CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter details the market and technology assessment that the U.S. Department of Energy (DOE) has carried out in support of the preliminary analysis for energy conservation standards for residential furnace fans. It consists of two sections: the market assessment and the technology assessment. The goal of the market assessment is to develop a qualitative and quantitative characterization of the residential furnace fan industry and market structures, based on publicly available information and data and information submitted by manufacturers and other interested parties. The key result of the technology assessment is a preliminary list of technologies that can improve the efficiency of residential furnace fans.

Because furnace fans are a component used in central residential heating, ventilation and air-conditioning (HVAC) products, DOE gathered relevant market information for residential furnaces, modular blowers, and hydronic air handlers. The majority of furnace fans covered in this rulemaking are components of residential furnaces. In addition, data are more extensive and readily available for residential furnaces compared to the other HVAC products that use furnace fans covered in this rulemaking. As a result, DOE relied heavily on residential furnace information to assess the furnace fan market. Little market data is available for electric furnaces/modular blowers. AHRI does not include information regarding electric furnaces/modular blowers in either its furnaces or central air conditioner (CAC) products databases. DOE expects that shipments of hydronic air handlers are significantly fewer than for furnaces. In addition, there are no DOE energy conservation standards for hydronic air handlers. Consequently, little market data is available for these products as well.

3.1.1 Product Definitions and Scope of Coverage

EPCA gives DOE authority to consider and prescribe new energy conservation standards or energy use standards for electricity used for purposes of circulating air through duct work. (42 U.S.C. 6295(f)(4)(D)) Consequently, DOE tentatively defines "furnace fan" to mean any electrically-powered device used in residential central HVAC systems for the purposes of circulating air through ductwork. DOE considers a typical furnace fan as consisting of a fan motor and its controls, an impeller, and a housing, all of which are components of an HVAC product that includes additional components, such as the cabinet.

DOE recognizes that a significant number of products may fit its broad interpretation of the statutory language. Figure 3.1.1 shows the various combinations of HVAC products that are used to construct typical residential HVAC systems. The boxes outlined in red represent HVAC products that include a furnace fan according to DOE's interpretation of the statutory language.

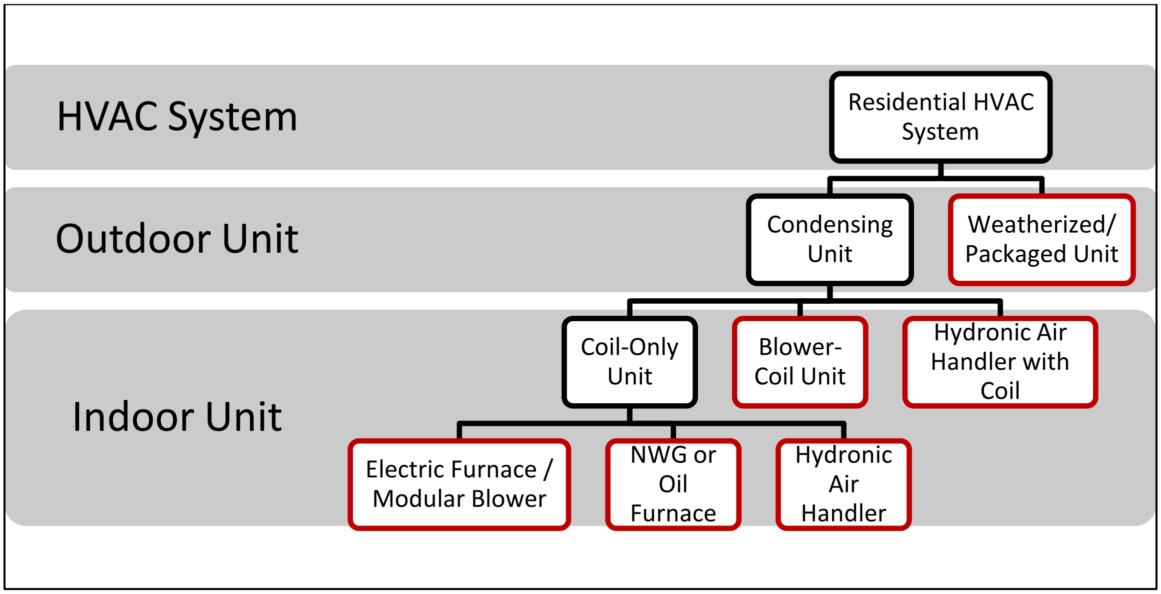

Figure 3.1.1: Residential HVAC System Component Combinations

DOE's preliminary approach is to address products for which DOE has sufficient data and information in this rulemaking, and DOE may consider other such products in a future rulemaking, as data become available. . For this rulemaking, DOE considered furnace fans used in products: (1) for which circulation fan energy consumption is not already covered in associated rulemakings; (2) for which sufficient data were available for its analyses; and (3) that could be tested using a similar test method (*i.e.*, setup and equipment, instruments and methods of measure, and range of operating conditions). . The following list describes the furnace fans which DOE plans to address in this rulemaking.

- Products addressed in this rulemaking: the furnace fans used in weatherized and non-weatherized gas furnaces, oil furnaces, electric furnaces, modular blowers, and hydronic air handlers
- Products not addressed in this rulemaking: other products that incorporate furnace fans, such as CAC blower-coil units, through-the-wall air handlers, SDHV air handlers, ERV, HRV, draft inducer fans, or exhaust fans

The products for which DOE is not considering standards in this rulemaking did not compare favorably to the included products based on the aforementioned criteria. DOE is not considering in this rulemaking fans used in any non-ducted products, such as whole-house ventilation systems without ductwork, CAC condensing unit fans, room fans, and furnace draft inducer fans because these products do not circulate air through ductwork. DOE did not prioritize furnace fans used in CAC blower-coil units, SDHV air handlers, and through-the-wall air handlers because the electrical energy consumption of these furnace fans is included in the

SEER and HSPF metrics that DOE uses to regulate residential CAC and heat pump products. Chapter 2 of this TSD includes a detailed discussion of how the SEER metric accounts for furnace fan electrical energy consumption as it relates to the scope of coverage of this rulemaking.

The HVAC products considered in this rulemaking can be broadly classified as either a furnace or central air conditioner (note that DOE's definition of furnace extends to hydronic air handlers). 77 FR 28677 Therefore, using the identified scope of coverage, the energy conservation standard will be broadly applicable to HVAC products with heating input capacities less than 225,000 Btu per hour and cooling capacities less than 65,000 Btu/h. These specifications are consistent with the DOE definitions for residential "furnace" and "central air conditioner" (10 CFR 430.2).

Figure 3.1.2 depicts the market share by shipments of HVAC products that include furnace fans. The slices outlined in black represent products that are not addressed in this rulemaking. The provisional scope of coverage of this preliminary analysis includes 63% of HVAC products that include furnace fans.

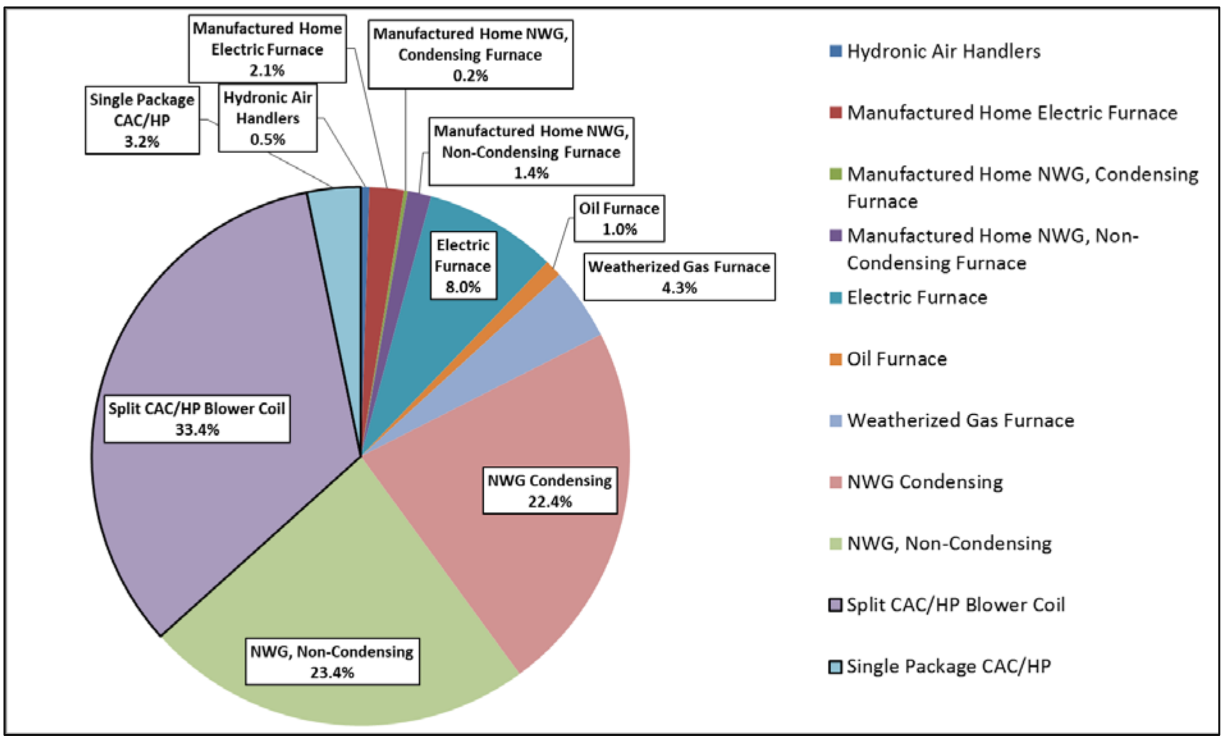

Figure 3.1.2: Market Share of Products Containing Furnace Fans (AHRI) [1]

According to Residential Energy Consumption Survey 2009 (RECS 2009) data, 61.6% (70 million) of U.S. homes have central warm-air furnaces.[2] Similar statistics are not available for modular blowers or hydronic air handlers.[a] Electrical consumption attributable to residential furnace fans accounts for 0.40 quads/year in source energy, which is approximately 2 percent of total residential energy use.[3]

3.1.2 Product Classes

DOE categorized furnace fans into product classes and intends to formulate a separate energy conservation standard for each in this rulemaking. EPCA specifies the criteria for product class separation, which include: (1) the type of energy consumed; (2) capacity; or (3) other performance-related features, such as those that provide utility to the consumer or other features deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 U.S.C. 6295(q)) DOE identified nine key product classes and 12 additional product classes differentiated by application and internal structure. Key product classes are those representing most of the energy use associated with furnace fans. DOE directly analyzed the nine key product classes. The 12 additional product classes represent significantly fewer shipments and significantly less energy use. For the preliminary analysis, DOE grouped each non-key product class with a key product class to which it is closely related in application and internal structure (i.e. the primary criteria used to differentiate between product classes). DOE assigned the engineering results of each key product class to the non-key product classes with which it is grouped. Table 3.1.1 presents the 21 product classes and maps the additional product classes to the nine key product classes.

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[a] RECS 2009 provides data on the heating source but not the distribution system. For hydronic air handlers, the heat is provided either by a boiler or a water heater and distributed with the air handler. Modular blowers generally are paired with a separate heating product such as an electric duct heater, or they may be installed in systems that do not provide heat.

Table 3.1.1: Product Classes

Key Product Class	Additional Product Classes
Non-Weatherized, Non-Condensing Gas Furnace Fan (NWG-NC)	
Non-weatherized, Condensing Gas Furnace Fan (NWG-C)	
Weatherized Gas Furnace Fan (WG-NC)	Weatherized, Non-Condensing Oil Furnace Fan (WO-NC)
	Weatherized Electric Furnace/Modular Blower Fan (WEF/WMB)
	Manufactured Home Weatherized Gas Furnace Fan (MH-WG)
	Manufactured Home Weatherized Oil Furnace Fan (MH-WO)
	Manufactured Home Weatherized Electric Furnace/Modular Blower Fan (MH-WEF/WMB)
Non-weatherized Oil, Non-Condensing Furnace Fan (NWO-NC)	Non-Weatherized, Condensing Oil Furnace Fan (NWO-C)
	Manufactured Home Non-Weatherized Oil Furnace Fan (MH-NWO)
Non-weatherized Electric Furnace / Modular Blower Fan (NWEF/NWMB)	
Heat/Cool Hydronic Air Handler Fan (HAH-HC)	Heat-Only Hydronic Air Handler Fan (HAH-H)
	Hydronic Air Handler Fan with Coil (HAH-C)
	Manufactured Home Heat/Cool Hydronic Air Handler Fan (MH-HAH-HC)
	Manufactured Home Heat-Only Hydronic Air Handler Fan (MH-HAH-H)
	Manufactured Home Hydronic Air Handler Fan with Coil (MH-HAH-C)
Manufactured Home Non-Weatherized Gas, Non-Condensing Furnace Fan (MH-NWG-NC)	
Manufactured Home Non-Weatherized Gas, Condensing Furnace Fan (MH-NWG-C)	
Manufactured Home Electric Furnace/ Modular Blower Fan (MH-EF/MB)	

Each product class title includes descriptors that indicate the application and internal structure of its included products. Weatherized and non-weatherized are descriptors that indicate whether the HVAC product is installed outdoors or indoors, respectively. Weatherized products also include an internal evaporator coil, while non-weatherized products are not shipped with an evaporator coil but may be designed to be paired with one.

Condensing refers to the presence of a secondary, condensing heat exchanger in addition to the primary combustion heat exchanger in certain furnaces. The presence of a secondary heat exchanger increases internal static pressure. As a result, DOE expects that furnace fans used in condensing units will consume more electrical energy than similar, non-condensing units.

Manufactured home products meet certain design requirements that allow them to be installed in manufactured homes. They require direct venting and are usually subject to more stringent space constraints. As a result, DOE expects that furnace fans used in manufactured home products will consume a different amount of electric energy than furnace fans installed in similar HVAC products that are designed for site-built applications.

Descriptors like gas, oil, electric or hydronic indicate the type of fuel or working fluid that the HVAC product uses to produce heat, which determines the type and geometry of the primary heat exchanger used in the HVAC product. Hydronic products include parenthetical descriptors to indicate whether the product is designed to be used for both heating and cooling, or heat only, as well as whether the product includes an internal evaporator coil.

