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BUILDING TECHNOLOGIES OFFICE

Residential Central Air Conditioning and Heat Pump Installation–Workshop Outcomes

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Preface

The U.S. Department of Energy's (DOE) Building Technology Office (BTO), a part of the Office of Energy Efficiency and Renewable Energy (EERE) engaged Navigant Consulting, Inc., (Navigant) to facilitate a workshop to identify policy changes, deployment strategies, and technology development initiatives for improving design and installations of residential central air conditioners (CAC) and heat pumps (CHP).

The initiatives identified in this report are Navigant's recommendations to BTO and other stakeholders for pursuing in an effort to achieve DOE's energy conservation goals. Inclusion in this report does not guarantee funding; individual initiatives must be evaluated in the context of all potential activities that BTO could undertake to achieve its goals.

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List of Acronyms

A/C	Air Conditioning
ACCA	Air Conditioning Contractors of America Association
ASRAC	Appliance Standards and Rulemaking Federal Advisory Committee
BTO	Building Technologies Office
CAC	Central Air Conditioning
CHP	Central Heat Pump
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
EERE	Office of Energy Efficiency and Renewable Energy
FDD	Fault Detection and Diagnostics
HVAC	Heating, Ventilation, and Air Conditioning
QI	Quality Installation
R&D	Research and Development
RECS	Residential Energy Consumption Survey
SEER	Seasonal Energy Efficiency Ratio
TAB	Testing, Adjusting, and Balancing

Executive Summary

The U.S. Department of Energy's (DOE) Building Technologies Office (BTO) within the Office of Energy Efficiency and Renewable Energy works with researchers and industry partners to develop and deploy technologies that can substantially reduce energy consumption in residential and commercial buildings. This report aims to advance BTO's energy savings, emissions reduction, and other program goals by identifying research and development (R&D), demonstration and deployment, and other non-regulatory initiatives for improving the design and installation of residential central air conditioners (CAC) and central heat pumps (CHP). Improving the adoption of CAC/CHP design and installation best practices has significant potential to reduce equipment costs, improve indoor air quality and comfort, improve system performance, and most importantly, reduce household energy consumption and costs for heating and cooling by addressing a variety of common installation issues.

This report identifies and characterizes a set of policy changes, deployment strategies, and technology development initiatives for BTO and other stakeholders to consider that could incentivize greater adoption of CAC/CHP quality installation (QI) practices. The investigation scope covers design and installation of CAC/CHP systems common for residential buildings.

To gather input for this report, on May 12, 2016, BTO convened a stakeholder workshop of experts with wide-ranging backgrounds, including manufacturers, energy efficiency programs, and representatives from key industry groups. During the workshop discussions, stakeholders emphasized the need for R&D investment to better understand current CAC/CHP installation practice, encourage wider awareness and adoption of QI practices, and develop the next generation of technologies, policies, and practices that reduce installation losses. The key themes that arose from the stakeholder workshop include:

- Conduct research to quantify of benefits QI
- Evaluate best practices of energy efficiency QI programs
- Develop and promote QI practices among installers, energy efficiency program implementers, and policymakers
- Improve education to consumers on the value of QI
- Develop policies and programs that increase the installer adoption of QI certifications and best practices
- Conduct R&D to improve and validate new tools, techniques, and equipment designed to reduce losses associated with installation practices.

In all, stakeholders provided 66 unique ideas for R&D and other non-regulatory initiatives that could benefit CAC/CHP equipment design and installations. Following the stakeholder workshop, we characterized the full set of initiatives and combined similar ideas into a final list of 31 initiatives. We then evaluated this list using several qualitative prioritization metrics such as expected impact on key barriers and criticality of involvement for key stakeholders. We then selected the most promising initiatives recommended for BTO and other stakeholders to pursue, and supporting initiatives that would have a more moderate impact. For each initiative, we assigned lead stakeholders who are critical to the initiative's success as well as any additional stakeholders who can have a supporting role.

Table ES-1 outlines the resulting five recommended initiatives for BTO to lead on improving CAC/CHP installations. These initiatives represent some of the key areas in which BTO could improve the adoption of QI practices and achieve significant energy savings for U.S. homes with collaboration from other stakeholders.

Table ES-1: Recommended Initiatives for BTO to Lead

ID	Initiative	Category
BTO #1	Conduct research to quantify the benefits and energy savings of QI to support trade practices and energy efficiency programs	Deployment
BTO #2	Expand federal programs to incentivize QI	Policy
BTO #3	Develop and promote better tools for field measurements	Technology
BTO #4	Conduct research to support energy efficiency programs that minimize duct losses	Deployment
BTO #5	Develop guidelines on duct leakage and repair techniques by home type and duct location	Deployment

Because each initiative only targets a specific issue, no single initiative can solve the multifaceted problems facing manufacturers, installers, energy efficiency program managers, and other stakeholders. Furthermore, other parties may be better suited than BTO to lead certain initiatives. As such, Table ES-2 delineates the eight key areas in which other stakeholders can lead initiatives to improve the design and installation of CAC/CHP equipment. A combined effort between BTO and other industry stakeholders, coupled with a multi-initiative approach could provide the best pathway to achieving the desired savings.

Table ES-2: Recommended Initiatives for Other Stakeholders to Lead

ID	Initiative	Category
Other #1	Develop resources to promote education across the value chain	Deployment
Other #2	Develop energy efficiency and state programs to incentivize QI	Policy
Other #3	Review policies surrounding installer certification requirements	Policy
Other #4	Remove regulatory barriers to duct sealing installers	Policy
Other #5	Include whole home energy audits as part of QI energy efficiency programs	Deployment
Other #6	Develop procedures for 3rd-party verifications and penalties for poor installations	Deployment
Other #7	Conduct a study to evaluate success and failures of past and current QI programs	Deployment
Other #8	Develop user-friendly tools for QI and promote their usage	Deployment

This report provides background on BTO's role in improving CAC/CHP installations, discusses key trends facing the HVAC industry, and describes recommended and supporting initiatives.

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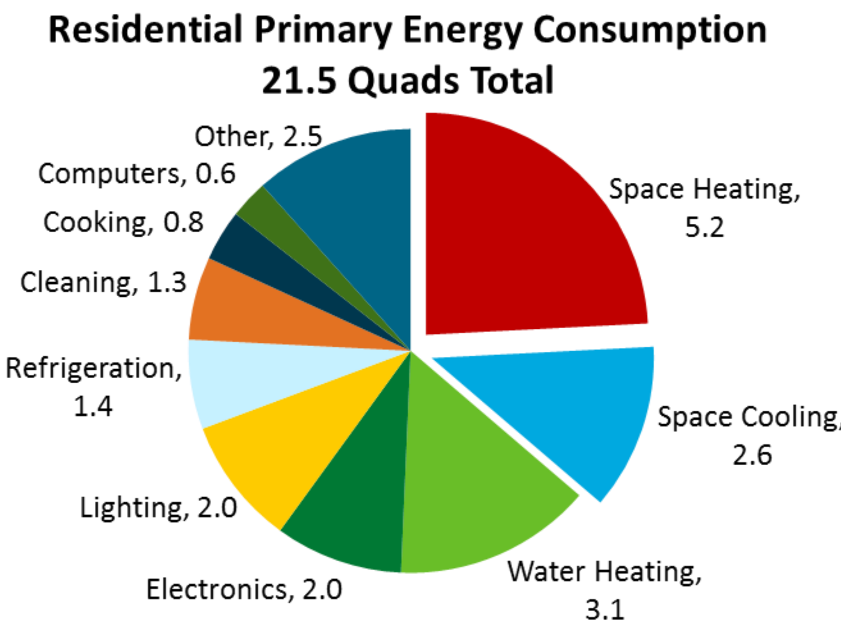
1 Introduction

