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U.S. Department of Energy's Workshop on Smart Tools for Improving Installed Performance of Residential and Small Commercial HVAC Systems

Stakeholder Workshop

March 16, 2017
Arlington, VA

Prepared by Navigant Consulting Inc.

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Summary and Background

On March 16, 2017, Navigant Consulting, Inc., on behalf of the U.S. Department of Energy's (DOE) Building Technologies Office (BTO), facilitated a stakeholder discussion workshop to identify and continue to discuss the major challenges and potential solution pathways to improve the quality of residential and small commercial HVAC system installation in the U.S. using smart tools and best practices. This document serves as a record of the workshop, the perspectives presented, and its outcomes. The advancement of quality installation (QI) practices provides a significant opportunity to reduce equipment and installation costs to contractors, improve indoor air quality and comfort for building occupants, increase HVAC system performance and lifetime, and reduce energy use and costs to heat and cool homes and small commercial buildings. This discussion builds on a prior workshop on residential central air conditioning and heat pump installation held in May 2016 in Washington, DC, and focused on several of the proposed initiatives including research on the benefits and energy savings of QI, and development of tools and resources that support contractor trades and energy efficiency programs.[1] More specifically, this workshop focused on smart tools and monitoring devices, such as on-board diagnostics, technician tools, and duct leakage diagnostics and repair tools. These technologies may help optimize installed HVAC system performance (including duct systems), and integrate new monitoring technologies into HVAC equipment and technician tools.

BTO hosted the workshop on March 16, 2017 during the annual BTO Peer Review in Arlington, VA. Twenty-eight stakeholders participated, including university researchers, national laboratories, Building America teams, program implementation contractors, technology manufacturers, and representatives from industry and regional organizations. An additional 16 participants were affiliated with DOE or support DOE in this effort. A list of attendees and their affiliations is included in the Appendix.

Objectives and Workshop Format

Advancing HVAC quality installation (QI) practices in the market is a common goal for many stakeholders. QI involves the proper design, selection, installation, and final testing of HVAC equipment and systems to deliver improved occupant satisfaction and energy savings.[2]

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[1] See the May 2016 workshop outcomes report for more detail, https://energy.gov/sites/prod/files/2016/11/f34/CAC-CHP%20Installation%20Workshop%20Report%20-%2011-30-16.pdf

[2] Adapted from ANSI / ACCA 5 QI – 2015 (HVAC QI Specification). Available at: http://www.acca.org/communities/community-home/librarydocuments/viewdocument?DocumentKey=b1d2a39d-fda8-4af9-b8de-0ae579bfe24a

Therefore, DOE BTO brought together various industry players to help identify the highest priority challenges and potential solution areas where stakeholders can collaborate.

The purpose of this meeting was to bring together experts and stakeholders to discuss key issues and potential solutions associated with this rapidly evolving topic. More specifically, the objectives for the workshop included the following:

- Review the **value proposition of improved and reliable installed performance** to manufacturers, contractors, consumers and utility program administrators
- Obtain stakeholder input on a 'Vision for Success' for **smart tools for QI and performance monitoring**
- Identify and discuss the **technical, research, and standardization barriers** that impact the development and integration of these smart tools
- Outline recommended **incremental steps or pathways** to overcome these barriers
- Discuss methods to **better evaluate savings potential** of improved installed performance.

The format of the workshop included the following elements:

- Short overview presentations from Residential BTO programs (Building America and Home Improvement Catalyst), Commercial BTO programs (examples from Better Buildings Alliance), and the Building Energy R&D (BERD) Sensors and Controls sub-program
- Brief presentations from stakeholder participants
- Discussion on objectives and vision
- Breakout discussions on the challenges and opportunities to advance the development and adoption of smart tools
- Discussion on evaluation of QI and retro-commissioning energy savings potential
- Final discussion and wrap-up.