3.1.3 Test Procedures

Pursuant to EPCA, DOE must establish test procedures in order to allow for the development of energy conservation standards that will address the electrical consumption of furnace fan products. (42 U.S.C. 6295(o)(3)(A)) In the framework document, DOE sought comment on a number of furnace fan test procedure related issues primarily regarding selection of an appropriate reference standard and rating metric. DOE considered the feedback it received on the test procedure related issues in the development of the test procedure. A detailed discussion of these comments and DOE's responses is included in the furnace fan test procedure notice of proposed rulemaking (NOPR) that DOE published on May 15, 2012. 77 FR 28674 A summary of the proposed test procedure is provided in the paragraphs that follow. DOE based its preliminary analyses for furnace fans on this proposed test procedure.

In the test procedure NOPR, DOE proposed to incorporate by reference provisions from American National Standards Institute (ANSI)/Air Movement and Control Association International, Inc. (AMCA) 210-07 | ANSI/American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) 51-07, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating, hereinafter referred to as "ANSI/AMCA 210-07." The specific provisions DOE proposed to include from ANSI/AMCA 210-07 are definitions, test setup and equipment, test conditions, and procedures for measuring airflow and external static pressure. In addition to these provisions, DOE proposed provisions for measuring electrical energy consumption using an electrical power meter. DOE also proposed to specify methods for measuring standby mode and off mode energy consumption for hydronic air handlers that are identical to those of the DOE residential furnaces test procedure for these modes. (10 CFR part 430, subpart B, appendix N, section 8.0) In addition, DOE proposed calculations to derive the rating metric based on the measured values.

DOE proposed to establish a new metric, the fan efficiency rating (FER), as the furnace fan efficiency rating metric. FER is the estimated annual electrical consumption normalized by total annual operating hours and the airflow measured in the maximum airflow-control setting at a specified external static pressure (ESP). The estimate of annual electrical consumption is a weighted average of Watts measured separately for multiple airflow-control settings at different ESPs. These ESPs are determined by a reference system curve, which is developed using a specified airflow-control setting and ESP. This reference system curve is intended to represent typical ductwork systems used for circulation of air. DOE also proposed an integrated fan efficiency rating (IFER) for hydronic air handler units that integrates standby and off mode electrical consumption with active mode electrical consumption. DOE determined the reference system criteria specified in the test procedure NOPR through analysis of ductwork field data. 77 FR 28683 Figure 3.1.3 provides an example of the measured data that is collected to calculate FER and how the reference system curve is used to identify the operating points.

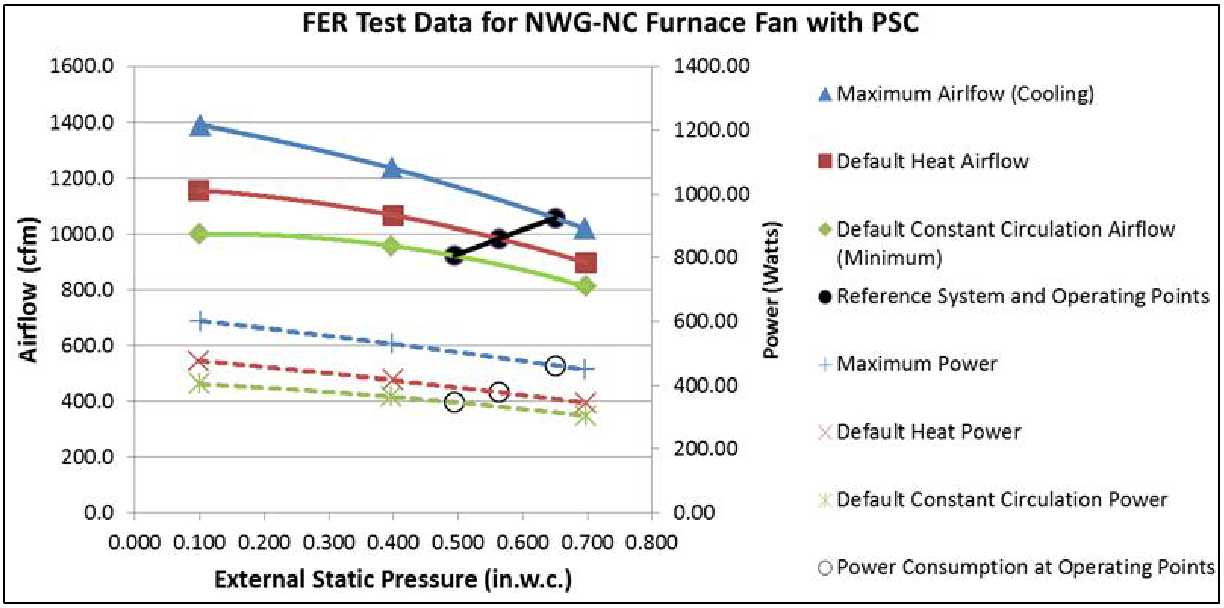

Figure 3.1.3: Example of Test Data Required to Derive FER for a 70KBtu/h, 3-ton, NWG-NC Furnace Fan with PSC Fan Motor

Table 3.1.2 presents the inputs that DOE proposes to use to calculate FER. These inputs include the power measured at the operating points identified in the example above and the proposed estimates for annual operating hours for each function, each of which is associated with an airflow-control setting (i.e. a furnace fan performs the cooling function in the maximum airflow-control setting. The example power measurements are multiplied by the estimated annual operating hours to calculate the estimated annual electrical energy consumption for each respective function. The sum of estimated annual consumption for each function represents the total estimated electrical energy consumption of the furnace fan.

Table 3.1.2: FER Inputs (Test Data from Above and Annual Operating Hour Assumptions)

Function	Power (W)	Annual Operating Hours	Annual Energy Consumption (Wh)
Cooling	450	640	288,000
Heating	375	830	311,250
Constant-Circulation	350	400	140,000
Standby	NA	NA	NA
Total		1,870	739,250

The equations that follow illustrate how DOE proposes that the inputs above be used to calculate the FER for the example furnace fan. As described previously, the estimated annual energy consumption is normalized by the total operating hours and airflow at the operating point in the maximum airflow-control setting.

$$FER = \frac{Annual\ Energy\ Consumption}{Airflow\ at\ Max\ Operating\ Point \times Total\ Annual\ Operating\ Hours} \times 1000$$

$$FER = \frac{739{,}250\ Wh}{1{,}050\ cfm \times 1{,}870\ hours} \times 1000 = \boldsymbol{376\ Watts\ per\ 1000\ cfm}$$

Figure 3.1.4 provides a comparison between example FER and IFER values. The example FER values represent a baseline unit and high-efficiency unit, respectively. The example IFER value represents a high-efficiency hydronic air handler (heat/cool) furnace fan. The contribution to the total rating value of electrical energy use for each function is shown.

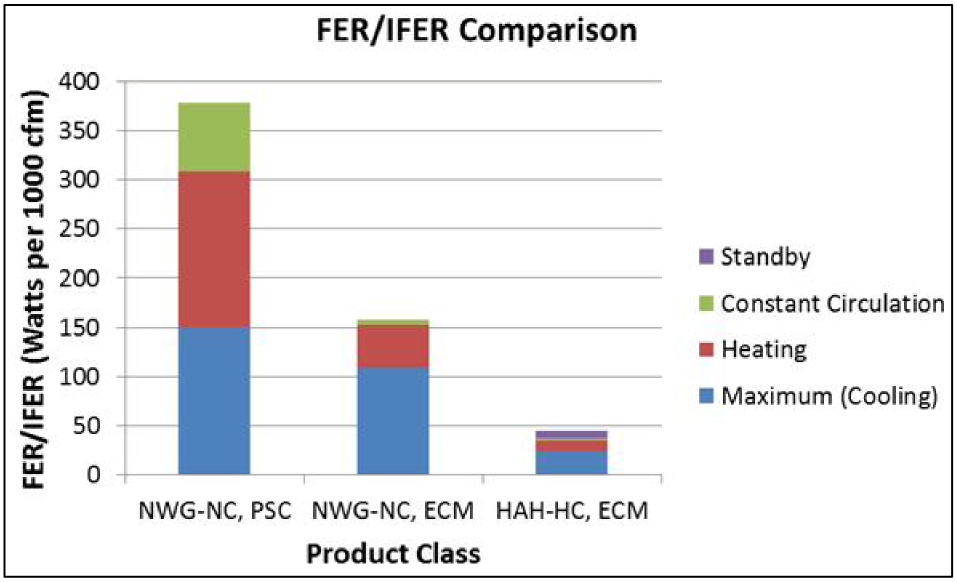

Figure 3.1.4: FER/IFER Comparison between Various 70KBtu/h, 3-ton HVAC Products

For comparison, Table 3.1.3 and the equations that follow provide details on how the example IFER value above is calculated.

Table 3.1.3: IFER Inputs

Function	Power (W)	Annual Operating Hours	Annual Energy Consumption (Wh)
Cooling	400	640	256,000
Heating	150	830	124,500
Constant-Circulation	80	400	32,000
Standby	11	6,890	75,790
Total		8,760	488,290

$$IFER = \frac{Annual\ Energy\ Consumption}{Airflow\ at\ Max\ Operating\ Point \times Total\ Annual\ Operating\ Hours} \times 1000$$

$$IFER = \frac{488,290\ Wh}{1{,}240\ cfm \times 8{,}760\ hours} \times 1000 = \mathbf{45\ Watts\ per\ 1000\ cfm}$$

As mentioned above, DOE used the proposed test procedure and rating metric variations (FER and IFER) to conduct the preliminary analysis.

3.2 MARKET ASSESSMENT

The following market assessment identifies manufacturer trade associations, domestic and international manufacturers of residential furnace fans and their corresponding market shares, and regulatory and non-regulatory programs to incentivize or mandate improved efficiency. The market assessment also describes the cost structure for the residential furnace fan industry and summarizes relevant market performance data.

3.2.1 Trade Associations

DOE identified the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), Air Movement and Control Association, Inc. (AMCA), Heating, Air-conditioning & Refrigeration Distributors International (HARDI), and Air Conditioning Contractors of America (ACCA) as the key trade groups that support, or have an interest in, the residential furnace fan industry.

AHRI is a national trade association of manufacturers of residential, commercial, and industrial appliances and equipment, components, and related products. AHRI was established in January of 2008 when the Air-Conditioning and Refrigeration Institute (ARI) merged with the Gas Appliance Manufacturers Association (GAMA). AHRI's member companies are responsible for over 90 percent of the residential and commercial air conditioning and space heating equipment sold in North America.[4] AHRI develops and publishes technical standards for residential and commercial equipment using rating criteria and procedures for measuring and certifying equipment performance. AHRI also participates in developing U.S. and international standards. AHRI administers the GAMA Certification program that tests and certifies the performance of gas- and oil-fired central furnaces that use single-phase electric current or DC and that have a heat input rate of less than 225,000 Btu/h. AHRI maintains the AHRI Directory of Certified Product Performance that lists all products that have been certified by the AHRI. AHRI also administers the ARI Performance Certified program that tests and certifies the performance of central air conditioners and heat pumps, as well as many other products manufactured by AHRI members. AHRI maintains the AHRI Directory of Certified Product Performance that lists all products that have been certified by the AHRI.[b] AHRI maintains certified performance directories for both air conditioners and heat pumps rated below 65,000 Btu/h. The AHRI directories subdivide these products based upon certain defining characteristics, such as single package or split system and coil only or coil and blower combinations.

AMCA is a not-for-profit international association of the world's manufacturers of related air system equipment - primarily, but not limited to: fans, louvers, dampers, air curtains, airflow measurement stations, acoustic attenuators, and other air system components for the industrial, commercial and residential markets. AMCA publications and standards are developed when sufficient interest has been expressed by AMCA members. The proposed DOE test procedure uses AMCA 210-2007 as a reference standard. [5]

[b] http://www.ahridirectory.org/ahridirectory/pages/home.aspx

HARDI is an international trade organization that represents over 450 wholesale companies in the HVAC industry, including 17 international companies, plus over 300 manufacturing associates and nearly 140 manufacturer representatives. HARDI estimates that its members represent 80 percent of the dollar value of the HVACR products sold through distribution. In 2003, the organization was formed from the consolidation of the North American Heating, Refrigeration & Air Conditioning Wholesalers (NHRAW) and Air-conditioning & Refrigeration Wholesalers International (ARWI).[6]

ACCA is a nationwide trade organization that represents over 4,000 air conditioning contractors. ACCA supports the HVACR industry by bringing contractors together and providing technical, legal, and marketing resources. ACCA is "the only nationwide organization of, by and for the small businesses that design, install and maintain indoor environmental systems."[7]

3.2.2 Manufacturers and Market Share

DOE considers the manufacturer of the HVAC product in which the furnace fan is used to be the furnace fan manufacturer. DOE is aware that HVAC product manufacturers purchase many of the components in the furnace fan assembly, such as the motor and impeller, from separate component manufacturers. However, the HVAC product manufacturer determines the design requirements, selects the purchased components based on these requirements, and performs the final assembly and integration of the fan assembly into the HVAC product. For these reasons, DOE considers the HVAC product manufacturer to be the furnace fan manufacturer. DOE examined its database of residential furnaces, the AHRI directories for residential CAC and heat pumps, HVAC product manufacturers' websites, and product catalogs to identify HVAC product manufacturers. All manufacturers listed in DOE's database for residential furnaces and CAC and heat pumps are shown in Table 3.2.1. DOE is aware that some manufacturers included in this table also manufacture hydronic air handlers. However, DOE was unable to find a central source of information to identify and create an exhaustive list of hydronic air handler manufacturers. HVAC product manufacturers may offer multiple brand names. DOE identified more than 50 brands under which HVAC products are manufactured and marketed.