1.1 Background

The Building Technologies Office (BTO) within the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy works with researchers and industry to develop and deploy technologies that can substantially reduce energy consumption and emissions in residential and commercial buildings. Residential heating, ventilation, and air-conditioning (HVAC) systems experience significantly increased energy consumption when improperly installed. As depicted in Figure 1-1, HVAC systems account for approximately 36% of all residential primary energy consumption.[1]



Source: 2013 data from DOE/BTO Prioritization Tool[2]

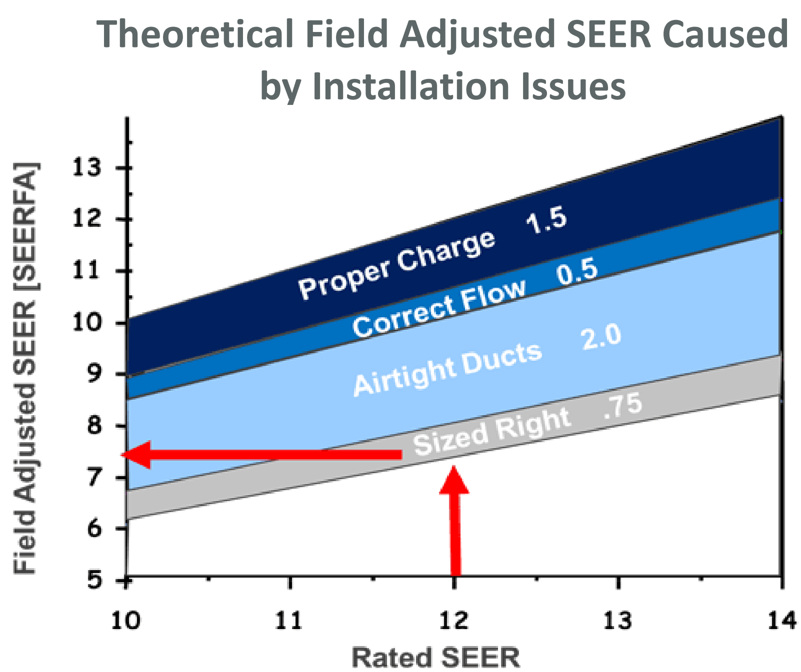
Figure 1-1: Residential primary energy consumption; 21.5 quads total

HVAC systems that provide space conditioning throughout the home rather than a single room are known as central air conditioners (CAC) and central heat pumps (CHP). The installation of CAC/CHP systems is of particular interest due to their prevalence in U.S. homes and increasing performance and efficiency in recent years. Today, 60% of U.S. homes use CACs for space cooling, with an additional 14% of homes using CHPs for space cooling and 9% for space

[1] Figure includes space cooling and space heating energy consumption from all HVAC system types, not just CAC/CHPs.
[2] 2013 data from DOE/BTO Prioritization Tool, which references U.S. Energy Information Administration's (EIA) 2010 Annual Energy Outlook

heating.[3] Increasing adoption of CAC/CHP design, and installation best practices[4] represents a significant opportunity to reduce energy consumption across residential building stock. Conservative estimates of unit savings potential from improved design and installation practices show 20% energy savings[5], which could achieve savings of 0.5 Quads annually.[6]

Several federal initiatives have identified specific opportunities for energy savings through quality installation (QI) practices and programs. For example, U.S. Environmental Protection Agency's (EPA) ENERGY STAR program has a long history of working with manufacturers, homebuilders, energy efficiency programs, and other stakeholders to address energy efficiency issues, such as CAC/CHP installation. ENERGY STAR initiatives to support the adoption of QI programs have identified equipment sizing, airtightness of ducts, correct flow, and proper refrigerant charge as some common installation issues that reduce the efficiency and performance of residential CAC and CHP. As shown in Figure 1-2, these issues can cause a significant discrepancy between the factory-rated efficiency of equipment (e.g., Seasonal Energy Efficiency Ratio [SEER] for cooling) and its performance in the field.



Source: ENERGY STAR Verified HVAC Installation Program[7]

Figure 1-2: Theoretical field adjusted SEER caused by installation issues

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[3] EIA's 2009 Residential Energy Consumption Survey (RECS), Table HC 6.6 and HC 7.6. Accessed May 2016. Available at: http://www.eia.gov/consumption/residential/

[4] Installation of a residential CAC or CHP system requires a multistep process that combines factory-built equipment, field-assembled components, and estimates of the home's characteristics. Throughout this report we refer to "design and installation" to include all of the necessary steps to properly install CAC/CHP equipment and achieve the performance, comfort, and energy efficiency expected for CAC/CHP systems.

[5] Estimated 20%-40% energy savings cited in ASRAC, CAC/CHP Working Group, Final Term Sheet, January 19, 2016. Available at: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0076 Note – the source for this estimate is not provided in the Final Term Sheet

[6] Energy consumption associated with CAC/CHP estimated by DOE Scout Market Calculator Tool, which references EIA's 2015 Annual Energy Outlook. Accessed May 2016. Available at: https://trynthink.github.io/scout/calculator.html

[7] EPA ENERGY STAR. Sponsoring an ENERGY STAR Verified HVAC Installation Program. Accessed May 2016. Available at: https://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_sponsoring_hvac_installation_esvi_program

The figures above highlight the magnitude of potential savings associated with improved practices for CAC/CHP design and installation. Furthermore, these resources identify some of the specific practices that contribute the most losses to the overall efficiency of CAC/CHP systems.

Reducing CAC/CHP installation losses is an important goal for many stakeholders, but past efforts have resulted in limited adoption by industry. Several energy efficiency programs offer QI programs that incentivize installers to perform CAC/CHP installations to Air Conditioning Contractors of America Association (ACCA) Standard 5 or other QI specifications. Despite these efforts, a California study revealed that only 10% of residential installers were participating in energy efficiency QI programs. In this case, only 42% of residential installers were aware of ACCA Standard 5 and only 14% said they adhere to all its specifications.[8] Because installers play such an important role in the design and installation of CAC/CHP systems, engaging the installer community is key to achieving greater adoption of QI practices.

1.2 CAC and CHP Rulemaking Working Group

In July 2015, DOE established a working group of industry experts under the Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) to discuss and develop recommendations on amending energy conservation standards and proposed test procedure for residential CAC/CHPs.[9] The working group consisted of a diverse set of 15 members from DOE, manufacturers, energy efficiency programs, industry organizations, and other parties having a defined stake in CAC/CHP standards.[10] As part of the final Term Sheet approved by the DOE and the ASRAC CAC/CHP Working Group, the parties committed to exploring routes to improve installations of CACs and CHPs. Specifically, as part of Recommendation #11 (below), the DOE agreed to convene a workshop for all stakeholders to consider and rank alternatives for improving system design and installation practices:

> **Recommendation #11.**
> "All parties recognize that the performance for any HVAC system relies on high quality installation. A typical residential system can lose 20% to 40%[11] of the energy available at the equipment plenum because of poor installation practices, depriving the homeowner of expected gains in efficiency while increasing operating costs.
>
> Typical deficiencies include: (1) selecting the wrong equipment for the home (climate conditions, capacity sizing, matching of components and controls, application usage), (2) poor installation and commissioning procedures (issues include: refrigerant charging, airflow/waterflow), (3) poor design, installation, and retrofitting of the air distribution system (excessive air leakage in supply or return, high ESP [External Static Pressure],

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[8] NMR Group. 2015. "Baseline Characterization Market Effects Study of Investor-Owned Utility Residential and Small Commercial HVAC Quality Installation and Quality Improvement Programs in California." CALMAC Study ID CPU0102.01. January 14, 2015. Available at: http://www.calmac.org/publications/CPUC_HVAC_Baseline_Market_Study_Final_Report.pdf

[9] ASRAC, CAC/CHP Working Group, Final Term Sheet, January 19, 2016. Available at: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0076

[10] Appendix C contains a list of working group members.

