High Efficiency Residential Gas Heating

Initiative Description

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1 Background

Space heating accounts for 41 percent of all residential energy use in the United States, of which, 52 percent of households use natural gas as their primary space heating fuel.[1] In the early 1990s, when CEE first analyzed the natural gas heating market, less than 20 percent of furnaces sold were high efficiency models. By 2007, the percentage of high efficiency shipments increased to 37 percent.[2] CEE has been unable to obtain shipment data by efficiency for boilers, but analysis of product availability indicates that there has been only a 5% increase in the number of high efficiency residential boilers available over the past few years.[3] To address this significant end use and the market barriers to increased efficiency, CEE launched the High Efficiency Residential Gas Heating Initiative in 1998. The purpose of this initiative is to a) provide market focus through the promotion of a common definition of high efficiency for residential gas heating equipment and b) build awareness of the benefits of efficient equipment and quality (energy efficient) installation. The CEE Board of Directors originally adopted this Initiative Description in 1997, which was updated most recently in 2010.

2 Initiative Goal and Objectives

The goal of the High Efficiency Residential Gas Heating Initiative is to increase the penetration and quality installation of high efficiency residential gas furnaces and boilers.

The initiative will achieve this goal when:

- High efficiency equipment is requested by consumers
- High efficiency equipment is promoted to consumers by contractors
- Quality installation is requested by customers
- Quality installation is provided by contractors

The initiative's primary objectives are to:

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[1] U.S. Department of Energy, Energy Information Agency, 2005. Residential Energy Consumption Survey.

[2] Release on Annual Shipments, Gas Appliance Manufacturers Association.

[3] Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment, Gas Appliance Manufacturers Association.

- Increase the percentage of sales of high efficiency equipment
- Reduce the cost of high efficiency equipment
- Increase the number of contractors who promote high efficiency equipment
- Increase consumer awareness of the components of a quality installation
- Increase the number of quality installations

3 Market Overview

3.1 Market Structure

Following the typical market channel, furnaces and boilers go from manufacturer to wholesale distributor to HVAC contractor to consumer. Alternative paths may include a retailer or a builder or bypass one of the above market actors. The bullets below describe the various market players.

- **Manufacturers:** While there are more than 40 gas furnace brand names, six manufacturers produce over 80 percent of equipment.[4] The top three manufacturers, by sales, of gas furnace equipment are Carrier, Goodman, and Lennox.[5] Three manufacturers produce the bulk of residential boilers: Slant/Fin Corporation, Burnham, and ECR International (as Dunkirk Radiator Corporation, Pennco Boilers, and Utica Boilers).[6]
- **Wholesale Distributors:** There are independent and manufacturer-owned distributors. Some manufacturers use independent wholesalers exclusively, some own all of their wholesale operation, and others use a combination of both.

[4] Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment, Air-Conditioning, Heating, and Refrigeration Institute.

[5] 29th Annual Portrait of the U.S. Appliance Industry, September 2006. Appliance Magazine.

[6] Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment, Air-Conditioning, Heating, and Refrigeration Institute. Last searched March 2009.

- **HVAC Contractors:** HVAC contractors are a key link in the sales chain because they have direct contact with the end users and have the opportunity to influence equipment purchase decisions.
- **Retailers:** Retailers include national mass merchandisers (buyer groups), 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 since most states require licenses for installation of gas equipment.
- **Builders/Developers:** Homebuilders and developers are also important players in the sale of furnace equipment since they sell equipment to customers as part of home purchases. They may make decisions about equipment efficiency levels without offering the homebuyer high efficiency options.

3.2 Market Barriers to Improved Efficiency

The key barriers to increasing market penetration of efficient, gas-fired heating equipment and achieving more quality installations are listed below.