Table 3.2.1: Manufacturers Whose Products are Included in DOE's Residential Furnaces and CAC/Heat Pumps Databases*

Manufacturer	Parent Company (if applicable)	NWG**	WG**	Oil	MH-NWG**	CAC & Heat Pumps	Hydronic
Aaon, Inc.	N/A		X			X	
Adams Manufacturing Company***	N/A			X			
Aerosys***	N/A					X	
Aire-Flo	N/A					X	
Airquest	N/A					X	
Airwell-Fedders North America, Inc.	Elco Holdings Ltd.	X				X	
Bard Manufacturing Company***	N/A		X	X		X	
Beutler Corporation	N/A					X	
Boyertown Furnace Company***	N/A			X			
Broan	N/A					X	
Carrier Corporation	United Technologies Corporation	X	X	X	X	X	
Cold Point Corp.	N/A					X	
Crown Boiler Company	Burnham Holdings, Inc.	X		X			
Dayton Electric Manufacturing Company	WW Grainger, Inc.					X	
Eair LLC***	N/A					X	
Ecotemp	N/A					X	
ECR International ***	N/A	X		X			
EFM Sales Company***	General Machine Corporation			X			
Espitech, LLC***	N/A					X	
First Co.	N/A						X
Friedrich Air Conditioning Co.	US Natural Resources, Inc.					X	
Fujitsu General America, Inc.	Fujitsu General Group					X	
GD Midea Commercial Air-Conditioning Equipment Co,, Ltd.	N/A					X	
Goodman Manufacturing Company	Goodman Global Group, Inc.	X	X			X	X

Manufacturer	Parent Company (if applicable)	NWG**	WG**	Oil	MH-NWG**	CAC & Heat Pumps	Hydronic
Grandaire	N/A					X	
H.E.P. Materials Corp. ***	AllStyle Coil Company, L.P.						X
Haier America	Haier Group Company	X				X	
Heat Controller, Inc. ***	N/A	X				X	X
Intertherm	N/A					X	
Kerr Energy Systems	Granby Industries Limited Partnership			X			
Lennox Industries, Inc.	Lennox International, Inc.	X	X	X		X	X
LG Electronics, Inc.	N/A					X	
Mammoth, Inc.	Thomas H. Lee Partners, LP					X	
McQuay International	Daikin Industries, Ltd.					X	
Mitsubishi Electric and Electronics USA, Inc.	N/A					X	
National Coil Company	N/A					X	
National Comfort Products	N/A	X				X	
Newmac Manufacturing, Inc.	William Newport Holdings Limited			X			
Nordyne, Inc.	Nortek, Inc.	X	X	X	X	X	
Quietside	N/A					X	
Rheem Manufacturing Company	Paloma Group	X	X	X		X	
Style Crest Products	N/A					X	
Summit Manufacturing, Inc.	N/A					X	
Texas Furnace, LLC***	AllStyle Coil Company, L.P.	X				X	X
Thermo Products, LLC	Burnham Holdings, Inc.	X		X	X	X	
Trane Inc.	Ingersoll Rand	X	X	X	X	X	
United Refrigeration Distributers, Inc.	N/A					X	
V-Aire	N/A					X	
York International Corporation	Johnson Controls, Inc.	X	X	X	X	X	
Weil-McLain	SPX Corporation	X					X

Manufacturer	Parent Company (if applicable)	NWG**	WG**	Oil	MH-NWG**	CAC & Heat Pumps	Hydronic
Whirlpool Home Cooling and Heating	Whirlpool Corporation	X	X			X	
Wolf Steel Ltd.	N/A	X					
Xenon	N/A					X	

* Airwell-Fedders North America, Inc., owned by Israeli parent company Elco Holdings Ltd., refers to Fedders, Eubank, and Airtemp products. Airxcel Holdings, Inc. is owned by private equity firm Bruckmann, Rosser, Sherrill & Co. L.L.C. and refers to subsidiaries Marvair and Suburban Manufacturing Company. Carrier Corporation is owned by United Technologies Corporation and refers to its subsidiaries: Carrier North America Home Comfort, Bryant Heating and Cooling Systems, International Comfort Products (ICP), Payne Heating and Cooling Systems, and Day & Night Heating and Cooling Products. Brands under ICP include: Heil, Tempstar, Arcoaire, Comfortmaker, Airquest, KeepRite, and Lincoln. ECR International includes Climate Energy, LLC and Oneida Royal. Goodman Manufacturing Company is a division of Goodman Global, Inc. and primarily markets its products under the Goodman and Amana brand names. Haier America is a subsidiary of the Haier Group Company. Heat Controller, Inc. manufactures and distributes the Comfort-Aire and Century brands. Lennox Industries, Inc., a subsidiary of Lennox International Inc., includes Lennox, Armstrong Air, AirEase, Concord, Ducane Air Conditioning and Heating, Allied Commercial, and Magic-Pak. Newmac Manufacturing, Inc. is a subsidiary of William Newport Holdings Limited. Nordyne, Inc. is a subsidiary of Nortek Incorporated and manufactures furnaces under the following brands: Broan, Elect-Aire, Frigidaire, Garrison, Gibson, Grandaire, Intertherm, Kelvinator, Maytag, Miller, Nutone, Philco, Tappan, Thermal Zone, and Westinghouse. Rheem Manufacturing Company refers to Rheem Manufacturing Company, Rheem Air Conditioning Division, Rheem Sales Company, Inc., and Ruud Air Conditioning Division. All Rheem and Ruud companies are subsidiaries of the Paloma Group. Sears, Roebuck and Company is a subsidiary of the Sears Holdings Corporation. Texas Furnace, LLC is a subsidiary of AllStyle Coil Company, L.P. Crown Boiler Company and Thermo-Products, LLC are owned by Burnham Holdings, Inc. Trane Inc. manufactures products under the American Standard and Trane brand names. Ingersoll Rand owns Trane. York International Corporation refers to the following brands: Coleman, Evcon, Fraser-Johnston, Guardian, Luxaire, and York. York International Corp. is owned by Johnson Controls. Weil-McLain, which includes Williamson-Thermoflo, is a division of SPX Corporation. Whirlpool Home Cooling and Heating is a division of the Whirlpool Corporation. Wolf Steel Ltd. also does business as Napoleon Fireplaces.

** NWG is non-weatherized gas furnaces; WG is weatherized gas furnaces; and MH-NWG is mobile home, non-weatherized gas furnaces

*** Small businesses, according to http://www.sba.gov/

The domestic gas furnace market is almost entirely held by seven U.S. manufacturers: Carrier, Goodman, Lennox, Trane,[c] Rheem, York, and Nordyne.[8] Figure 3.2.1 shows the 2008 market shares for residential furnace manufacturers as depicted in the September 2009 issue of *Appliance Magazine*.

[c] Prior to 2007, Trane was a subsidiary of American Standard Companies. On November 28, 2007 Trane separated from the two other branches of American Standard Companies. On June 5, 2008, Ingersoll Rand acquired Trane. For more information, visit www.trane.com/Corporate/About/history.asp.

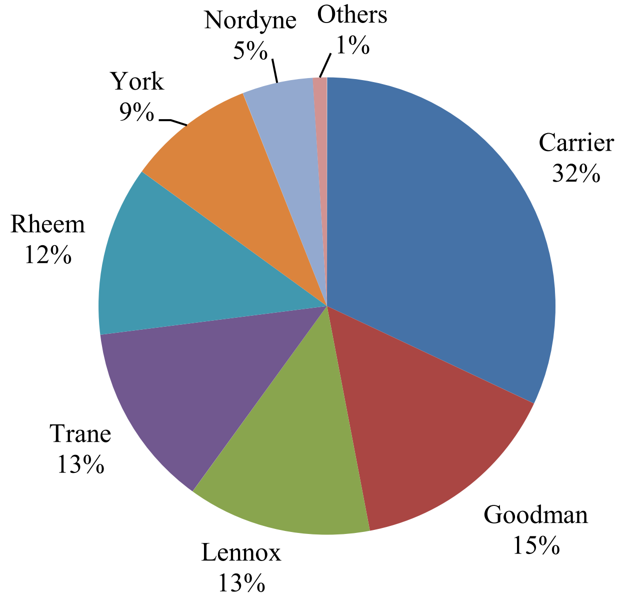

Figure 3.2.1: 2008 Market Shares for U.S. Manufacturers of Residential Gas Furnaces[9]

In contrast to the gas furnace market, the U.S. residential oil-fired furnace market is composed almost entirely of minor manufacturers. Minor manufacturers include Adams, Bard, Boyertown, Crown Boiler, ECR International, EFM, Kerr, and Newmac; major manufacturers include Thermo Pride and Lennox. Some of the major gas furnace manufacturers (including Carrier, Nordyne, Rheem, Trane, and York) also market oil-fired furnaces, although these furnaces are commonly rebranded units from another original equipment manufacturer (OEM). DOE estimated the market shares of oil-fired furnace manufacturers based on publicly available information and manufacturer feedback. Oil furnace manufacturers are shown in Table 3.2.1.

DOE examined AHRI's Directory of Certified Product Performance for residential central air conditioners to identify residential central air conditioner manufacturers that would use furnace fans in their products. Many of the previously identified furnace manufacturers fabricate central air conditioners as well. DOE identified 45 separate companies that manufacture and market air conditioner and coils. The manufacturers found in the AHRI Directories of Certified Product Performance for residential central air conditioners and heat pumps are listed in Table 3.2.1, along with their parent company in parentheses, if applicable.

Figure 3.2.2 displays the 2008 market shares for the residential central air conditioner market.

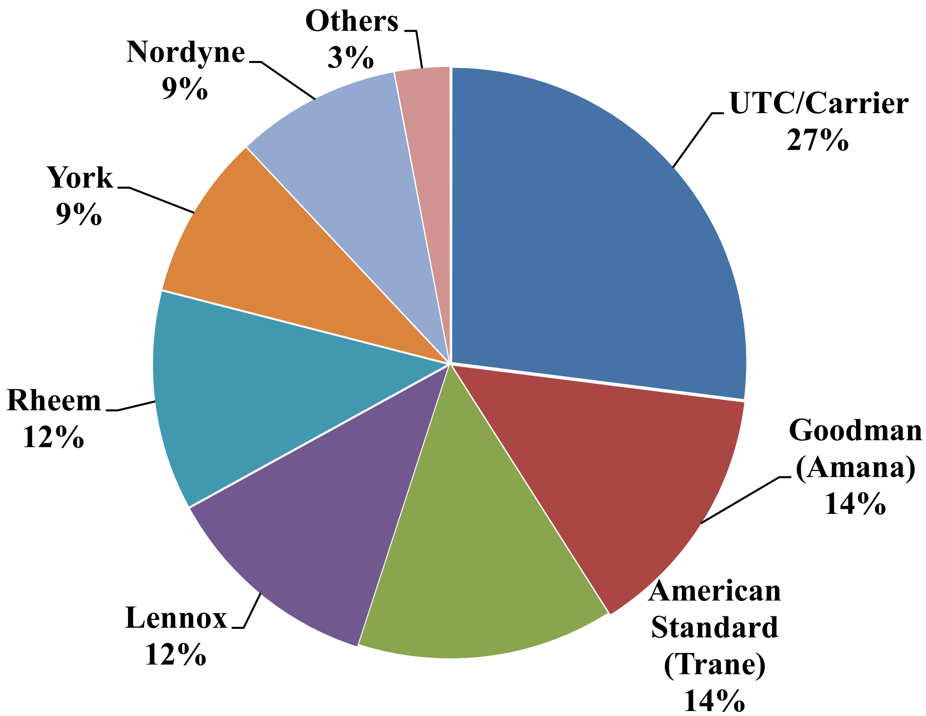

Figure 3.2.2: 2008 Market Shares for Unitary Air Conditioners[10]

Comparing Figure 3.2.1 to Figure 3.2.2, DOE recognizes that the seven largest residential gas furnace manufacturers control 97 percent of the central air conditioner market share (as of 2008). These seven manufacturers include Carrier, Goodman, Trane[d], Lennox, Rheem, York, and Nordyne.

Little market information is available for hydronic air handlers because they are an emerging product. DOE finds that the hydronic air handler market is segmented from the gas furnace and residential CAC markets, similar to oil furnaces. While some of the major manufacturers identified above offer hydronic air handler models, DOE expects that the majority of the market is composed almost entirely of minor manufacturers. Minor hydronic manufacturers include: First Company; H.E.P. Materials Corporation; Heat Controller Incorporated; Texas Furnace, LLC; and Weil-McLain. Of the seven major manufacturers of residential furnace and CAC and heat pump products, DOE is aware that Rheem, Goodman, and Lennox manufacture hydronic air handlers.

[d] Trane Inc. was acquired by American Standard Companies in 1984. On November 28, 2007 Trane separated from the two other branches of American Standard Companies. On June 5, 2008, Ingersoll Rand acquired Trane. For more information, visit www.trane.com/Corporate/About/history.asp.

3.2.2.1 Mergers and Acquisitions

A trend in the HVAC industry over the past decades has been the consolidation of major manufacturers. In the last ten years or so, the seven major manufacturers (*i.e.*, Goodman, Lennox, Carrier, York, Rheem, Nordyne, and Trane) have gone through various mergers and acquisitions, and have materialized as differentiated leaders in the HVAC industry. A brief summary of the recent history of each of the seven largest manufacturers is as follows:

- Goodman Global, Inc. was founded and purchased Janitrol in 1982. In 1997, Goodman acquired Amana, which was then sold to Maytag in 2001, and later acquired by Whirlpool when Whirlpool purchased Maytag in 2006.
- Lennox Industries is a subsidiary of Lennox International, Inc., a holding company that was created in 1984. Lennox International acquired Armstrong Air Conditioning Inc. in 1988. In 1999, Lennox International completed an Initial Public Offering and became a public company.[11] Around this time, Lennox also acquired Service Experts and other equipment service companies.
- Carrier has been a wholly-owned subsidiary of United Technologies Corporation since 1979. In 1999, Carrier Corporation acquired International Comfort Products (ICP). [12]
- York Unitary Products Group and York International are subsidiaries of Johnson Controls, Inc, which purchased York in 2005. [13]
- Rheem is a privately held firm that was acquired by Paloma Industries of Japan in 1987. Paloma Industries also acquired Rheem Australia (Solahart) in 2002. [14]
- Nordyne is a subsidiary of the privately held Nortek, Inc. [15]

3.2.2.2 Small Businesses

DOE realizes that small businesses may be disproportionately affected by the promulgation of new energy conservation standards for residential furnace fans. The Small Business Administration (SBA) lists small business size standards for industries as they are described in the North American Industry Classification System (NAICS). The size standard for an industry establishes the largest size that a for-profit entity can be while still qualifying as a small business for Federal Government programs. These size standards are generally expressed in terms of the average annual receipts or the average employment of a firm. Residential furnace fan manufacturing is classified as a subset under NAICS 333415, "Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing." The size standard is 750 employees or fewer for this NAICS code.

