EXECUTIVE SUMMARY

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ES.1 OVERVIEW OF PRELIMINARY ACTIVITIES

Section 6295(o)(3)(B) of Title 42 of the United States Code (U.S.C.) requires the U.S. Department of Energy (DOE) to establish energy conservation standards for covered products that are technologically feasible and economically justified and would achieve the maximum improvement in energy efficiency. This Executive Summary presents the preliminary activities that DOE conducted in consideration of new energy conservation standards for electricity used for purposes of circulating air through duct work (hereafter referred to as "residential furnace fans"). The Executive Summary describes the preliminary activities and reports key results from DOE's preliminary analyses. Additionally, the Executive Summary delineates issues identified during the analyses about which DOE seeks comments from interested parties. These issues are highlighted in the public meeting presentation and are further discussed in chapter 2 of the preliminary technical support document (TSD).

Figure ES.1.1 presents a summary of the analytical components of the standards-setting process and illustrates how key results are generated. The focal point of the figure is the center column, labeled "Analyses." The columns labeled "Key Inputs" and "Key Outputs" show how the analyses fit into the process and how they relate to each other. Key inputs are the types of data and other information that the analyses require. Some key information is obtained from public databases; DOE collects other inputs from interested parties or persons having special knowledge and expertise. Key outputs are analytical results that feed directly into the standards-setting process. The issues on which DOE seeks comment from interested parties derive from the key results that are generated by the preliminary analyses. Arrows connecting analyses show the types of information that flow from one analysis to another.