Group Discussion

The group discussion focused on identifying industry's needs for smart tools and sensing technologies that could enable cost-effective, high quality installations for residential and light-commercial forced-air HVAC systems and ensure efficient and optimal operation throughout their lifecycle.

BERD Sensors and Controls, Residential Buildings Integration (RBI), and Commercial Buildings Integration (CBI) technology managers first presented on current and planned activities that relate to technology development and demonstration and ways to address market barriers. Within BTO, the BERD program conducts R&D initiatives to advance early-stage technologies through cost reduction and performance improvement, while the RBI and CBI programs accelerate deployment of energy efficient technologies and advanced practices in the market. As part of the introduction to the group discussion, several industry stakeholders then presented one slide each on their current focus areas related to this topic.

After the presentations, the group discussion turned to objectives and the available options or potential pathways for improving the installation, comfort, efficiency, and reliability of residential and light-commercial forced-air HVAC systems. The group identified several necessary considerations when determining these pathways including: high cost to contractors, overall awareness and value proposition to both contractors and consumers, contractor proficiency with tools, as well as the collection and sharing of the associated data. One stakeholder pointed out that achieving higher efficiency through improved equipment and/or QI increases the cost for contractors. However, participants noted that real time diagnostics and data could reduce contractor visits for minor issues and the number of call backs for poor installations, therefore reducing overall cost for contractors.

Other stakeholders brought up the need to increase building occupant awareness and demand for high quality HVAC system performance, including association of better system performance with improved comfort. Another stakeholder suggested that several technologies are already available, but the market does not understand or appreciate their value. A DOE team member asked the group what data should be collected by these smart tools that will lead to different behavior in the market. Others commented that the data can be collected, but HVAC technicians often do not know how to interpret the data in useful and valuable ways.

The group discussion then shifted to current market incentives for QI of HVAC systems and assigning value to these improvements. Several stakeholders commented that contractors need to be paid to participate in QI energy efficiency programs or to utilize ACCA Standard 5, due to the additional effort to complete QI procedures during installation and the required time for

utility program participation. Also, code officials often do not know how to assess the level of quality. The group then discussed reasons why utilities do not have greater interest in improved installation practices to capture additional energy savings. A utility representative commented that they have a small program that requires verification, but many contractors do not participate due to hassle of paper work. Another stakeholder suggested it can be difficult to assign incentives because installation is not associated with a certain type of technology. There is also no mechanism (or technical staff) in these programs to support or assess contractors in systems engineering or design and technical education such as how to perform a better load calculation. Finally, several stakeholders pointed out that utilities have offered incentives for high efficiency HVAC equipment for decades and may not want to suggest that these installations were sub-optimal. Overall, many stakeholders believed that customer energy savings are the basis of utility incentives in the long term. Therefore, it is important for the utilities to include QI requirements as part of traditional incentive programs to fully realize the expected savings from higher efficiency HVAC systems. Utilities can even incentivize QI for baseline HVAC systems to capture any additional savings. Once creating the right incentive, developing utility programs to engage contractors and consumers will be key to market adoption.

Stakeholders then discussed currently available research on the benefits of optimal HVAC system installation and whether the documentation is sufficient to demonstrate the value proposition. Stakeholders suggested that a NIST study provided potential energy savings estimates from analysis and limited laboratory testing, but could be built upon with additional data from the field.[3] Individuals suggested several research needs including:

- Field studies on the energy efficiency and performance impacts of common faults and the potential energy savings of QI practices
- National or regional profiles on frequency of equipment faults based on field studies or anecdotal evidence from contractors
- A solid and defensible benchmark for savings that clarifies the issue on a national basis
- Pilot utility incentive programs for QI and evaluation, measurement, and verification (EM&V) studies to demonstrate cost effectiveness.

