

U.S. DEPARTMENT OF  
**ENERGY**

Office of  
ENERGY EFFICIENCY &  
RENEWABLE ENERGY

# Home Improvement Catalyst: HVAC Installations that Deliver

September 2017



# Optimizing HVAC System Performance



**3 million** HVAC replacements annually



**\$14 billion** HVAC service/repair expenditures annually



**Improper installations can increase energy use for heating and cooling by 30%**



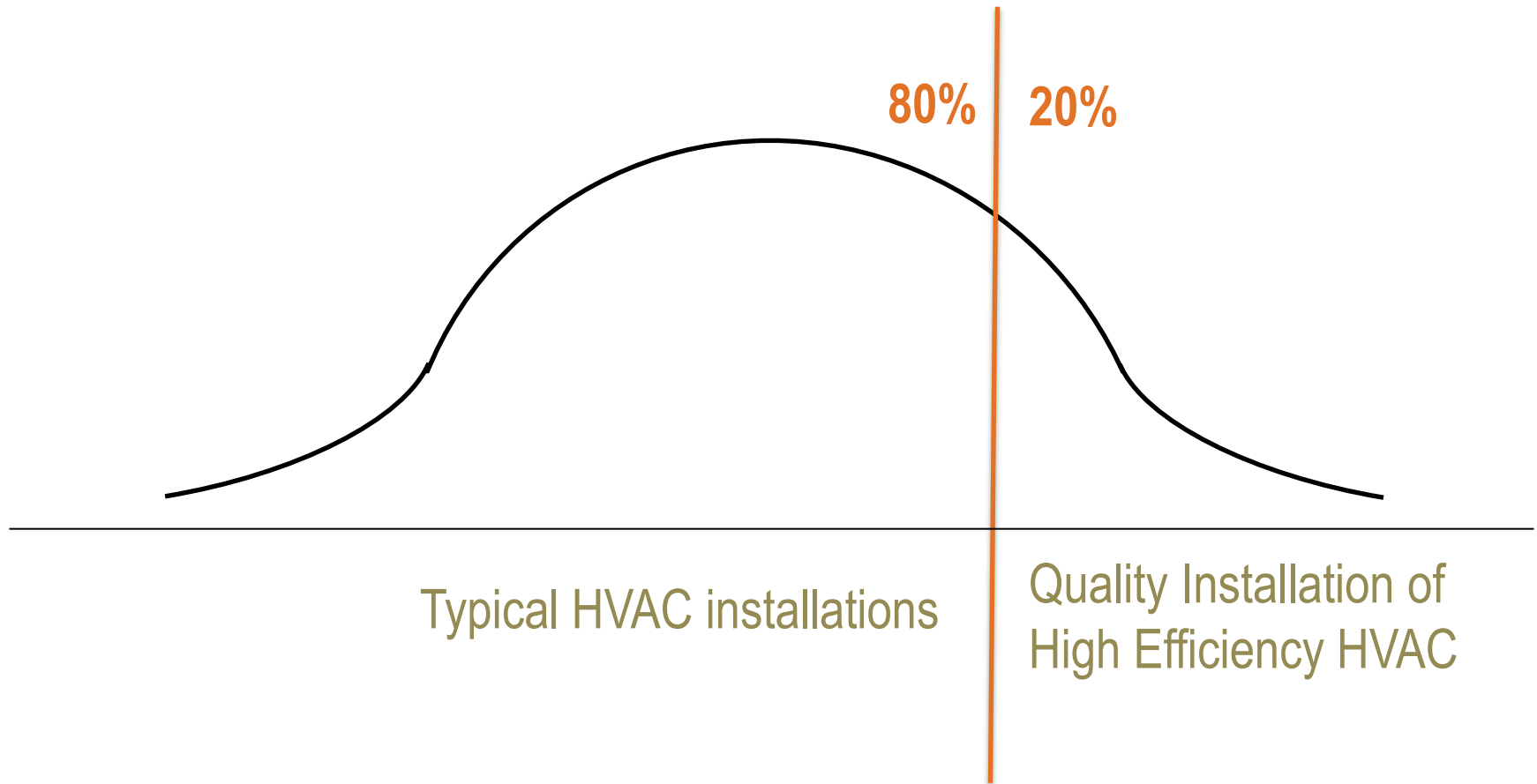
**Proper installations improve comfort, system performance and save energy**