DOE has identified small business residential furnace fan manufacturers, including small business parent companies, if applicable in Table 3.2.1. DOE is aware of 11 small business manufacturers associated with the products anticipated to be affected by this rulemaking. These manufacturers are primarily associated with oil furnaces and hydronic air handlers.

3.2.3 Distribution Channels

Two types of distribution channels describe how most furnace fan products pass from the manufacturer to the consumer. The first distribution channel applies to furnace fan products installed in replacement markets. In the replacement distribution channel, the manufacturer generally sells the equipment to a wholesaler, who in turn sells it to a mechanical contractor, who in turn sells it and installs it for the consumer.[e] The second distribution channel applies to furnaces that are installed in new construction and, thus, includes an additional link in the chain—the general contractor. In the new construction distribution channel, the manufacturer sells the equipment to a wholesaler, who in turn sells it to a mechanical contractor, who in turn sells it to a general contractor.

Figure 3.2.3 illustrates the two main distribution channels for most residential furnaces.

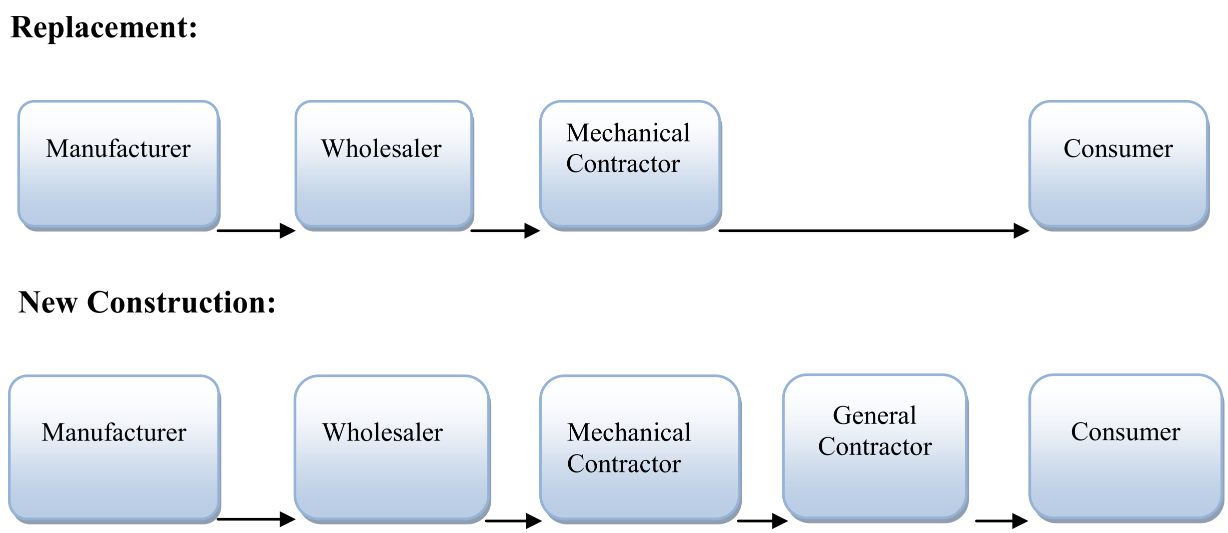

Figure 3.2.3: Distribution Channels for Residential Furnaces

The new construction market tends to be a low-cost, low-efficiency market, as the decision-makers are not the beneficiary of the system installed.

After installation, mechanical contractors typically perform additional lifecycle service on the system, including inspection, maintenance, and repair.

Manufactured home gas furnaces are sold as part of manufactured homes, so these furnaces have a specific distribution chain when purchased for the new construction market. The furnace manufacturer sells to the maker of the manufactured home, who installs the equipment in

[e] One major manufacturer uses one-step distribution (manufacturer to contractor) and is the only known exception. Several large retailers are trying to replace the wholesalers in the distribution chain, but most experts do not expect the trend to change the distribution chain significantly in the near term.

the home. The manufactured home manufacturer sells the home to a contractor, who in turns sells it to a homebuyer and provides installation services. The equipment manufacturer markup for manufactured home gas furnaces is identical to the manufacturer markup for other furnaces. For manufactured home furnaces purchased for the replacement market, the distribution channel should be the same as the replacement distribution channel for non-weatherized gas furnaces.

3.2.4 Regulatory Programs

The following section details current regulatory programs mandating energy conservation standards for residential furnace fans. Section 3.2.4.1 discusses other current Federal energy conservation standards that affect furnace fan products. Section 3.2.4.2 reviews standards in Canada that may impact the companies servicing the North American market.

3.2.4.1 Other Federal Energy Conservation Standards Affecting Furnace Fan Products

There are currently no Federal energy conservation standards for residential furnace fans, i.e. standards that specifically regulate energy use for circulating air through ductwork. However, there are Federal energy conservation standards for other functions of the HVAC products that use furnace fans. Part A of Title III of EPCA addresses the energy conservation standards for consumer products other than automobiles, which include residential furnaces and residential central air conditioners and heat pumps. (42 U.S.C. 6291-6309) Federal energy conservation standards for residential furnaces are based on the annual fuel utilization efficiency (AFUE) metric, which measures the efficiency of the delivery of heat, but does not account for the electrical energy consumption of the furnace fans used in furnaces. Consequently, the electrical energy consumption of furnace fans used in furnaces is not subject to the current DOE standard for furnaces. (10 CFR part 430, subpart B, Appendix N) Federal energy conservation standards for CAC and heat pump products are based on the seasonal energy efficiency ratio (SEER) and heating seasonal performance factor (HSPF). Both of these metrics account for the electrical consumption of the furnace fan used in CAC products, some of which are included in the provisional scope of coverage of this rulemaking (modular blowers and weatherized furnaces). (10 CFR part 430, subpart B, Appendix M) Chapter 2 of this TSD includes a detailed discussion of how the SEER metric accounts for furnace fan electrical energy consumption as it relates to the scope of coverage of this rulemaking.

3.2.4.2 Canadian Energy Conservation Standards

In June 2010, the Office of Energy Efficiency (OEE) of Natural Resources Canada (NRCan) published a bulletin to announce that it would be proposing new electricity reporting requirements for air handlers used in central heating and cooling systems that are imported or shipped across provincial boundaries for sale or lease in Canada. NRCan proposed to base the new requirements on the test procedure and rating metric specified in Canadian Standard Association (CSA) C823-11 - Performance of air handlers in residential space conditioning systems. At the time of the June 2010 bulletin CSA C823 was still in development, but has since been finalized (2011). In the bulletin, NRCan identified HVAC products that would be subject to the proposed regulation: gas and oil furnaces, air handlers used in geothermal heat pumps and air-source heat pumps, and combination space and water heating (combo) air handlers.[f] NRCan announced in a more recent November 2011 bulletin that it intends initially to extend the proposed new electricity reporting requirements to air handlers used in residential gas furnaces only. NRCan added that it intends to expand the requirements to air handlers used in other heating and cooling systems in the future.[g]

3.2.5 Non-Regulatory Programs

DOE identified non-regulatory programs aimed at improving the energy efficiency of residential furnace fans. One such program is based on voluntary efficiency targets: the ENERGY STAR program. In addition, DOE identified rebate programs and Federal and State tax credits for residential purchasers of higher-efficiency central air conditioners and heat pumps, and reviewed Federal procurement specifications for these products as well.

3.2.5.1 ENERGY STAR

ENERGY STAR is a voluntary labeling program conducted by the U.S. Environmental Protection Agency (EPA) and DOE that identifies and promotes energy-efficient products. To qualify, a product must usually exceed federal minimum standards by a specified amount, or if no federal standard exists, it must meet minimum efficiency levels set by the program and/or exhibit selected energy saving features. ENERGY STAR creates minimum energy efficiency specifications for various products, including residential furnace fans used in residential furnaces and split system and single package air conditioners and heat pumps.

ENERGY STAR originally set specifications for residential gas and oil furnaces in 1995. ENERGY STAR specifications for furnaces did not include provisions for the electrical consumption of the furnace fan until the most recent revisions, Versions 3.0 and 4.0. In versions 3.0 and 4.0, the furnace fan electrical consumption must account for less than 2% of the total energy consumption (electrical and fuel) of the furnace. Version 3.0 took effect on February 1, 2012 and Version 4.0 will take effect on February 1, 2013.[h] Furnace fan energy consumption for ENERGY STAR compliance is based on ENERGY STAR's "Interim Approach for Determining Furnace Fan Energy Use." This approach includes calculations based on measurements taken in accordance with ANSI/ASHRAE Standard 103–1993, which is incorporated by reference in the DOE furnace and boiler test procedure. (10 CFR part 430, subpart B, appendix N) ANSI/ASHRAE Standard 103–1993 specifies a steady state measurement of fan electrical consumption at an airflow at which a specified temperature rise and minimum ESP are achieved. The ESP specified by ENERGY STAR (from 0.18 in.w.c. to 0.33 in.w.c. in heating mode depending on input capacity) differs from the ESP proposed in the DOE furnace fan test procedure NOPR (0.3 in.w.c. to 0.65 in.w.c. in cooling mode depending on product application

[f] The June 2010 NRCan bulletin regarding proposed new electricity reporting requirements for air handlers used in central heating and cooling systems is accessible at the following website: http://oee.nrcan.gc.ca/regulations/bulletins/14551
[g] The November 2011 NRCan bulletin regarding proposed new electricity reporting requirements for air handlers used in central heating and cooling systems is accessible at the following website: http://oee.nrcan.gc.ca/regulations/bulletins/17839#Air_Handlers

and internal structure). Another important distinction between ENERGY STAR furnace fan specifications and the proposed DOE test procedure is that the "e" metric used to determine ENERGY STAR compliance is a function of Eae, which includes the electrical consumption of other furnace components besides the circulation fan (e.g. the inducer fan and gas valve).

ENERGY STAR originally set specifications for central air conditioners and heat pumps in 1995, followed by revisions in 2002, 2006, and 2009. The current (2009) ENERGY STAR levels for CAC and heat pump products are shown in Table 3.2.2.

Table 3.2.2: ENERGY STAR Specifications for Central Air Conditioner Products (2009)

Product	ENERGY STAR Specification
Central Air Conditioners	>=14.5 SEER/ >=12 EER* for split systems >=14 SEER/ >=11 EER* for single package equipment including gas/electric package units

* Energy efficiency ratio (EER) means the ratio of the average rate of space cooling delivered to the average rate of electrical energy consumed by the air conditioner or heat pump. These rate quantities must be determined from a single test or, if derived via interpolation, must be tied to a single set of operating conditions. EER is expressed in units of Btu/h/W. (10 CFR part 430, subpart B, appendix M)

3.2.5.2 Consumer Rebate Programs

In addition to the Federal and State tax credits available for purchasers of residential furnaces, central air conditioners, and heat pumps many States and local utility companies offer rebates for higher efficiency products, typically for existing home retrofits only. DOE maintains a database of such rebates, called the Database of State Incentives for Renewables & Efficiency (DSIRE), in addition to information on other state, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency. For more information on individual rebate programs, please visit the DSIRE website at www.dsireusa.org.

3.2.5.3 Federal Tax Credits

Until December 31, 2011, a Federal tax credit provided consumers a credit toward their Federal income tax if they purchased a furnace that uses a qualifying main circulating fan. This tax credit applied only to products being installed in existing homes, not new housing construction. Consumers that purchased a furnace with an "advanced main air circulating fan", which consumes less than 2% of the furnace's total energy consumption (electrical and fuel, based on the same measurement for the ENERGY STAR specification), were eligible to receive a $50 tax credit.[i] This tax credit is not available for 2012.

Manufacturers stated that residential tax credits, weatherization programs, utility rebates, and manufacturer consumer rebates all drive the consumer towards purchasing high efficiency

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[h] ENERGY STAR specifications for residential furnaces are accessible at the following link: http://www.energystar.gov/index.cfm?c=revisions.furnace_spec

[i] Details regarding the 2011 Federal tax credit for furnace fans is available at the following link: http://www.energystar.gov/index.cfm?c=tax_credits.tx_index

equipment. Manufacturers stated that they are selling more high efficiency products such as air handlers and ECM motors to meet these tax credits and rebate programs.

3.2.5.4 State Tax Credits

DOE also identified two states that have tax credits for furnace fans used in residential furnaces: Oregon and Kentucky.

Table 3.2.3: State Tax Credits for Residential Gas Furnaces[16]

State	Furnace Fan Requirement*	Available Tax Credit
Oregon	< 2% total furnace energy consumption	$350
Kentucky	< 2% total furnace energy consumption	$250

*Fraction of total furnace energy consumption calculated according to the DOE test procedure for furnaces codified in 10 CFR part 430, subpart B, Appendix N.

Oregon's Residential Energy Tax Credit (RETC) was created in 1977 to encourage the use of renewable resources in households. The Oregon legislature expanded the program to include high-efficiency heat pump systems, air conditioners, and water heaters (2001); furnaces and boilers (2002); and other equipment and measures.[17] Oregon's RETC now includes credits for advanced main air circulating fans.

Kentucky offers a 30 percent state income tax credit beginning in 2009 for taxpayers who install certain energy efficiency measures on their principal residence or residential rental property. These energy efficiency measures include "Qualified Energy Property Installation," which includes advanced main air circulating fans. Equipment must meet the efficiency guidelines specified in the Federal tax credit for residential energy property (see section 3.2.5.3). The total annual tax credit for this equipment may not exceed $250. These credits apply to equipment purchased in taxable years 2009 to 2015 and may be carried forward for one year.[18]

3.2.5.5 FEMP Procurement Guidelines

DOE reviewed the Federal Energy Management Program (FEMP) procurement guidelines for Federal government equipment purchasing. The mission of DOE's FEMP[j] is "to reduce the cost and environmental impact of the Federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at Federal sites."[19] FEMP helps Federal buyers identify and purchase energy-efficient equipment.

FEMP designates standards for residential gas furnaces purchased by the Federal government. The designated FEMP gas furnace standard level is the ENERGY STAR level, which includes requirements for the main circulating air fan (i.e., furnace fan).[20]

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[j] For more information, please visit www.eere.energy.gov/femp.

3.2.6 Industry Cost Structure

DOE is unaware of any publicly available industry-wide cost data specific to only manufacturers of residential furnace fans. DOE examined the North American Industry Classification System (NAICS) codes for small business sizes and determined that furnace fan manufacturing is classified as a subset under NAICS code 333415, Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing.[21] Therefore, DOE presents the data below as a broader industry proxy for the furnace fan industry, which, in combination with information gained in interviews, inform DOE's analysis of the industry cost structure.

