Consortium for Energy Efficiency

Residential Heating and Cooling Systems

Initiative Description

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Contents

1 Background

Significant energy goes into the heating and cooling of residential spaces in the United States and Canada. Space heating accounts for 42 percent of energy consumption in US households,[1] and 63 percent of residential energy use in Canada.[2] Fully half of all homes in both countries are heated with natural gas furnaces or boilers.[3] Residential central air conditioners and air source heat pumps represent between 14 and 25 percent of household electricity consumption in the United States.[4] Additionally, the percentage of US households with central air conditioner and air source heat pump systems has increased from less than 40 percent in 1991 to over 70 percent in 2011.[5] In order to identify energy saving opportunities and address the market barriers to advancing efficiency, this *CEE℠ Residential Heating and Cooling System Initiative* was updated in 2014, and integrates the former *CEE℠ Residential Central Air conditioner and Air Source Heat Pump Initiative,* launched in 1995, with the *CEE℠ Residential Gas Heating Initiative*, launched in 1998. This Initiative Description provides the foundation for coordinated binational program approaches based on the following three core elements: 1) promotion of high efficiency space heating and cooling equipment, 2) quality installation, and 3) quality maintenance.

2 Initiative Scope

The *CEE℠ Residential Heating and Cooling System Initiative* covers residential central air conditioners, air source heat pumps, gas furnaces, furnace fans, and gas-fired boilers. Single-phase central air-conditioner and air source heat pump equipment, both ducted and ductless, up to 65,000 Btu/hour cooling capacity are within the scope of this Initiative, including both single-package and split systems. The Initiative scope also includes residential natural gas furnaces with input rates of less than 225,000 Btu/hour and residential natural gas boilers with input rates of less than 300,000 Btu/hour.

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[1] U.S. Department of Energy—Energy Information Agency, "Residential Energy Consumption Survey (RECS), 2009 RECS Survey Data," accessed November 14, 2013, http://www.eia.gov/consumption/residential/data/2009/.

[2] Natural Resources Canada, "Energy Efficiency Trends in Canada, 1990 to 2009," accessed November 13, 2013, http://oee.rncan.gc.ca/publications/statistics/trends11/chapter3.cfm.

[3] Statistics Canada, "Type of main heating fuel used, by province, 2011," accessed November 14, 2013, http://www.statcan.gc.ca/pub/11-526-s/2013002/t002-eng.htm.

[4] "End Use Consumption of Electricity," *Energy Information Administration*, 2001.

[5] "American Housing Survey," *U.S. Census Bureau, Housing and Household Economic Statistics Division*, http://www.census.gov/hhes/www/housing/ahs/ahs.html, accessed March 19, 2014.

In recognition of common market characteristics that apply to the products covered by this Initiative, and programs' desire to promote HVAC **system** efficiency in addition to **equipment** efficiency, the Initiative merges two previous CEE Board-sanctioned initiatives, the *Residential Central Air conditioner and Air source Heat Pump Initiative*, launched in 1995, and the *Residential Gas Heating Initiative*, launched in 1998. The combined Initiative provides a strategic framework for efficiency program administrators to leverage the best opportunities for energy savings in today's HVAC market, taking into consideration systemic efficiency opportunities that involve and draw upon both electric and gas technologies.

Evaporative cooling equipment and geothermal or ground source heat pumps are outside the scope of this Initiative. Due to differences in equipment and market characteristics, commercial air conditioners, including 3-phase equipment and equipment with greater than 65,000 Btu/hour cooling capacity, are covered under a separate *CEE High Efficiency Commercial Air Conditioning and Heat Pump Initiative*.[6] Natural gas boilers with input rates of 300,000 Btu/hour and above are classified as commercial units by American and Canadian standards, and are therefore covered under the *CEE Commercial Boiler System Initiative*.

3 Initiative Goals and Objectives

The primary objective of the *CEE^{SM} Residential Heating and Cooling System Initiative* is to drive efficient in-field performance by increasing the market penetration and quality installation of high efficiency equipment and HVAC systems.

The goals of the Initiative are to:

- Increase the percentage of sales of high efficiency equipment
- Reduce the cost of high efficiency equipment to consumers
- Increase the number of contractors who promote high efficiency equipment, quality installations as defined in the CEE HVAC Quality Installation Specification, and proper system maintenance
- Increase consumer awareness of the benefits and components of a quality installation
- Increase the number of quality installations and system improvements
- Highlight new areas for energy savings and peak demand reduction, where appropriate

4 Products and Services Overview

The following subsections detail the technology behind high efficiency central air conditioners, air source heat pumps, furnaces, furnace fans, and boilers.

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[6] "CEE High Efficiency Commercial Air Conditioning and Heat Pump Initiative," *Consortium for Energy Efficiency*, library.cee1.org/content/consortium-energy-efficiency-cee-high efficiency-commercial-air-conditioning-hecac-initiativ/

4.1 Central Air Conditioners

Central air conditioning, which can be ducted or ductless, is increasingly common in the United States and accounts for almost 15 percent of total US residential electricity consumption.[7] Close to 65 percent of US households have central air-conditioning equipment, the majority of which is ducted.[8] Moreover, nearly 90 percent of new homes are built with central air-conditioning.[9] Shipments of residential central air conditioners are expected to increase in the US by more than 15 percent between 2012 and 2017, with the market for this equipment exhibiting a compound annual growth rate of three percent.[10] The estimated market penetration of ENERGY STAR certified central air conditioners reached 20 percent in 2012.[11] Estimates of average expected useful life for unitary air conditioners range from eight to 14 years in one study[12] to just over 19 years in a second analysis.[13]

Central air conditioners can be configured as either split systems or packaged systems. As described in the 2011 DOE Technical Support Document, "the air conditioner uses a blower, which for split systems may be contained in the furnace, to propel circulation air over the outside of a heat exchanger (i.e. evaporator coil), transferring heat from warm circulation air to the cool refrigerant. The cooled air is then distributed via ductwork to the conditioned space, while a compressor is used to further raise the refrigerant temperature before the refrigerant transfers heat to the atmosphere through another heat exchanger (i.e. condenser coil). Split system air conditioners are comprised of an indoor unit, which contains the evaporator coil and indoor blower, and an outdoor unit, often referred to as the condenser, which contains the compressor, condenser coil, and a condenser fan to blow ambient air over the coil. Packaged systems contain all of these components in a single unit."[14]

Ductless mini-split air conditioners, which consist of an outdoor compressor/condenser and indoor air-handling unit, are considered split system air conditioners, but deliver space cooling without ductwork. The US Department of Energy notes that "since mini splits have no ducts, they avoid the energy losses associated with ductwork of central forced air

[7] "Residential Energy Consumption Survey," *Energy Information Administration*, http://www.eia.gov/consumption/residential/, 2009.
[8] "Residential Energy Consumption Survey," *Energy Information Administration*, http://www.eia.gov/consumption/residential/, 2009.
[9] "Air Conditioning in Nearly 100 Million Homes," *Energy Information Administration*, http://www.eia.gov/consumption/residential/reports/2009/air-conditioning.cfm, August 19, 2011.
[10] "62nd Annual U.S. Appliance Industry Forecast," *Appliance Magazine*, January 2014.
[11] "ENERGY STAR Unit Shipment and Market Penetration Reports, calendar year 2012," *U.S. Environmental Protection Agency*, http://www.energystar.gov/index.cfm?c=partners.unit_shipment_data
[12] "The U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture 2013," *Appliance Magazine*, December 2013.
[13] "Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners, Heat Pumps, and Furnaces: Chapter 8 Lifecycle Cost and Payback Period Analysis," *U.S. Department of Energy*, http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012, 2011.
[14] "Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners, Heat Pumps, and Furnaces: Chapter 3 Market and Technology Assessment," *U.S. Department of Energy*, http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012, 2011.

systems. Duct losses can account for more than 30 percent of energy consumption for space conditioning, especially if the ducts are located within an unconditioned interior space such as an attic."[15] Ductless systems are often two-speed or variable capacity and can allow for zoning configurations. CEE is assessing savings opportunities from these products to determine whether their performance warrants separate treatment in future CEE specifications.

4.2 Air Source Heat Pumps

A residential air source heat pump consists of the same components as a central air conditioner, but is capable of both space heating and space cooling owing to a reversing valve that can change the direction of the system refrigerant flow.[16] Air source heat pumps, like central air conditioners, can be either split or single package systems. From 2012 to 2017, shipments of heat pumps are forecast to increase in the US by more than 30 percent, with a compound annual growth rate of six percent.[17] The expected useful life for heat pumps ranges from nine to 15 years.[18] Another estimate places the mean lifetime for heat pumps at over 16 years.[19] Of these systems, the estimated market penetration of ENERGY STAR certified air source heat pumps was 32 percent in 2012.[20]

In addition to the general background on ductless products outlined under the central air-conditioner section, ductless heat pumps may find applications in specific climates or with certain housing stock where there may be an opportunity to offset heating from electric resistance or other fuels. CEE continues to monitor this potential opportunity to determine if the performance of ductless equipment will warrant separate treatment in future CEE specifications.

The federal minimum efficiency standard for air source heat pumps increased January 1, 2015. There is no regional distinction in the standard for air source heat pumps, but the changes to the SEER and HSPF requirements for both split and packaged air source heat pumps resulted in increased baselines for efficiency programs across the United States.

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[15] "Ductless Mini-Split Air Conditioners," *U.S. Department of Energy*, http://energy.gov/energysaver/articles/ductless-mini-split-air-conditioners, accessed March 19, 2014.

[16] "Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners, Heat Pumps, and Furnaces: Chapter 3 Market and Technology Assessment," *U.S. Department of Energy*, http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012, 2011.

[17] "62nd Annual U.S. Appliance Industry Forecast," *Appliance Magazine*, January 2014.

[18] "The U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture 2013," *Appliance Magazine*, December 2013.

[19] "Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners, Heat Pumps, and Furnaces: Chapter 8 Lifecycle Cost and Payback Period Analysis," *U.S. Department of Energy*, http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012, 2011.

[20] "ENERGY STAR Unit Shipment and Market Penetration Reports, calendar year 2012," *U.S. Environmental Protection Agency*, http://www.energystar.gov/index.cfm?c=partners.unit_shipment_data

4.3 Gas Furnaces

Gas furnaces are the most commonly used residential heating system in the US, with 50 percent of households relying on natural gas furnaces for primary space heating.[21] Additionally, furnaces account for 52 percent of total annual residential gas consumption and 78 percent of annual residential gas heating consumption.[22] The average equipment life is 15 years, meaning that savings from high efficiency equipment persist for many years after installation.[23]

Standard efficiency furnace technology uses natural draft venting to move combustion byproducts outside through a vertical vent such as a chimney. This open vent allows useable heat to be lost through the chimney thereby lowering system efficiency. High efficiency gas furnaces use condensing equipment to remove extra heat from the flue gases, thereby recovering heat energy from the byproducts of combustion. As heat is removed, water vapor in the flue gases condenses, producing a corrosive condensate that must be handled in a corrosion resistant drainage system. In addition to the drain, condensing equipment typically incorporates a fan to help vent exhaust gases. The drainage and venting requirements are the primary sources of higher equipment and installation costs with these units. Condensing furnaces and boilers typically have an Annual Fuel Utilization Efficiency (AFUE) rating of 90 percent or higher.