[11] Note – the source for this estimate is not provided in the Final Term Sheet

> under insulation of ducts), and (4) failing to assure that the owner can operate the system as designed.
>
> All parties commit to exploring routes to improve installations for all consumers, using multiple processes and approaches, ranging from policies (such as tax incentives or inspections) to improved training and consumer information. Within six months, DOE shall convene a workshop for all stakeholders to consider and rank alternatives, and to develop a roadmap for action, including both technical and policy items".

Navigant, on behalf of the BTO, hosted a workshop on May 12th, 2016, at BTO offices in Washington, DC, to gather stakeholder input on CAC and CHP installation challenges, and technical and policy options for the industry. The ideas proposed during this workshop informed this report by identifying initiatives that BTO and other stakeholders could pursue to improve the performance, reliability, and energy efficiency of CAC/CHP systems installed in U.S. homes

1.3 Project Objective

The project objective was to identify and highlight initiatives that BTO and other industry stakeholders could support to help reduce energy losses associated with improper design and installation of residential CAC and CHP equipment.

2 Project Approach

Figure 2-1 outlines the three stages for developing and evaluating opportunities.

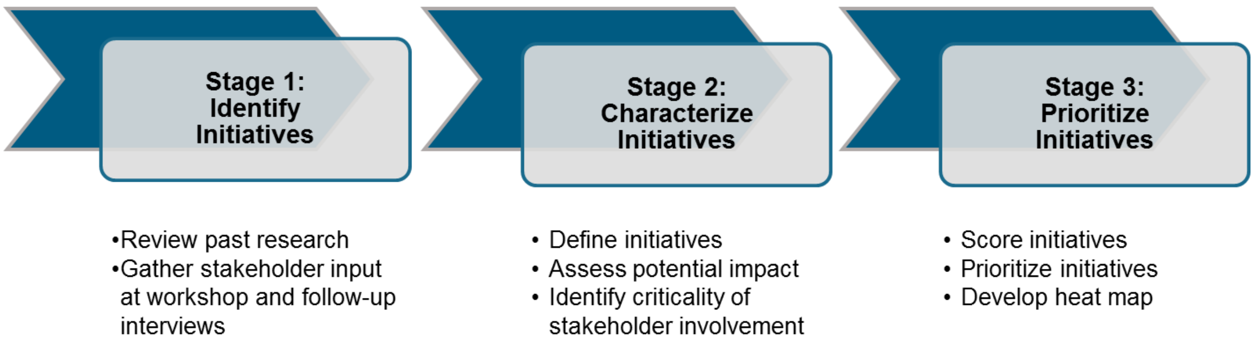


Figure 2-1: Opportunity development steps

2.1 Stage 1: Identify Initiatives

We gathered information on current industry practices and field studies of residential CAC/CHP installations through review of past research, hosting a stakeholder workshop, and conducted several post-workshop interviews. We began with secondary research of available academic studies on efficiency losses during installation, their prevalence in new and retrofit equipment installations, and the potential for new technologies to mitigate these losses. We then hosted a stakeholder workshop to better understand the key barriers to widespread adoption of QI practices, the reasons why approaches to promote QI have faltered, as well as gather expert insights into non-regulatory approaches to address these efficiency degradations. For those who could not attend the workshop in person, we then conducted several follow-up interviews to capture their thoughts. The participating stakeholders helped generate the majority of the opportunities, barriers, and ideas that we subsequently developed into clear initiatives and prioritized.

2.2 Stage 2: Characterize Initiatives

Following the workshop, we refined the 66 initiatives suggested at the workshop to eliminate duplicates and combine similar ideas. We segmented the remaining 31 initiatives into one of three categories highlighted in Table 2-1: technology, deployment, or policy (technology development, deployment strategies, or policy changes; see Section 4). Each category includes a set of opportunities to increase energy savings and reduce the losses associated with improper installation practices. Given the interacting drivers and impacts of CAC/CHP installations, opportunity areas may overlap into multiple categories, but designating each initiative into a category assists in finding key themes and patterns of roles for each stakeholder. We then outlined each initiative's purpose and goals, its potential to address key installation barriers, and identified which key stakeholder groups would have a leading or supporting role in the initiative.

Table 2-1: Key Opportunities

Category	Opportunity Areas

Technology	• Manufacturer equipment / system designs that facilitate QI for installers
	• Installer equipment / system design practices to reduce pre-installation losses
	  ○ Equipment sizing, selection, and matching
	  ○ Air distribution system design, balancing, etc.
	• Installer equipment / system practices to reduce on-site installation losses
	  ○ Proper refrigerant charging
	  ○ Airflow leakage, high static pressure, duct insulation, etc.

Deployment	• Research initiatives on installation practices • Field evaluations • Increasing consumer awareness • Enhancing installer training requirements • Strategies to reduce any additional installation costs • Innovative 3rd-party products to improve installation processes • Manufacturer tools to verify equipment performance
Policy	• Voluntary programs through industry organizers and energy efficiency program implementers • Bridging the gap between policies and in-field installations • DOE and other industry programs to incentivize technology and policy initiatives • Supplemental standard evaluations and test procedures for technologies such as fault detection and diagnostics (FDD) systems

Note – Given the interacting drivers and impacts of CAC/CHP installations, opportunity areas may overlap into multiple categories, but designating each initiative into a category assists in finding key themes and patterns of roles for each stakeholder.

2.3 Stage 3: Prioritize Initiatives

In consultation with BTO, Navigant prioritized the initiatives, then identified the stakeholder group (BTO, EPA, energy efficiency programs, manufacturers, trade associations, and research organizations) most appropriate to lead each initiative. To prioritize initiatives, we scored each using three metrics (see Table 2-2). The aggregation of these scores, along with the number of stakeholder votes for each initiative, determined its final ranking.

Table 2-2: Initiative Scoring Metrics – Definitions

Scoring Metric	Scale for Scoring	Definition
Impact	1 – 5	Expected impact on developing new technology or performing research that addresses a critical knowledge gap and/or key barrier to improved design and installation of CAC/CHP systems.
Criticality of BTO Involvement	1 – 3	Relative importance for BTO to participate and/or lead the initiative or whether industry will be successful without BTO's participation.
Criticality of Other Stakeholders' Involvement	1 – 3	Relative importance for other stakeholders to participate and/or lead the initiative or whether other parties are better suited to carrying out the initiative.