[3] Available at: http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1848.pdf

One stakeholder noted that a regional energy efficiency organization is currently rolling out quality HVAC system installation via third party verification across multiple states, and collecting energy savings and cost data to support EM&V of the programs. Other stakeholders suggested there is enough research on the topic and the prevalence of faults but the information may not be detailed or dynamic enough to inform decision making or solutions in real time. It may be helpful to analyze other industries for examples of how smart technologies are built into and priced as part of the whole product (e.g., tire pressure indicator in a car). Creating standards and/or a common format for sharing data without personal identifying information would be helpful to perform data analytics on HVAC system installations, as well as aid energy efficiency programs to effectively verify proper installation.

The group then discussed potential pathways to successfully increase adoption of QI. Low consumer awareness was identified as a key barrier limiting market demand for QI. Stakeholders suggested developing a national specification with the Consortium for Energy Efficiency (CEE) to inform consumers about the level of performance to expect, how to better identify quality service, and request QI tools. Stakeholders also thought a helpful step could be to build an app that allows consumers to assess their current level of performance based on HVAC system configuration to determine if their HVAC system and ducts are working effectively. The app could leverage data on installed HVAC performance collected from national surveys and databases, and offer multiple levels of insight to more widely communicate with different parties (e.g., homeowner vs. building manager). The next step would be to model behavioral data with actual sensor data to understand if consumers would use or value them.

Breakout Discussions and Results

In three small group break-out discussions, attendees discussed the following questions:

- What are potential smart tools and advanced sensing technologies that can improve the installed performance over the lifetime of residential and light-commercial forced-air HVAC systems?
- How can we overcome technical and market barriers to address industry challenges and advance the adoption of smart tools?

To address these questions, each group brainstormed and listed top challenges and opportunities to improve and further advance adoption of smart tools, which support QI of HVAC systems. Table 1 shows a summary of the challenges.

Table 1: Challenges to Adoption of Smart Tools and Advanced Sensing Technologies

Challenges
High costs for manufacturers, contractors, consumers, utilities, etc.
Need for more specific field data on the most impactful faults
Poorly performing existing duct systems
Consumers do not understand the value of QI or how to define comfort, so difficult to evaluate contractor performance
Limited cooperation between HVAC OEMs and smart tool OEMs to standardize communication platforms, design, testing, calibration, and other topics
Need strategy & algorithms to assess duct performance
Lack of integrated ventilation & humidity control
Poor contractor awareness and knowledge
Unknown longevity of sensors & their performance
Difficulties to monitor variable speed equipment
Defining "good enough" accuracy & performance through sensitivity analysis to develop lower cost solutions
Open access to equipment performance data

The groups each presented their ideas to address the identified challenges, and Navigant asked the participants to prioritize the solutions by voting on those that appear to be the most promising and necessary. Each participant received 5 votes (stickers) to distribute among the different solution areas as they saw fit, while also recognizing that some solutions are similar. Table 2 lists the solution topic areas and the total votes they received after the small break out discussions.[4] In addition, the phases of the product lifecycle to which each topic relates are indicated by the check boxes. Highlighting the related lifecycle phases helps identify which stakeholders may be part of designing and implementing each opportunity.

Note – The opportunities, barriers, and ideas generated at the workshop and voting process helps DOE understand the perspectives of various industry stakeholders. The list of

[4] Note - The total number of votes does not equal 5 votes/person multiplied by 44 attendees because: 1) some attendees departed prior to voting; 2) DOE and EPA staff and contractors did not vote; 3) some attendees did not use all their votes.

opportunities and voting results in Table 2 reflects the raw outputs of the workshop with only minor clarification, and, therefore, requires further refinement to ensure that all the proposed initiatives are unique and actionable. Further discussed in the "Next Steps" section, stakeholders should review these initiatives when planning activities to address current barriers QI.