4.3.1 Furnace Fans

All furnaces use electric fans to circulate heated air. Estimates of electric savings for a furnace meeting the CEE specification for electrical efficiency indicate that, on average, these units save 500 kWh during the heating season and 200 kWh during the cooling season, provided the central air-conditioning system uses the same air handler.[24] These estimates are for the average US household; actual savings depend on many factors, including climate, equipment sizing, and duct pressure. A US national standard will be introduced on July 3, 2019, using the fan energy rating (FER) metric as a measurement of fan energy use.

4.4 Gas Boilers

Gas boilers heat water and use a pump to circulate hot water around a home to deliver heat from baseboard radiators, under-floor radiators, or other means. They represent a smaller percentage of national heating equipment than furnaces. Approximately six percent of US households and 11 percent of Canadian households rely on natural gas boilers for primary space heating. In the Northeast US census region, approximately 21 percent of households have gas boilers. The estimated lifetime of a boiler is 25 years.[25]

Effective September 1, 2012, the US minimum standard for gas boiler efficiency is 82 percent AFUE for gas-fired water boilers and 80 percent AFUE for gas-fired steam boilers. This

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[21] U.S. Department of Energy—Energy Information Agency, "Residential Energy Consumption Survey, 2009 Data," accessed November 14, 2013, http://www.eia.gov/consumption/residential/data/2009/.

[22] Ibid.

[23] *Appliance Magazine*, "The Life Expectancy/Replacement Picture," September 2009.

[24] Sachs, H.M. and Smith, S., "Saving Energy with Efficient Residential Furnace Air Handlers: A Status Report and Program Recommendations," April 2003.

[25] U.S. Department of Energy, "Chapter 8 Life Cycle Cost and Payback Period Analysis," Residential Furnaces and Boilers Technical Support Document, 2007.

standard also requires that the design for hot water systems incorporate an automatic means for adjusting water temperature and a nonconstant burning pilot.[26] Half of all available boiler models are made with cast iron heat exchangers and have efficiencies between 82 percent and 84 percent AFUE. The most efficient boilers, like furnaces, use condensing technology that removes additional heat from the flue gases by condensing hot water vapor from those gases. These units typically have higher installation costs. Condensing boiler efficiency begins at 90 percent AFUE, with efficiencies up to 96 percent AFUE available among current products.[27]

4.5 Equipment Installation

In recent years, evidence has been mounting that efficient laboratory ratings for equipment alone are not sufficient for assessing in-field performance and predicting energy savings.[28] A number of studies have shown that the performance of high efficiency equipment is only as strong as the quality of its installation, and building scientists have concluded that equipment installation significantly influences the performance of the HVAC system.[29] For example, a high efficiency central air-conditioning system exhibiting duct leakage may waste significantly more energy than a properly installed, but lower efficiency unit. The US Environmental Protection Agency estimates that if a central air conditioner or heat pump is improperly installed, only 73 percent of the cooling or heating is actually delivered, with the remainder attributable to energy losses from improper installation, including an estimated four percent lost from improper refrigerant charge, three percent from improper air flow, five percent from improper equipment sizing, and up to 15 percent from duct leakage.[30] Similarly, a typical furnace installation results in 15 percent of useable heat lost to duct leakage,[31] with up to 35 percent heat loss occurring when ducts are located in unconditioned space such as attics and garages.[32]

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[26] US Department of Energy, "Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers, Final rule and technical amendment" *Federal Register*, Volume 73, Number 145 (July 28, 2008), pages 43611-43613.

[27] Air-conditioning, Heating, and Refrigeration Institute, "Directory of Certified Product Performance," 2014 accessed August 28, 2014, http://www.ahridirectory.org.

[28] Neme, C., Proctor, J., and Nadel, S., "Energy Saving Potential from Addressing Residential Air-conditioner and Heat Pump Installation Problems," February 1999; and Leopkey, T. "ENERGY STAR HVAC Quality Installation—An Opportunity for Program Savings." Governor's Energy Advisory Committee. June 25, 2008.

[29] Installation decisions that affect system performance are commonly broken into four categories: equipment sizing and selection, duct system design and installation, air flow over the indoor coil, and refrigerant system and charge. For more information on these aspects of a quality installation, visit http://www.acca.org and http://library.cee1.org/content/hvac-quality-installation-specification-standard-number-ansiacca-5-qi-2010/. For details on the prevalence and energy savings potential of addressing each component see Neme, Chris, John Proctor, and Steve Nadel, "National Energy Savings Potential from Addressing Residential HVAC Installation Problems," 1999.

[30] "ENERGY STAR Verified HVAC Installation Program," U.S. Environmental Protection Agency, http://www.energystar.gov/index.cfm?c=hvac_install.hvac_install_program_development.

[31] "ENERGY STAR Quality Installation," U.S. Environmental Protection Agency. http://www.energystar.gov/index.cfm?c=hvac_install.hvac_install_index.

[32] "Energy Saver" Furnaces and Boilers," U.S. Department of Energy, http://energy.gov/energysaver/articles/furnaces-and-boilers.

The relative value of quality installation has risen over time with increases to the federal equipment efficiency standards. For example, as the baseline for central air conditioners and air source heat pumps increases, there is diminishing energy savings potential from promoting high SEER equipment alone. In this environment, many programs will be compelled to demonstrate savings through other strategies, such as promotion of quality installation or ongoing system maintenance.

5 Market Overview

5.1 Market Structure

Residential HVAC equipment, both electric and gas, typically reaches the end consumer through a distribution chain consisting of manufacturers, wholesale distributors, and HVAC contractors. The pathways for both electric central air conditioners and heat pumps and for natural gas furnaces and boilers are generally similar in the United States and Canada. Alternative channels may include a retailer or builder, or may otherwise bypass the primary market actors; for example, manufacturers may employ a direct-to-dealer approach. The approach may also vary based on whether equipment is being replaced or deployed as part of a new construction project. The various market players are described below.

- **Manufacturers** Of the 45 manufacturers of central air conditioners and air source heat pumps, seven manufacturers control over 95 percent of the US central air-conditioner and air source heat pump market.[33] In the US, Carrier, Goodman, and Trane are the top three manufacturers of central air-conditioner and air source heat pump equipment by sales.[34] While there are more than 40 gas furnace manufacturers selling equipment in the US under more than a hundred brand names, six manufacturers make up more than 90 percent of market share.[35] The top three manufacturers, by sales, of gas furnace equipment are Carrier, Goodman, and Lennox.[36] There are approximately 40 manufacturers and more than 70 brands of residential gas boilers, with more than a quarter of the available models being made by Slant/Fin Corporation and ECR International, under the Argo, Dunkirk, Pennco Boilers, and Utica Boilers lines.[37]

- **Wholesale Distributors** There are both independent and manufacturer-owned distributors of gas and electric residential HVAC equipment. Some manufacturers use independent wholesalers exclusively, some own all of their wholesale operations, and others use a combination of both. Buying groups, also known as purchasing alliances or

[33] "Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners, Heat Pumps, and Furnaces: Chapter 3 Market and Technology Assessment," *U.S. Department of Energy*, http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012, 2011.

[34] "Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners, Heat Pumps, and Furnaces: Chapter 3 Market and Technology Assessment," *U.S. Department of Energy*, http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012, 2011.

[35] U.S. Department of Energy, "Chapter 3 Market and Technology Assessment," *Residential Furnaces, Central Air-conditioners and Heat Pumps Technical Support Document*, 2011.

[36] Ibid.

[37] Air-Conditioning, Heating, and Refrigeration Institute, "Directory of Certified Product Performance," 2013, accessed November 14, 2013, http://www.ahridirectory.org.

marketing cooperatives, offer greater purchasing power and lower product costs to independent distributors. The distributor trade association, HARDI, represents more than 475 distributor members representing nearly 4,100 branch locations, and close to 500 suppliers, manufacturer representatives and service vendors.[38]

- **HVAC Contractors** Contractors and installing technicians, who may also be general contractors, have direct contact with residential customers and play a key role in influencing purchasing decisions for gas and electric residential HVAC equipment. More than 60,000 contractors and 4,000 businesses in the indoor environment and energy services community are represented by ACCA, a contractor trade association. The Plumbing-Heating-Cooling Contractors (PHCC) National Association includes more than 4,000 members and benefits from regional chapters across the US and Canada.

- **Retailers** Retailers include national mass merchandisers, national retailers, and retail dealers. National mass merchandisers and retailers typically purchase equipment directly from manufacturers and sell directly to customers, using their own affiliated contractors for installation.

- **Builders and Developers** Home builders and developers are also important players in the sale of residential heating and cooling equipment since they sell equipment to customers as part of home purchases. Builders and developers may make decisions about equipment selection with or without engaging the eventual homebuyer on the subject of high efficiency options.

5.2 Market Trends

5.2.1 Central Air Conditioners and Air Source Heat Pumps

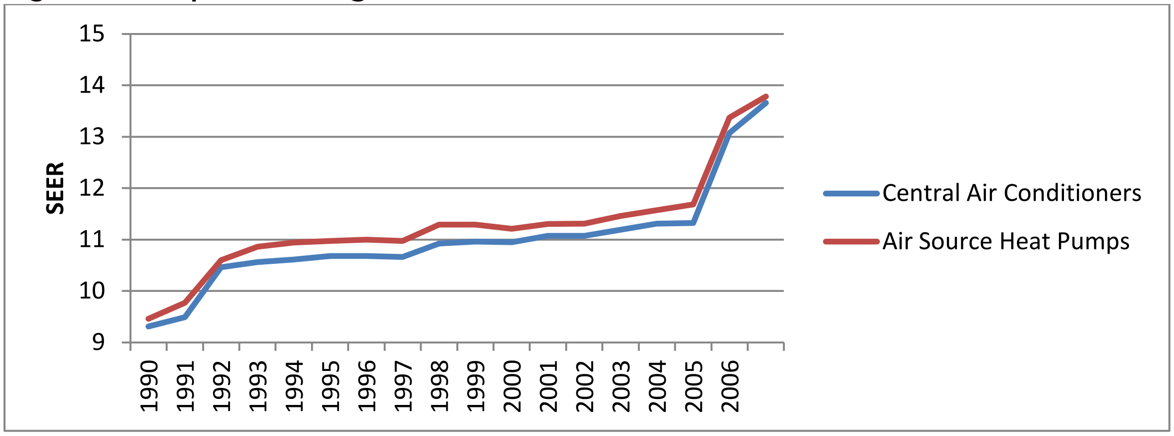
When the *CEE[SM] Residential Central Air Conditioner and Air Source Heat Pump Initiative* was first introduced in 1995, only 10 percent of the market attained a rating of 12 SEER. Since then, the average, maximum, and shipment-weighted efficiencies have increased steadily, as demonstrated in Table 1 and Figure 1 below.