DOE obtained the below data from the U.S. Census Bureau's Annual Survey of Manufacturers, Statistics for Industry Groups and Industries from 2002 to 2010.[22]

Table 3.2.4 presents the industry employment levels and earnings from 2002 to 2010. The statistics illustrate approximately a 23.3% decrease in production workers and a 23.0% percent decrease in overall number of employees from 2002 to 2010. This may be due to the decrease in shipments from 2005 to 2010, as seen in Figure 3.2.4.

Table 3.2.4: Employment and Earnings for the Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing

Industry Year	**Production Workers**	**All Employees**	**Annual Payroll *$1000s***
2002	80,400	108,252	3,815,129
2003	77,471	104,646	3,775,799
2004	73,559	99,669	3,707,969
2005	76,011	102,354	3,942,808
2006	74,909	98,097	4,019,813
2007	74,728	101,485	4,034,043
2008	70,787	96,610	4,020,656
2009	60,259	85,475	3,768,643
2010	61,668	83,361	3,778,633

Source: U.S. Census Bureau. *Annual Survey of Manufacturers*, 2002-2010.

Table 3.2.5 presents the costs of materials and industry payroll as a percentage of shipment value of the entire HVAC product from 2002 to 2010.[k] Note that the shipment values presented later in Table 3.2.7 are only attributable to the furnace fan components of the HVAC products (i.e., 10% of the total). From 2002 to 2010, the cost of materials as a percentage of shipment value has increased 6.5%, the cost of payroll for production workers as a percentage of shipment value has decreased 20.8%, and the cost of total payroll as a percentage of shipment value has decreased 15.2%.

[k] Includes just manufacturing cost, and not distribution.

Table 3.2.5: Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing Industry Material and Payroll Costs

Year	Cost of Materials *% of shipment value*	Cost of Payroll for Production Workers *% of shipment value*	Cost of Total Payroll *% of shipment value*
2002	49.36	9.83	15.85
2003	50.59	9.53	15.39
2004	51.81	8.99	14.57
2005	53.78	8.52	13.78
2006	53.17	8.87	13.80
2007	55.59	8.17	13.43
2008	54.83	8.13	13.50
2009	54.14	7.89	14.05
2010	52.59	7.79	13.44

Source: U.S. Census Bureau. *Annual Survey of Manufacturers*, 2002-2010.

3.2.7 Product Lifetime

The lifetime of residential furnace fans can vary greatly depending on how often the system is used, which is dependent upon the climate of the region, where the product is installed, and the personal preferences of the consumer. The lifetime is also dependent on how regularly the HVAC product is maintained and serviced. DOE expects that the lifetime of the furnace fan is equivalent to the lifetime of the HVAC product in which it is incorporated. DOE modeled furnace fan lifetime based on the distribution of furnace lifetimes developed for the recent HVAC rulemaking. DOE assumed that the lifetime is the same for fans at different efficiency levels. Generally, most sources estimate the lifetime of furnaces to be between 10 and 30 years. Appliance Magazine publishes an Annual Portrait of the U.S. Appliance Industry, [23] in which it estimates low, high, and average lifetimes for a range of home appliances, including gas and oil furnaces, based on input from appliance experts and many additional sources. Table 3.2.6 shows the average lifetime for each product class. Additional information about furnace lifetimes is contained in the Life-Cycle Cost and Payback Period Analysis chapter (Chapter 8) of this TSD.

Table 3.2.6: Average Lifetime for Furnace Fans

Product Class	Average *years*
Non-Weatherized Gas Furnace Fans (Condensing and Non-Condensing)	23.6
Manufactured Home Gas Furnace Fans (Condensing and Non-Condensing)	18.7
Oil-Fired Furnace Fans	26.5
Weatherized Gas Furnace Fans; Electric Furnace/Modular Blower Fans; Manufactured Home Electric Furnace/Modular Blower Fans; Hydronic Air Handlers	18.0

3.2.8 Historical Shipments and Efficiencies

3.2.8.1 Historical Shipments

Information about annual furnace fan shipment trends allows DOE to estimate the impacts of energy conservation standards on the residential furnace fan industry. DOE has examined unit shipments and value of shipments using publicly available data from the U.S. Census Bureau's Annual Survey of Manufacturers (ASM) and Current Industrial Reports (CIR) and estimates from AHRI and *Appliance Magazine*.

AHRI provides estimates of annual unit shipments for various appliances. The data, however, do not distinguish between shipments for new construction and replacement. Figure 3.2.4 presents annual shipments of furnaces from 1990 to 2011 reported by AHRI.[24]

From the data, it is apparent that gas furnaces comprise the vast majority of the residential furnace fan product industry. Shipments of gas furnaces grew steadily until 2005, then plunged in the subsequent four years to 30 percent below the unit shipments at the beginning of the decade. This trend mirrors that of new housing starts over the same time period, indicating that gas furnace shipments may be driven, in part, by the new construction market. Shipments of oil-fired furnaces remained relatively steady over the first part of the decade, before dropping by more than half between 2005 and 2009.

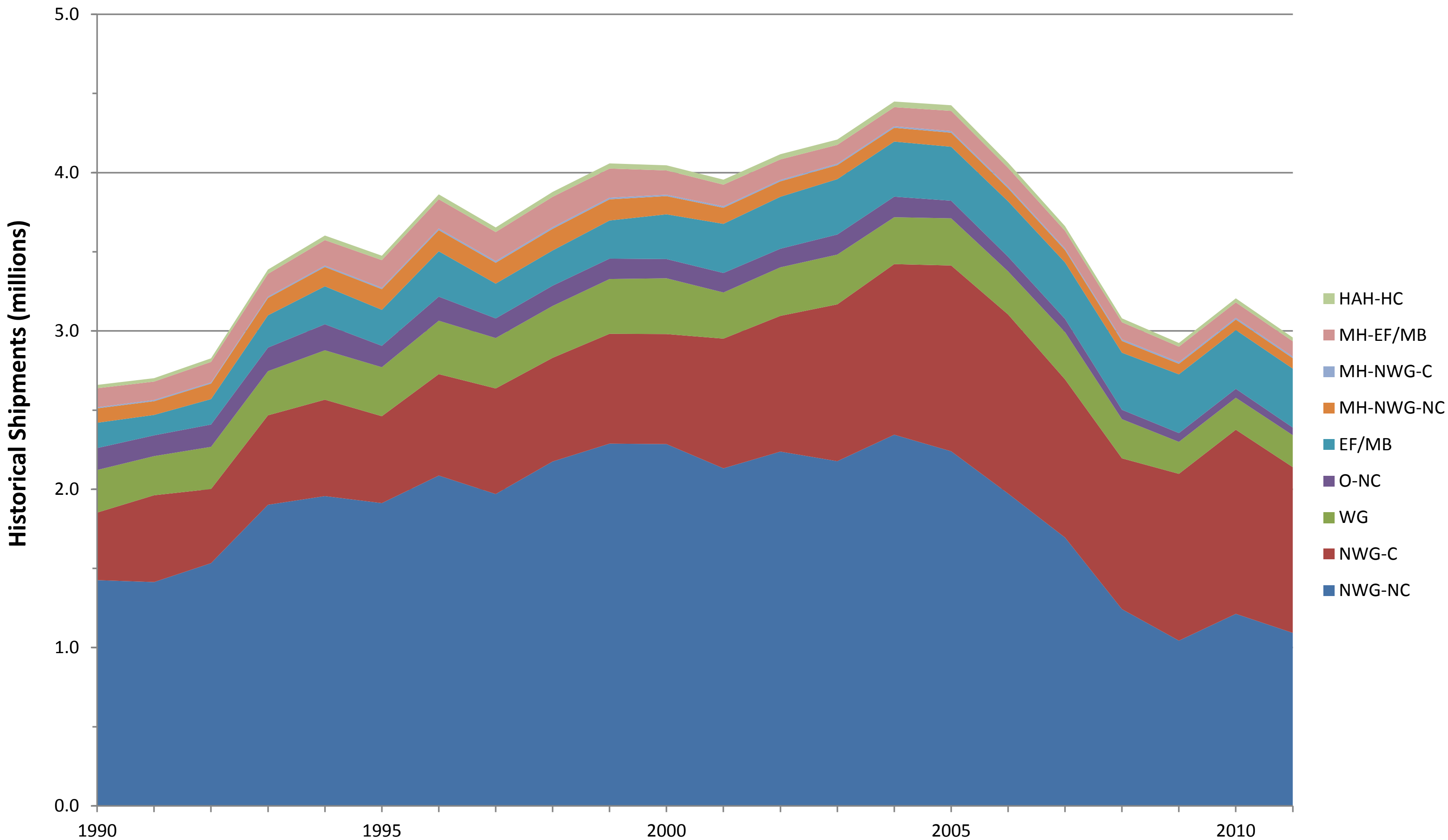

Figure 3.2.4: Residential Furnace Fan Industry Shipments (Domestic and Imported)

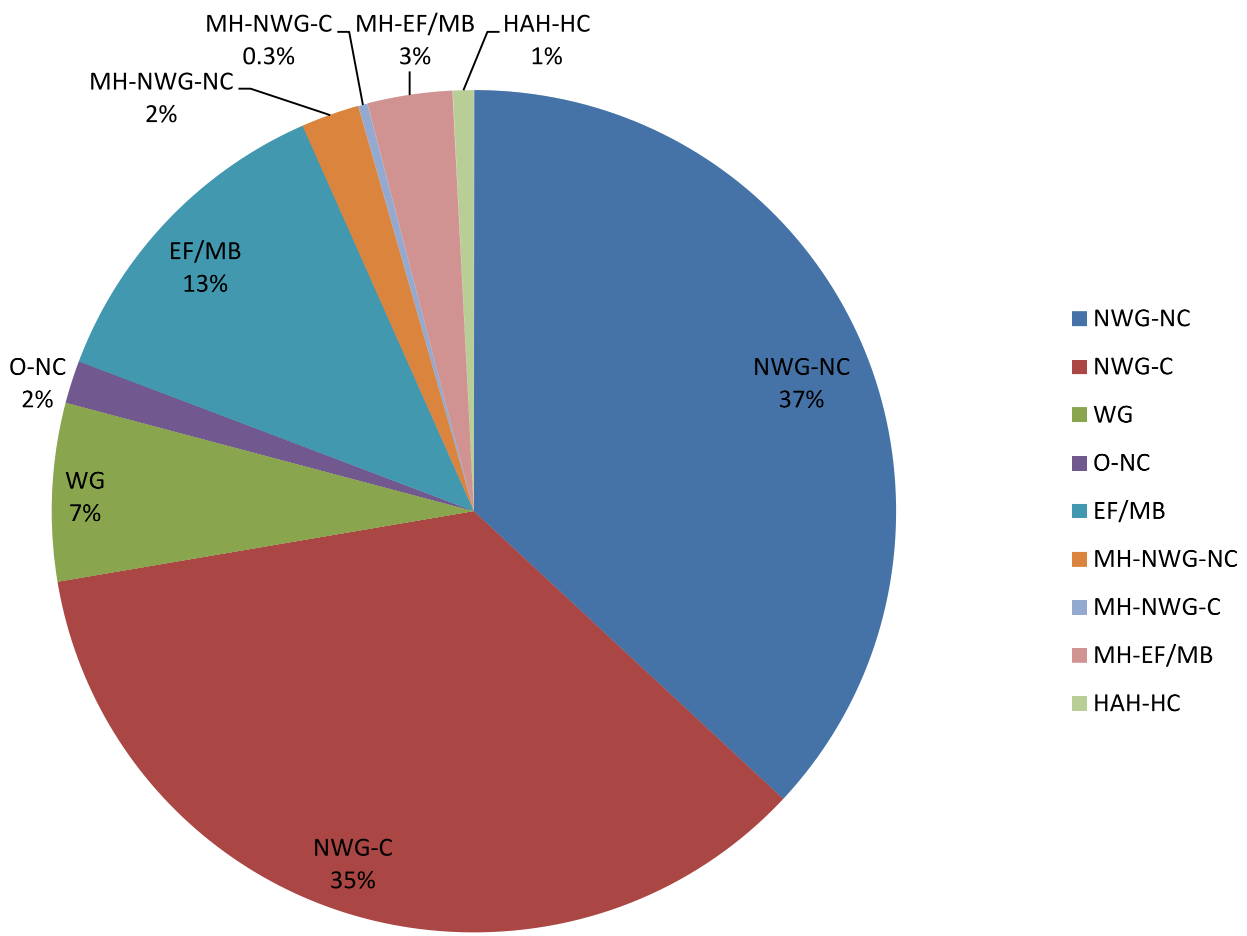

Figure 3.2.5: Residential Furnace Fan Industry Share 2011 (Domestic and Imported)

3.2.8.2 Value of Shipments

Table 3.2.7 provides the value of shipments attributable to the furnace fan components of HVAC products for the residential furnace fan industry from 2006 to 2010 using the U.S. Census Bureau CIR.[25] The product description in the CIR is "warm air furnaces, including duct furnaces and humidifiers, and electric comfort heating." The values of shipments reported in the CIR represent the total value of the HVAC products in which the furnace fans are incorporated. Based on its manufacturing cost modeling, DOE estimated that furnace fans account for 5-15% of the total furnace cost, depending on the type of motor (PSC or ECM) and the type of furnace. Accordingly, DOE estimates that furnace fan shipment values represent 10% of the total furnace shipment values reported in the CIR. The CIR expresses all dollar values in current dollars (*e.g.*, 2006 data are expressed in 2006$). Using the gross domestic product (GDP) deflator, DOE converted each year's shipment values to 2011$; 2010 was the last year included in the CIR data set.

Table 3.2.7: Value of Residential Furnace Fan Shipments by Year[26]

Year	Value of Shipments *$, millions*	Value of Shipments in 2011$ *$, millions*
2010	200	205
2009	183	186
2008	183	189
2007	209	221
2006	221	251

3.2.8.3 Saturation in U.S. Households

Stock saturation refers to the percentage of the housing stock equipped with a given product or exhibiting a certain feature. According to RECS 2009 data, 61.6% (70 million) of U.S. homes have central warm-air furnaces.[27] Of these furnaces, 44.3 million are gas furnaces, 19.1 are electric furnaces, 2.7 million are oil-fired furnaces, and 3.9 million are liquid petroleum gas (LPG) furnaces. Similar statistics for modular blowers and hydronic air handlers is not available.