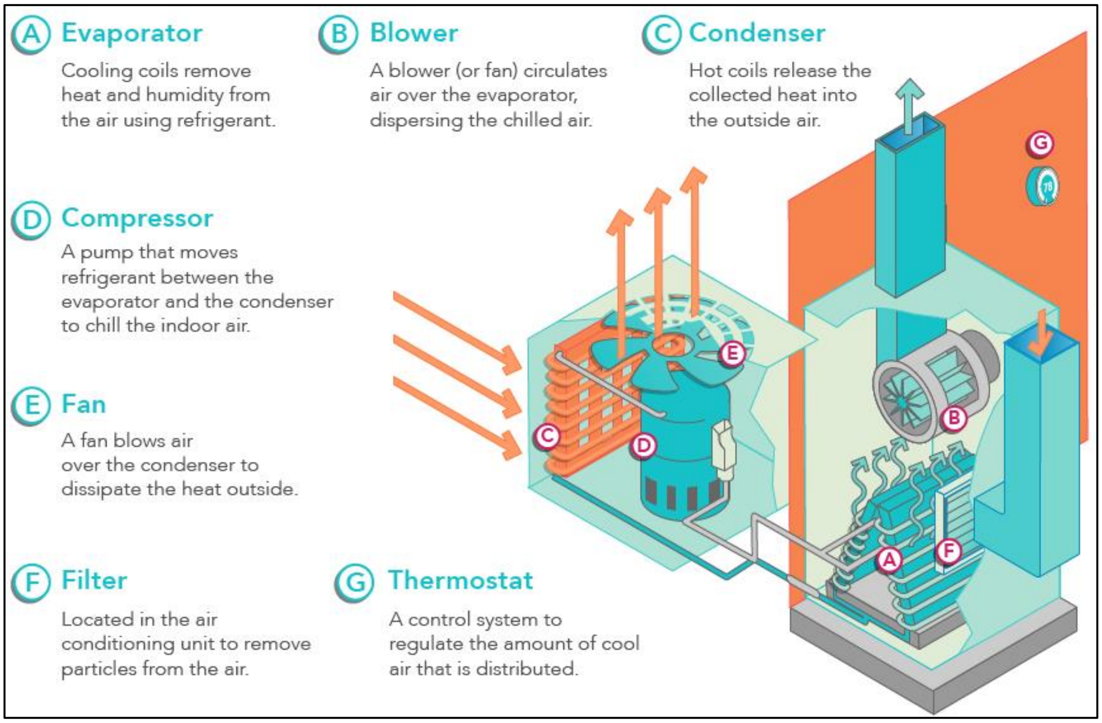
Several members of the Navigant team independently scored each initiative, and we averaged these scores for each metric. Appendix A outlines the specific scoring criteria for each metric. To incorporate voting from the stakeholder workshop (Section 2.1), we assigned each initiative to a scoring tier, depending on the relative number of votes:

- Tier 1: More than 10 votes
- Tier 2: 2 to 10 votes
- Tier 3: Fewer than 2 votes.

We present the prioritized set of initiatives and key characteristics in the form of a "heat map" shown in Appendix A. The heat map visually displays the scoring and prioritization of each initiative determined by the number of stakeholder votes, initiative impact, and criticality of involvement for each stakeholder group.

3 Market Overview

Installation of a residential CAC or CHP system requires a multistep process that combines factory-built equipment, field-assembled components, and estimates of the home's characteristics (e.g., dimensions, occupants, envelope, etc.). Figure 3-1 highlights several of the key components in residential split-system CAC and CHP installations. At each step of this process, industry developed best practices are not followed, which result in lower performance, efficiency, and/or occupant comfort. While not exhaustive, the following sections describe key issues to proper design and installation for residential CAC and CHP systems.



Source: energy.gov[12]

Figure 3-1: Illustration of key CAC/CHP components

3.1 Equipment Sizing

Prior to selecting a CAC/CHP system, an installer must determine the thermal load required to cool and/or heat the home. This process, commonly referred to as "equipment sizing," incorporates an analysis based on the physical dimensions of the conditioned space, characteristics of the enclosure (e.g., air tightness and insulation of walls, roof, windows, etc.), climate, and other factors. When the properties of a residence are input to an ACCA Manual J load calculation spreadsheet or software, the installer can estimate the required capacity for both space cooling and space heating.

[12] U.S. Department of Energy. 2014. Energy Saver 101: Home Cooling Infographic. Accessed October 2016. http://energy.gov/downloads/energy-saver-101-home-cooling-infographic

Nevertheless, the ACCA Manual J process is only accurate if followed correctly and if using accurate input data. Especially for existing homes, rather than using Manual J, installers frequently specify new equipment with the same capacity, or larger, compared to the existing CAC/CHP system to save time and avoid callbacks. Without a new load calculation, installers may be mistakenly assuming that the existing system was correctly sized in the first place, and the home has not experienced any changes that would affect load (e.g., recent additions, occupancy changes, window replacements, etc.). Replacing a system with one of equal capacity, however, can perpetuate system inefficiencies resulting from either system over-sizing or system under-sizing. In addition, installers may not have access to accurate information on the home's insulation levels, air tightness, duct leakage, and other parameters, which can result in an inaccurate sizing recommendation. Using empirical data and analyses (e.g., blower door tests, duct blaster tests, infrared images, duty-cycle measurements on existing heating/cooling equipment, billing analyses, and/or indoor-outdoor temperature-difference measurements with known heat inputs) to develop inputs could significantly improve the accuracy of equipment sizing methodologies and reduce time/cost for on-site walkthroughs. Also, photo-based software to streamline geometry measurements could provide significant cost reductions, improved accuracy, and increase use of Manual J. For new homes, installers should work with the homebuilder and architect to gather correct sizing plans for the Manual J calculation, while also identifying other solutions to avoid installation inefficiencies (e.g., duct location and layout, equipment placement, etc.).

Further discussed in Section 3.2, CHPs introduce additional design complexity because the single system must satisfy both space heating and space cooling loads, which may lead to equipment being over-sized or under-sized for cooling and/or heating modes.

3.2 Equipment Selection

When designing the CAC/CHP system, numerous issues can arise when selecting the correct components (e.g., outdoor unit, indoor coil and air handler). Matching an indoor unit with an outdoor unit is of particular importance in split system CAC/CHPs, and mismatched pieces can result in poor performance and efficiency. In addition, the blower fan must be adequately sized (e.g., airflow rate, static pressure, etc.) to the indoor coil specifications, and duct configuration to provide proper airflow temperatures and distribution. CHP systems in particular pose significant problems because the equipment must satisfy both space heating and space cooling loads using the same outdoor unit. In situations where the design cooling and heating loads are significantly different, selection problems can occur where the outdoor unit or blower is over-sized or under-sized relative to the load.

3.3 Equipment Installation

When installing CACs and CHPs at a customer's home, installers have numerous subsystems and components to place, connect, and adjust in a short amount of time, providing the temptation to overlook best practices to save time and money. Common issues that affect performance and efficiency include:

- **Refrigerant Charging** – Manufacturers typically ship CAC/CHP equipment pre-charged with refrigerant, and require the installer to adjust the refrigerant charge to accommodate the specific home's needs. An improperly charged system, whether under-charged or over-charged, can increase energy consumption and the risk of system failure. New technologies are available to accurately determine the correct refrigerant charge, such as digital gauges and tools, but many installers still use rule-of-thumb methods or rely on less expensive analog gauges. Traditional methods allow installers to quickly start up equipment for customers, but can create long-term inefficiencies through over- and/or under-charging.

- **Duct Systems** – Improperly designed, sealed, insulated, or balanced duct systems reduce the effectiveness of in CAC/CHP systems. Leaky duct systems allow conditioned air to escape, draw potentially polluted or unconditioned air through the return, and increase fan energy consumption. Poorly insulated duct systems increase heat transfer, resulting in less thermal energy reaching its intended zone and potentially introducing condensation issues. Finally, improperly balanced systems disproportionally allocate airflow to specific rooms within a home, so that the CAC/CHP system needs to overcompensate to reach zones with insufficient airflow.