Table 1. **Changes in Average Efficiency Ratings Over Time[39]**

	Average SEER		Max SEER		Average EER		Max EER		Average HSPF		Max HSPF	
	2007	2014	2007	2014	2007	2014	2007	2014	2007	2014	2007	2014
Split AC	14	15.55	23	26	11.8	12.59	15.5	16	-	-	-	-
Pkg AC	13.34	15	16.4	20	11.1	12.18	13.35	14.75	-	-	-	-
Split HP	14.1	15.67	19.5	24	11.75	12.46	14.1	16	8.38	8.85	10.2	13
Pkg HP	13.44	14.56	16	16.4	11.1	11.92	12.75	13	7.82	8.03	8.2	8.5

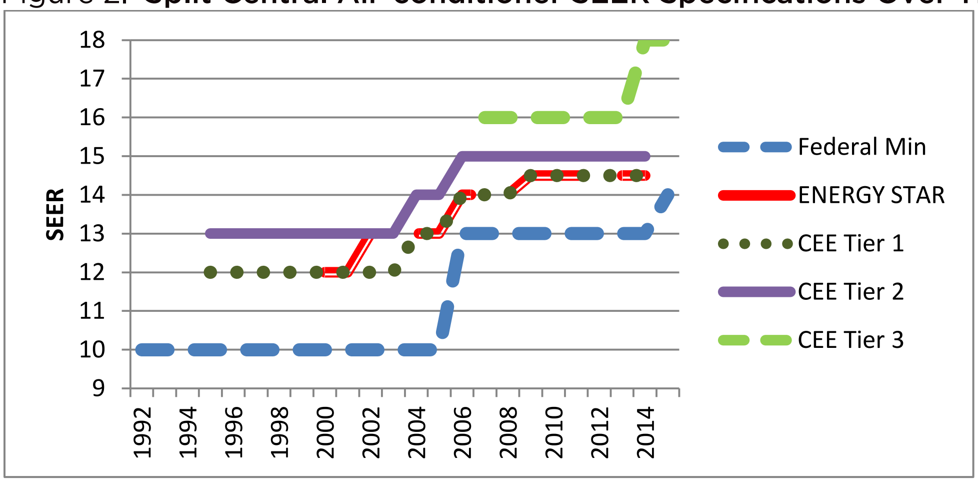
[38] "About HARDI," *HARDI*, http://www.hardinet.org/about-hardi-0, accessed March 19, 2014.
[39] CEE Directory of AHRI Verified HVAC Equipment, http://www.ceedirectory.org/

Figure 1. **Shipment-weighted SEER Over Time**[40]



Historic increases in the SEER requirements for CEE tiers, ENERGY STAR requirements, and federal minimums for split central air conditioners are shown in Figure 2. While the increase in efficiency can be attributed in part to changes in the federal minimum standard, periodic enhancements the CEE tiers and ENERGY STAR performance requirements continue to raise the bar for efficient equipment.

Figure 2. **Split Central Air-conditioner SEER Specifications Over Time**[41]



The availability of efficient equipment has also increased significantly since 1995, when 1,693 central air conditioners and heat pumps were listed on the California Energy Commission's electronic database. In March 2014, the CEE Directory of Efficient Equipment listed more than 515,000 active central air conditioner and 86,000 heat pump combinations that would qualify for a CEE tier or the ENERGY STAR performance requirements.[42] Efficiency requirements were relatively consistent between 2007 and March 2014, yet model availability at the CEE tiers increased significantly during that time (Table 2).

[40] Adapted from ARI as reported by Air Conditioning, Heating & Refrigeration News, 10 September 2007. Includes single package type, year round (except heat pumps), and split systems under 65,000Btu/h

[41] Alignment was achieved between the CEE tier 1 and ENERGY STAR SEER metric for split system central air-conditioners and air source heat pumps, with the exception of 2002-2003, as indicated in the red line in the chart below.

[42] Due to brand proliferation, the unit data may not be representative of unique models.

Table 2. **Total Split and Packaged Equipment Availability Over Time**

	CAC 2007	CAC 2014	ASHP 2007	ASHP 2014
CEE Tier 1	108,613	512,210	17,876	81,877
CEE Tier 2	35,485	330,913	5,406	47,059
CEE Tier 3[43]	5,240	15,385	n/a	1,624

5.2.2 Gas Furnaces

The market penetration of high efficiency furnaces has increased significantly since the Initiative began, rising from 23 percent of all US shipments in 1998, to 61 percent in 2010 and to 55 percent of shipments in 2011.[44, 45] Table 3 illustrates the recent changes in the estimated market penetration of condensing furnaces in the US market.

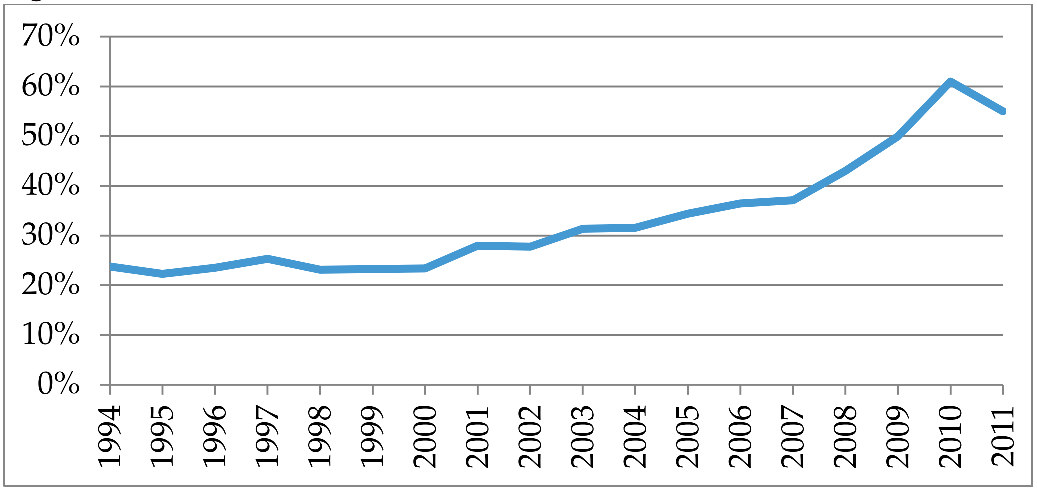
Table 3. **Model Availability of Residential Furnaces**

Level	2009 # of Available Models	% of Available Models	2014 # of Available Models	% of Available Models
All Models[46]	9722	100%	7282	100%
90% AFUE and higher	2905	30%	2162	30%
95% AFUE and higher	851	9%	1522	21%
97% AFUE and higher	125	1%	185	3%

As of August 2014, 47 percent of all available non-weatherized gas furnace models qualified for the CEE tier 1 fuel efficiency specification, up from just 12 percent of models in 1998 and 29 percent in 2009. In addition, 33 percent of models meet or exceed the CEE tier 2 specification of 95 percent AFUE, and five percent meet or exceed the CEE tier 3 specification of 97 percent.[47] Increased availability of efficient equipment improves awareness and increases the likelihood that contractors will market these products. Despite greater availability, high efficiency models continue to be more expensive. This may be due to the fact that high efficiency is commonly marketed as a premium feature.

[43] Tier 3 requirements for split central air-conditioners increased in March 2014 to 18 SEER, 13 EER. Split central air-conditioning systems with 16 SEER, 13 EER (the tier 3 level effective 2007-2013 for more direct comparison to the 2007 table) totaled 168,241 in March 2014. A tier 3 for air source heat pumps was added in 2014.
[44] This decrease from 2010–2011 may be explained by the expiration of a $1,500 federal tax credit.
[45] US Environmental Protection Agency, "ENERGY STAR® Unit Shipment and Market Penetration Report," Calendar Year 2011 Summary.
[46] This represents the total number of approved models of gas-fired hot water boilers available based on October 2009 and August 2014 searches of the AHRI Directory of Certified Product Performance.
[47] Ibid.

Figure 3. **Estimated US Market Penetration of Furnaces at or above 90% AFUE**[48]



These national averages, however, mask the true impact that efficiency programs can have. For example, in regions of North America where the heating season is long and where condensing furnaces have been widely promoted by efficiency programs, penetration rates are significantly higher. This includes the state of Wisconsin, where 90 percent of sales are high efficiency condensing units.[49] The national average in the US is affected by states with little heating demand—where condensing furnaces may not yet be cost-effective—and by states where there is little promotion or understanding of the benefits of high efficiency equipment. By leveraging the efforts of active programs employing a consistent specification, the initiative aims to increase the penetration rate further in all markets.

5.2.3 Gas Boilers

The availability and market penetration of high efficiency boilers has also risen. In 1998, four boiler manufacturers produced a total of only 15 models of condensing boilers (90 percent AFUE or higher).[50] As of August 2014, 36 manufacturers produce 415 condensing boiler models.[51]

[48] Data from 1994 to 2007 are extracted from shipment data provided by the Gas Appliance Manufacturers Association. Data from 2008 to 2011 are extracted from ENERGY STAR® Unit Shipment and Market Penetration Reports.
[49] Energy Center of Wisconsin, *Wisconsin Residential HVAC Equipment Market, Q4 2011*, 2012, accessed November 14, 2013, http://www.ecw.org/ecwresults/FACTS2011Q4.pdf.
[50] Stanonik, Frank, "Condensing Boilers: A Key to Success," *AHRI Trends*, Fall/Winter 2008.
[51] Air-Conditioning, Heating, and Refrigeration Institute, "Directory of Certified Product Performance," 2013, accessed November 14, 2013, http://www.ahridirectory.org.

Table 4. **Model Availability of Residential Boilers**

Level	2009 # of Available Models	2009 % of Available Models	2014 # of Available Models	2014 % of Available Models
All Models[52]	1,095	100%	1,115	100%
85% AFUE and higher	262	24%	485	43%
90% AFUE and higher	153	14%	365	33%

The boiler market is smaller than the furnace market and is concentrated in the Northeast United States. Table 5 provides regional insight on the overall market for boilers, including both hot water and steam systems.

Table 5. **US Households with Boilers for Space Heating (in millions)**

Year	Entire US[53]		Northeast		Midwest		South		West	
	House-holds	%	House-holds	%	House-holds	%	House-holds	%	House -holds	%
1993	8.7	9%	4.3	22%	2.9	12%	0.7	2%	0.8	4%
1997	7.3	7%	3.6	18%	2.5	10%	0.5	1%	0.7	3%
2001	7.9	7%	4.3	21%	2.3	9%	0.6	2%	0.7	3%
2005	8.2	7%	4.9	24%	1.6	6%	1.0	2%	0.6	3%
2009	6.9	6%	4.3	21%	1.7	7%	0.4	1%	0.4	2%

Similarly, in Canada the boiler market represents only a small percentage of heating systems. Table 6 provides insight on the overall market for boilers as a percentage of households across Canada.

Table 6. **Canadian Households with Boilers for Space Heating (in millions)**

Year	Canadian Households	Percentage
2003 [54]	1.2	11%
2007 [55]	1.4	11%

5.3 Market Barriers to In-field Energy Efficiency

The key barriers to increasing market penetration of efficient space heating and cooling equipment and achieving a greater number of quality installations are listed below.

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[52] This represents the total number of "approved" models of gas-fired hot water boilers available based on October 2009 and August 2014 searches of the AHRI Directory of Certified Product Performance.

[53] U.S. Department of Energy, Energy Information Agency, "Residential Energy Consumption Surveys, 1993, 1997, 2001, 2005, 2009," accessed November 14, 2013, http://www.eia.gov/consumption/residential.

[54] Natural Resources Canada, "2003 Survey of Household Energy Use," accessed November 14, 2013, http://oee.nrcan.gc.ca/Publications/statistics/sheu03/index.cfm.

55 Natural Resource Canada, "2007 Survey of Household Energy Use," accessed November 14, 2013, http://oee.nrcan.gc.ca/Publications/statistics/sheu-summary07/space-heating.cfm.