**HI Cat Focus: Improving field performance of HVAC system installation**

- Selection guidance for verification tools
- Field implementation support: application/scenario based approaches; prioritizing installation elements

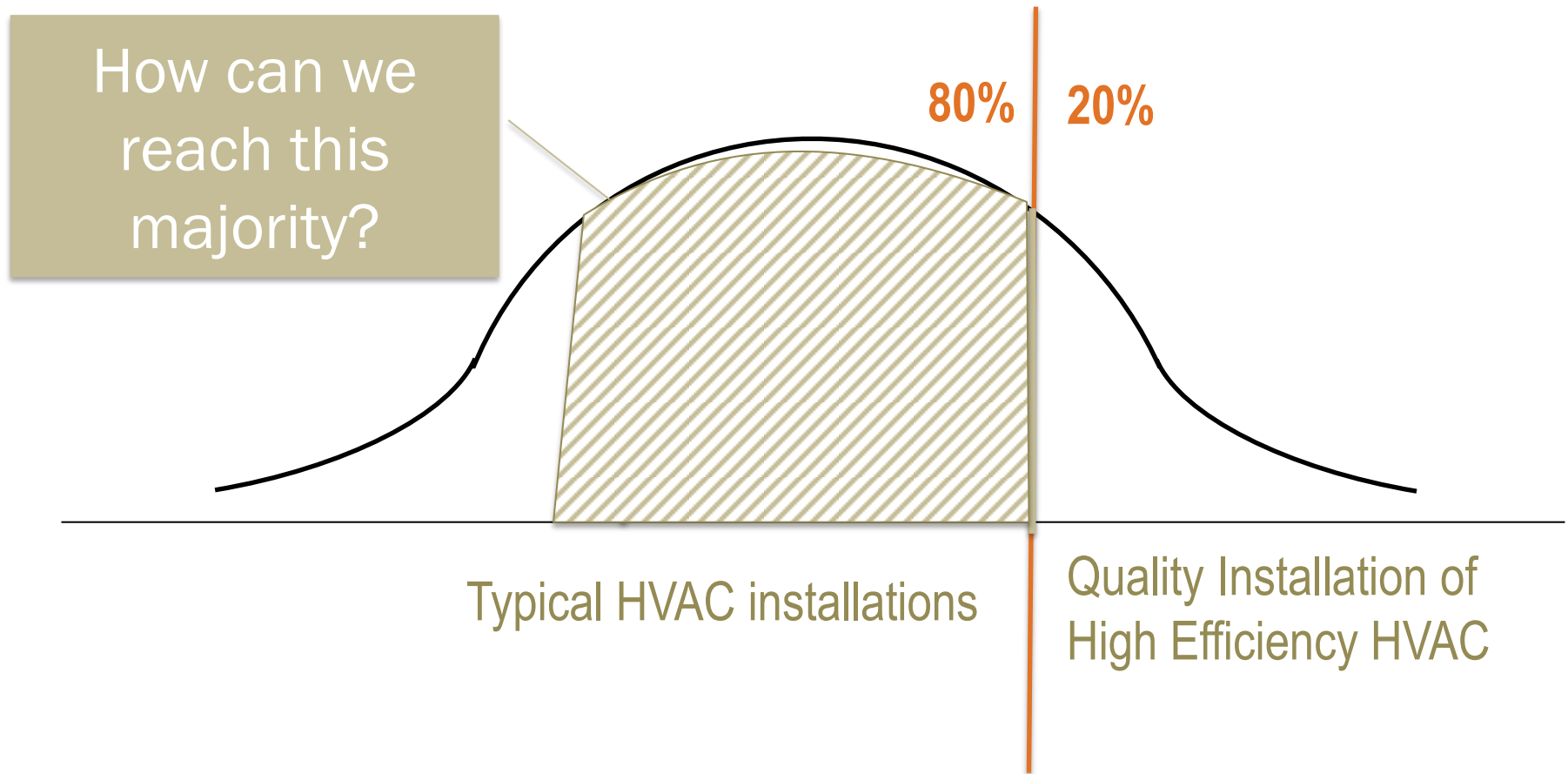
# Focusing on Retrofit (Existing Homes) Market