- HVAC contractors often do not have the appropriate marketing tools and are not proficient in selling high efficiency equipment. Lowest bid quotes strongly drive the residential HVAC equipment sales industry. Contractors, however, have an opportunity to sell high efficiency equipment (which is often higher cost and higher profit margin) by educating customers about the life cycle benefits of that investment. The EPA has determined that the HVAC contractors often lack the training and tools to educate the consumer effectively and to promote the benefits and cost effectiveness of high efficiency equipment.
- Consumers are unaware of the benefits of investing in high efficiency equipment. The majority of heating equipment sales take place in the replacement market where consumers often need to replace equipment quickly. Consumers lack information to make informed decisions on equipment and rely on the contractor as an expert to guide them through the purchase. While there is an increased awareness of energy efficiency among consumers, the proliferation of “green” messages could cause confusion that energy efficiency programs could help to alleviate.
- Consumers are unaware of what constitutes a “quality installation” or which contractors provide quality services. There is lack of consistent or clear criteria for what constitutes a “quality installation” that will maximize system efficiency. Most consumers are unaware that installation can affect the operating efficiency of heating equipment. Even if consumers are aware of this fact, they do not know how to achieve a quality installation.
- Contractors have limited reasons to provide a quality installation. If consumers do not demand a quality installation, contractors are most likely to provide a low cost (quote competitive) installation. Other factors that limit the use of quality installation practices are: perceived high

first cost in a low bid industry; contractors not fully understanding key aspects of good installation; high turnover and easy entry into the industry; and skepticism or misunderstanding of some of methods (e.g., ACCA Manual J calculation).

- Split incentives – building owners versus tenants: Building owners lack the incentive to purchase higher priced, energy efficient equipment since they are typically not responsible for the energy bills for that equipment.
- Split incentives – builders versus homebuyers: Homebuilders often choose heating equipment that is low first cost. They do so to reduce the overall price of a house, increase profit margins, and spend money in areas more visible to consumers, such as kitchen or bath features.

3.3 Market Trends

The availability of high efficiency equipment has increased significantly since the initiative began. As of January 2009, 29 percent of all available gas furnace models qualified for the CEE fuel efficiency specification, up from just 12 percent of models in 1998 and 22 percent in 2002. Of these, 20 percent meet the CEE Tier 2 specification or higher.[7] Increased availability of efficient equipment certainly increases the likelihood that contractors will market these products and that consumers will ask for them. Despite this increased 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 product with additional costly features that may enhance quality or performance but not the core efficiency of the unit.

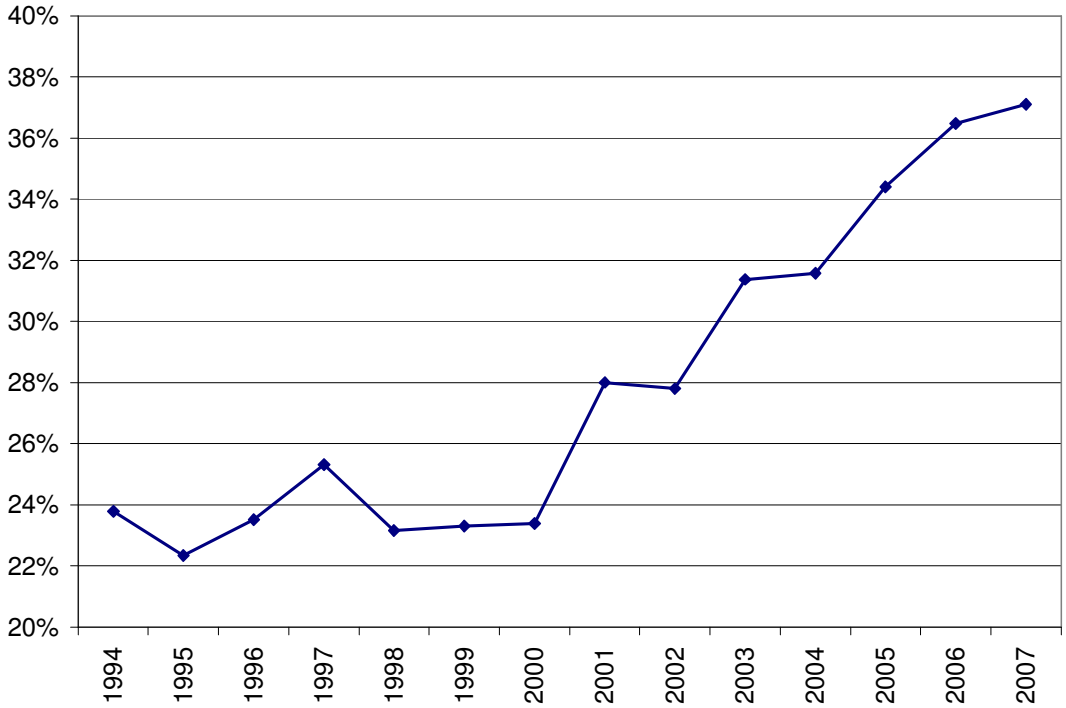
Since this initiative began, the penetration rate of high efficiency furnaces has increased 60 percent, from 23 percent of all U.S. shipments in 1998 to over 37 percent of shipments in 2007.[8] Penetration rates since 2005 have increased particularly rapidly between 2004 and 2007. Figure 1 illustrates the recent change in the penetration of condensing furnaces in the U.S. market.