- **Consumers are unaware of the benefits of investing in high efficiency equipment.** The majority of heating equipment sales occurs in the replacement market where the need is often to replace equipment quickly, and first cost is an important consideration. Consumers may lack information to make informed decisions on equipment and rely on the contractor as an expert to guide them through the purchase. HVAC contractors may lack the training and tools necessary to educate consumers effectively and to promote the benefits and cost-effectiveness of high efficiency equipment.
- **Consumers are unaware of what constitutes a "quality installation"** or which contractors provide quality services. Consumers may be unaware of the degree to which installation can affect the operating efficiency of heating equipment. Moreover, even if consumers are aware of this fact, they do not know how to achieve a quality installation.
- **Contractors lack appropriate tools to sell equipment.** HVAC contractors may lack the appropriate marketing tools or may not be proficient in selling the benefits of high efficiency equipment. Lowest bid quotes are a strong driver in the sale of residential HVAC equipment. Contractors, however, have an opportunity to sell high efficiency equipment by educating customers about the life cycle benefits of such investments. This equipment may be more costly up front, but may also offer a higher profit margin to installers.
- **Contractors have limited reasons to provide a quality installation.** If consumers do not demand a quality installation, contractors may provide a low cost installation as a means of supporting a competitive quote. Other factors that deter the use of quality installation practices are: perceived high first cost in a low bid industry; limited understanding by contractors of key aspects and benefits of quality installation steps; need for additional recruitment, training, and certification by organizations such as North American Technician Excellence (NATE), and high turnover and relatively low barriers to entry into the industry.
- **Split incentives—building owners versus tenants.** Building owners may lack the incentive to purchase higher priced, energy efficient equipment, especially in instances where they are not responsible for the residents' energy bills.
- **Split incentives—builders versus homebuyers.** Homebuilders are understandably concerned with up front equipment costs but may be indifferent to ongoing energy costs. Builders can reduce their expenses by choosing lower efficiency equipment. Premium features such as kitchen finishes and bath amenities tend to be highly visible to consumers. HVAC equipment is less visible, and therefore may constitute less of a selling point.
- **Existing technologies face technical limitations to increased efficiency.** Existing single-stage central air-conditioner and air source heat pump equipment may be nearing its thermodynamic limits of performance, particularly for EER in larger capacity systems. Incremental efficiency improvements at peak have diminishing returns, meaning that additional improvements may not be cost justified and, in fact, may even be cost prohibitive. The most efficient residential furnaces available now exceed 98 percent AFUE. As furnaces approach their technical limits of performance, the efficiency of the overall heating system, including ducts, grows in importance.

6 Initiative Components

This Initiative focuses on identifying and encouraging the purchase, installation, and maintenance of energy efficient residential central air conditioners, air source heat pumps, furnaces, and boilers. In order to achieve high in-field efficiency, realize savings, and overcome market barriers, the Initiative includes three major elements: common efficiency specifications, a quality installation specification, and promotion of quality maintenance.

6.1 Common Efficiency Specification

Efficiency programs can promote CEE multitier performance specifications to build demand for higher efficiency among consumers and to encourage manufacturers to design products to meet that demand.

CEE tier 1 is generally set at a level proven to be attainable by products currently available on the market, and may also align with ENERGY STAR performance requirements in a specific product category. Intermediate tiers are developed, if appropriate, at levels reflecting significant performance improvement, but which remain technologically feasible and within the realm of what efficiency program administrators can cost-effectively promote. The highest tier often represents a stretch target, which may not be cost-effective today, thus capturing only a small fraction of top performing models. This highest tier may be aligned with ENERGY STAR Most Efficient criteria. The CEE tiers are updated periodically to enable CEE members to continue promoting the most efficient, cost-effective equipment available, while also sending signals to industry about the future equipment performance they are interested in promoting with financial incentives. Occasionally, when program needs dictate, a CEE tier 0 can be added to the specification, sometimes accompanied by planned date for obsolescence, and with the typical goal being to support programs in addressing temporary market conditions.

Over time, efficiency requirements of the CEE tiers have increased to address advances in technology and changing market conditions. Additional drivers of revisions include increasing model availability, incremental cost, energy savings potential, the potential for alignment with ENERGY STAR, and rising federal minimum standards.

6.1.1 Central Air Conditioners and Air Source Heat Pumps

The CEE tiers for cooling performance of central air conditioners and air source heat pumps are based on both SEER and EER ratings, while the efficiency performance for heating by air source heat pumps is based on the HSPF rating. Some efficiency program administrators are focus primarily on the peak load performance of residential central air conditioners and air source heat pumps, while others are more concerned with annual energy use, or a combination of the two. The CEE tiers are structured to offer programs the flexibility to address various needs and conditions present at the local level.

CEE tier 3 for split central air conditioners was most recently revised in 2014, followed by revision of the remaining CEE tiers, with an effective date of January 1, 2015, to address the need for sources of savings above the new federal minimum standard. The specific levels were set in consultation with CEE members and the HVAC industry to capture increasing levels of efficiency that would be both cost effective and technologically feasible. Where possible, previous CEE tier levels were retained as lower CEE tiers in order to leverage the existing market traction those levels have with both industry and efficiency program administrators. Where previous CEE tiers could not be retained, such as with packaged equipment, natural breaks in model availability were considered, as well as the kW and kWh savings potential of various levels. For the 2015 revision, alignment was achieved with the ENERGY STAR Version 5.0 levels for split and packaged central air conditioners and air source heat pumps. Additionally, CEE tier 3 for split central air conditioners achieved alignment with the ENERGY STAR Most Efficient 2015 criteria, as did tier 2 for packaged central air conditioners and air source heat pumps.

The current specifications for split and packaged system central air conditioners and air source heat pumps are provided in the tables below.

Figure 4. **Split Central Air Conditioners**

Level	SEER	EER
CEE Tier 0*	14.5	12
CEE Tier 1	15	12.5
CEE Tier 2	16	13
CEE Tier 3	18	13

Figure 5. **Packaged Central Air Conditioners**

Level	SEER	EER
CEE Tier 1	15	12
CEE Tier 2	16	12

Figure 6. **Split Air Source Heat Pumps**

Level	SEER	EER	HSPF
CEE Tier 0*	14.5	12	8.5
CEE Tier 1	15	12.5	8.5
CEE Tier 2	16	13	9.0
CEE Tier 3	18	13	10.0

Figure 7. **Packaged Air Source Heat Pumps**

Level	SEER	EER	HSPF
CEE Tier 1	15	12	8.2
CEE Tier 2	16	12	8.2

* CEE tier 0 was introduced during the 2015 revision in an effort to temporarily address shifting market conditions resulting from the transition to the new federal minimum. For split central air conditioners, there is an 18-month non-enforcement period, during which time a sell-through of noncompliant inventory manufactured prior to 2015 will be permitted. The introduction of a temporary Tier 0 for split central air conditioners enables continued promotion of the previous CEE tier 1 by programs that still wish to reference those levels. Since the CEE tier 0 levels, formerly CEE tier 1 from 2009-2014, for split air source heat pumps remain above the federal minimum and CEE members have identified a continuing need for that level, CEE will also retain a temporary tier 0 for split air source heat pumps. The addition of a tier 0 for packaged equipment was not deemed necessary by CEE members. CEE will assess the viability of tier 0 for split central air conditioners and air source heat pumps in advance of the expiration of the 18-month sell-through period; barring any new information, CEE intends to sunset tier 0 for split central air conditioners and air source heat pumps in mid-2016.

6.1.2 Central Air Conditioner and Heat Pump Savings Potential

While actual savings will vary based on factors such as equipment size, climate, and whether a quality installation was performed, savings estimates for central air conditioners and air source heat pumps meeting the CEE tier criteria are provided in the tables below.

These savings are in comparison to the 2015 federal minimum requirements of 13 SEER for the North and 14 SEER for the South and Southwest, and assume a three-ton system.

Table 7. **Estimated Percent Energy Savings of CEE Tiers Compared to 2015 Federal Minimums for Split Central Air Conditioners**

Level	Estimated % Savings over 13 SEER	Estimated % Savings over 14 SEER
CEE Tier 0	10%	3%
CEE Tier 1	13%	7%
CEE Tier 2	18%	12%
CEE Tier 3	23%	18%

For efficiency programs focused on managing peak load, the kW savings from 13 EER can be up to 10 percent over the 11.7 EER baseline for <45,000Btu/h central air-conditioning equipment in the Southwest, and up to 30 percent over the lowest EER (9.0) equipment available on the market as of summer 2014.

Table 8. **Estimated Percent Savings of CEE Tiers Compared to 2015 Federal Minimum for Split Air Source Heat Pumps**

Level	Estimated % kWh Savings over 14 SEER (cooling)	Estimated % kWh Savings over 8.2 HSPF (heating)	Estimated % kW Savings[56]
CEE Tier 0	3%	3%	29%
CEE Tier 1	7%	3%	32%
CEE Tier 2	13%	7%	35%
CEE Tier 3	22%	12%	35%

Packaged equipment sees average cooling energy savings over the 14 SEER minimum of approximately seven percent for 15 SEER and 12.5 percent for 16 SEER. Packaged central air-conditioner savings from EER increases above the baseline range from approximately ten to twenty percent, depending on the region. Heating savings for packaged air source heat pumps with 8.2 HSPF average up to approximately five percent compared with the 8.0 HSPF federal minimum.

6.1.3 Furnaces and Boilers

Historical success with this Initiative and others shows that widespread adoption of common efficiency specifications provides a consistent signal to all market actors. This Initiative originally adopted fuel efficiency levels consistent with the Environmental Protection Agency's ENERGY STAR Residential Heating and Cooling program. The specification has since been updated to include additional fuel efficiency tiers, as well as an optional electrical efficiency specification for furnaces. The initiative promotes equipment that meets or exceeds these efficiency levels. The test procedure for furnaces and boilers is ASHRAE 103-1993, *Methods of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers*.

The current specifications are detailed in Tables 13 and 14.

[56] Savings based on EER compared to lowest EER (8.5) equipment available on the market as of summer 2014.

Table 9. **CEE Furnace Specification**

Level	Furnace AFUE
CEE Tier 1	90%
CEE Tier 2	95%
CEE Tier 3	97%

Table 10. **CEE Boiler Specification**

Level	Furnace AFUE
CEE Tier 0*	85%
CEE Tier 1	90%
CEE Tier 2	95%

* CEE tier 0 for residential boilers is intended for boiler systems where condensing equipment meeting tier 1 or tier 2 is not practicable due to system or building constraints. Additional considerations for condensing equipment are described in this Initiative.

6.1.4 Furnace Fans

In addition to developing advanced tiers for heating and cooling appliances, in November 2003, CEE added a specification for electricity use by gas furnaces. Power use for air handling, which involves a fan motor to move heated air through the ducts into the conditioned spaces, represents a large proportion of the electricity drawn by furnaces.[57] The furnace fan efficiency specification requires that the annual fan motor electricity use must be less than or equal to two percent of the total energy used by the furnace. This specification applies only to furnaces that meet or exceed the fuel efficiency specifications set in tier 1, tier 2, or tier 3. A federal minimum for furnace electricity use is scheduled to become effective in 2019. In early 2014, CEE adopted the approach for determining furnace fan efficiency referenced in ENERGY STAR Program Requirements for Furnaces Version 4.0.