Table 2: Opportunities to Utilize Smart Tools or Advanced Sensing Technologies that can Improve HVAC System Installed Performance

Opportunities	Number of Votes	Manufacture	System Design	System Installation	Consumer Education	EM &V
Empower consumer to understand performance through 3rd party apps, developed to a DOE standard	10		✓	✓	✓	
Create tools to measure performance throughout distribution system	9		✓	✓		✓
Standardize communications between smart tools and equipment (e.g., auto OBD2 ports)	7	✓		✓		✓
Develop low cost sensors for event/fault notification	7	✓		✓		✓
Enable better technician response to installation issues through better interfaces	6	✓		✓		✓
Develop lower cost, lower accuracy sensors for airflow, pressure, refrigerant charge, etc.	6	✓		✓		✓
Document/define commissioning and retro-commissioning of each system	5			✓		
Work with manufacturers on sensors & data exchange	4	✓		✓		✓
Develop smart tools for 3rd party verifier	4					✓
Raise consumer awareness of comfort through smart tools	3		✓	✓	✓	
Develop standardized messaging for contractor regarding value proposition and key performance indicators	3		✓	✓	✓	
Arm technician with data to show improvement impact to customer	3		✓	✓	✓	✓

Opportunities	Number of Votes	Manufacture	System Design	System Installation	Consumer Education	EM &V
Support research partnerships with EPRI, ORNL, manufacturers, DOE BA teams	3	✓	✓	✓		✓
Obtain data from utility programs	3					✓
Develop open source platform including apps, robust tools, real time feedback	3			✓		✓
Help consumer understand the performance of building, including expected system function and performance benchmarks, to help create market demand for QI	2		✓	✓	✓	
Make it easier for contractor to communicate value proposition to consumer	2		✓	✓	✓	
Develop “drone” to insert in duct system and map performance throughout system	2		✓	✓		
Support a voluntary specification (ENERGY STAR)	2		✓	✓		
Develop tools that inform design and system performance (i.e., design as a system)	2		✓	✓		
Create a user dashboard integrated with unit and interoperable with thermostat	2	✓		✓		✓
Create smart processes for design, installation, commissioning, and maintenance	1		✓	✓		
Automate Manual J load calculations	1		✓	✓		
Collaborative R&D with industry to address unmet needs for installation/commissioning and optimization	1	✓	✓	✓		
Engage other industries and market actors (e.g. insurance, fire, health)	1		✓			✓
Work with manufacturers to create tools to inform contractors & consumers	0	✓	✓	✓	✓	
Develop strategies to reduce costs for utility M&V	0					✓
Support improved technician training	0		✓	✓	✓	

Opportunities	Number of Votes	Manufacture	System Design	System Installation	Consumer Education	EM &V
More focus on system data collection, design interoperability	0	✓		✓		✓

Final Discussion

Attendees encouraged DOE to engage more stakeholders, including a range of contractors and manufacturers, and vet the results of this workshop with them. Stakeholders need to come together and create common definitions. It was noted that consumers are not aware that HVAC installation practices vary, and technicians following QI practices can achieve greater system performance and energy cost savings. Average consumers think about their HVAC installation decision once every 12 years or so, and typically do not inspect the existing ducts when replacing their equipment. In addition, a broader group of stakeholders, such as the Western HVAC Performance Alliance, is working on these issues, and DOE needs to coordinate with them. It is also important to leverage how consumers get their information (e.g., HGTV, home improvement channels on YouTube) and to bridge the generation gap and get in front of younger generation consumers.

Several BTO programs are already taking steps to address these issues through current activities. Table 3 provides a sample list of activities from the BERD Sensors and Controls and the RBI, and CBI programs.