Figure 1. Percentage of Furnace Shipments Above 90 percent AFUE.[9]

[7] Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment, Air-Conditioning Heating, and Refrigeration Institute.

[8] Release on Annual Shipments, Gas Appliance Manufacturers Association.

[9] Data courtesy of the Gas Appliance Manufacturers Association (www.gamanet.org)



These national averages, however, mask the true impact that efficiency programs can have. For example, in some regions of North America where condensing furnaces have been widely promoted by efficiency programs and the heating season is long, penetration rates are significantly higher: 74 percent in the state of Iowa and approximately 54 percent in Ontario, Canada.[10,11] The national averages are kept low by states with little heating demand (where condensing furnaces may not yet be cost effective) or heating dominated states where there is little promotion or understanding of the benefits of high efficiency equipment. By leveraging the efforts of active programs with a consistent specification, the initiative aims to increase the penetration rate further in all markets.

Data for boilers are less readily available; however, model availability data can be a proxy for market penetration. In 1998, only four boiler manufacturers produced a total of 15 models of condensing boilers.[12] Since then, the number of manufacturers producing condensing boilers has increased to 20 in 2009.[13] Additionally, the number of available of high efficiency models has increased in recent years.

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[10] Midwest Residential Market Assessment and DSM Potential Study, March 2006. Midwest Energy Efficiency Alliance.

[11] Update of Market and Economic Analysis of Residential Gas Furnace Efficiency Levels in Canada, January 2006. Natural Resources Canada.

[12] Stanonik, Frank. 2008. "Condensing Boilers: A Key to Success". AHRI Trends, Fall/Winter 2008.

[13] Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment, Air-Conditioning, Heating, and Refrigeration Institute. Data from March 2009.

Table 1. Model Availability of High Efficiency Boilers

Level	2005		2009	
	# of Available Models[14]	% of Available Models	# of Available Models	% of Available Models
Total[15]	1,157	100%	1,095	100%
85 % AFUE	146	13%	262	24%
90 % AFUE	61	5%	153	14%

Based on this data, it is reasonable to assume that the number of shipments of high efficiency boilers has also increased. In addition to this being a smaller market than furnaces, it is clear that the market is heavily concentrated in the Northeast United States. Table 2 provides some insight on the overall market for boilers by region.

Table 2. Households with Boilers for Space Heating

Year	US Total[16]		Northeast		Midwest		South		West		Canada[17]	
	Amt	%	Amt	%	Amt	%	Amt	%	Amt	%	Amt	%
1993	8.7	9%	4.3	22%	2.9	12%	0.7	2%	0.8	4%	n/a	n/a
1997	7.3	7%	3.6	18%	2.5	10%	0.5	1%	0.7	3%	n/a	n/a
2001	7.9	7%	4.3	21%	2.3	9%	0.6	2%	0.7	3%	n/a	n/a
2003	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.2	11%

[14] Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment, Air-Conditioning, Heating, and Refrigeration Institute (f/k/a GAMA).

[15] This represents the total number of "approved" models of gas-fired hot water boilers available based on an October 2009 search.

[16] 2005 Residential Energy Consumption Survey, US DOE Energy Information Agency (U.S. statistics only).

[17] 2003 Survey of Household Energy Use, Natural Resources Canada (Canadian statistics only).

2005	8.2	7%	4.9	24%	1.6	6%	1.0	2%	0.6	3%	n/a	n/a

"Amt" is the total number of households with "steam or hot water systems" (in millions)

"%" is percentage of total households with space heating that have "steam or hot water systems"

4 Energy Savings Potential

The following three subsections detail the technology behind high efficiency furnaces and boilers. They also quantify the potential energy and monetary savings from both types of equipment as well as a proper installation that ensures efficient operation.