Figure 8. **CEE Furnace Fan Efficiency Specification**

Equipment Requirement	Furnace Fan Efficiency Level
Gas Furnaces with a minimum of 90% AFUE	e = ≤2% of Total Furnace Energy Use as calculated by approach referenced in ENERGY STAR Program Requirements for Furnaces Version 4.0

Promotion of the furnace fan efficiency specification is optional for initiative participation, though it is encouraged, particularly where cost effective for consumers.

6.1.5 Furnace and Boiler Savings Potential

The US minimum standard for nonweatherized furnaces is currently 78 percent AFUE; this is scheduled to rise to 80 percent on November 19, 2015. Canada established a minimum standard of 90 percent AFUE in 2010.[58] Increasing the market penetration of high efficiency units meeting the tier 1 specification of 90 percent AFUE from 60 to 80 percent would save approximately 1,813,000 MMBtu annually, enough to provide all the natural gas needs for 25,000 houses annually. Greater market penetration of tier 2 and tier 3 units would lead to

[57] Energy Center of Wisconsin, *Electricity Use by New Furnaces—A Wisconsin Field Study*, October 2003:1, www.doa.state.wi.us/docview.asp?docid=1812.
[58] Natural Resources Canada, "Energy Efficiency Regulations– Gas Furnaces," accessed November 13, 2013, http://oee.nrcan.gc.ca/regulations/products/13141.

even greater savings. Since 2012, the US minimum standard for hot water boilers has been 80 percent AFUE.

Table 11. **Estimated Percent Energy Savings of CEE Tiers Compared to 2015 Federal Minimums for Residential Furnaces**

Level	Estimated % Savings over 80% AFUE Furnace
CEE Tier 1	13%
CEE Tier 2	17%
CEE Tier 3	19%

Table 12. **Estimated Percent Energy Savings of CEE Tiers Compared to 2012 Federal Minimums for Residential Boilers**

Level	Estimated % Savings over 82% AFUE Boiler
CEE Tier 0	3%
CEE Tier 1	9%
CEE Tier 2	13%

Nearly all furnaces and boilers rated with an AFUE of 90 percent or higher are condensing models that require certain system settings, such as correct return water temperature, in order to achieve condensing conditions. Additional costs can result from the materials necessary to handle corrosive condensation and the added installation expense to ensure the proper removal of condensate. Although most homes are suited for condensing equipment, this Initiative recognizes that programs may choose to set a lower specification level in instances where the design of a home does not allow for condensing equipment.

6.2 Quality Installation

While significant energy savings can be attained through high efficiency equipment, improper installation can negatively impact overall system performance. CEE originally incorporated a quality installation specification into its HVAC work in 2000. As interest in quality installation grew, CEE worked closely with the Air Conditioning Contractors of America (ACCA) to develop a single, credible standard for a quality installation that is recognized by industry stakeholders, particularly contractors. The *ANSI/ACCA 5 Quality Installation Specification* outlines energy efficient installation practices for residential and light commercial HVAC systems. This specification is a comprehensive document providing consistent guidelines that can be incorporated into an efficiency program with the goal of maximizing energy savings through quality installation. The specification was adopted by the CEE Board of Directors in May 2007 and was last updated in 2010. The full specification may be found in Appendix A. Initiative participants are encouraged to sponsor HVAC contractor training opportunities that focus on the principles of selling and performing quality installations based on *ANSI/ACCA 5 QI-2010*.

6.3 Education and Awareness Building

6.3.1 Contractor Training

The replacement market is the largest market for heating and cooling equipment. Contractors represent the primary market channel for the sale of this equipment, and the HVAC contractor can significantly influence the consumer's decision about which equipment to purchase. Early in its history, the Residential Gas Heating Initiative took advantage of resources provided by EPA, including an HVAC contractor training course and materials packet, to provide contractors with the skills and tools to sell high efficiency equipment. CEE arranged for Initiative implementers to attend EPA sponsored "train-the-trainer" courses, enabling utility staff to gain the skills needed to provide similar workshops to their local contractors. Initiative participants are now encouraged to sponsor HVAC contractor training opportunities that focus on promoting high efficiency equipment and the principles of selling and performing quality installations based on *ANSI/ACCA 5 QI-2010*. Education offerings should refer contractors to manufacturers for additional guidance on advanced venting and condensate drains required for condensing boilers and furnaces.

6.3.2 Consumer Education and Awareness

Consumer education and awareness play a critical role in the market penetration of high efficiency equipment. Programs should provide a consumer awareness campaign on the benefits of choosing high efficiency residential heating equipment. An effective campaign targets both the replacement and new construction markets. Successful campaigns may include the use of customer brochures, bill stuffers, fact sheets, advertisements, or online messaging. Education and awareness materials targeted at contractors and installers serve as an additional opportunity to promote the benefits of efficient equipment—and quality installation—to key influencers in purchasing decisions.

6.4 CEE Directory

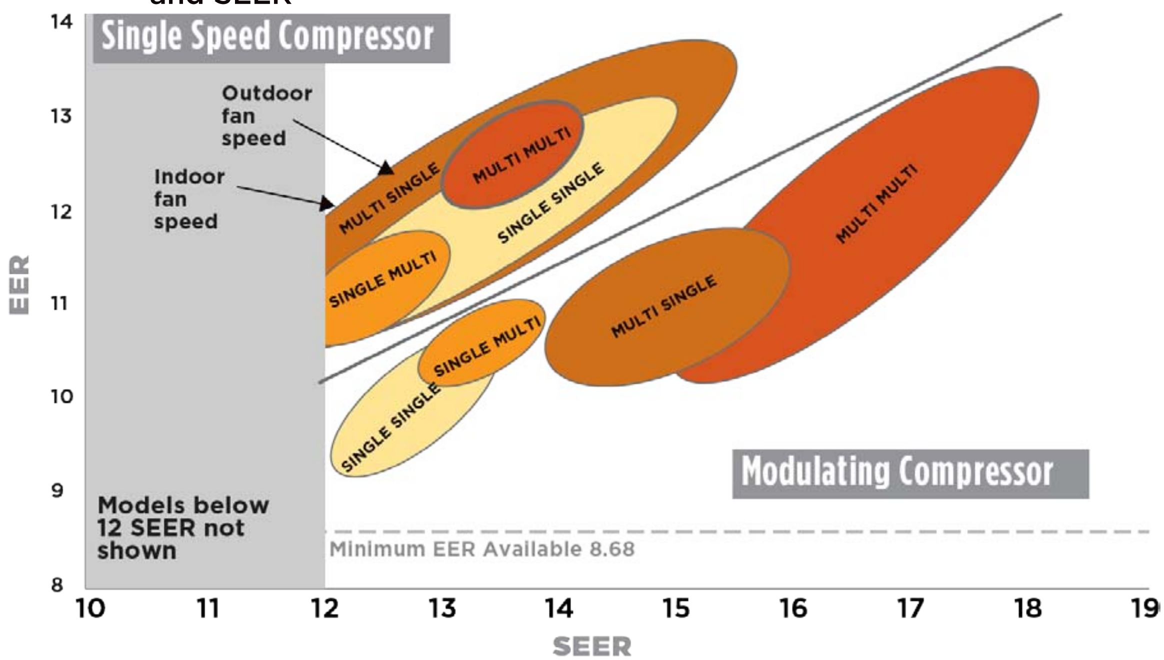
The CEE Directory of Efficient Equipment serves as the qualified products list for the *CEE Residential Heating and Cooling Systems Initiative*, enabling users to sort AHRI-verified equipment by CEE tier and a range of other criteria. Since 2004, the CEE Directory has covered residential central air conditioners and air source heat pumps, and the scope was expanded in 2014 to include gas water heaters, gas boilers, and residential gas furnaces. For central air conditioners and air source heat pumps, the CEE Directory also serves as the ENERGY STAR qualified products list. In addition to providing efficiency performance information to assist HVAC contractors, consumers, and efficiency program administrators, the CEE Directory serves as a public-facing resource on quality installation. Equipment does not have to be listed in the CEE Directory to comply with the CEE specification. CEE requires only that the complete system, including any supplemental devices, be listed by Underwriters Laboratories or another nationally recognized testing organization in accordance with UL standards as appropriate.

6.5 Potential Future Enhancements to the Initiative

6.5.1 Variable Capacity Equipment

Variable capacity HVAC systems that have indoor and outdoor variable speed motors as well as an inverter-driven compressor, or compressor controls that enable nearly infinite levels of modulation, are anticipated to represent an increasing share of manufacturers' product mixes. Modulating equipment may also mitigate other sources of system inefficiency, such as frequent cycling caused by oversized equipment. Variable capacity equipment is typically optimized for low capacity operation to boost SEER and may offer greater humidity control than single-speed equipment, although the performance of the system at full load conditions tends to be lower due to technical limitations that constrain the ability of these systems to achieve higher EER ratings. Figure 9 demonstrates how SEER and EER are affected by adding variable-speed fans and modulating compressors.

Figure 9. **Effects of Modulating Compressors and Variable Speed Fans on EER and SEER**[59]



Variable capacity units could potentially reduce efficiency program need to focus performance criteria on high EER as a proxy for peak savings potential, especially if the system modulating capabilities can be coupled with utility load management programs and can be supported by the necessary communication capabilities. CEE is contributing to discussions about developing an industry standard for equipment capable of demand response. When a viable specification is established, CEE will consider its inclusion in this Initiative Description.

6.5.2 Leveraging the CEE Relationship with AHRI to Address Connected HVAC

CEE members seek a nationally consistent definition of HVAC systems that are efficient, demand response ready, and capable of sharing data to verify energy and capacity benefits, contribute to consumer engagement platforms, and provoke energy saving behavior. To this end, CEE is partnering with AHRI and its manufacturer members to develop a national specification and associated test procedure that could ultimately serve as a basis for determining which equipment is eligible for promotion in voluntary programs.

[59] Adapted from "Technical Support Document," *U.S. Department of Energy*, October 2000, page 4-55.

DOE and industry are already developing connected test procedures for several product categories—appliances, pool pumps, and thermostats—that will prove an important tool for use by CEE members. However, for two very important end uses, variable capacity HVAC equipment and water heating, a DOE test procedure is not currently in development. Throughout 2014, the CEE Connected Committee worked closely with an ad hoc committee of the Air Conditioning, Heating, and Refrigeration Institute (AHRI)[60] to develop a joint vision, specification and test procedure for residential variable capacity HVAC equipment. In December of 2014, AHRI voted to develop an ANSI standard for connected residential HVAC equipment. AHRI affirmed their commitment to actively engage CEE and its members to ensure the resulting standard would identify equipment likely to be promoted in voluntary DSM programs.

6.5.3 Cold Climate Heat Pumps

CEE recognizes the potential for additional savings as air source heat pump technology advances to perform more reliably and efficiently in cold climates. As outdoor temperatures drop, the heating capacity of heat pumps decreases, but technology advances are allowing for heat pumps, in both ducted and ductless configurations, to be designed specifically for cold climates and to retain their heating capacity, even when subjected to much lower outdoor temperatures. Given remaining questions about test procedures and appropriate metrics to capture heating performance, CEE is not specifically addressing cold climate heat pumps in this current Initiative Description. In a future revision of the Initiative, CEE may consider developing requirements targeting cold climate heat pumps that are capable of operating efficiently at low outdoor temperatures.