Table 3: Example BTO Activities related to Smart Tools and Advanced Sensing Technologies

BTO Program	Example Activities
Residential Buildings Integration (RBI)	• Early stage research through national labs and Building America teams to better understand impacts of QI and develop innovative automated verification systems (AVS) and fault detection and diagnostics (FDD) technologies to improve QI processes • Develop taxonomy of AVS tools • Develop and implement approach for evaluating AVS tools to facilitate and verify HVAC installations • Document HVAC SAVE successes/challenges • Conduct meta research/gather existing data on energy savings from proper installation • Engage industry stakeholders to advance deployment of AVS supported strategies • Full list of activities available at: Link

BTO Program	Example Activities
Commercial Buildings Integration (CBI)	• Better Buildings Alliance, including High Performance RTU Challenge and Advanced RTU Campaign • Laboratory testing of fault detection tools • Workforce Development and Training • Consortium for Building Energy Innovation • State and Local Energy Efficiency Action Network • Full list of activities available at: Link
Building Energy R&D (BERD) Sensors and Controls Sub-program	• Portfolio of early-stage research and development of sensor and control technologies to optimize building operations, energy management, and integration with the electric grid, in the following focus areas of interest: o Multifunction plug-and-play wireless sensors o Occupant-centered and -comfort sensors and controls o Whole-building sub-metering o Adaptive and fault tolerant controls o Auto-configurable controls • DOE Grid Modernization Laboratory Consortium: Link • Full list of activities available at: Link

Next Steps

This document serves as a record of the workshop, the perspectives presented, and its outcomes. This information is valuable to DOE and other stakeholders when considering activities to address the many challenges and opportunities for QI. Advancing QI practices for residential and small commercial HVAC systems will require collaborative efforts from government agencies, utility programs, manufacturers, trade associations, and other stakeholders.

Appendix: Workshop Attendees

Navigant and DOE would like to thank all of the workshop participants. The suggestions, insights, and feedback provided during the session are very important for helping to identify solution pathways to support installed performance of residential and small commercial HVAC systems in the market.

The stakeholder discussion brought together more than 40 individuals representing a range of organizations across the industry, many of which also attended the BTO Peer Review earlier in the week. Table 4 lists all the attendees and their affiliations.

Table 4: Stakeholder Workshop Attendee List

Attendee Name	Organization
Robb Aldrich	Steven Winter Associates
Michael Baechler	Pacific Northwest National Laboratory
Will Baker	Midwest Energy Efficiency Alliance
Lena Burkett	U.S. Department of Energy
Jennifer Butsch	Emerson
Rebecca Ciraulo	Navigant
Wes Davis	Air Conditioning Contractors of America
Steve Dunn	U.S. Department of Energy
Chris Early	U.S. Department of Energy
Robert Fares	U.S. Department of Energy
Cory Fox	CSRA
Paul Francisco	University of Illinois
Bill Goetzler	Navigant
Caroline Hazard	CSRA
Nguyen Ho	Lennox
Dale Hoffmeyer	U.S. Department of Energy
Glenn Hourahan	Air Conditioning Contractors of America
James Jackson	Emerson
Ely Jacobsohn	U.S. Department of Energy
David Lee	U.S. Department of Energy
Mark Lessans	Ingersoll Rand
Dave Mallay	Home Innovation
Eric Martin	Florida Solar Energy Center
Tim Merrigan	National Renewable Energy Laboratory
Cheryn Metzger	Pacific Northwest National Laboratory

Attendee Name	Organization
Andrew Mitchell	U.S. Department of Energy
Courtney Moriarta	CSRA
Jeffrey Munk	Oak Ridge National Laboratory
Jacob Nielson	Emerson
Jonathan Passe	U.S. Environmental Protection Agency
Hung Pham	Emerson
Sam Rashkin	U.S. Department of Energy
Wayne Reedy	CSRA
Dave Roberts	National Renewable Energy Laboratory
Sydney Roberts	Southface
Kurt Roth	Fraunhofer
Stacey Rothgeb	National Renewable Energy Laboratory
Harvey Sachs	American Council for an Energy-Efficient Economy
Tom Schirber	University of Minnesota
Marina Sofos	U.S. Department of Energy
Buck Taylor	Roltay Inc.
Robert Weber	Bonneville Power Administration
Eric Werling	U.S. Department of Energy
Jon Winkler	National Renewable Energy Laboratory
Dave Winningham	Lennox
Scott Yee	CLEAResult