## HVAC Contractor Landscape/ Market Share for High Efficiency HVAC

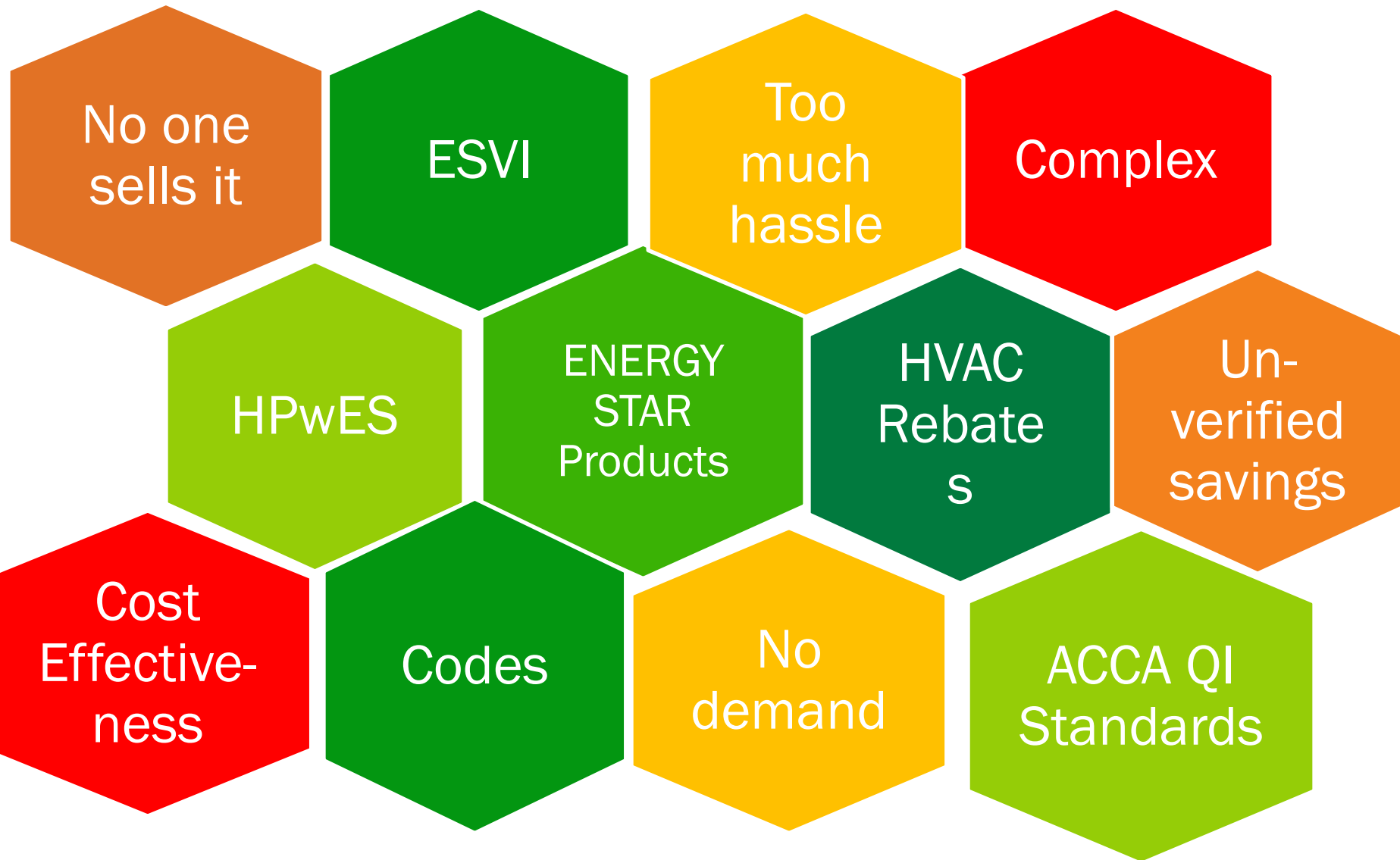


# Focusing on Retrofit (Existing Homes) Market

## HVAC Contractor Landscape/ Market Share for High Efficiency HVAC



# Challenges and Opportunities

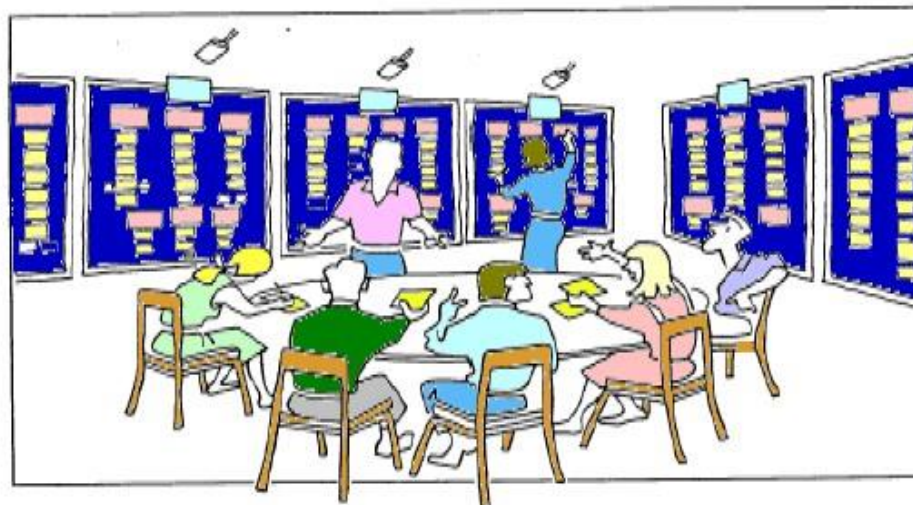


# Gathering Industry Feedback

## DOE Hosted Workshops in May 2016 and March 2017

Key action areas identified:

- ✓ Conduct research on the measured benefits of HVAC QI
- ✓ Develop/promote better tools for field measurement and verification
- ✓ Develop programs/tools to encourage ductless systems and duct sealing/repairs in existing systems



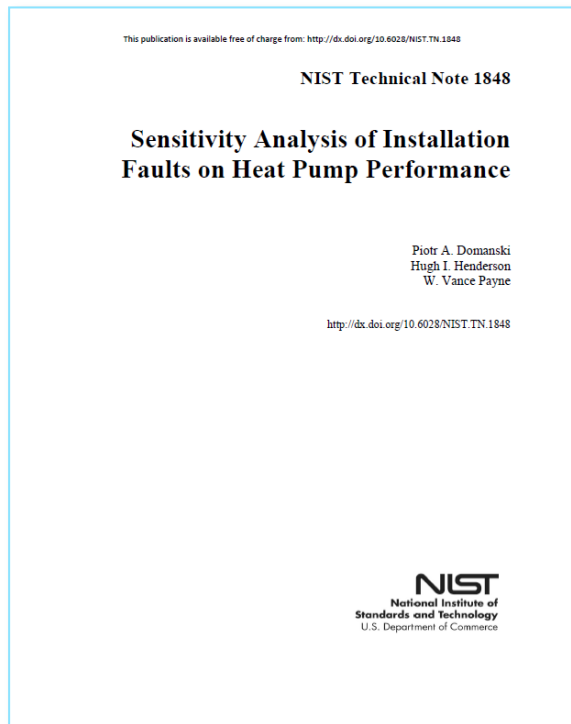
March 2017  
Workshop  
Summary  
- *Forthcoming* -

To review outcomes and stakeholder recommendations from May 2016 HVAC QI Stakeholder Meeting, visit:

<https://energy.gov/eere/buildings/downloads/residential-central-air-conditioning-and-heat-pump-installation-workshop>



# Documenting the Benefits and Energy Savings of QI



## Great Report! But Questions Remain:

- How would field data, with imperfect conditions, change the results?
- Do we understand the prevalence of installation faults?
- What are the impacts of the studied faults on other types of systems and other aspects of HVAC system performance (e.g. occupant comfort, indoor air quality, and equipment durability)?

- Documents potential energy impacts of improper heat pump installations
- Computer simulations and lab tests quantifying the impact of common faults

# Conducting a Systematic Review of Available Literature

## HI Cat Team Question:

What information has been published since September 2014 (or prior to) that would be helpful as it relates to the industry's thinking around QI?

### ➤ **Annotated Bibliography**

- 35+ reports documenting the impacts of improper HVAC installation on energy performance

### ➤ **Actions to Address Key Findings**

- Examining opportunities for “expert” systems and automated verification tools
- Researching the prevalence of faults (and possible regionality issues)
- Coordinating with ENERGY STAR products and ESVI
- Disseminate findings to key industry stakeholders



# Preliminary Findings of Systematic Review

**In addressing HVAC installations for existing homes, performance is most impacted by**

- Proper airflow
- Proper refrigerant charge
- Sealed ducts (and overall duct design)

**The importance of sizing is relative the scenario/application**

- More important for low load homes
- Accurate sizing is difficult in many retrofit applications
- Duct performance is an important limiting factor