3.2.9 Market Performance Data

DOE examined the AHRI,[28] the CEC,[29] and ENERGY STAR[30] directories and other publicly available data from furnace, CAC, and hydronic air handler manufacturers' catalogs and websites to develop an understanding of the industry and its market. These databases contain information such as manufacturer name, model number, input rating, and efficiency. DOE's goal in researching HVAC products was to better understand the furnace fan market and product distribution. DOE excluded from its analysis any products that were manufactured for Canada or export only and any products in the AHRI Directory of Certified Product Performance that were not labeled as "active".

3.2.9.1 Capacity Data

In characterizing the residential furnace fan market, DOE first examined the distribution of furnace models by their input capacity ratings. DOE divided the products into bins based on their input capacities. The capacities were separated into bins of 10 kBtu/hr. The bin labels represent the bin ranges' upper bounds (i.e., the 40 Btu/hr bin includes products with input capacity from 31 Btu/hr through 40 Btu/hr). Figure 3.2.6 shows these distributions for most key product class covered in this rulemaking.

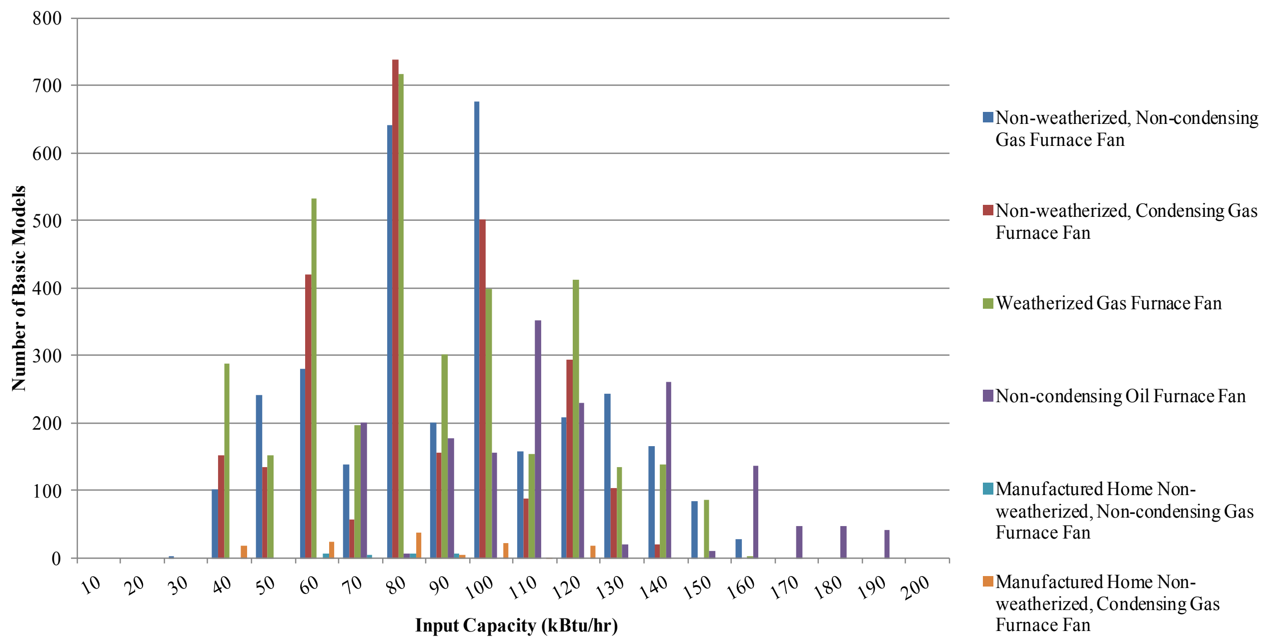

Figure 3.2.6: Distribution of Furnace Models by Input Capacity

Figure 3.2.6 shows a spike in the number of basic models for the 80 kBtu/hr bin. Accordingly, DOE chose to focus on models in 70-80 kBtu/hr range for further analysis.

3.2.9.2 Airflow Data

DOE recognizes that HVAC products with a given heat input capacity can have varying cooling capacities. DOE also recognizes that cooling capacity determines the nominal maximum airflow capacity of the HVAC product. Typically, HVAC products are designed to provide between 350 and 450 cfm/ton. An HVAC product with a cooling capacity of 3 tons will have a nominal maximum airflow capacity of approximately 1200 cfm, for example. The marked cells in Table 3.2.8 reflect the input capacity and nominal maximum airflow for the most common input and nominal maximum airflow capacities of furnace models in the June 2010 AHRI Directory.[25]

Table 3.2.8: Common Furnace Input Capacity and Airflow Combinations

Airflow Sizing in cfm *tons*	Input Capacity *kBtu/h*											
	45	50	60	70	75	80	90	100	115	120	125	140
800 cfm (2 tons)	x	x	x									
1,200 cfm (3 tons)	x	x	x	x	x	x	x	x				
1,600 cfm (4 tons)				x	x	x	x	x	x	x	x	
2,000 cfm (5 tons)							x	x	x	x	x	x

Based on historical shipment information of residential central air conditioners by capacity, DOE constructed the airflow capacity percentiles table for air conditioners. (See Table 3.2.9). The Department restricted the airflow sizes to two, three, four, or five tons—the equivalent of 800, 1,200, 1,600, or 2,000 cfm at 0.5 in. w.g. static pressure. Since there are no available shipment data on the airflow capacity of furnaces, the Department used the airflow capacity of residential central air conditioners as a proxy.

Table 3.2.9: Expected Distribution of Airflow for Furnace Fans

Airflow Rating *cfm*	2010 AHRI Shipments *%*	Cumulative Fraction *%*
800	37.3	37.3
1200	35.0	72.3
1600	16.8	89.0
2000	11.0	100.0

A mentioned in section 3.2.9.1, DOE chose to focus on models in 70-80 kBtu/hr range for further analysis based on input capacity distribution data. Table 3.2.8 shows that furnaces in this input capacity range typically have nominal maximum airflow capacities of 1200 or 1600 cfm. Table 3.2.9 shows that between these two nominal maximum airflow capacities, DOE expects the majority of models to have a nominal maximum airflow capacity of 1200 cfm. Accordingly, DOE chose to focus on models with a nominal airflow capacity of 1200 cfm. Note that DOE developed the information provided in Table 3.2.8 and Table 3.2.9 for chapter 7 of the HVAC products direct final rule TSD.

3.2.9.3 Energy Metric

DOE does not have an existing standard for residential furnace fans. Consequently, values of the proposed rating metric, FER, are unavailable for evaluating market-wide trends in energy performance. A related energy metric, the average annual auxiliary electrical energy consumption (Eae), is widely available for residential furnace models, however. Eae includes the electrical energy consumption of the circulation fan, but also includes the electrical consumption of other components of the furnace, such as the induced draft blower. (10 CFR part 430, subpart B, Appendix N) DOE used Eae as a proxy for FER to evaluate market-wide energy performance of furnace fans. DOE characterized the distribution of Eae for commercially-available furnaces by dividing the products listed in the AHRI database into bins based on their Eae. DOE determined bin sizes based on the range of Eae within each key product class. The bin labels represent the bin ranges' upper bounds (i.e., the 500 kWh Eae bin includes products with Eae values from 401 kWh to 500 kWh). As mentioned in 3.2.9.1, a large number of furnace fan basic models fall in the 70-80 kBtu/hr input capacity range. Thus, DOE analyzed the Eae of models in this range. Figure 3.2.7 shows a histogram of the energy data for products having 70-80 kBtu/hr input capacity a subset of key product class.

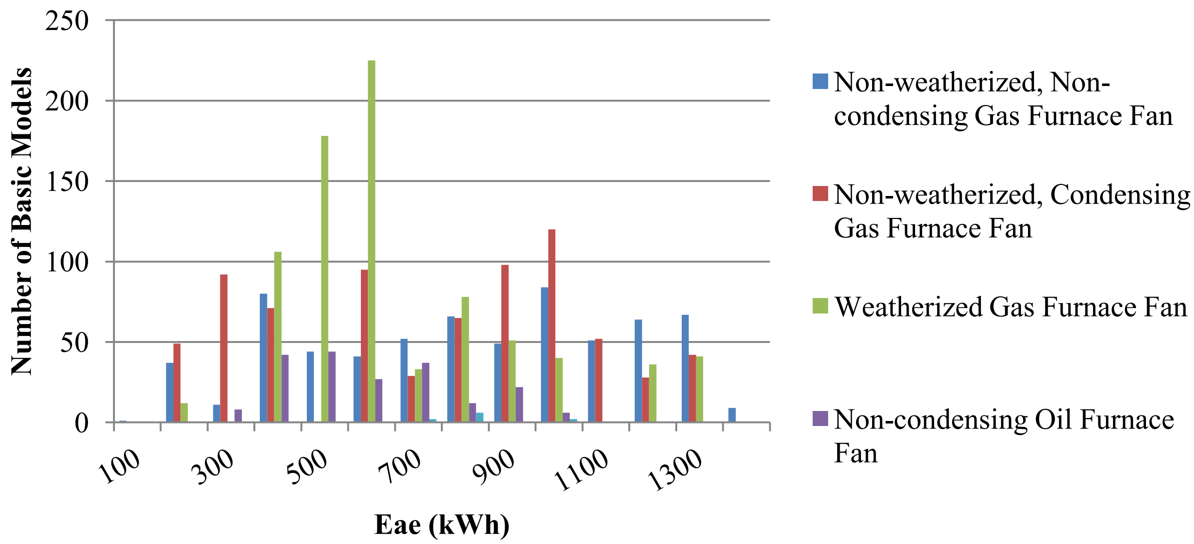

Figure 3.2.7: Distribution of 70-80 kBtu/hr Input Capacity Furnace Models by Eae[l]

As Figure 3.2.7 shows, energy performance differs across the major product classes at similar capacities. DOE did not include modular blowers and hydronic air handlers in these assessments because Eae values are not generated for these products. DOE expects that the energy consumption of these products will also be different at a given capacity due to differences in application and internal structure.

3.2.9.4 Motor Data

DOE also examined the distribution of motor types in residential furnaces. The two motor types are PSC and ECM.[m] DOE further divided ECM motors into constant-torque ECMs, referred to as X13, and constant-circulation ECMs, referred to simply as ECMs. DOE used the AHRI database to develop motor distributions, when motor information was available. Figure

[l] Source: AHRI database

[m] See Section 3.3.2.4 for motor type descriptions

3.2.8 through Figure 3.2.11 show these distributions for a subset of key product classes covered in this rulemaking.

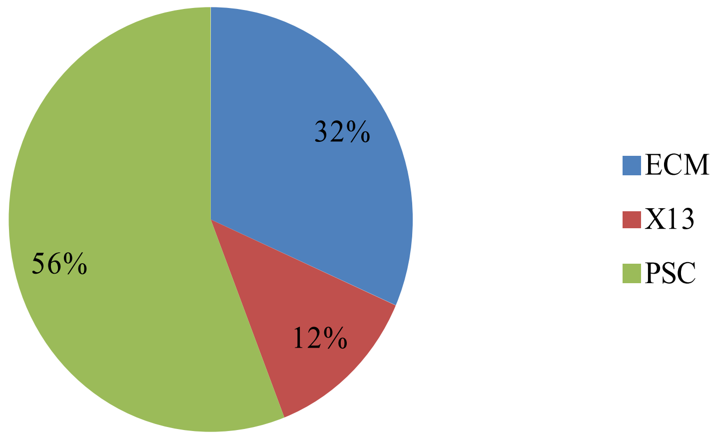

Figure 3.2.8: Motor Distribution for Non-Weatherized Gas Furnaces

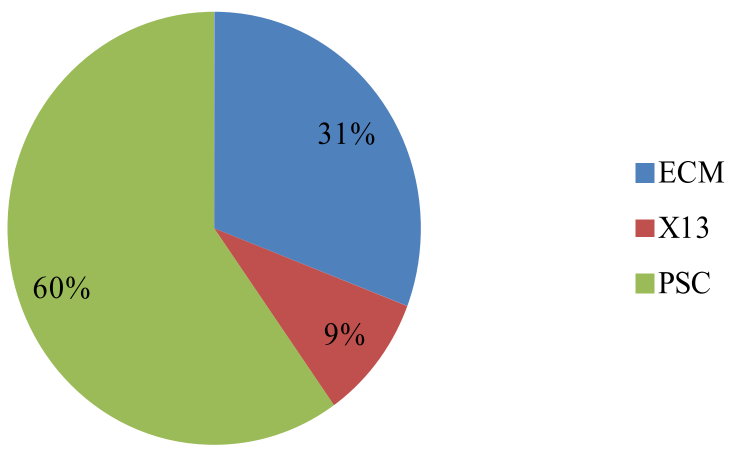

Figure 3.2.9: Motor Distribution for Weatherized Gas Furnaces

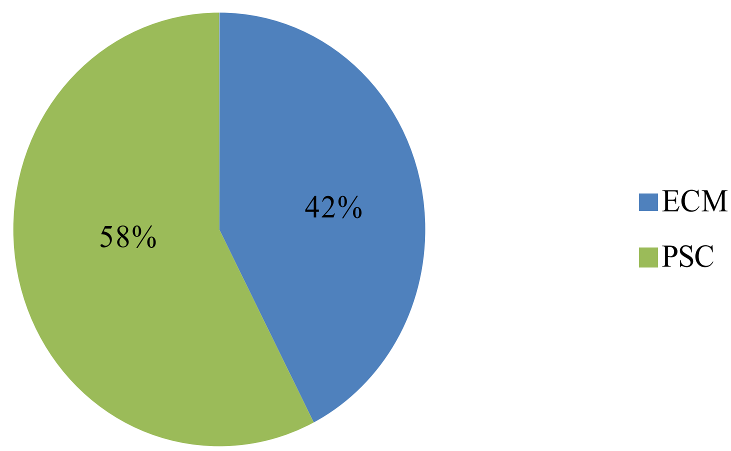

Figure 3.2.10: Motor Distribution for Oil Furnaces

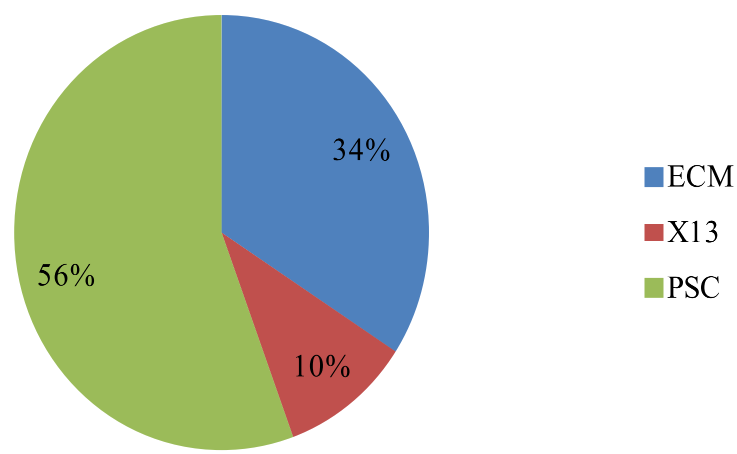

Figure 3.2.11: Motor Distribution for All Furnace Types

As shown above, the PSC motor dominates the furnace fan market at 56 percent market share, followed by ECM at 34 percent market share, and X13 with 10 percent.