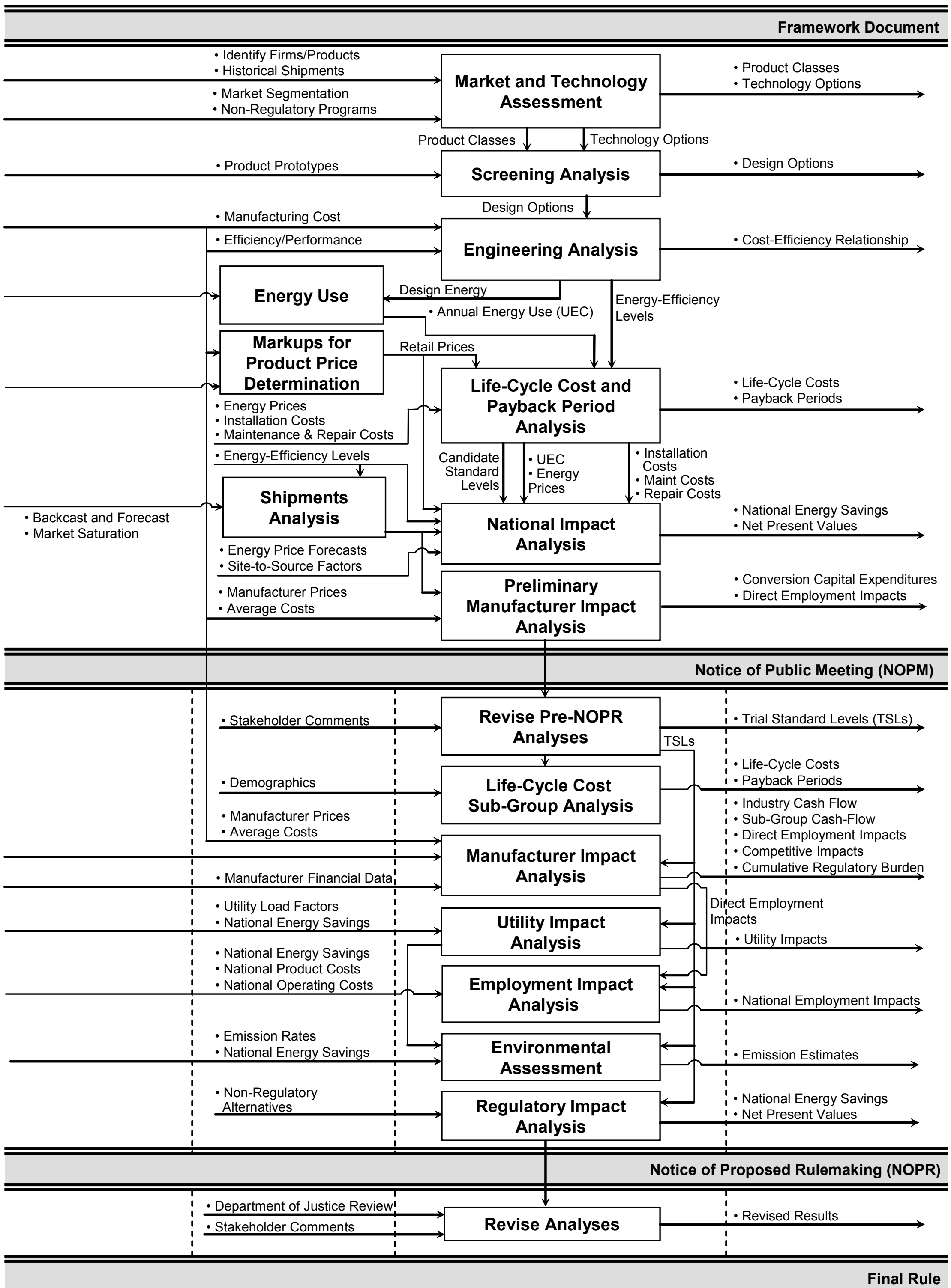

Figure ES.1.1 Flow Diagram of Analyses for the Furnace Fan Standards Rulemaking

ES.2 OVERVIEW OF THE PRELIMINARY ANALYSIS AND THE PRELIMINARY TECHNICAL SUPPORT DOCUMENT

For the preliminary analysis stage, DOE publishes a notice of public meeting (NOPM) in the *Federal Register*, which announces the availability of the preliminary TSD, the date and place of the public meeting, and presentation materials that interested parties may review before the public meeting. In addition, the NOPM highlights the major analyses DOE developed in the preliminary analysis stage. The preliminary TSD describes each preliminary analysis step in detail, providing descriptions of inputs, sources, methodologies, and results. The following chapters of the preliminary TSD address the analyses performed for the preliminary analysis stage.

Chapter 1 - The introduction provides an overview of standards for furnace fans and describes DOE's process for setting energy conservation standards.

Chapter 2 - The analytical framework describes each preliminary analysis step, the comments received in response to the analytical approaches DOE described in the Framework Document, and DOE's responses to those comments.

Chapter 3 - The market and technology assessment (MTA) characterizes the relevant product markets and technology options, including prototype designs.

Chapter 4 - The screening analysis reviews each technology option uncovered in the MTA to determine whether it is technologically feasible; is practicable to manufacture, install, and service; would adversely affect product utility or product availability; or would have adverse impacts on health and safety.

Chapter 5 - The engineering analysis develops cost-efficiency relationships that show a manufacturer's cost of achieving increased efficiency.

Chapter 6 - The markup analysis estimates consumer product prices based on market structures, and the manufacturing costs developed in the engineering analysis.

Chapter 7 - The energy use analysis determines the annual energy consumption of the products under consideration.

Chapter 8 - The life-cycle cost (LCC) and payback period (PBP) analysis discusses the effects of standards on individual customers and users of the products and compares the LCC and PBP of products with and without higher efficiency standards.

Chapter 9 - The shipments analysis documents historic unit shipments and forecasts future shipments of products at potential energy conservation standards under consideration.

Chapter 10 - The national impact analysis (NIA) assesses the cumulative national energy savings (NES) from potential standards and the net present value (NPV) of consumer costs and savings associated with standards at different efficiency levels.