- **Controls Setup** – CAC and CHP systems rely on thermostats, zoning systems, humidifiers/dehumidifiers, and other control systems to properly satisfy indoor conditions, which can introduce additional installation issues. Placing thermostats in areas with direct sunlight or in direct contact with the supply air stream can produce unrepresentative readings. Although more user-friendly products have been introduced in recent years, many consumers have difficulty setting up and configuring their thermostats to maintain a comfortable temperature schedule. CHPs pose additional challenges for installers when configuring the switchover to auxiliary or secondary heating sources and setting a quick-recovery schedules.

4 Recommended CAC/CHP Installation Initiatives

Workshop outcomes are summarized below in five sections:

- *Central Themes (Section 4.1)*: Summary of themes that emerged during the stakeholder workshop that carry common threads through many (if not all) of the initiatives
- *CAC/CHP Installation Initiative Summary (Section 4.2)*: Summary of recommended initiatives
- *Recommended Initiatives for BTO to Lead (Section 4.3)*: Detailed descriptions for recommended initiatives that require critical BTO involvement.
- *Recommended Initiatives for Other Stakeholders to Lead (Section 4.4)*: Detailed descriptions for recommended initiatives requiring extensive contributions from other industry stakeholders.
- *Supporting Initiatives (Section 4.5)*: Brief descriptions of supporting initiatives with limited impact and stakeholder involvement.

4.1 Central Themes

The stakeholder workshop in Washington D.C., in addition to providing valuable input on specific initiatives, also uncovered some key themes that can guide much of the future work that BTO or industry groups may pursue. Stakeholders emphasized the need for R&D investment to better understand current CAC/CHP installation practices, encourage wider awareness and adoption of QI practices, and develop the next generation of technologies, policies, and practices that will reduce losses related to installation. The key themes arose from the stakeholder workshop, including:

- Conduct research to quantify of benefits QI
- Evaluate best practices of energy efficiency QI programs
- Develop and promote QI practices among installers, energy efficiency program implementers, and policymakers
- Improve education to consumers on the value of QI
- Develop policies and programs that increase the installer adoption of QI certifications and best practices
- Conduct R&D to improve and validate new tools, techniques, and equipment designed to reduce losses associated with installation practices.

Because of the multifaceted nature of CAC/CHP installation issues, numerous stakeholders will play with a key role in overcoming shortcomings with current practices. Table 4-1 lists key industry stakeholders and describes the areas in which each can contribute to improved CAC/CHP installation processes.

Table 4-1: Key Roles for Industry Stakeholders

Stakeholder	Key Roles
BTO	Support research initiatives and case studies, provide guidelines on specific practices, conduct field demonstrations to test and validate approaches
EPA	Develop enabling government programs, promote education, evaluate successes and failures of other programs
Energy Efficiency Programs	Develop incentive programs, conduct 3rd-party evaluations, perform energy audits, and encourage specific practices
Manufacturers	Develop more resilient equipment, collect installation data, provide installation guidance to installer networks
Trade Associations	Provide a single source for performance information, educational resources, industry standards, and training programs
Research Organizations (e.g., National Labs)	Perform validation studies, research equipment faults, and evaluate systems

4.2 CAC/CHP Installation Initiative Summary

We prioritized the initiatives to provide guidance to BTO and other stakeholders on which initiatives showed greater potential impact, closer fit with each stakeholder's mission, and other considerations (see Section 2.2 above). While not exhaustive, these initiatives represent some of the key areas in which BTO and other stakeholders could work to improve the quality of CAC/CHP installations. Each initiative targets only a specific issue, and no single initiative can solve the multifaceted problems manufacturers, installers, and energy efficiency program managers' experience with current CAC/CHP installation practices. A multi-initiative approach could prove more effective. Either way, recommended initiatives offer a substantial opportunity to reduce energy losses due to poor design and installation practices.

Table 4-2 and Table 4-3 identify the most promising initiatives recommended for BTO and other stakeholders to pursue in the areas of policy changes, deployment strategies, and technology development. We categorize recommended initiatives to be lead by either BTO or other stakeholders to highlight where each group has a major role in the most impactful initiatives. For each initiative, we designate lead stakeholders who are critical to the initiative's success as well as any additional stakeholders who can have a supporting, but less critical role. The sections that follow detail the recommended initiatives, with supporting initiatives described further in Section 4.5.

The following list highlights key findings from the recommended initiatives:

- Stakeholders developed consensus around the need for improved education, research and development opportunities, and programs to enable specific QI practices.
- The Tier 1 initiatives for both BTO and other stakeholders to lead have good alignment with the stakeholder votes assigned at the workshop.

- BTO has a primary role for developing initiatives that quantify the benefits of QI, supporting potential federal incentives that enable QI, and evaluating better tools for field measurements.
- Other stakeholders (e.g. EPA, energy efficiency programs, manufacturers, trade associations, and research organizations) primarily should focus on initiatives that promote education for both customers and contractors, support certifications and QI adoption among contractors, and support the development and promotion of utility programs around QI.

Table 4-2: Recommended Initiatives for BTO to Lead

ID	Initiative
Tier 1-BTO #1	Conduct research to quantify the benefits and energy savings of QI to support trade practices and energy efficiency programs
Tier 1-BTO #2	Expand federal programs to incentivize QI
Tier 1-BTO #3	Develop and promote better tools for field measurements
Tier 1-BTO #4	Conduct research to support energy efficiency programs that minimize duct losses
Tier 1-BTO #5	Develop guidelines on duct leakage and repair techniques by home type and duct location

Table 4-3: Recommended Initiatives for Other Stakeholders to Lead

ID	Initiative
Tier 1-Other #1	Develop resources to promote education across the value chain
Tier 1-Other #2	Develop energy efficiency and state programs to incentivize QI
Tier 1-Other #3	Review policies surrounding installer certification requirements
Tier 1-Other #4	Remove regulatory barriers to duct sealing installers
Tier 1-Other #5	Include whole home energy audits as part of QI energy efficiency programs
Tier 1-Other #6	Develop procedures for 3rd-party verifications and penalties for poor installations
Tier 1-Other #7	Conduct a study to evaluate success and failures of past and current QI programs
Tier 1-Other #8	Develop user-friendly tools for QI and promote their usage

4.3 Recommended Initiatives for BTO to Lead

Table 4-4 provides brief descriptions of recommended initiatives that BTO could lead to address CAC/CHP installation issues, as well as list of other lead and supporting stakeholders.

Table 4-4: Descriptions of Recommended Initiatives for BTO to Lead

ID	Initiative	Description	Lead Stakeholder(s)	Supporting Stakeholder(s)	Category
Tier 1-BTO #1	Conduct research to quantify the benefits and energy savings of QI to support trade practices and energy efficiency programs	Develop case studies and national scale studies on potential benefits of QI as well as the effectiveness of specific QI practices such as proper ACCA Manual J sizing, matching indoor and outdoor components, and duct sealing. These studies could assist with customer education and industry support for QI programs.	BTO, Energy Efficiency Programs, Research Organizations	EPA, Trade Associations	Deployment
Tier 1-BTO #2	Expand federal programs to incentivize QI	Create a federal incentive program that provides rebates or tax credits to consumers or homeowners who perform QI on eligible installations. Ideas include: tying state energy efficiency funding to QI program participation, tax credits to homeowners who install equipment with QI from a certified installer, and incentives for installers that have their technicians complete QI training.	BTO, EPA	Trade Associations	Policy
Tier 1-BTO #3	Develop and promote better tools for field measurements	Current installer field measurement tools and methods are insufficient for quick, cost-effective, and accurate assessments of building envelope, duct system, and HVAC equipment characteristics. Further research into improved field measurement strategies could support more installers performing QI practices.	BTO, EPA, Manufacturers	Energy Efficiency Programs, Trade Associations	Technology