Figure 3.2.12 and Figure 3.2.13 show the distribution of motor type by Eae for all input capacities for the two major product classes (non-weatherized, non-condensing gas furnaces and non-weatherized, condensing gas furnaces). As shown below, ECM motors have a lower Eae than PSC motors for both types of non-weatherized gas furnaces.

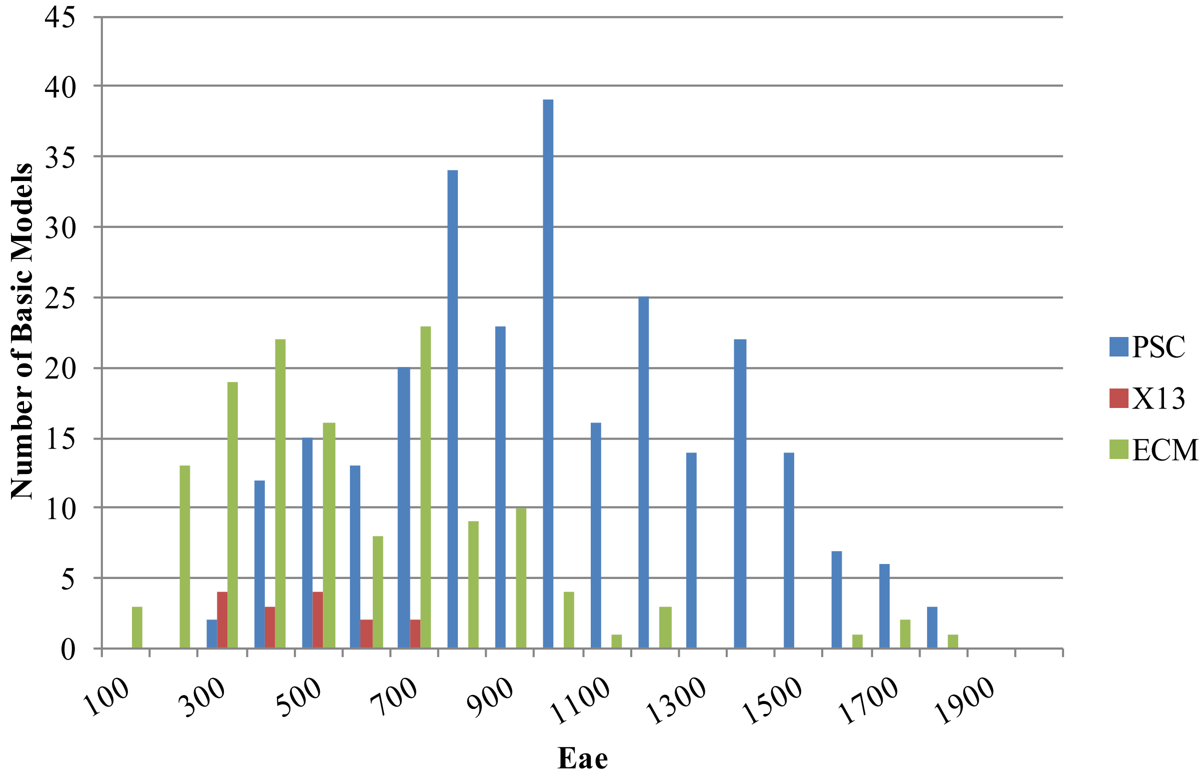

Figure 3.2.12: Motor Distribution by Eae for Non-weatherized, Non-condensing Gas Furnaces

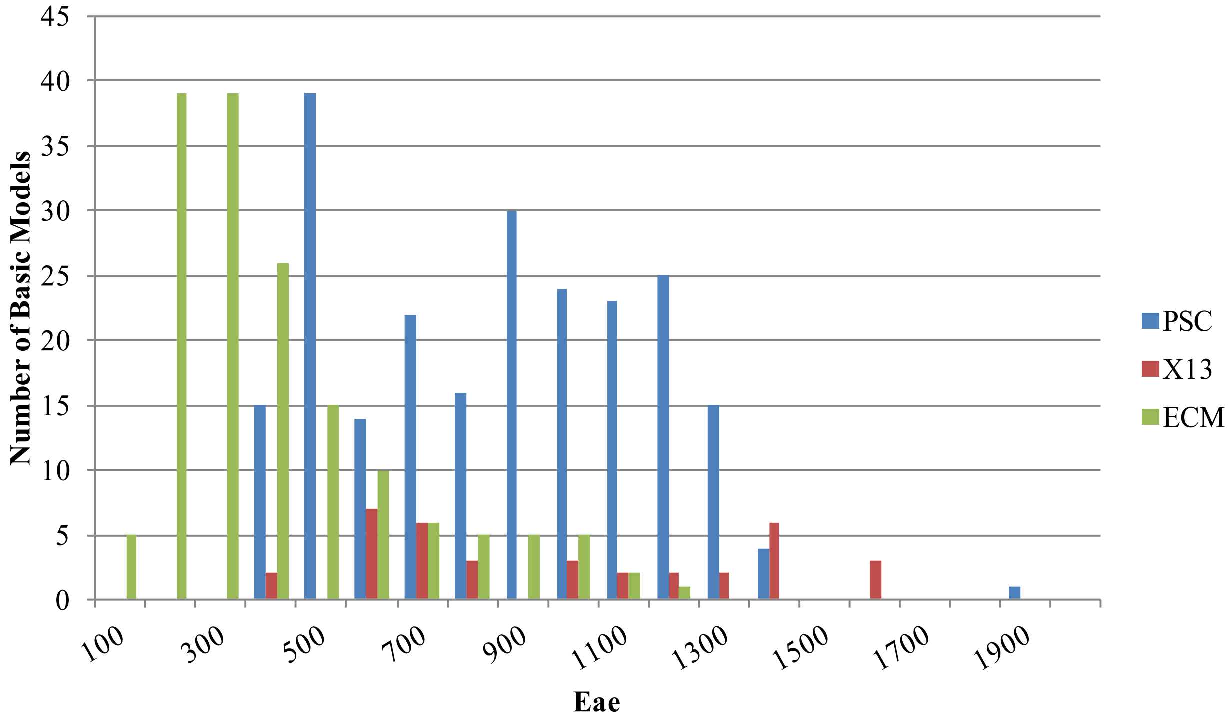

Figure 3.2.13: Motor Distribution by Eae for Non-weatherized, Condensing Gas Furnaces

3.3 TECHNOLOGY ASSESSMENT

This section provides a technology assessment for residential clothes dryers and room air conditioners. Contained in this technology assessment are details about product characteristics and operation (section 3.15.1), an examination of possible technological improvements for each product (section 3.15.2) and a characterization of the product efficiency levels currently commercially available (section 3.15.3).

3.3.1 Furnace Fan Operation

In preparation for the screening and engineering analyses, DOE prepared a brief description of the characteristics and operation of the furnace fans covered by this rulemaking. These descriptions provide a basis for understanding the technologies used to improve product efficiency.

DOE considered a typical furnace fan as consisting of a fan motor and its controls, an impeller, and a housing, all of which are components of an HVAC product that includes additional components, including the cabinet. To circulate air through ductwork, the furnace fan motor rotates the impeller, which increases the velocity of an airstream. As a result, the airstream gains kinetic energy. This kinetic energy is converted to a static pressure increase when the air slows downstream of the impeller blades. This static pressure created by the fan must be enough to overcome the pressure losses the airstream will experience throughout the ductwork, and to a smaller degree, within the HVAC product itself, to provide sufficient delivery of conditioned air to the residence. Pressure losses are the result of directional changes in the ductwork, friction between the moving air and surfaces of the ductwork, and possible appurtenances in the airflow path. (In layman's terms, the conditioned air slows and eventually would stop the further it travels from the fan. However, in effective systems, continued action of the furnace fan overcomes such resistance and provides conditioned air to the intended space.) Therefore, the geometry of any HVAC component that obstructs the airflow path, the length of the ductwork path, and number and nature of direction changes in the ductwork of a given system contribute to the pressure losses of the system. In most duct systems, the static pressure required to move the air is approximately equal to the square of the airflow rate.

Installed furnace fans can have as many as five or more airflow-control settings. In a given HVAC system, energy consumption of the furnace fan increases as airflow increases. Therefore, power input is higher for higher airflow-control settings. As mentioned, DOE finds that each airflow-control setting is often designated for a specific function, such as cooling, heating, or constant circulation. DOE understands that higher airflow-control settings are almost always factory set for cooling operation. Therefore, DOE expects that the electrical energy consumption of a furnace fan is higher while performing the cooling function. Median airflow-control settings are designated for heating operation. DOE further recognizes that the potential for significant power reduction occurs when the fan is operating in its lowest airflow-control setting, which DOE finds is typically factory set for constant-circulation. Constant circulation is the mode in which the furnace fan circulates air continuously but the HVAC product does not condition (heat or cool) the air. The significant power reduction in constant circulation mode is consistent with the theory that fan input power is proportional to the cube of the airflow.

The relative efficiency of certain furnace fan technologies is dependent on operating conditions (i.e. airflow-control setting and ESP). For instance, DOE is aware that some furnace fan technologies, such as improved impeller designs, may improve efficiency in some, but not all, of the expected range of operation. Therefore, DOE anticipates that evaluating energy performance of furnace fans across the entire range of expected field operation is necessary to meaningfully compare technology options.

3.3.2 Technology Options

The purpose of the technology assessment is to develop a list of technology options that manufacturers can use to improve product efficiency. The following assessment provides descriptions of technology options for furnace fans. DOE examined efficiency-improving technologies used today.

3.3.2.1 Housing Design Modifications

The housing of a furnace fan is typically made of sheet metal. The design of the housing may impact fan efficiency. According to one manufacturer, the following housing design improvements can improve fan efficiency: 1) optimizing the shape of the inlet cone; 2) minimizing the gaps between the impeller and the inlet cone; and 3) optimizing cut off location and the manufacturing tolerances. [n] However, many manufacturers estimate these impacts to be minimal, and DOE has little quantitative data correlating specific housing design modifications with efficiency improvements.

3.3.2.2 Airflow Path Design

The internal structure (i.e., geometry and configuration of components in the airflow path) determines the internal static pressure. For example, the geometry of a hydronic heat exchanger is different than the geometry of a clamshell heat exchanger, a furnace heat exchanger design typically found in non-weatherized gas furnaces. This difference results in different internal static pressure levels. Manufacturers could modify the design and configuration of elements in the airflow path, such as the heat exchanger, to reduce internal static pressure. Reduced internal static pressure levels result in lower expected energy consumption levels. Airflow path design improvements may also involve an increase in package size.

3.3.2.3 ECM Control Relay

During testing of standby and off mode components for the furnace rulemaking, DOE found that ECM motors and their associated controls consumed 3 watts in off mode, while PSC motors did not have any off mode power draw. Therefore, the ECM motor could be disconnected to further reduce a system's off mode power consumption. To accomplish this task, a control relay would need to be added to the circuit. A typical control relay activates a switch when current runs through it and when there is no current a spring holds the switch in the open position.

Manufacturer feedback provided during the interview process (see chapter 12 of this TSD) indicated that ECMs are subject to an inrush of current upon startup. The power supply on the ECM's control board, which is typically a switching mode power supply, cannot withstand the repeated surge of current that occurs at ECM startup and, therefore, completely depowering and reactivating the motor by use of a control relay would shorten the motor's lifetime significantly. DOE considers a premature failure of the blower to be a reliability issue that has an adverse impact on product utility to the consumer.

3.3.2.4 High-Efficiency Fan Motors

Furnace fan manufacturers typically use either a permanent split capacitor (PSC) motor or a more-efficient, electronically-commutated motor (ECM). (DOE is aware that "ECM" is a trade name specific to a certain motor manufacturer. DOE is using "ECM" to refer to any three-phase permanent magnet furnace fan motor.) DOE divided both PSC motors and ECMs into two further categories each. In all, DOE considered four motor types: baseline PSC motors; improved PSC motors; constant-torque ECMs, referred to as X13; and constant-airflow ECMs. The specific design and energy performance differences between these motor types are described in the following paragraphs. Each of these motor types operates based on the interaction of the magnetic fields produced by the stator (the stationary portion of the motor) and the rotor (the

[n] The cut-off partially blocks the fan discharge opening at the side of the opening closest to the impellor axis.

rotating portion of the motor). These magnetic fields can be produced by electromagnets or permanent magnets.

PSC motors are a type of induction motor. In induction motors, the stator is an electromagnet that consists of electrical wire windings. Current is driven through the windings to produce a magnetic field. Through electromagnetic induction, this magnetic field induces current in the conductor bars of the rotor. The conductor bars of the rotor, often made of copper or aluminum, are arranged in such a manner that they produce another magnetic field once current is induced. The interaction of the two magnetic fields results in rotation of the rotor. In a PSC motor, a smaller, start-up winding is present in addition to the main winding in the stator. The start-up winding is electrically connected in parallel with the main winding and in series with a capacitor. At startup, the interactions between the magnetic fields generated by the start-up winding and the main winding initiate rotation in the correct direction. Because of the capacitor, however, the current to the start-up winding is cut off as the motor reaches steady state.