6.5.4 Diagnostics and Equipment Intelligence

Although onboard communications and intelligence capabilities such as fault detection and diagnostics for residential central air-conditioner and air source heat pump equipment are not yet widespread and remain largely proprietary, there is anecdotal indication that these technologies may help avoid instances of poor installation, and may contribute to improved system maintenance. As of 2014, the ENERGY STAR Most Efficient recognition criteria for central air conditioners and air source heat pumps included requirements for two-way communications capable of supporting the transmission of system status and fault codes, and incorporation of automated configuration for settings such as airflow for heating or cooling.[61] CEE will continue to monitor developments regarding fault detection and diagnostics in order to gain a better understanding of the savings potential and the role that equipment intelligence may play in delivering efficient in-field performance.

6.5.5 Quality Maintenance

In addition to high efficiency equipment and quality installation, proper maintenance is necessary to achieve efficient in-field performance for the life of air-conditioning and space heating equipment. Regularly scheduled inspections, maintenance, and cleaning of HVAC systems help maintain equipment efficiency and prolong useful life. While some energy efficiency program administrators promote proper maintenance or tune-ups with financial incentives, equipment maintenance is not required to participate in the *CEE[SM] Residential*

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[60] AHRI is the trade association for manufacturers of HVAC and water heating equipment.
[61] "ENERGY STAR Most Efficient Criteria 2014," *U.S. Environmental Protection Agency*, http://www.energystar.gov/index.cfm?c=partners.most_efficient_criteria, accessed March 19, 2014.

Heating and Cooling System Initiative. Resources such as the *ANSI/ACCA 4 Standard for Maintenance of Residential HVAC Systems*, updated in 2013, may offer guidance in this area.[62] CEE may consider including a more comprehensive maintenance and tune-up element in a future version of the Initiative.

7 Initiative Participation Requirements

Initiative participation is open to individual efficiency organizations. Other Initiative stakeholders have a variety of opportunities to engage in Initiative activities and to influence Initiative focus.

To be considered an Initiative participant, individual efficiency organizations must fulfill each of the following requirements:

1. Equipment Specifications

- Incorporate at least one of the CEE specifications for residential central air conditioners, air source heat pumps, furnaces, or boilers in an educational or incentive (e.g., rebate) program

2. Quality Installation

- Deploy a significant and focused educational or promotional program that expresses the importance of taking an integrated approach to encouraging efficient heating and cooling systems through the identification and marketing of the CEE Quality Installation Specification

OR

- Provide incentives for installations that address integrated heating and cooling system efficiency that are verified to achieve the CEE Quality Installation Specification

3. Communicate to CEE that you voluntarily elect to participate in the Initiative to enable analysis of Initiative uptake and impacts

These requirements provide participants with discretion to design programs that optimize effectiveness around local conditions, including whether to offer incentives and the relative amount of any incentives offered. The requirements do not preclude the existence of additional program elements such as: (a) promoting equipment that achieves the CEE specifications in this Initiative as well as equipment that does not; (b) promoting quality installation either for equipment that achieves the CEE specifications in this Initiative, or equipment that does not, or both; and (c) differing levels of promotion or incentives relating to (a) and (b).

8 CEE Role in Initiative Promotion

Since 1995, CEE has played a central role in providing a platform for efficiency program administrators to exchange best practices, identify shared needs and opportunities, and craft national strategies that generate tangible results. This coordination and consistency helps CEE members have a larger impact on the market.

[62] "ANSI/ACCA 4 QM - 2013: Maintenance of Residential HVAC Systems," *Air Conditioning Contractors of America*, http://www.acca.org/wp-content/uploads/2014/02/quality-maintenance.pdf.

CEE and its members work closely and collaboratively with the US Environmental Protection Agency on ENERGY STAR equipment as well as the agency's Verified HVAC Installation programs to ensure the ENERGY STAR brand continues to serve the needs of efficiency program administrators and represents a trusted mark for consumers searching for quality efficient products and services. As a national brand, ENERGY STAR has achieved a high level of consumer awareness, reaching 87 percent in 2013. [63]

Another hallmark of CEE HVAC work has been its productive relationship with national trade associations representing HVAC manufacturers, distributors, and contractors. CEE, acting as the representative of the energy efficiency program community, regularly communicates and collaborates with industry on program administrator priorities, goals, and program design.

Additionally, CEE provides other supports for its initiatives, which may include undertaking further research, tracking market impacts, compiling program summaries, or monitoring developments related to residential heating and cooling equipment installation and maintenance in the United States and Canada.

[63] National Awareness of ENERGY STAR® for 2013, cee1.org/content/2013-energy-star-survey

Appendix A CEE Quality Installation Standard

The elements of this installation component are excerpted from the ANSI-recognized *ACCA 5 Quality Installation Standard* (v.2010)

1.0 PURPOSE

This standard details the nationally recognized minimum criteria for the proper installation of HVAC systems in residential and commercial applications.

2.0 SCOPE

This standard applies to HVAC equipment/components being installed in residential and commercial buildings:

2.1 EQUIPMENT TYPES

2.1.1 Unitary air conditioners, air source/water-source heat pumps, and geothermal heat pumps,

2.1.2 Furnaces (gas-fired, oil-fired, electric, and other)

2.1.3 Boilers (gas-fired, oil-fired, electric, and other).

EXCEPTIONS:
Due to differing design aspects and control/operation situations, built-up systems (i.e., chillers, custom or specialty-built penthouse units, etc.) are not included in this specification. Buildings employing built-up systems are generally designed by architects or professional engineers. Additionally, commercial buildings using built-up equipment are more likely to benefit from increased owner scrutiny via building commissioners, owner agents, etc.

2.2 EQUIPMENT SYSTEMS / COMPONENTS

2.2.1 <u>Heating Systems / Components – Single Zone and Multizone</u>

a) Heating-only equipment and heat pumps including air source, water-source, and geothermal heat pumps.
b) Hot-water coil and/or fin-tube radiation, and/or unit heaters, and/or unit ventilators
c) Electric resistance coil and/or fin-tube radiation, and/or gas unit heaters, and/or unit ventilators
d) Hot air heating (fossil fuel or electric furnace, direct-fired and indirect-fired makeup air equipment)
e) Radiant heat equipment

2.2.2 <u>Cooling Systems / Components – Single Zone and Multizone</u>

a) Cooling-only equipment and heat pumps including air source, water-source, and geothermal heat pumps.
b) Rooftop single zone, rooftop multi-zone (hot-deck/cold-deck)
c) Single-zone unitary (packaged terminal air conditioners/heat pumps, split-coil-ductless)

3.0 DESIGN ASPECTS

This section focuses on the upfront design procedures/tasks[64] undertaken before the equipment is actually installed.

3.1 VENTILATION

The contractor shall ensure that ventilation calculations are performed for every HVAC system installation/replacement.

3.1.1 REQUIREMENTS

The contractor shall ensure:

Building ventilation requirements (outside air, exhaust air and building pressurization) are performed to recognized standards, codes, or requirements.[65]

3.1.2 ACCEPTABLE PROCEDURES

The contractor shall follow an appropriate methodology to perform building ventilation calculations.

3.1.3 ACCEPTABLE DOCUMENTATION

The contractor shall include documentation in the installation file indicating that the ventilation calculations were addressed.[66]

3.2 BUILDING HEAT GAIN / LOSS LOAD CALCULATIONS

The contractor shall ensure that heat loss and heat gain load calculations are performed for every HVAC system installation/replacement.

3.2.1 REQUIREMENTS

The contractor shall ensure:

a) For NEW CONSTRUCTION, or when adding new ducts to an existing structure, room-by-room heat gain/loss load calculations are completed

or

b) For EXISTING CONSTRUCTION, without contractor modification of the existing duct system, block load heat gain/loss load calculations are completed.

NOTE 1. EXISTING BUILDING EXCEPTION:
Building heat gain / loss load calculations are not required if the original load calculations are on hand and accurately reflect the building's current construction and use.

NOTE 2. LOAD CALCULATIONS:
Room-by-room load calculations may be undertaken if so chosen by the contractor.

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[64] Informative Note: During the HVAC system design process, duct sizing calculations need to meet subsequent QI requirements:
– §4.1 & §4.2 Airflow & water flow Across Indoor Heat Exchangers
– §5.2 Airflow Balance

[65] Mechanical ventilation connected to the HVAC system shall not allow the entering mixed air temperature to be outside the temperature and humidity limits of the OEM heating and air conditioning equipment requirements.

[66] The ventilation load is to be included in the overall heat gain/loss load calculations (§3.2)

3.2.2 ACCEPTABLE PROCEDURES

The contractor shall perform one of the following acceptable procedures for fulfilling the desired criteria:

a) Follow an appropriate methodology/procedure to perform building load calculations (e.g., ACCA Manual J®, ACCA Manual N®, ASHRAE Handbook Guidelines, DOE EnergyPlus™, or other approved equivalents per the authority having jurisdiction)

   or

b) Confirm that the calculations were performed by a qualified third party.

3.2.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Load calculation worksheets included in the installation file

   or

b) Appropriate documentation in the installation file.

3.3 PROPER EQUIPMENT CAPACITY SELECTION

The contractor shall ensure that all equipment is properly sized and selected prior to being installed.

3.3.1 REQUIREMENTS

The contractor shall ensure:

a) For CENTRAL AIR CONDITIONERS and HEAT PUMPS - the selected equipment will satisfy the building's load requirements at design conditions

   i. OEM product data demonstrates that latent requirements are addressed,[67]

      and

   ii. Total equipment capacity is between:

      - 95% and 115% of total cooling requirements (for air conditioners and heat pumps)

        or

      - 95% and 125% of total cooling requirements (for heat pumps with heating dominated requirements)

        or

      - the next largest nominal piece of equipment, per OEM increment,[68] that is available for either to satisfy the latent and sensible requirements.

b) For gas-fired or oil-fired WARM AIR SYSTEMS and HEATING BOILERS - the heating capacity of the selected equipment will satisfy the heating requirement at design conditions

   i. WARM AIR SYSTEMS - output capacity between 100% and 140% of calculated system load unless dictated by the cooling equipment selection

[67] It is acceptable to include supplemental dehumidification equipment with the HVAC system to meet excess latent loads.

[68] For *Residential Applications*: Single-speed systems generally have nominal size increments of ½ ton. Multispeed or multistage equipment may have nominal size increments of one ton. For *Commercial Applications*: The nominal size increases can be 1 – 5 tons.

ii. HEATING BOILERS - equipment capacity between 100% and 115% of calculated system load, OR the next largest nominal piece of equipment that is available

3.3.2 ACCEPTABLE PROCEDURES

Using OEM performance information and industry-approved procedures (e.g., ACCA Manual S® for residential applications, ACCA Manual CS® for commercial applications, OEM guidelines, OEM equipment selection programs, or other approved equivalent per the authority having jurisdiction), the contractor is to confirm that the selected equipment satisfies/meets the load requirements at the system design conditions.

3.3.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Equipment performance information in the-installation file
and

b) Written job documentation or checklist in installation file

3.4 GEOTHERMAL HEAT PUMP GROUND HEAT EXCHANGER

The contractor shall observe industry design practices for the proper design of the exterior ground heat exchanger.