ID	Initiative	Description	Lead Stakeholder(s)	Supporting Stakeholder(s)	Category
Tier 1-BTO #4	Conduct research to support energy efficiency programs that minimize duct losses	Especially in existing homes, leaky ducts contribute to higher thermal energy loads and higher fan energy consumption to deliver space heating and cooling throughout the home. Strategies such as duct inspection and sealing, or incorporating ductless CAC/CHP systems, and locating ducts in conditioned space can reduce duct losses and should be promoted in deployment programs. Conducting research to quantify duct losses and developing low-cost prevention strategies can support the development of energy efficiency programs that incentivize practices that minimize duct losses.	BTO, EPA	Energy Efficiency Programs, Trade Associations	Deployment
Tier 1-BTO #5	Develop guidelines on duct leakage and repair techniques by home type and duct location	Duct placement and its impact on HVAC system efficiency can vary greatly depending on the design of the home. For example, ducts located in an uninsulated and vented attic require different approaches than those located within the conditioned space, such as a ceiling chase. Guidelines for reducing duct leakage in common home types could help improve duct systems.	BTO	EPA, Energy Efficiency Programs, Trade Associations, Research Organizations	Deployment

4.4 Recommended Initiatives for Other Stakeholders to Lead

Table 4-5 provides brief descriptions of recommended initiatives that other stakeholders (e.g., EPA, energy efficiency programs, manufacturers, trade associations, research organizations) could lead to address CAC/CHP installation issues, as well as list of other lead and supporting stakeholders.

Table 4-5: Descriptions of Recommended Initiatives for Other Stakeholders to Lead

ID	Initiative Name	Description	Lead Stakeholder(s)	Supporting Stakeholder(s)	Category
Tier 1-Other #1	Develop resources to promote education across the value chain	Increased consumer and installer awareness of QI practices and programs can help overcome some of the misconceptions about CAC/CHP installations. A coordinated marketing and educational effort from ENERGY STAR, trade associations, manufacturers, energy efficiency incentive programs, and others should help communicate the importance of QI, what QI involves, and how consumers are missing out on efficiency and performance.	EPA, Trade Associations	BTO, Energy Efficiency Programs, Manufacturers, Research Organizations	Deployment
Tier 1-Other #2	Develop energy efficiency and state programs to incentivize QI	High efficiency CAC/CHP equipment cannot deliver its promised energy savings when improperly installed, reducing the energy savings captured by energy efficiency incentive programs. Basing HVAC incentive programs on HVAC system performance would reward true savings achieved with QI practices, rather than assuming that poor installation practices will not erode savings of high efficiency equipment.	EPA, Energy Efficiency Programs	BTO	Policy
Tier 1-Other #3	Review policies surrounding installer certification requirements	Supporting standardized educational and certification programs for CAC/CHP installers to ensure that installers are aware of industry QI standards and best practices for mitigating installation losses.	Trade Associations	EPA, Energy Efficiency Programs	Policy
Tier 1-Other #4	Remove regulatory barriers to duct sealing installers	Some states require an installer license or certification to repair ducts, which limits the potential for weatherization or other home efficiency companies from offering duct sealing services. Revising state requirements for installers regarding duct sealing could encourage more companies to offer duct sealing.	Energy Efficiency Programs	BTO, Trade Associations	Policy

ID	Initiative Name	Description	Lead Stakeholder(s)	Supporting Stakeholder(s)	Category
Tier 1-Other #5	Include whole-home energy audits as part of energy efficiency QI programs	QI practices require a thorough understanding of the home's building envelope and duct system to properly design and install the right CAC/CHP equipment in existing homes. Energy efficiency programs should encourage or require a detailed energy audit for existing homes prior to HVAC installations to help installers estimate thermal loads and identify other opportunities to improve energy efficiency prior to HVAC system selection.	Energy Efficiency Programs	BTO, EPA, Trade Associations, Research Organizations	Deployment
Tier 1-Other #6	Develop procedures for 3rd-party verifications and penalties for poor installations	Requiring 3rd-party verification for installations, either as part of building code requirements, energy efficiency incentive programs (as part of T1-Other #2), or manufacturer installer programs, would help ensure that installers follow QI practices. In addition, these programs should develop simplified validation tools for inspectors and potentially carry penalties as part of the verification process.	Energy Efficiency Programs	EPA, Trade Associations	Deployment
Tier 1-Other #7	Conduct a study to evaluate success and failures of past and current QI programs	Energy efficiency programs across the U.S. have offered a variety of CAC/CHP energy efficiency and QI programs for many years, but limited information exists on their effectiveness and best practices. Studying the history of QI programs across various utilities and states, and investigating what made them successful or unsuccessful through a root cause analysis, would help other utilities and other energy efficiency program implementers improve their QI programs.	EPA, Energy Efficiency Programs	BTO, Trade Associations, Research Organizations	Deployment
Tier 1-Other #8	Develop user-friendly tools for QI and promote their usage	The lack of cost-effective and simple installer tools increases the time and cost for QI practices and limits their adoption. Developing intuitive, user-friendly tools could help achieve widespread adoption and therefore, facilitation, of QI programs.	EPA, Trade Associations	BTO, Energy Efficiency Programs	Deployment

4.5 Supporting Initiatives

Supporting initiatives are also valuable opportunities to address CAC/CHP installation issues and should be considered for future action. Stakeholders identified these initiatives as important in reducing installation losses, and they can have at least a moderate impact. Appendix B contains the list of supporting initiatives.

Appendix A – Heat Map of CAC/CHP Installation Initiatives

The heat map in Figure A-1 indicates which stakeholder groups are most critical to each initiative. This heat map aggregates data surrounding an initiative's potential impact (as described by the legend in Figure A-2), criticality of specific stakeholders' involvement (detailed in Figure A-3), and number of stakeholder votes at the industry workshop, and can be sorted according to each of those parameters.

Each cell in the heat map is colored according the associated scoring metric:

- Green cells represent significant impact, critical levels of involvement, and ultimately Tier 1 initiatives.
- Yellow cells represent moderate impact initiatives, beneficial levels of stakeholder involvement, and a Tier 2 rating.
- Red cells represent initiatives with minimal impact, unnecessary stakeholder involvement, and Tier 3 overall score.

