants broke into three breakout groups to complete worksheets to define future R&D activities necessary for high-priority capabilities. A fourth worksheet was also created in a small side breakout group that did not have as many votes, but was still considered to be highly impactful.

This document presents the key takeaways from each of the breakout groups that were presented in the Report Outs to the full group at the end of the day and the raw data from the large group's brainstorming discussion.

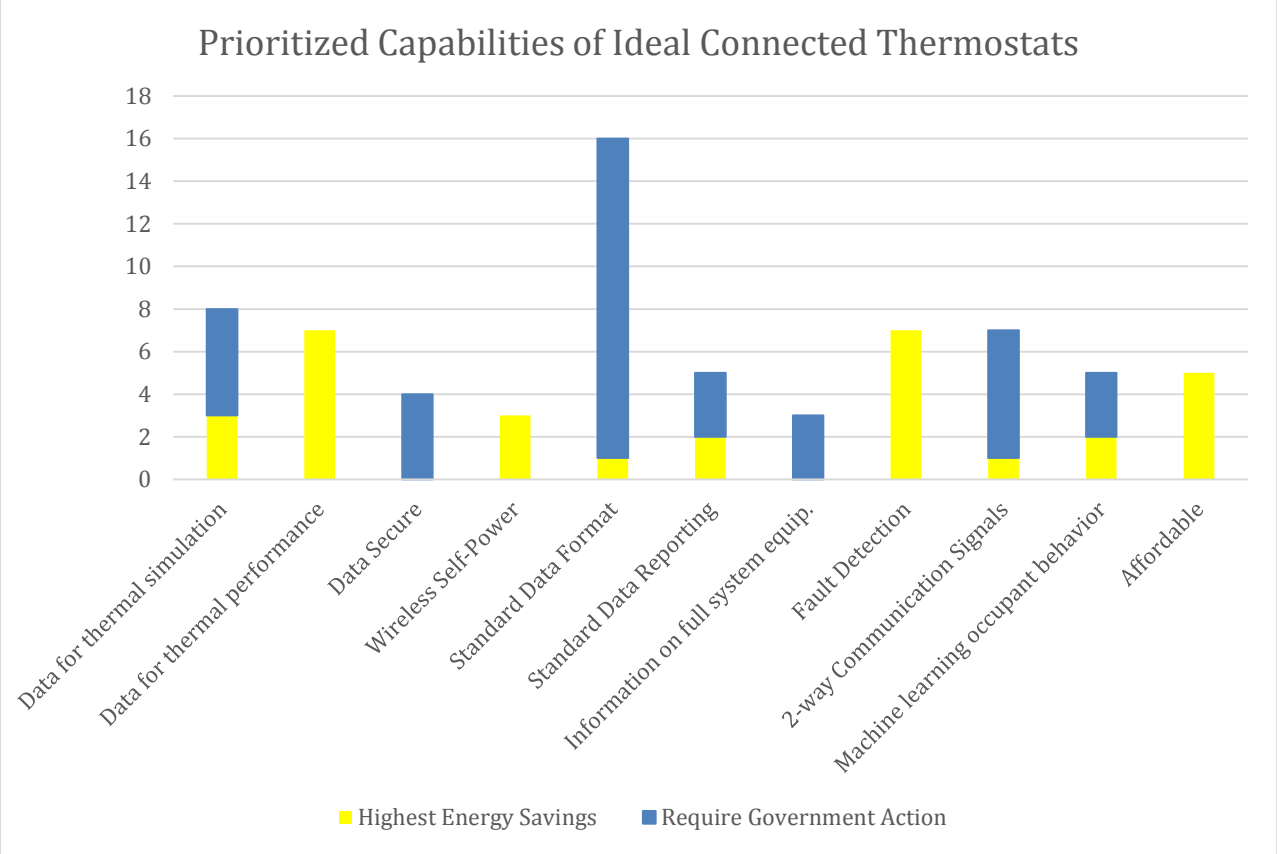
Key Side Session Takeaways

The following summary includes a summary of the plenary discussion, the highest rated capabilities of the ideal connected thermostat prioritized by the group, and high-level summaries of the three breakout groups from the highest rated capabilities. Further details, including the four corresponding action plan worksheets to the highest priority items, are presented in the following section.

Plenary

- Roth presented on the R&D opportunities and limitations he sees in the connected thermostat space. His presentation was followed by a lively Q&A session, where audience members were interested in the interplay between simulation and whole-home experimentation, data availability and sharing, utility data needs, and baselining for M&V of retrofits.