DOE considered PSC motors with 3 or less airflow-control settings to be baseline PSC motors, and PSC motors with more than 3 airflow-control settings to be improved PSC motors. PSC motors with more airflow-control settings provide more flexibility for designating which setting will be used for which HVAC product function (i.e. cooling, heating, or constant circulation). In addition, DOE expects that improved PSC motors have a higher turndown ratio, allowing them to increase fan efficiency by taking advantage of the cube law relationship between fan shaft power and airflow for operation with a given ductwork system.

Manufacturers integrate an autotransformer in PSC motors to create distinct, selectable airflow-control settings (speed taps). The autotransformer is a single-winding electrical transformer that is wound to the stator assembly and connected to the main and auxiliary motor windings. The autotransformer is tapped at various points along the winding. The location of each tap determines the number of winding turns that are powered and in turn, the voltage applied to the stator windings when the tap is selected. Taps are powered through a selector switch, which allows only one lead to be connected at a time. Each tap corresponds to an airflow-control setting.

ECM motors are three-phase permanent magnet motors. Like a PSC motor, the stator of an ECM motor is an electromagnet used to produce a magnetic field. Unlike the PSC motor, the rotor of an ECM motor consists of a permanent magnet. The interaction of the magnetic field of the electromagnet and the magnetic field of the permanent magnet rotor result in rotation of the rotor. ECM type motors can be divided into two categories: constant-torque ECMs and constant-airflow ECMs. Constant-torque ECMs, often called X13 motors (which is the name of a particular motor manufacturer's line of constant-torque ECMs), maintain a predetermined torque in each airflow-control setting as operating conditions change. Constant-airflow ECMs, often referred to simply as ECMs, maintain a constant airflow in each airflow-control setting as operating conditions change. Another difference between X13 motors and ECMs is that manufacturers design X13 motor controls to mimic the speed tap interface of PSCs to facilitate integration. ECMs on the other hand, have variable speed controls. Theoretically variable speed controls allow a furnace fan to operate at any airflow rate between its minimum and maximum. Both X13 motors and ECMs operate more efficiently than PSC motors by:

- operating more efficiently at a given operating condition;
- maintaining efficiency throughout the expected operating range; and
- achieving a higher turndown ratio (i.e., ratio of airflow in lowest setting to airflow in highest setting).

X13 motors are less efficient than ECMs because they are designed to have a narrower speed range and lower turndown ratio, as a result. DOE used airflow data from publicly-available product literature to calculate average turndown ratios for typical motor type/speed control combinations. Table 3.3.1 presents DOE's turndown ratio investigation results.

Table 3.3.1: Average Turndown Ratio by Motor Type

Motor Type	Speeds/Controls	Average Turndown Ratio
PSC	2-Speed	82%
	3-Speed	78%
	4-Speed	64%
	5-Speed	55%
	Inverter	48%
X13	5-Speed	68%
ECM	Variable	53%

3.3.2.5 Inverter Controls for PSC Motors

DOE is aware of an inverter-driven PSC furnace fan motor that was once commercially available in a furnace product that is no longer for sale. Inverter technology can improve PSC-driven furnace fan efficiency through more efficient control of the motor. Using an inverter, the incoming AC current is converted to DC current by a rectifier and then back to AC current at a specific frequency. The output AC current is used to drive the motor, the operating speed of which depends on the frequency of the AC current. Though there are other ways to change motor speed, inverter technology allows for more intermediate speeds within the same range of speeds from the voltage steps associated with the autotransformer approach used for conventional PSC motors. This allows PSC motors with inverter controls to better match demand. DOE finds that an inverter-driven PSC motor is more efficient than the other PSC motor types, but less efficient than both X13 motors and ECMs.

3.3.2.6 Backward-Inclined Impellers

Furnace fans use an impeller to move air across the heat exchanger and through ductwork. Impellers are composed of a number of fan blades, or ribs, mounted around a hub. The air enters from the side of the impeller parallel to the axis of rotation, turns 90 degrees and accelerates due to centrifugal force as it flows over the fan blades and exits the fan housing. (AMCA News Spring 2010). DOE finds that centrifugal, forward-curved impellers are ubiquitous in commercially-available furnace fans. The forward-curved blades are made of thin, stamped sheet metal. These impellers are compact, inexpensive, easy to manufacture, and provide acceptable performance over a wide range of field operating conditions.

Energy savings may be possible by using backward-inclined impellers. These impellers incorporate backward facing inclined blades that are generally wider in the air flow direction across the blade as compared with forward-curved impellers. Unlike forward-curved designs, backward-inclined impellers are more efficient because the airflow direction change is less as the air flows over the blade, thus reducing losses associated with turbulence and separation. However, because the blades are inclined backwards as compared with the direction of the impeller rotation, backward-inclined impellers must have significantly higher tip speed to accelerate air to the same rotational velocity as the air leaves the blades. The higher tip speed requires either larger impeller diameter or higher rotational speed.

DOE was unable to find a commercially available residential HVAC product that incorporates a backward-inclined impeller. However, DOE is aware of research performed by General Electric and testing performed at national laboratories that include evaluation of a series of prototype residential furnaces that include backward-inclined impellers.[31] Figure 3.3.1 shows the results of these tests.

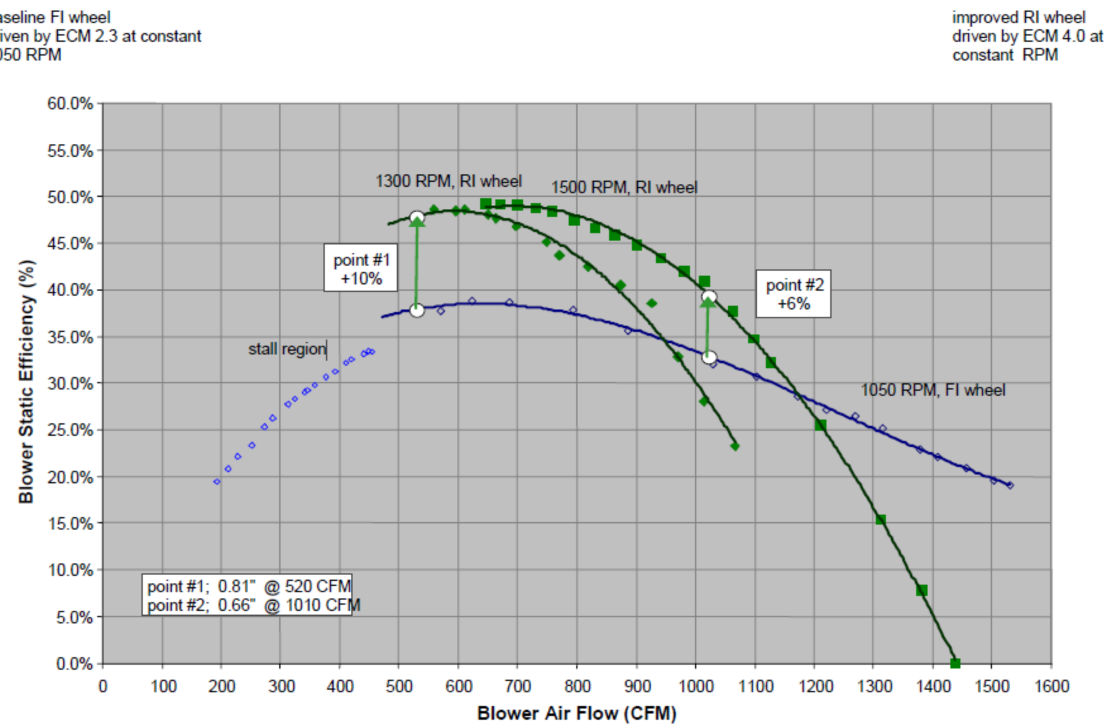

Figure 3.3.1: Performance Curves for Both Forward- and Backward-Inclined Impellers

The results of these tests show that backward-inclined impellers can improve furnace fan efficiency considerably, depending on the operating conditions. Notably, the efficiency of the backward-inclined design appears to be more sensitive to operating conditions than that of forward-curved designs. A backward-inclined impeller design may not perform more efficiently across the entire range of expected operation, as a result. For the preliminary analysis, DOE used a fixed 10% reduction in FER to represent the improvement in efficiency associated with using a backward-inclined impeller design. However, a proper evaluation of the technology will require a more careful review of available data over the range of furnace fan operating requirements. Thus DOE intends to review and adjust the analysis based on a more thorough assessment in the NOPR phase.

3.3.2.7 Standby Mode and Off Mode Technology Options for Hydronic Air Handlers

Pursuant to 42 U.S.C. 6295(o), DOE must address the standby mode and off mode energy use of residential furnace fans in this rulemaking. However, DOE has already incorporated standby mode and off mode energy use in energy conservation standards (or proposed energy conservation standards) for several of the products in the preliminary analysis scope of coverage. DOE accounts for standby mode and off mode energy use for non-weatherized gas furnaces, weatherized gas furnaces, oil-fired furnaces, electric furnaces, and modular blowers in separate rulemaking activities. However, there are no current energy conservation standards for electrical energy use in hydronic air handlers, nor is there an ongoing rulemaking for which such test procedures have been proposed. Hence, the standby mode and off mode energy use for furnace fans that are incorporated into these products must be considered in this rulemaking pursuant to EPCA. Table 3.3.1summarizes DOE's consideration of standby mode and off mode electrical energy consumption of the furnace fans in the scope of coverage of this preliminary analysis.

Table 3.3.2: Rulemaking Activities Addressing Furnace Fan Standby Mode and Off Mode Energy Consumption

HVAC Products	Status	DOE Rulemaking Activity
• Gas Furnaces • Oil-fired Furnaces • Electric Furnaces	Addressed in separate rulemaking	• Codified Furnaces Test Procedure October 20, 2010 final rule (75 FR 64621) (10 CFR part 430, subpart B, appendix N, section 8.0) • September 13, 2011 NOPR (76 FR 56339).
• Modular Blowers • Weatherized Gas Furnace	Addressed in separate rulemaking	• Codified CAC Test Procedure October 22, 2007 final rule (72 FR 59906). (10 CFR part 430, subpart B, appendix M) • June 2, 2010 NOPR (75 FR 31224). • April 1, 2011 SNOPR (76 FR 18105). • October 24, 2011 SNOPR (76 FR 65616).
• Hydronic Air Handlers	Addressed in current rulemaking	• N/A

DOE plans to establish a standard for the standby mode and off mode electrical energy consumption of hydronic air handlers using an integrated metric that combines the standby mode and off mode electrical energy consumption measurements for hydronic air handlers with the active mode energy use for these furnace fans, as required by EPCA. 77 FR 28688

DOE proposed the following definitions for standby mode and off mode for furnace fans used in hydronic air handlers. 77 FR 28677

- Standby mode means the mode during which the HVAC product is connected to the power source and the furnace fan is not activated.

- Off mode means the mode during which the HVAC product is not powered.

DOE identified the following design options as having the potential to reduce the electrical power consumption of a hydronic air handler operating in standby and off modes. These technology options are similar to those DOE considered in the residential furnaces rulemaking.

1. Toroidal Transformer
2. ECM Control Relay
3. Switching Mode Power Supply

3.3.2.8 Toroidal Transformer

A toroidal transformer is smaller in size and weight and operates more quietly and efficiently than a typical laminated core power transformer. It also has lower noise-inducing stray magnetic fields. A toroidal transformer has an annular core made of very tightly-wound, grain-oriented, silicon steel ribbons. The steel ribbons are arranged such that all their molecules are aligned with the direction of flux. This allows better performance than a traditional laminated transformer, in which unaligned molecules increase the core's reluctance, or capacity for opposing magnetic induction.[32]

Toroidal transformers also have virtually no air gap because they are made of continuously wound ribbon. Eliminating the air gap minimizes flux leakage, which is the principle source of power loss in a laminate transformer, such that nearly all flux is utilized. Additionally, toroidal transformers have a copper coating that reduces heat (*i.e.*, power) loss. These improvements in efficiency allow an up to 50 percent reduction in size and weight, such that they can be used in new, innovative applications. Overall efficiency of toroidal transformers is 90 to 95 percent.

Because transformers continue to supply power to the control board in all modes of operation, including standby mode, increasing their operating efficiency will reduce standby electrical power consumption. However, although toroidal transformers have significant advantages over laminated transformers in efficiency, size, and weight, they are also more expensive to manufacture. Their tight, ring-shaped windings may make large scale manufacturing difficult, especially in contrast with the simple windings of a rectangular, laminated transformer design.

3.3.2.9 ECM Control Relay

During testing of standby and off mode components, DOE found that ECM motors and their associated controls consumed 3 watts in off mode, while PSC motors did not have any off mode power draw. Therefore, the ECM motor could be disconnected to further reduce a system's off mode power consumption. To accomplish this task, a control relay would need to be added to the circuit. A typical control relay activates a switch when current runs through it and when there is no current a spring holds the switch in the open position. However, DOE has not found any products which completely disconnect the ECM fan motor. Additionally, manufacturer feedback indicated that ECM motors are subjected to large currents upon start up and using a control relay to completely depower them could reduce the lifetime of the motors, leading to a reduction in utility of the product.

3.3.2.10 Switching Mode Power Supply

DOE identified switch mode power supplies as having the potential to reduce the electrical power consumption of a hydronic air handler operating in standby mode. While linear power supplies regulate voltage supply to the dc circuit with a series element, switching mode power supplies (SMPS) do so in an alternative, more effective way. In a switching mode power supply, power handling electronics switch on and off (where 'on' means switch is closed and voltage drop is negligible and 'off' means the switch is open and current is negligible) with high frequency, effectively connecting and disconnecting the output (load) to the input source. Continuous power flow to the load can be maintained/controlled by varying the duty cycle or frequency of the SMPS.

Linear power supplies experience significant heat losses because they use resistance elements, which convert electrical energy to heat energy, to regulate power supply. By using a switch to control energy flow instead, switching mode power supplies avoid such heat losses and have higher efficiency. SMPS do introduce transient losses that increase with frequency, but these losses are negligible in comparison to the energy saved.

Switching mode power supplies also allow the use of a smaller transformer than a linear power supply. This is because the size of the transformer (*i.e.,* the number of turns) is inversely related to power frequency. In one respect, switching mode power supplies are at a relative disadvantage in comparison to linear power supplies, which regulate voltage with greater precision and have simpler controls.

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