ID	Activity/Initiative	Topic	Impact	BTO Role	EPA Role	Utility Role	OEM Role	Trade Asc. Role	Research Org Role	Stake-holder Votes		BTO Tier Rating	Other Tier Rating
Tier 1-BTO #1	Conduct research to quantify the benefits and energy savings of QI	Deployment	4.5	3	2	3	1	2	3	20		Tier 1	Tier 2
Tier 1-BTO #2	Expand federal programs to incentivize QI	Policy	5.0	3	3	1	1	2	1	19		Tier 1	Tier 2
Tier 1-BTO #3	Develop and promote better tools for field measurements	Technology	4.0	3	3	2	1	2	1	14		Tier 1	Tier 2
Tier 1-BTO #4	Conduct research to support energy efficiency programs that minimize duct losses	Deployment	4.5	3	3	2	1	2	1	1		Tier 1	Tier 2
Tier 1-BTO #5	Develop guidelines on duct leakage and repair techniques by home type and duct location	Deployment	4.5	3	2	2	1	2	2	0		Tier 1	Tier 2
Tier 1-Other #1	Develop resources to promote education across the value chain	Deployment	4.0	2	3	2	2	3	2	16		Tier 2	Tier 1
Tier 1-Other #2	Develop energy efficiency and state programs to incentivize QI	Policy	5.0	2	3	3	1	1	1	15		Tier 2	Tier 1
Tier 1-Other #3	Review policies surrounding installer certification requirements	Policy	4.0	1	2	2	1	3	1	14		Tier 2	Tier 1
Tier 1-Other #4	Remove regulatory barriers to duct sealing installers	Deployment	5.0	2	2	3	1	2	1	5		Tier 2	Tier 1
Tier 1-Other #5	Include whole home energy audits as part of QI energy efficiency programs	Deployment	4.5	2	2	3	1	2	2	4		Tier 2	Tier 1
Tier 1-Other #6	Develop procedures for 3rd-party verifications and penalties for poor installations	Policy	4.5	1	2	3	1	2	1	4		Tier 3	Tier 1
Tier 1-Other #7	Conduct a study to evaluate success and failures of past and current QI programs	Deployment	4.0	2	3	3	1	2	2	0		Tier 2	Tier 1
Tier 1-Other #8	Develop user-friendly tools for QI and promote their usage	Deployment	4.5	2	3	2	1	3	1	0		Tier 2	Tier 1
Supporting #1	Develop CAC/CHP systems with improved on-board diagnostics and monitoring	Technology	3.5	2	2	1	3	1	3	12		Tier 2	Tier 2
Supporting #2	Develop more adaptable and fault tolerant CAC/CHP systems	Technology	3.5	2	2	1	3	1	3	11		Tier 2	Tier 2
Supporting #3	Periodically review QI standards to continually improve industry practices	Deployment	3.0	2	3	2	1	3	1	7		Tier 2	Tier 2
Supporting #4	Develop policies that ensure premium equipment is only installed by premium installers	Policy	2.5	2	2	2	2	3	1	4		Tier 2	Tier 2
Supporting #5	Conduct validation studies on baseline CAC/CHP ratings	Technology	3.5	2	2	1	2	2	3	3		Tier 2	Tier 2
Supporting #6	Develop a standard or specification for residential testing, adjusting, and balancing	Deployment	3.5	2	2	2	1	3	2	1		Tier 2	Tier 2
Supporting #7	Develop simpler load calculation tools and measurement equipment	Technology	4.5	1	1	1	2	3	2	4		Tier 3	Tier 2
Supporting #8	Consider practices to dry-ship equipment to incentivize proper charging in the field	Deployment	3.5	1	1	1	3	3	2	1		Tier 3	Tier 2
Supporting #9	Develop a standardized proposal form for installers	Deployment	3.0	1	2	3	2	3	1	1		Tier 3	Tier 2
Supporting #10	Develop and promote sales training programs and requirements for selling home	Deployment	3.0	1	2	2	1	3	1	1		Tier 3	Tier 2
Supporting #11	Conduct research on the frequency of different airflow faults	Technology	4.0	1	2	1	1	2	3	0		Tier 3	Tier 2
Supporting #12	Develop design tools capable of accurately calculating small loads	Technology	3.5	1	2	1	2	2	3	0		Tier 3	Tier 2
Supporting #13	Conduct research on thermal energy dissipation in homes	Technology	3.0	2	1	1	1	1	3	4		Tier 2	Tier 3
Supporting #14	Develop and promote asset rating systems that include QI provisions	Deployment	2.5	2	3	1	1	2	1	1		Tier 2	Tier 3
Supporting #15	Conduct research on sensitivity to sizing of system performance	Technology	3.0	1	1	1	2	2	3	2		Tier 3	Tier 3
Supporting #16	Develop and promote a single source for retrieving sensible and total performance	Deployment	1.5	1	1	1	2	3	1	1		Tier 3	Tier 3
Supporting #17	Develop and promote better design approaches for zoned systems	Deployment	2.5	1	1	1	2	2	3	0		Tier 3	Tier 3
Supporting #18	Conduct research on the potential benefits of smaller capacity equipment	Deployment	2.0	1	1	1	2	1	3	0		Tier 3	Tier 3

Figure A-1: Heat map of CAC/CHP initiatives

Note – Initiatives that could have a significant impact with a clear lead organization were deemed Tier 1 even without high stakeholder support.

Impact Score		
5	Significant	Significant impact on developing new technology or performing research that results in a high level of energy savings.
4	Semi-Significant	Semi-significant impact on developing new technology or performing research that addresses a critical knowledge gap or overcomes a key barrier.
3	Moderate	Impactful in developing new technologies or key research initiatives with limited potential for energy savings.
2	Modest	Limited outcomes in research and development of potential energy saving technologies.
1	Minimal	Initiatives with minimal relevance or negligible energy saving potential.

Figure A-2: Heat map legend – impact score

Criticality of Involvement		
3	Critical	Stakeholders should focus their efforts on these initiative to maximize impact. Initiatives falling under this category will likely go unaddressed without their involvement. Each initiative has at least one lead stakeholder of critical involvement.
2	Beneficial	A score of 2 represents a Tier 2 initiative of medium criticality. These initiatives could greatly benefit from the stakeholder involvement, however, could be carried out by a different group within the industry. The stakeholder group can achieve a positive impact by offering support in developing the initiative.
1	Unnecessary	A score of 1 represents a low level of criticality. Initiatives that fall under this category do not specifically depend on the stakeholder involvement to be enacted. A score of 1 represents a low level of relevance to the stakeholder group.

Figure A-3: Heat map legend – criticality of involvement

Appendix B – Summary of Supporting Initiatives

Table B-1 provides brief descriptions of supporting initiatives to address CAC/CHP installation issues, as well as list of lead and supporting stakeholders. We scored these initiatives during the prioritization process (see Section 2.2) and present them here in order of decreasing rank.

Table B-1: Descriptions of Supporting Initiatives for BTO and Other Stakeholders

ID	Initiative Name	Description	Lead Stakeholder(s)	Supporting Stakeholder(s)
Supporting #1	Develop CAC/CHP systems with improved on-board diagnostics and monitoring	On-board FDD systems would assist installers by verifying proper start up and monitoring the performance of the CAC/CHP system over time. Developing on-board or after-market FDD systems could improve the certainty and effectiveness of QI practices, increasing their adoption.	Manufacturers, Research Organizations	BTO, EPA
Supporting #2	Develop more adaptable and fault tolerant CAC/CHP systems	During CAC/CHP installations, installers must pair an outdoor unit, indoor coil, air handler, and other components into a complete system, and sometimes encounter compatibility issues that reduce system efficiency. More adaptable systems would have adjustable operating settings to accommodate a wider range of equipment. For example, a standardized communication kit that identifies the specific indoor and outdoor components, refrigerant pipe length, and other parameters could communicate necessary adjustments to installers or automatically modify on-board controls.	Manufacturers, Research Organizations	BTO, EPA
Supporting #3	Periodically review QI standards to continually improve industry practices	The HVAC industry continues to evolve as new technologies, installer tools, and installation techniques enter the marketplace. QI standards, such as ACCA Standard 5, should be continually reviewed by industry stakeholders and updated as necessary, with each update promoted to energy efficiency programs and other QI stakeholders.	EPA, Trade Associations	BTO, Energy Efficiency Programs