# Contact info

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- **Steve Dunn, Project Manager**  
DOE Building Technologies Office  
t: 720.356.1527 e-mail: [steve.dunn@ee.doe.gov](mailto:steve.dunn@ee.doe.gov)
- **Caroline Hazard, CSRA International**  
t:240.514.2656 e-mail: [caroline.hazard@csra.com](mailto:caroline.hazard@csra.com)
- **Courtney Moriarta, CSRA International**  
t:518.577.4860 e-mail: [courtney.moriarta@csra.com](mailto:courtney.moriarta@csra.com)
- **Cory Fox, CSRA International**  
t:571.325.4515 e-mail: [cory.fox@csra.com](mailto:cory.fox@csra.com)

# Appendix

## Summary of Reports Reviewed

### Evolution of Research on HVAC Installations

Publication Date	Report	Topics Addressed (even if only partially)										Testing Method			
		Instrumentation Accuracy	Ducts	Refrigerant Charge	Sizing & Load Calculations	Airflow	Peak Demand	Building Shell (Leakage Rates)	Contractor Concerns	Demand Concerns (Customer)		Modeled	Lab Testing	Field Testing	Survey
1995	Blasnik, M., Proctor, J., Downey, T., Sundal J., & Peterson, G. Assessment of HVAC Installations in New Homes in Southern California Edison’s Service Territory.		x	x	x	x	x	x				x		x	
1995	Blasnik, M., Proctor, J., Downey, T., Sundal, J., & Peterson, G. Assessment of HVAC Installations in New Homes in Nevada Power Company's Service Territory.		x	x	x	x	x	x				x		x	
1996	Blasnik, M., Downey, T., Proctor, J., & Peterson, G. Assessment of HVAC Installations in New Homes in APS Service Territory.		x	x	x	x	x	x				x		x	
1996	Jump, D., Walker, I., & Modera, M. Field Measurements of Efficiency and Duct Retrofit Effectiveness in Residential Forced Air Distribution Systems.		x			x		x						x	

1998	Proctor, J. Monitored In-Situ Performance of Residential Air-Conditioning Systems.		x	x	x	x	x	x			x		x	
1998	Walker, I., Sherman, M., Modera, M., & Siegel, J. Leakage Diagnostics, Sealant Longevity, Sizing and Technology Transfer in Residential Thermal Distribution Systems: Part II.		x			x		x					x	
2000	Siegel, J., Walker, I., & Sherman, M. Delivering Tons to the Register: Energy Efficient Design and Operation of Residential Cooling Systems.		x		x	x	x	x			x			
2001	Xenergy. New Jersey Residential HVAC Baseline Study.		x	x	x	x			x	x			x	x
2002	Foster, R., South, M., Neme, C., Edgar, G., & Murphy, P. Residential HVAC Quality Installation: New Partnership Opportunities and Approaches.				x				x					x
2003	Walker, I. Register Closing Effects on Forced Air Heating System Performance.		x			x		x			x	x		
2004	Wilcox, B. & Larsen, J. Measured Cooling load, Energy, and Peak Demand Savings from High-Performance Glass in a California Production House.						x						x	
2006	Sonne, J., Parker, D., & Shirley, D. Measured Impacts of Proper Air Conditioning Sizing in Four Florida Case Study Homes.		x		x	x	x						x	
2006	Proctor, J., & Cohn, G. Two-Stage High Efficiency Air Conditioners: Laboratory Ratings vs. Residential Installation Performance.		x	x	x	x	x	x					x	
2006	Titus, E. Strategies to Increase Residential HVAC Efficiency in the Northeast.		x	x	x	x	x	x	x	x		x		x
2006	Walker, I. Residential Furnace Blower Performance.		x			x	x	x				x	x	
2007	Henderson, H., & Shirley, D. Closing the Gap: Getting Full Performance from Residential Central Air Conditioners.		x		x	x		x				x		