Chapter 12 - The preliminary manufacturer impact analysis (MIA) assesses the potential impacts of energy conservation standards on manufacturers, such as effects on expenditures for capital conversion, marketing costs, shipments, and research and development costs.

The remaining chapters of the preliminary TSD describe the analyses to be performed for the notice of proposed rulemaking (NOPR) stage:

Chapter 11 - The consumer subgroup analysis evaluates the effects of potential energy conservation standards on subgroups of the population (*e.g.*, low-income consumers and senior-only households).

Chapter 13 - The employment impact analysis examines the effects of potential energy conservation standards on national employment.

Chapter 14 - The utility impact analysis examines impacts of potential energy conservation standards on the generation capacity of electric utilities.

Chapter 15 - The emissions analysis examines the effects of potential energy conservation standards on various airborne emissions.

Chapter 16 - Monetization of emissions reductions quantifies the anticipated benefits from potential energy conservation standards.

Chapter 17 - A regulatory impact analysis examines the national impacts of non-regulatory alternatives to mandatory energy conservation standards.

ES.3 KEY RESULTS OF THE ANALYSIS

The following sections describe analyses DOE performed for the preliminary analysis stage and present the key results.

ES.3.1 Market and Technology Assessment

When initiating an analysis of potential energy efficiency standards for a residential product, DOE develops information for the products and characterizes the market and industry structure, evaluating both current and historical information. This activity is primarily based on a review of publicly-available information.

When evaluating and establishing energy conservation standards, DOE generally divides covered products into product classes by the type of energy used or by capacity or other performance-related features that affect efficiency. DOE has decided to differentiate between furnace fan product classes based on two performance-related features: (1) product application, and (2) internal structure (*i.e.*, geometry and configuration of components in the airflow path). Different energy conservation standards may apply to different product classes. (42 U.S.C. 6295(q)) The product classes identified for this rulemaking are furnace fans used in the heating, ventilating, and air-conditioning (HVAC) products listed below. DOE divided these product classes into nine key product classes and 12 additional product classes. Key product classes are those for which DOE is aware of significant shipments and enough public data were readily available to conduct robust analyses. The additional product classes represent significantly fewer shipments and significantly less energy use. Analyses for these product classes were in some cases extrapolated from the results for the key product classes. 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 analytical results of each key product class to the non-key product classes with which it is grouped. Table ES.3.1 presents the 21 product classes and maps the additional product classes to the nine key product classes.

Table ES.3.1 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. "Manufactured home" products meet certain design requirements that allow them to be installed in manufactured homes. Details regarding these design requirements are included in chapter 3 of this TSD. Descriptors such as 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 heating and cooling or heat only, as well as whether the product includes an internal evaporator coil.

For the residential furnace fans that are the topic of this rulemaking, DOE addressed as part of the market assessment: (1) manufacturer market share and characteristics; (2) existing regulatory and non-regulatory initiatives for improving product efficiency; and (3) trends in product characteristics and retail markets. The analysis conducted for this assessment provided data and resource materials that were used throughout this preliminary analysis.

DOE reviewed literature and interviewed manufacturers to develop an overall understanding of the furnace fan industry in the United States. Industry publications, including trade journals, literature from manufacturers, government agencies, and trade organizations provided the bulk of the information, including: (1) manufacturers and their market share; (2) shipments by product type; (3) product information; and (4) industry trends.
Figure ES.3.2 shows market share of shipments by product type. Chapter 3 of the preliminary TSD describes the market analysis and resulting information.