3.4.1 REQUIREMENTS

The contractor shall ensure:

Ground heat exchangers are designed to satisfy the HEATING AND COOLING load requirements of the building.

i. The ground interface heat exchanger fluid[69] temperatures [extremes] and flow rates used as the basis for design equipment capacity are within the range specified in OEM guidelines
and

ii. The ground heat exchange design methodology incorporates:
- building loads and total installed equipment capacity
- ground heat exchanger type, materials, and geometry
- soil thermal characteristics
- climatic characteristics of the project location

3.4.2 ACCEPTABLE PROCEDURES

The contractor shall follow OEM guidance, recognized industry practices (ASHRAE, IGSHPA, NGWA), or procedures approved by the authority having jurisdiction.

3.4.3 ACCEPTABLE DOCUMENTATION

The contractor shall include documentation in the installation file indicating that the ground heat exchanger design objectives were met using OEM, IGSHPA, NGWA ASHRAE, or procedures approved by authority having jurisdiction.

[69] Fluids may be water-or antifreeze solution for closed loop ground heat exchangers - or refrigerants in DX based ground heat exchangers. Verify fluid is allowed by local ground water authority or administrative authority.

3.5 MATCHED SYSTEMS

The contractor shall ensure that all heating and cooling equipment are properly matched systems as identified by industry-recognized certification programs.

3.5.1 REQUIREMENTS

The contractor shall ensure:

Matched systems in accordance with one of the following:

a) AHRI Product Certification directory/database (www.ahridirectory.org)
or
b) CEE directory of AHRI-verified equipment (www.ceehvacdirectory.org)
or
c) Selection of indoor coil and air handler to correctly match OEM performance data for matching indoor and outdoor components that meet §3.3 and §3.4 requirements.

3.5.2 ACCEPTABLE PROCEDURES

The contractor shall use one of the following acceptable procedures for fulfilling the desired criteria:

a) Confirmation of system matching compliance as compared to a recognized product certification database
or
b) Confirmation of the matched system operational performance data to OEM documentation for all equipment being installed (i.e., air handling unit, indoor coil, outdoor condensing unit)

3.5.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Copy of the AHRI *or* CEE-AHRI record/certificate, with appropriate reference number indicated for the matched system, in the installation file.
or
b) Copy of OEM-provided catalog data, indicating acceptable combination selection and performance data, in the installation file.

4.0 EQUIPMENT INSTALLATION ASPECTS

This section focuses on the HVAC system installation.

4.1 AIRFLOW THROUGH INDOOR HEAT EXCHANGERS

The contractor shall verify that the airflow through the indoor blower unit, (e.g. furnace, fan coil, air handler) is within acceptable CFM ranges.

4.1.1 REQUIREMENTS

The contractor shall ensure:

Measured airflow[70] through the indoor heat exchanger (with all accessories and system components in place):

a) For cooling (e.g., refrigerant, water) and heat pump applications
   i. Airflow through the unit, at fan design airflow under steady state condition is within 15% of the airflow required per the system design,
   and
   ii. Airflow through the unit is within the CFM range listed in the OEM product data,[71]
   and
   iii. Measured external static pressure (ESP)[72] is:
      1) Within OEM-specified acceptable range,
      and
      2) Not more than 25% or 0.10 iwc (which ever is greater) over the calculated ESP used to design the duct system. [Exception for existing buildings: measured ESP is not required for change-out applications if there has been no modification to the pre-existing ductwork.]

b) For gas-fired, oil-fired, or electric heat exchanger applications
   i. Airflow, through the heat exchanger, at the selected fan speed under steady-state conditions is within 15% of the airflow required per the system design,
   and
   ii. Airflow through the indoor heat exchanger is within the CFM range listed in the OEM product data,
   and
   iii. Heat exchanger airflow requirements shall be considered separately from any combined and attached cooling coils sharing the same distribution duct system,
   and
   iv. Measured external static pressure (ESP) is:
      1) Within OEM-specified acceptable range,
      and
      2) Not more than 25% or 0.10 iwc (whichever is greater) over the calculated ESP used to design the duct system. [Exception for existing buildings: measured ESP is not required for change-out applications if there has been no modification to the pre-existing ductwork.]

4.1.2 ACCEPTABLE PROCEDURES

The contractor shall use one of the following acceptable methods for fulfilling the design criteria:

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[70] When verifying design airflow at design fan speed, there is little distinction between a split capacitor fan motor (PSC) or a variable speed fan motor (e.g., brushless DC, electronically commutated motor; ECM). See "Airflow" in Appendix B. Note: ECM fan motors are designed to modify their RPMs in order to provide a prescribed (programmed) air volume in response to static pressure conditions (actually torque on the output shaft). Hence, an ECM may use more or less power than a comparable PSC motor in the same application.

[71] Airflow across the coil is typically between 350 to 450 CFM per ton. Adjustments may be needed between dry and wet coils.

[72] Static pressure measurements require clean components: filters, coils, and fans for each indoor unit type

a) OEM CFM/static pressure drop coil table method using a manometer and probe to determine the static pressure drop across a cooling coil, furnace, or fan coil unit and compare with OEM values
or
b) Traversing using a manometer and probe, or an anemometer (e.g., hot wire, rotary style) or other methods per ACCA, AABC, ASHRAE, ASTM, NEBB, SMACNA, or TABB procedures
or
c) Flow grid measurement method
or
d) Pressure matching method[73]
or
e) The temperature rise method (for heating only: gas or oil furnace, electric resistance heat, geothermal and water source heat pump) to verify proper airflow through the heat exchanger or heater elements. [NOTE: It is not acceptable to use the temperature rise method to determine cooling airflow over the indoor coil.]

4.1.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Documented field data and calculations recorded on start-up sheet
or
b) Documented field data and calculations recorded on service records
and
c) Written job documentation or checklist in the installation file

4.2 WATER FLOW THROUGH INDOOR HEAT EXCHANGERS

The contractor shall verify that the water flow[74] through the refrigerant-to-water, water-to-water, or water-to-air heat exchanger are within acceptable ranges.

4.2.1 REQUIREMENTS

The contractor shall ensure:

a) Water flow through the heat exchanger is within 10% of the water flow required per the system design.
and
b) Water flow through the heat exchanger is within the range listed in the OEM product data.

4.2.2 ACCEPTABLE PROCEDURES

The contractor shall test using one of the following acceptable methods for fulfilling the desired criteria:

a) The water pressure drop method
or
b) The water temperature change method

[73] Use of a calibrated fan to match the supply plenum pressure and measurement of the system airflow through the active fan. Note: Methods for use with brushless DC or ECM blowers in accordance with the motor or OEM instructions.
[74] Water may be treated or contain antifreeze.

or

c) Any method approved and specifically stated by the OEM that can be used to determine the water flow rate

4.2.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Documented field data and calculations recorded on start-up sheet

or

b) Documented field data and calculations recorded on service records

and

c) Written job documentation or checklist in the installation file

4.3 REFRIGERANT CHARGE

The contractor shall ensure that the HVAC system has the proper refrigerant charge.

4.3.1 REQUIREMENTS

The contractor shall ensure:

a) For the SUPERHEAT method, system refrigerant charging per OEM data/instructions and within ± 5°F of the OEM-specified superheat value.

or

b) For SUBCOOLING method, system refrigerant charging per OEM data/instructions and within ± 3°F of the OEM-specified subcooling value

or

c) Any method approved and specifically stated by the OEM that will ensure proper refrigerant charging of the system

NOTE 1. FLOW THROUGH THE HEAT EXCHANGER:
Proper airflows §4.1 and/or water flows §4.2 through the heat exchanger must be within acceptable OEM tolerances before the refrigerant charge can be measured and/or adjusted.

NOTE 2. MEASUREMENT PARAMETERS:
The system must be within the OEM's temperature parameters at steady state conditions before system charge measurements are undertaken.

NOTE 3. REFRIGERANT CHARGE TOLERANCES:
Refrigerant charge tolerances noted (i.e., ± 5°F and/or ± 3°F of the OEM-recommended optimal refrigerant charge) are not additive to any OEM-specified tolerances.

4.3.2 ACCEPTABLE PROCEDURES

The contractor shall use one of the following acceptable procedures for completing the desired measurements after confirmation of required airflow (per §4.1) and/or water flow (per §4.2) through the indoor coil:

a) Superheat test done under outdoor ambient conditions, as specified by the OEM instructions (typically, 55°F drybulb temperature or higher)

or

b) Subcooling test done under outdoor ambient conditions, as specified by the OEM instructions (typically, 60°F or higher)

or

c) Any method approved and specifically documented by the OEM that will ensure proper refrigerant charging of the system.

NOTE: If outdoor conditions require a follow-up visit to finalize the charging process, this should be recorded at both the initial visit and the follow-up visit.

4.3.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Documented field data AND operating conditions recorded on start-up sheet
or
b) Documented field data AND operating conditions recorded on service records
and
c) Written job documentation or checklist in the installation file

4.4 ELECTRICAL REQUIREMENTS

The contractor shall ensure all electrical requirements are met as related to the installed equipment.

4.4.1 REQUIREMENTS

The contractor shall ensure:

a) LINE and LOW VOLTAGES per equipment (single and three-phase) rating plate - the percentage (or amount) below or above nameplate values are within OEM specifications and/or code requirements
and
b) AMPERAGES per equipment (single and three-phase) rating plate - the percentage (or amount) below or above nameplate values are within OEM specifications and/or code requirements
and
c) LINE and LOW-VOLTAGE wiring sizes per NEC (National Electric Code) or equivalent
and
d) GROUNDING/BONDING per NEC or equivalent

4.4.2 ACCEPTABLE PROCEDURES

The contractor shall test using the following acceptable procedures for fulfilling the design criteria:

a) Volt meter to measure the voltage
and
b) Amp meter to measure the amperage
and
c) Verify measurements with nameplate and over current protection criteria

4.4.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Documents showing that selections are in compliance with OEM specifications
and
b) Written job documentation or checklist in the installation file

4.5 On-Rate for Fuel-Fired Equipment

The contractor shall ensure the equipment combustion is "on-rate", for gas-fired or oil-fired equipment, and is at the equipment nameplate value.

4.5.1 Requirements

The contractor shall ensure:

a) Gas-Fired Equipment:

The contractor shall ensure:

i. Firing rate within ± 5% of nameplate input for gas equipment (or per OEM specifications)

and

ii. Temperature rise within the nameplate limits

b) Oil-Fired Equipment:

The contractor shall ensure:

i. Correct nozzle flow rate and spray angle for correct firing rate per nameplate input,

and

ii. Correct oil pump pressure for nozzle installed and at OEM's specified values

and

iii. Temperature rise per nameplate limits

4.5.2 Acceptable Procedures

a) Gas-Fired Equipment:

The contractor shall test using one of the following acceptable procedures for fulfilling the desired criteria:

i. Clocking the meter or other fuel input measurement per OEM instructions,

and

ii. Measuring the temperature rise at steady state conditions (with airflow first verified by §4.1) – furnaces only.

or

iii. Perform a combustion analysis per OEM installation or gas burner instructions.

b) Oil-Fired Equipment:

The contractor shall fulfill the following criteria:

i. Verify nozzle or alternate input nozzle per OEM installation and oil burner instructions.

and

ii. Verify oil pump pressure with a dial or electronic gauge designed for oil pressure measurement

and

iii. Measure the temperature rise at steady-state conditions (with airflow first verified by §4.1) –furnaces only.

or

iv. Perform a combustion analysis per OEM installation and oil burner instructions.[75]

4.5.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Documented field data recorded on start-up sheet

and

b) Written job documentation or checklist in the installation file

4.6 COMBUSTION VENTING SYSTEM

The contractor shall ensure proper sizing, design, material selection and assembly of the combustion gas venting system.