Prioritization



Modeling

- The breakout group asked themselves what data has value that will actually drive modeling? Specifically, they noted that while integrating data from connected thermostats will be challenging, so too will knowing the right level of data needed to

drive modeling. Too much or too little data can be equally problematic. Given what data is available, the group asked what modeling can be done? The group focused on improving predictions of energy use, enabling remote energy audits, and creating profiles for building stock to better understand real comfort levels in buildings.

Data Standards

- The group strongly agreed that the most useful thing for the community would be simple and limited in scope, proposing prioritizing action to develop a standard data transfer format. Stakeholders felt that this was the right time to start working on this important first step and should be continually updated as technology and data needs changed.

Fault Detection

- The group focused on the potential for connected thermostats to play a role in fault detection and diagnosis of HVAC system performance and home envelope diagnostics. They discussed R&D needs in relation to defining the opportunity space, most specifically around defining the necessary sensing set and time interval data, defining a fault list, and determining other data that would be available. Fault detection in connected thermostats in residential homes would be used to help determine the user behavior effect and separating it out from actions that could be taken to fix other issues in the home for energy savings.

Group Brainstorming: Ideal Connected Thermostat Capabilities – Session Output[1]

Modeling	Data Management	Hardware	Data Standards	Software Controls	Usability (1 yellow)
Enough data for thermal simulation (5 blue, 3 yellow)	Ensure high security (data) (4 blue)	Wireless self-power (3 yellow)	Standard data format with data and sensors validated and verified (15 blue) (4 yellow)	Fault detection (7 yellow)	User friendly interface (2 yellow)
Enough data for thermal modeling of performance (7 yellow)	Pay for performance utility incentive, performance path (2 yellow)	Reproducible temp measurement—same temp measurement each time, even if systematically off (1 yellow)	Standard reporting -HVAC performance metrics -comfort metrics -whole building metrics (3 blue) (2 yellow)	LEAD or follow standard communication signals (1 yellow) (6 blue)	True user access control (1 blue)
Forecastability (Anticipate weather) (2 yellow)	Data: homeowner control—share, use, etc. (1 blue)	Multi-sensing thermostats (temp, sound, light)	Standardized knowledge of type of equipment connected (3 blue)	Machine learning occupant behavior (2 yellow) (3 blue)	Ease commissioning -connect to network/thermostat (1 blue)
Define comfort with both temperature and humidity, possibly insulation	Allow homeowner to provide additional information about their house	Integrated IAQ sensors	Energy consumption (1 blue)	Connection to other devices and sensors in the home (2 yellow)	Comfort vs temp setting. Learning thermostat (1 yellow)
Many temperatures	Awareness of envelopes loads coming into the house	Low absorb. Enclosure (reduce radiant gain)	Consumer intent (1 yellow)	CGI tech smartest thermostat would be able to sense higher elevation and lower elevation air temperature sensing more in the back (1	An easy to use thermostat. Two buttons, hot and cold.

[1] Yellow = highest energy-saving potential; Blue = will not happen without government intervention

				blue) (1 yellow)	
Calibrated thermal response curve		Accurate, reliable occupancy sensors (not motion)	Record data continuously all year round	CGI technology non-performance, performance in multi-level (1 blue) (1 yellow)	Ease of installation
Diagnostic/calibration cycle mode(s)		Local data storage backup	Record data of: -temperature setting -actual temperature -occupancy -outdoor temperature	Works with var. speed	**Other**
User friendliness		Store data while temporarily disconnected	Relay status (fan, auxiliary heat)	Ability to measure/know weather	Affordable (5 yellow)
Equipment performance		Multiple remote sensors	HVAC Capacity & ER	Show electric meter reading real time in the home	
Use historical data to detect problems (fault detection)		Warranty violations?	Min Accuracy Req/Standard like (e.g. revenue grade elec. Net)	Locally "smart" without always on connectivity	
Awareness of user changes, e.g. open windows		Distributed (cheap) (many rooms) thermostat	Show actual temp not set point with decimal (Emerson)	Controller BAS home	
HVAC capacity				Adjust to energy price	
When vendors are applying management algorithms					
Simulation modeling					
How many thermostats in home: I.D. one home					