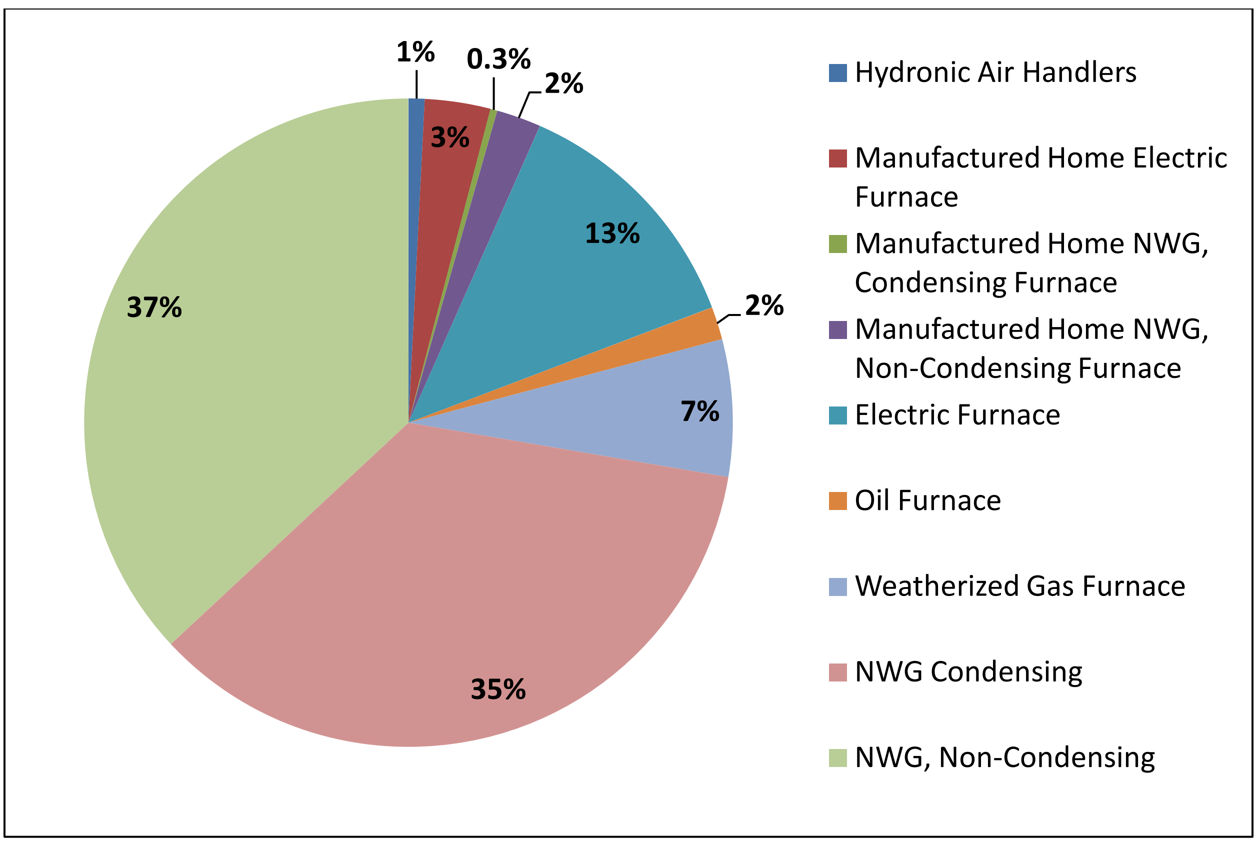

Figure ES.3.2 Market Share of Shipments by Product Class (2009)

DOE typically uses information about existing and past technology options and prototype designs to determine which technologies and combinations of technologies manufacturers use to attain higher performance levels. In consultation with interested parties, DOE develops a list of technologies to be considered. In the current rulemaking, DOE considered the following technology options in its analysis:

- High-efficiency fan motors;
- Fan motor inverter controls; and
- Improved impeller design.

DOE developed its list of technology options for furnace fans based on a review of trade publications, technical papers, and manufacturer literature and through consultation with manufacturers of components and systems. Because existing products contain many technologies for improving product efficiency, product literature and direct examination provided additional information. Detailed information regarding these technology options is included in chapter 3 of this TSD.