4.6.1 REQUIREMENTS

The contractor shall install the vent system to:

a) CATEGORY I vent system sized per OEM instructions and the National Fuel Gas Code (NFGC, NFPA 54)

or

b) CATEGORY I vent system sized per OEM instructions and the International Fuel Gas Code (IFGC)

or

c) CATEGORY II, III and IV vent system sized per OEM instructions

and

d) CATEGORY II, III and IV vent system sized per required local code

4.6.2 ACCEPTABLE PROCEDURES

The contractor shall use one of the following acceptable procedures for fulfilling the installation criteria:

a) Comparison of the actual installation to appropriate fuel gas venting tables for Category I vent systems

or

b) Comparison of the actual installation to appropriate OEM instructions, and local codes for Category II, III and IV vent systems

4.6.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Documented field data recorded on start-up sheet

or

b) Documented field data recorded on service records

and

c) Written job documentation or checklist in the installation file

[75] Combustion analysis is necessary when setting up an oil burner. Additionally, new oil-fired equipment no longer standardizes the pump pressure at 100 psig. Hence, incorrect pump pressure may result in an incorrect input rate for the equipment.

4.7 System Controls

The contractor shall ensure proper selection and functioning of system operational and safety controls.

4.7.1 Requirements

The contractor shall ensure:

a) Operating controls and safety controls are compatible with the system type and application, and the selected controls are consistent with OEM recommendations and industry practices
and
b) Operating controls and safety controls lead to proper sequencing of equipment functions, with all controls and safeties functioning per OEM or customer design specifications

NOTE OPERATING CONTROLS:
Examples of operating controls include: thermostats, humidistats, economizer controls, etc. Examples of safety controls include: temperature limit switch, airflow switch, condensate overflow switch, furnace limit switch, boiler limit switch, etc.

4.7.2 Acceptable Procedures

The contractor shall use the following acceptable procedures for fulfilling the desired design criteria:

a) Confirmation of the control/safety selections made
and
b) Supporting OEM literature related to the selections made
and
c) Verification of correct cycling/operational sequences of controls and safety devices/systems per system design and OEM specifications

4.7.3 Acceptable Documentation

The contractor shall provide evidence of the following:

a) Documents showing that controls/safeties selections are in compliance with OEM specifications
and
b) Written job documentation or checklist in the installation file indicating that controls/safeties function properly

5.0 DISTRIBUTION ASPECTS

This section focuses on heating and cooling delivery elements of the installed HVAC system.

5.1 Duct Leakage

The contractor shall ensure the ducts are sealed and that air leakage (CFM) is minimized.

5.1.1 Requirements

The contractor shall ensure:

a) For NEW CONSTRUCTION, test using any one of the three options:

i. Ducts located inside the thermal envelope have no more than 10% total duct leakage (airflow in CFM: duct pressure 25 Pascals),

or

ii. Ducts located outside the thermal envelope have no more than 6% total duct leakage (airflow in CFM: duct pressure 25 Pascals),

or

iii. Per local code or authority having jurisdiction

b) For EXISTING CONSTRUCTION, test using any one of the three options:

i. No more than 20% total duct leakage (airflow in CFM: duct pressure 25 Pascals)

or

ii. 50% improvement on existing leakage rate or until 5.1.1.b.i. is achieved

or

iii. Per local code or authority having jurisdiction

NOTE 1. DUCT LEAKAGE:
The total duct leakage allowable pertains to the percentage of CFM leakage as compared to the overall air handling fan flow (see §4.1) operating at design conditions. The airflow leakage allowable shall be based on the higher of the winter heating airflow or of the summer cooling airflow.
TOTAL duct leakage = SUPPLY duct leakage + RETURN duct leakage.

NOTE 2. DUCT SEALING:
For duct sealing, all duct sealing materials shall be rated to UL 181A or UL 181B specifications and shall be used in strict accordance with OEM instructions.

5.1.2 ACCEPTABLE PROCEDURES

The contractor shall test using one of the following acceptable procedures for fulfilling the desired criteria:

a) Duct pressurization tests[76] at 25 Pascal

or

b) FOR COMMERCIAL BUILDINGS, airflow comparison method[77]

or

c) Hybrid blower door/airflow measuring device subtraction[78]

or

d) Duct pressurization test at referenced pressure standard by authority having jurisdiction.

[76] Duct leakage is measured using a duct pressurization test through a calibrated fan or orifice. Duct registers are sealed, a fan is attached to one opening, the ducts are pressurized, and the amount of air flowing through the fan is quantified. A commonly known system is Duct Blaster®; there are several others as well.

[77] Total room supply CFMs and return CFMs compared with blower capability (e.g., airflow measuring device method: Commonly referred to as Flow Hood™, Shortridge or Balometer™, Alnor), as per procedures specified by ACCA, AABC, ASHRAE, NEBB and TABB.

[78] A calibrated fan measures whole-building positive or negative pressure on the building, then duct leakage is measured by placing an airflow capture hood over the grilles and registers.

5.1.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Documented field data recorded on start up sheet

or

b) Documented field data recorded on service records

and

c) Written job documentation or checklist in the installation file

5.2 AIRFLOW BALANCE

The contractor shall ensure room airflows meet the design/application requirements.

5.2.1. REQUIREMENTS

The contractor shall ensure:

a) For NEW CONSTRUCTION or addition of new ducts to an existing structure (with interior doors closed AND open) –

For Residential Buildings: The individual room airflows are within the greater of ± 20%, or 25 CFM of the design/application requirements for the supply and return ducts.

For Commercial Buildings: The individual room airflows are within the greater of ± 10%, or 25 CFM of the design/application requirements for the supply and return ducts.

or

b) For EXISTING CONSTRUCTION without contractor modification of existing ductwork: No additional ACCA QI requirements apply.

or

c) For NEW OR EXISTING CONSTRUCTION the airflow balance is per local code or authority having jurisdiction.

NOTE ON AIRFLOW THROUGH INDOOR HEAT EXCHANGERS:
Per §4.1, airflow through the heat exchanger must be within the OEM's specified range for all furnace, fan coil, and air handler applications.

5.2.2 ACCEPTABLE PROCEDURES

The contractor shall test using one of the following acceptable devices for fulfilling the desired criteria:

a) Airflow measuring device (AMD)[79] used per specifications from the AMD manufacturer

or

b) Duct traverse with Pitot tube and manometer per procedures specified by ACCA, AABC, ASHRAE, NEBB, SMACNA or TABB

or

c) Measure the average airflow using an anemometer (hotwire or rotary) per specifications from the test equipment manufacturer.[80]

[79] Commonly referred to as Shortridge flow hood™ or Alnor Balometer™.

[80] The use of anemometers is acceptable if (1) grille "free areas" are known and if (2) the measurement tolerances for the instrument/device being used are considerable tighter than the airflow balance

5.2.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Documented field data recorded on start up sheet or test and balance form

or

b) Documented field data recorded on service records

and

c) Written job documentation or checklist in the installation file

5.3 HYDRONIC BALANCE

The contractor shall ensure water flows meet the design/application requirements.

5.3.1. REQUIREMENTS

The contractor shall ensure:

a) For NEW CONSTRUCTION, or addition of new piping to an existing HVAC system, the water flow to individual room or zone heat exchangers are within ± 10% of the design/application GPM requirements.

or

b) For EXISTING CONSTRUCTION without contractor modification of existing piping: No additional ACCA QI requirements apply.

or

c) For NEW OR EXISTING CONSTRUCTION the room/zone hydronic balance is per local code or authority having jurisdiction.

NOTE ON WATER FLOW THROUGH HEAT EXCHANGER:
Per §4.2, water flow through the heat exchanger must be within the OEM's specified range for all boilers, and water-to-water geothermal heat pump applications.

5.3.2 ACCEPTABLE PROCEDURES

The contractor shall use one of the following acceptable tests for fulfilling the desired criteria:

a) Manometer and probe used per instructions from the instrument manufacturer.

or

b) Ultrasonic/Doppler flow meter used per instructions from the instrument manufacturer.

or

c) Pressure gauge used per instructions from the instrument manufacturer

or

d) Procedures specified by OEM

5.3.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) A copy of documented field data recorded on start up sheet or test and balance form

or

tolerances. The grill "free area" is commonly known as the area-K (or Ak) and the values are provided by the grille/diffuser OEM.

b) Documented field data recorded on service records
and
c) Written job documentation or checklist in the installation file

6.0 SYSTEM DOCUMENTATION AND OWNER EDUCATION ASPECTS

This section focuses on providing owners with job documentation, operation instructions, and education to assist them in properly operating and maintaining their systems.

6.1 PROPER SYSTEM DOCUMENTATION TO THE OWNER

The contractor shall provide records pertaining to the HVAC system installation as well as the operation and maintenance to be performed.

6.1.1 REQUIREMENTS

The contractor shall ensure:

a) An installation file of required and relevant information is created and provided to the homeowner or the building owner/operator (or designated agent).
   i) Required documentation: Information detailed in the *Acceptable Documentation*[81] of each applicable section.
   and
   ii) Relevant documentation: additional information applicable to the HVAC activity undertaken.[82]

and
b) Copies of documents from §6.1.1.a and a record of the model and serial numbers of all equipment installed are maintained at the contractor's place of business.

6.1.2 ACCEPTABLE PROCEDURES

The contractor shall confirm that all the listed requirements are met.

6.1.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:
a) Written job documentation or checklist in the installation file
and
b) Signed documentation from the customer that the listed requirements were offered/met

[81] Examples of required acceptable documentation include: ventilation calculations (§3.1), load calculations (§3.2), OEM performance data (§3.3), AHRI certificates (§3.5), records of measurements (§4.1, §4.2, §4.3, §4.4, §4.5), documented field data (§4.6), written documentation of proper operation sequences (§4.7), duct leakage tests (§5.1), test and balance reports (§5.2, §5.3), and customer education (§6.2).
[82] Examples of relevant documentation include: permits, as-built drawings (including the type, size, and location of all underground heat geothermal heat exchange piping), survey data, equipment submittals, maintenance and operating instructions, and equipment/contractor warranties.

6.2 OWNER/OPERATOR EDUCATION

The contractor shall inform the customer on how to both operate and maintain the installed equipment and will promote system maintenance to aid in the continuing performance of the installed equipment.

6.2.1 REQUIREMENTS

The contractor shall ensure:

a) Customers are instructed on system operation of installed equipment
and

b) Customers are instructed on the maintenance requirements for the installed equipment
and

c) Customers are instructed on warranty procedures and responsibilities
and

d) Customers are provided with contact information for warranty, maintenance, and service requirements

6.2.2 ACCEPTABLE PROCEDURES

The contractor shall confirm that all the listed requirements are met.

6.2.3 ACCEPTABLE DOCUMENTATION

The contractor shall provide evidence of the following:

a) Written job documentation or checklist in the installation file
or

b) Signed documentation from the customer that the listed requirements were offered/met; including the date and names of the trainer and the building owner/operator (or designated agent) receiving the instruction.