4.1 Furnaces

Furnaces are the most commonly used residential heating system in the U.S., with 41 percent of households relying on natural gas furnaces for primary space heating.[18] The average equipment life is 15 years, meaning that savings from efficiency persist for quite some time after installation.[19]

Standard efficiency furnace technology uses a natural draft venting process to eliminate the combustion products through a vertical vent such as a chimney. This is possible due to the buoyancy of the hot gas combustion products. The open vent allows a substantial amount of heat to be lost through the chimney, contributing to the fairly low efficiency. High efficiency equipment removes extra heat from the combustion materials, recovering an estimated 10 to 20 percent of the heat energy from flue gases formed during the combustion of the natural gas. As the heat is removed, the water vapor in the flue gases condenses, yielding a corrosive condensate that requires a corrosive resistant drainage system. In addition to the drain, condensing furnaces, as they are known, typically incorporate a fan to power vent the exhaust. The drain and venting are the primary sources of higher equipment and installation costs.

The minimum efficiency standard for furnaces is 78 percent Annual Fuel Utilization Efficiency (AFUE).[20] The standard is set by the Department of Energy under the National Appliance Energy Conservation Act of 1987

[18] 2005 Residential Energy Consumption Survey, US DOE Energy Information Agency.

[19] 29th Annual Portrait of the U.S. Appliance Industry, September 2006. Appliance Magazine

[20] AFUE is the efficiency with which fuel-fired heating appliances convert energy in the fuel to heat in the house.

(NAECA) and went into effect January 1, 1992. Effective November 19, 2015, the new minimum efficiency standard for non-weatherized gas residential furnaces will be 80 percent AFUE.[21] Condensing furnaces have an AFUE of at least 90 percent. Currently, there are products manufactured with efficiencies of more than 96 percent AFUE.[22]

The annual energy savings for condensing (90 percent AFUE) gas-fired furnaces are 15 percent when compared to equipment meeting the NAECA minimum standard. Using a more conservative energy savings factor of 12 percent (based on replacement of the most commonly sold 80 percent AFUE furnace), the energy saving potential remains significant. Increasing the penetration of high efficiency furnaces from 24 percent to 60 percent, using 12 percent savings, would save approximately 9.35 million cubic feet of natural gas annually within the United States, or enough gas to supply approximately 140,000 residences with gas heating for one year.

The EPA has calculated that the average new high efficiency furnace can save an average of almost $300 in annual operating costs, resulting in approximately $3,600 in energy bill savings and $3,300 in total savings over the life of the equipment.[23] This analysis assumes a cost of $320 for the upgrade from standard to high efficiency gas fired furnace.

Estimates of electric savings for a furnace meeting the CEE specification for electrical efficiency indicate that on average these units 500 kWh during the heating season and 200 kWh during the cooling season if the central air conditioning system uses the same air handler.[24] These estimates are for the average U.S. household; actual savings depend on many factors, including climate, equipment sizing, and duct pressure. Savings analyses should acknowledge the slight increase in gas used in systems with efficient motors that is necessary to make up for lost heat generated from an inefficient motor.

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[21] July 28, 2008 Federal Register, Part II U.S. Department of Energy, Vol. 73, No. 145.

[22] Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment, Air-Conditioning Heating, and Refrigeration Institute.

[23] US EPA ENERGY STAR® Web site, Furnace Savings Calculator, www.energystar.gov. Assumed lifetime is 18 years and estimates are based on average percent of regional load.

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

4.2 Boilers

Boilers represent a smaller percentage of national heating equipment than furnaces. As indicated in Table 2 above, 7 percent of U.S. households and 11 percent of Canadian households rely on natural gas boilers for primary space heating. This national average, however, belies the regional variations and potential due to long equipment life. In the Northeast census region, approximately 24 percent of households have boilers.