2007	Wirtschafter, R., Thomas, G., Azulay, G., Blake, W. and Prah, R. Do Quality Installation Verification Programs for Residential Air Conditioners Make Sense in New England?		x	x	x	x	x				x		x	
2008	Pigg, Scott. Central Air Conditioning in Wisconsin: A compilation of recent field research.			x	x	x	x	x		x			x	x
2009	Proctor, J. AC Sizing, Electrical Peak, and Energy Savings.				x		x				x		x	
2009	Talerico, T., & Winch, R. State of Wisconsin Public Service Commission of Wisconsin - Focus on Energy Evaluation: ECM Furnace Impact Assessment Report.									x	x			x
2010	Kim, W. & Braun, J. Impacts of Refrigerant Charge on Air Conditioner and Heat Pump Performance.			x								x		
2010	Hunt, Marshall, PE, Kristin Heinemeier, PhD, Marc Hoeschele, PE, and Elizabeth Weitzel. HVAC Energy Efficiency Maintenance Study.	X	x	x		x	x					x		
2011	Proctor, J., Chitwood, R., & Wilcox, B. Efficiency Characteristics and Opportunities for New California Homes (ECO) PIER Program Final Project Report.		x			x			x				x	
2011	Rhodes, J. D., Stephens, B., & Webber, M. E. Using energy audits to investigate the impacts of common air-conditioning design and installation issues on peak power demand and energy consumption in Austin, Texas.						x						x	
2012	Brand, L., & Rose, W. Measure Guideline: High Efficiency Natural Gas Furnaces.				x				x				x	
2012	Heinemeier, K., Hunt, M., Hoeschele, M., Weitzel, E., & Close, B. Uncertainties in Achieving Energy Savings from HVAC Maintenance Measures in the Field.	X		x									x	x
2012	Walker, I., Dickerhoff, D., Faulkner, D., & Turner, W. Energy Implications of In-Line Filtration in California.		x			x	x	x					x	

2012	Yuill, David P., and James E. Braun. Evaluating Fault Detection and Diagnostics Protocols Applied to Air-Cooled Vapor Compression Air-Conditioners.	X											X		
2013	Kim, W. Fault Detection and Diagnosis for Air Conditioners and Heat Pumps Based on Virtual Sensors.	X		x		x							x	x	x
2013	Yee, S., Baker, J., Brand, L., & Wells, J. Energy Savings from System Efficiency Improvements in Iowa's HVAC Save Program.		x			x								x	
2014	Booten, C., Christensen, C., & Winkler, J. Energy Impacts of Oversized Residential Air Conditioners--Simulation Study of Retrofit Sequence Impacts.		x		x								x		
2014	Rhodes, J. D. Optimal Residential Energy Consumption, Prediction, and Analysis.		x		x		x						x		x
2014	Stephens, B. The impacts of duct design on life cycle costs of central residential heating and air-conditioning systems.		x		x	x		x					x		
2014	Braun, James E., and David Yuill. Evaluation of the Effectiveness of Currently Utilized Diagnostic Protocols.	X											x	x	
2014	Domanski, P.A., Henderson, H.I., & W.V. Payne. Sensitivity Analysis of Installation Faults on Heat Pump Performance.	X	x	x	x	x							x	x	
2015	Brand, L., Yee, S., & Baker, J. Improving Gas Furnace Performance: A Field and Laboratory Study at End of Life.					x							x	x	
2015	Cummings, J., Withers, C., & Kono, J. Cooling and Heating Season Impacts of Right-Sizing of Fixed and Variable-Capacity Heat Pumps with Attic and Indoor Ductwork.		x		x	x	x	x					x	x	
2015	NMR Group, Inc. Baseline Characterization Market Effects Study of Investor-Owned Utility Residential and Small Commercial HVAC Quality Installation and Quality Improvement Programs in California.		x	x		x		x	x	x				x	x



2015	Parmenter, K., Priyjanonda, J., & Dorton, D. The Coil & Blade Project: Combining Field Work and Interval Data to Measure Impacts.		x	x							x		x	
2015	Steiner, E., & Malinick, T. California HVAC Quality Installation/Quality Maintenance Customer Decision-Making Study.									x	x			x
2015	Sullivan, M., Smith, J., Afrat, K., & Bosco, P. Impacts of the OPA HVAC Installation Optimization Training Program on Realized Energy Efficiency in Retrofit AC Systems.					x					x		x	
2015	Vaidya, R., Fogel, C., Tolkin, B., & Poulin, B. Swimming Against the Tide--Gauging HVAC Quality Installation and Quality Maintenance Program Efforts to Establish a Foothold in the Market.		x	x		x				x	x		x	x
2016	House, D. M. Compact Buried Ducts in a Hot-Humid Climate House.		x			x	x					x		
2016	Pigg, S., Cautley, D., & Koski, K. Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners and Heat Pumps: Conservation Applied Research & Development (CARD) FINAL REPORT.		x	x		x	x			x	x		x	x