ID	Initiative Name	Description	Lead Stakeholder(s)	Supporting Stakeholder(s)
Supporting #4	Develop policies that ensure premium equipment is only installed by premium installers	Consumers who are paying a premium for high efficiency equipment should have an expectation that their system will operate as designed, and not experience unnecessary losses resulting from poor installation. Industry, state, or energy efficiency programs could develop policies that prohibit the sale of high efficiency equipment to installers that do not have QI certifications to ensure that premium equipment is installed by premium installers.	Trade Associations	BTO, EPA, Energy Efficiency Programs, Manufacturers
Supporting #5	Conduct validation studies on baseline CAC/CHP ratings	Equipment efficiency ratings rely on laboratory testing at design conditions and may not reflect in-field conditions that can impose a variety of performance and efficiency losses. Energy efficiency programs in particular could benefit from research studies in various locations/regions that characterize the performance losses that may be unavoidable for many installations.	Research Organizations	BTO, EPA, Manufacturers, Trade Associations
Supporting #6	Develop a standard or specification for residential testing, adjusting, and balancing	Even when selected and installed properly, CAC/CHP systems often require some fine tuning to ensure that adequate airflow reaches each thermal zone in the home. Incorporating standards and specifications for residential testing, adjusting, and balancing (TAB) into QI programs would help ensure that occupants experience peak comfort and efficiency.	Trade Associations	BTO, EPA, Energy Efficiency Programs, Research Organizations
Supporting #7	Develop simpler load calculation tools and measurement equipment	Though ACCA Manual J is recognized as the industry standard for load calculations, the complexity and time-consuming nature of the process leads lower installer participation. Simpler tools for load calculations could help reduce installer inclination to use rules-of-thumb for CAC/CHP system design. In addition, the load calculation tools are only as accurate as the estimated inputs. Using improved measurement equipment (e.g., infrared cameras, runtime loggers) to identify a home's characteristics (e.g., duct/envelope leakage, insulation levels, window characteristics and equipment runtimes) could significantly improve the accuracy of equipment design methodologies.	Trade Associations	Manufacturers, Research Organizations

ID	Initiative Name	Description	Lead Stakeholder(s)	Supporting Stakeholder(s)
Supporting #8	Consider practices to dry-ship equipment to incentivize proper charging in the field	Typically, manufacturers place a fixed refrigerant charge in CAC/CHP outdoor units and installers adjust the charge on site to match the installation conditions (e.g., refrigerant piping length, coil selection). Installers may not properly adjust the refrigerant charge, leading to performance and efficiency losses. Dry-shipping equipment may reduce the chance of improper equipment charging because the installer must charge the system completely in the field.	Manufacturers, Trade Associations	Research Organizations
Supporting #9	Develop a standardized proposal form for installers	Consumers often assume that installers follow QI practices, and may not appreciate the added cost and time necessary to perform QI. Standard installer proposal forms could provide more awareness of QI benefits by clearly stating the specific steps each installer will perform, so consumers can make an informed decision about choosing QI installers. In addition, consumers could compare quotes from multiple contractors more easily since each proposal would have all relevant information and terms in a standardized format.	Energy Efficiency Programs, Trade Associations	EPA, Manufacturers
Supporting #10	Develop and promote sales training programs and requirements for selling home performance	Many installers employ sales representatives who are not technicians to meet with homeowners and discuss CAC/CHP system options. Providing QI training and certification programs for sales representatives would better incentivize the sales representative to communicate the benefits and value of QI practice to consumers.	Trade Associations	EPA, Energy Efficiency Programs
Supporting #11	Conduct research on the frequency of different airflow faults	Airflow faults within the home, such as sagging flexible ducts or disconnected registers, often go unnoticed, but contribute to poor performance and efficiency. Conducting research to identify the most frequent airflow faults would allow for more targeted initiatives to resolve these issues.	Research Organizations	EPA, Trade Associations

ID	Initiative Name	Description	Lead Stakeholder(s)	Supporting Stakeholder(s)
Supporting #12	Develop design tools capable of accurately calculating small loads	Current CAC/CHP system design and load calculation tools often cannot correctly size the airflow and thermal capacity needed to serve high-performance homes that have low thermal demands. As low-load homes become more prevalent, industry should develop the next generation of design tools to provide accurate load and system design calculations for these homes.	Research Organizations	EPA, Manufacturers Trade Associations
Supporting #13	Conduct research on thermal energy dissipation in homes	Current HVAC design practices rely on assumptions for heating and cooling load in each room or zone based on activity level, room type, location, etc. However, several other contributing factors can affect thermal energy transfer and occupant comfort within the home such as the placement of air handlers, ducts, major appliances, and other loads in the home. Conducting research to study how thermal energy travels through homes could identify ways to improve HVAC system design methods.	Research Organizations	BTO
Supporting #14	Develop and promote asset rating systems that include QI provisions	Several asset rating systems have been developed to help homebuyers understand the energy-efficiency characteristics of homes before purchase. Asset rating systems should incorporate information on whether the HVAC system was installed to QI standards, ducts have been repaired/sealed, and other attributes so that consumers can communicate and understand the value of QI practices for efficient homes.	EPA	BTO, Trade Associations
Supporting #15	Conduct research on sensitivity to sizing of system performance	Because some installers may not follow ACCA Manual J procedures and manufacturers typically offer equipment in 0.5-1.0 ton increments, CAC/CHP systems may be sized larger or smaller than necessary. Performing research to quantifying performance, comfort, and efficiency issues associated with improper equipment sizing would highlight this issue, and stress the need for proper sizing and other QI practices.	Research Organizations	Manufacturers, Trade Associations

ID	Initiative Name	Description	Lead Stakeholder(s)	Supporting Stakeholder(s)
Supporting #16	Develop and promote a single source for retrieving sensible and total performance information	Proper design of CAC/CHP systems requires analysis of both sensible and total (sensible and latent) cooling capacities. Providing installers with open access to accurate information to both capacity metrics (e.g., AHRI website, equipment catalogs) allows for more accurate and consistent selection of indoor and outdoor components.	Trade Associations	Manufacturers
Supporting #17	Develop and promote better design approaches for zoned systems	Properly designed and installed zoning systems can provide energy and comfort benefits by distributing space conditioning where it is needed throughout the home. Zoned systems use a variety of dampers and controls that may introduce unintended issues during installation or operation. Conducting research to understand the QI practices needed for zoned systems would help identify strategies to reduce improper installation and potential losses in homes with zoned systems.	Research Organizations	Manufacturers, Trade Associations
Supporting #18	Conduct research on the potential benefits of smaller capacity equipment	When following proper QI procedures and incorporating duct sealing, installers can often specify a CAC/CHP system that is lower capacity than the equipment being replaced. The smaller equipment may be less expensive, which may offset any cost increases associated with QI procedures. Nevertheless, installers may hesitate downsizing to reduce homeowner misunderstanding or callbacks if the home's thermal loads increase in the future. Conducting research to document the benefits of using properly sized equipment would help clarify installer rules-of-thumb or apprehension that contributes to equipment over-sizing.	Research Organizations	Manufacturers

Appendix C – ASRAC CAC/CHP Working Group Members

The table below lists the members from the ASRAC CAC/CHP Working Group.[13]

Name	Organization
Antonio Bouza	U.S. Department of Energy
Don Brundage	Southern Company Services
Andrew DeLaski	Appliance Standards Awareness Project
Kristen Driskell	California Energy Commission
John Gibbons	Carrier Corporation
Marshall Hunt	California Investor-Owned Utilities
John Hurst	Lennox International Inc.
Charles McCrudden	Air Conditioning Heating and Refrigeration Institute
Karen Meyers	Rheem Manufacturing Company
Nick Mislak	Air Conditioning Heating and Refrigeration Institute
Steve Porter	Johnstone Supply
Harvey Sachs	American Council for an Energy-Efficient Economy
Rusty Tharp	Goodman Manufacturing
Jim VerShaw	Ingersoll Rand
Meg Waltner	Natural Resources Defense Council

[13] ASRAC, CAC/CHP Working Group, Final Term Sheet, January 19, 2016. Available at: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0076

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