The federal NAECA standard for boiler efficiency is 80 percent AFUE for gas-fired water boilers and 78 percent AFUE for gas fired steam boilers. Effective September 1, 2012, the new federal minimum standards will increase to 82 percent AFUE and 80 percent AFUE for hot water and steam boilers, respectively. This standard also requires that the design for hot water systems incorporate an automatic means for adjusting water temperature.[25] Most boilers are made with cast iron heat exchangers and have efficiencies between 80 and 82 percent AFUE. The most efficient boilers, like furnaces, use a technology that removes additional heat from the flue gases and condenses hot water vapor from those gases, which increases the installation cost of these units. Condensing boiler efficiency begins at 90 percent AFUE with units available with efficiencies up to 96 percent AFUE.[26]

Energy efficient boilers (85 percent AFUE) provide 6 percent annual energy savings compared to the minimally compliant unit. EPA estimates that, on average, an efficient boiler can save approximately $250 in annual energy costs compared to a standard efficiency boiler. An efficient upgrade over a standard boiler would save an estimated $3,200 in energy bills and $2,300 in total savings over the equipment's life.[27] This assumes a cost of $900 for moving from a standard efficiency to a high efficiency boiler.

The upgrade to a condensing boiler (90 percent AFUE) adds additional equipment and installation costs. The additional equipment costs result from increased costs of materials necessary to deal with the corrosive nature of the condensation. Additionally, there are increased installation costs due to the need to ensure proper disposal of the condensate. The cost of moving from a standard efficiency to condensing unit varies widely across North America, with estimates ranging from $900 to $1800. On average, a condensing boiler

[25] July 28, 2008 Federal Register, Part II U.S. Department of Energy, Vol. 73, No. 145.

[26] Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment, Air-Conditioning, Heating, and Refrigeration Institute.

[27] US EPA ENERGY STAR Web site, Boiler Savings Calculator, www.energystar.gov. Assumed lifetime is 21 years and estimates are based on average percent of regional load.

can save approximately $300 in annual energy costs compared to a standard efficiency boiler. Due to the significant increase in equipment and installation costs, the payback for a condensing unit can range from approximately six to nine years.[28] It should be noted, however, that the average lifespan for boilers is 21 years, which allows ample opportunity for operating savings to accumulate and pay for any increased first cost.[29]

4.3 Equipment Installation

While high efficiency equipment can achieve moderate energy savings, poorly installed equipment can significantly reduce the overall system efficiency. ENERGY STAR® estimates that up to 30 percent of system efficiency can be lost through improper installation, including sizing, and maintenance.[30] Even high efficiency furnaces can have very low system operating efficiencies when non-insulated, leaky ducts are installed in unconditioned spaces. Furthermore, oversized equipment costs the consumer more up front and may operate less efficiently than a properly sized unit. Contractor errors in setting airflow rates can also yield a system that operates inefficiently and delivers less comfort to the consumer. A proper installation will yield a system that operates efficiently and safely and provides the highest possible level of comfort to the homeowner.

This initiative aims to increase the market's demand for quality installation. A customer's ability to identify contractors that provide quality services may also foster increased demand. To address this opportunity, in May 2007 CEE adopted the Air Conditioning Contractors of America (ACCA) Standard: HVAC Quality Installations Specification, which outlines energy efficient installation practices for residential and light commercial HVAC systems. The American National Standards Institute (ANSI) recognized this specification in March 2007.

This specification, as written, does not specifically cover installation aspects associated with higher efficiency gas-fired equipment, such as condensate drains and advanced venting. Currently, ACCA and CEE recommend following manufacturer instructions or local code when installing this higher efficiency equipment. CEE will

[28] Ibid. Paybacks are calculated based on estimated incremental costs of $900 to $1,800.

[29] 29th Annual Portrait of the U.S. Appliance Industry, September 2006. Appliance Magazine..

[30] Heat and Cool Efficiently, ENERGY STAR website. http://www.energystar.gov/index.cfm?c=heat_cool.pr_hvac. Accessed March 25, 2009.

continue to work with appropriate groups like ACCA and NATE (North American Technical Excellence) to address this market barrier of quality installation and contractor training.

5 Initiative Approach

The approach advocated by this initiative consists of identifying and encouraging the purchase of energy efficient, gas-fired furnaces and boilers. To achieve the savings described above and overcome the market barriers identified by CEE, the initiative consists of four major components: common equipment specifications and three awareness-building aspects.

5.1 Common Efficiency Specification

Widespread adoption of a common efficiency specification 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 the ASHRAE 103-1993, Methods of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers.