Breakout Session – Worksheet – Group 1: Modeling

Ideal Feature:	**Better Data to Support Modeling**: Integration of/with multiple data sources, e.g., smart meter, weather station, building asset data sources (e.g. SEED, Zillow), HVAC run time.		
R&D Approach/Activities Needed:	• (Simulation) studies to determine utility of various data • Sources, granularities, fidelities • Modeling approaches depending on what data is available • Methods to test and evaluate algorithms used in thermostats (software as a service)		
Performance Goal/Target:	Predict energy use + or – 10%	Challenges/Limitations:	Cost of extra data points
What else could this feature enable?	• Remote energy audit and diagnosis to guide retrofit • Create house profiles (temp. settings, schedules) for model inputs (improved assumptions) • Understand comfort and energy use of building stocks • Evaluate and justify algorithm of smart thermostats		
Participants and Potential roles:	• Industry: ASHRAE, thermostat manufacturers • Government: DOE, EPA • National Labs: LBNL, ORNL		
Time-Frame to Deployment (circle one)	Near (1-3 years)	Mid (3-5 years)	Long (5-10 years)
Impacts/Benefits:	• Value of services from various thermostats • Energy savings and comfort improvements • Better data for energy modeling (user and operation profiles for houses and buildings)		

Breakout Session – Worksheet – Group 2: Data Standards

Ideal Feature:	**Standard Data Specification/Schema and Adhere to Data Transfer Standards**		
R&D Approach/Activities Needed:	• Keep focus on simple data transfer and specification • Recognize available data streams and build use cases • Coordination of efforts, →Fund industry organization to lead		
Performance Goal/Target:	• Start simple, less formal • Build critical mass and expand and go through formal process	Challenges/Limitations:	• Expanded scope/lack of focus could slow process • Hard to ensure coordination/inclusion of key players in a quick development
What else could this feature enable?			
Participants and Potential roles:	• Utility: adoption and input of standard and specification. Act as a catalyst • HVAC contactors • Trade groups: CEE, NIST, etc. as a convener→ some centralized organization • Extension from related standards activities: ex. Project Haystack. Ex. Data Transfer Standard (BPI) • Manufacturers: feedback for manufacturers		
Time-Frame to Deployment (circle one)	Near (1-3 years) Living standard	Mid (3-5 years)	Long (5-10 years)
Impacts/Benefits:			

Breakout Session – Worksheet – Group 3: Fault Detection

Ideal Feature:	**Fault Detection**: HVAC System Performance and Home Envelope Diagnostics		
R&D Approach/Activities Needed:	• Define needed sensing set and location, time interval needed • Define major fault list of interest to diagnose • What other data is available that would be complementary to existing data set (interval meter data, weather data, real-time pricing signal)		
Performance Goal/Target:	• Energy Impact of quick fault identification • Reduction of false positive rate • Prioritization of failure mode severity	Challenges/Limitations:	• Determining user behavior effect • Total versus sensible heat removal quantification • Current saturation of market with existing models
What else could this feature enable?	• Targeting energy efficiency/DR program • EM&V facilitation • Homeowner education/feedback/awareness • Schedule/envelope optimization		
Participants and Potential roles:	• Industry: HVAC OEMs/Controls Manufacturers—commercialization/physical integration, provide cost and reliability • Government: field demonstration, validation and funding R&D • National Labs: Determine data and sensors needed/validation • Other: Utilities—provide monetization of incentives		
Time-Frame to Deployment (circle one)	Near (1-3 years) Technology is moving quickly	Mid (3-5 years)	Long (5-10 years)
Impacts/Benefits:	• Helping educate homeowners and contractors regarding the impact of proper HVAC performance • Provide motivation for further connected device implementation by reducing associated technological uncertainties • Better data to base new equipment designs on • Service tech benefits (lower costs; fewer false calls, diagnostics)		

Breakout Session – Worksheet – Group 4: User Interface

Ideal Feature:	Key Consideration: After all the efforts to design smart thermostats that can increase efficiency and reduce HVAC consumption—someone has to install and commission them.		
R&D Approach/Activities Needed:	Oftentimes that person is an electrician who works for a contractor. His mission is to get in and install the thermostat as quickly as possible and unless the building owner has specifically written in the contract that commissioning of the smart thermostat is required, the electrician won't take the time to ensure that it happens.		
Performance Goal/Target:		Challenges/Limitations:	Now you have the efforts of many researchers, engineers, etc at the mercy of someone who is trying to meet his boss's expectations and get to the next job.
What else could this feature enable?			
Participants and Potential roles:	National Labs: A sequence of operations for start-up is not sufficient—it's typically too complex.		
Time-Frame to Deployment (circle one)	Near (1-3 years)	Mid (3-5 years)	Long (5-10 years)

Side Session Participants

BTO wishes to thank the below contributors for their participation in the BTO Peer Review Connected Thermostat side session:

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