The original specifications of the initiative, adopted in 1998, addressed fuel efficiency and coincided with the ENERGY STAR performance criteria, requiring furnaces to have an AFUE of 90 percent or above and hot water boilers an AFUE of at least 85 percent. In 2002, to reflect the increased availability and penetration of high efficiency furnaces, CEE revised the fuel efficiency specification to add two additional tiers for furnaces, at 92 percent and 94 percent AFUE. The CEE fuel efficiency specification was again revised in 2009 to add an additional tier for hot water boilers at 90 percent AFUE.

In addition to developing advanced tiers, CEE added an optional specification for electricity use by gas furnaces in November 2003. Power use for air handling (moving the heated air through the ducts into the house) represents a large proportion of the electricity drawn by furnaces.[31] The optional air handling performance level specifies that the annual energy use must be less than or equal to 2 percent of the total energy used by the furnace. This specification applies only to furnaces that meet the Tier 1 fuel efficiency specification. There is no federal minimum for furnace electricity use. E_{AE} (Annual Electricity Use) and E_F

[31] Focus on Energy, October 2003. Electricity Use by New Furnaces.

(Annual Fuel Energy Use) are outputs of the U.S. Department of Energy test procedure for residential gas furnaces. Both E_{AE} and E_F are listed in the Air-Conditioning, Heating and Refrigeration Institute's (AHRI) *Consumer's Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment*. Tables 3 and 4 detail the current specifications.

Table 3. CEE Fuel Efficiency Specifications

Gas Furnaces	**Tier 1**	90 percent AFUE
	Tier 2	92 percent AFUE
	Tier 3	94 percent AFUE
Gas Boilers	**Tier 1**	85 percent AFUE
	Tier 2	90 percent AFUE

Table 4. CEE Air Handling (Electricity Use) Specification

Gas Furnaces with a minimum of 90% AFUE	$\frac{3.412*E_{AE}}{3.412*E_{AE} + 1000*E_F}$	$\leq 2.0\%$

5.2 Consumer Education and Awareness

Initiative implementers will provide a consumer awareness campaign on the benefits of choosing high efficiency residential heating equipment. The campaign will target both the replacement and new construction markets. This campaign may include the use of customer brochures, bill stuffers, fact sheets, or advertisements. Early in the initiative's operation, CEE provided copy points for the development of these products and provided publicity as appropriate. CEE will continue to support participants' activities when requested if resources are available.

5.3 Quality Installation Practices

When this initiative was first launched in 1998, there was no common definition used in programs for quality installation practices. CEE pledged to research quality installation definitions and practices and work with EPA to quantify potential energy saving measures. To address this opportunity, CEE adopted the ACCA Standard: HVAC Quality Installations Specification, which outlines energy efficient installation practices for residential and light commercial HVAC systems, in May 2007. This specification is a comprehensive document providing consistent guidelines that can be incorporated into an efficiency program with the goal of encouraging energy efficient installations. CEE continues to advance quality installations through partnerships with the ACCA, NATE, other industry groups, and the ENERGY STAR program.

5.4 Contractor Training

The replacement market is the largest market for furnaces and boilers. Contractors represent the primary market channel for the sale of this equipment. The HVAC contractor has significant influence on the consumer's decision about what heating equipment to purchase. Early on, the 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 gas heating equipment and the principles of selling and performing quality installations.

These contractor training opportunities should be based on the ACCA Quality Installation Specification and should refer contractors to manufacturers for additional guidance on advanced venting and condensate drains required by condensing boilers and furnaces.

6 Initiative Participation

As with all initiatives of CEE, participation in the High Efficiency Residential Gas Heating Initiative is voluntary. To be considered an initiative participant, the following are required:

- Incorporate at least one of the CEE fuel efficiency specifications for furnaces or boilers in an educational or incentive based program
- Undertake at least one of the three awareness-building aspects of the initiative

Promotion of the air handling specification is optional for initiative participation, though it is encouraged where cost effective for consumers.

7 CEE's Role in Initiative Promotion

Since 1998, CEE has supported members in their promotion of the initiative by encouraging adoption of the specification within voluntary programs, developing guidelines for quality installation, and assisting with awareness-building efforts. In 2003, CEE began investigating the availability of product information needed by initiative participants for developing product lists of equipment that met the specifications. Since 2005, CEE has developed, maintained, and distributed lists of furnaces and boilers that meet the fuel efficiency and electricity specifications of the initiative. CEE works closely with manufacturers and industry associations to make information about equipment efficiency available to members.