ES.3.2 Screening Analysis

DOE develops an initial list of options for enhancing the efficiency of furnace fans from the technologies that the technology assessment identified as feasible. DOE then conducts a screening analysis (chapter 4) in which it examines, in consultation with interested parties, whether the identified technologies: (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on product utility or availability; or (4) have adverse impacts on health and safety. If the technology option does not meet the first two criteria or if the technology option does meet the last two criteria, DOE will not consider that technology option further. In the subsequent engineering analysis, DOE further examines the technology options that it did not remove from consideration in the screening analysis.

ES.3.3 Engineering Analysis

The engineering analysis establishes the relationship between the cost of manufacturing residential furnace fans and their efficiency. This relationship serves as the basis for calculating costs and benefits of modified product designs for consumers, manufacturers, and the Nation. Chapter 5 describes the product classes DOE analyzed, the representative baseline units, the efficiency levels DOE considered, the methodology DOE used to develop the manufacturing production cost model, and the cost-efficiency results.

ES.3.3.1 Product Classes Analyzed

The engineering analysis directly analyzed nine key product classes that represent more than 90 percent of product sales and broadly represent the range of product classes within the residential furnace fan product category. Based on its analysis, DOE generated nine cost-efficiency curves. After a review of publically-available product literature, teardowns, and discussions with manufacturers, DOE found that the baseline furnace fan across all key product classes includes: (1) a direct-drive permanent split capacitor (PSC) motor with three or fewer airflow-control settings; (2) a centrifugal forward-curved impeller; and (3) a standard housing design, typically made of sheet-metal.

DOE collected publicly-available performance data and conducted testing according to the proposed test procedure for furnace fans to calculate baseline fan efficiency rating (FER) values for each key product class.[1] The FER or IFER levels determined for the nine products serving as prototypical baseline-efficiency products are listed in Table ES.3.2. Chapter 5 includes additional details on the representative product classes and the prototypical products.

Table ES.3.2 Baseline Fan Efficiency Rating (FER) for Key Product Classes

Product Class	FER (W/1000 cfm)	IFER* (W/1000 cfm)
Non-weatherized, Non-condensing Gas Furnace Fan	380	
Non-weatherized, Condensing Gas Furnace Fan	393	
Weatherized Gas Furnace Fan	333	
Non-Weatherized Oil Furnace Fan	333	
Electric Furnace / Modular Blower Fan	312	
Manufactured Home Non-weatherized, Non-condensing Gas Furnace Fan	295	
Manufactured Home Non-weatherized, Condensing Gas Furnace Fan	319	
Manufactured Home Electric Furnace / Modular Blower Fan	243	
Hydronic Air Handler Fan (Heat/Cool)		107

*The rating metric for hydronic air handlers, integrated fan efficiency rating (IFER), integrates standby mode and off mode energy consumption, as well as active mode energy consumption.

ES.3.3.2 Manufacturing Cost Assessment

DOE estimated the manufacturing costs associated with reductions in FER for each of the nine key residential furnace fan product classes. The assessment method involved disassembling model units; analyzing the materials, components, and manufacturing processes used to manufacture the products; and developing a spreadsheet model itemizing all parts and associated costs. DOE calculated the manufacturer production cost (MPC) for each disassembled product. DOE obtained input from furnace fan and furnace fan component manufacturers on the manufacturing cost model inputs. DOE aggregated manufacturers' costs and other sensitive information to maintain confidentiality of the data. Chapter 5 of the preliminary TSD includes information on the inputs used to determine the manufacturing cost, including material, labor, and overhead prices. Chapter 5 also includes information on the various components and features incorporated into designs for residential furnace fan products.

[1] U.S. Department of Energy-Office of Energy Efficiency and Renewable Energy, *Energy Conservation Program for Consumer Products: Test Procedures for Furnace Fans, Notice of Proposed Rulemaking,* 77 FR 28674 (May 17, 2012).

The primary outputs of the engineering analysis are cost-efficiency curves for the nine key product classes. The cost-efficiency curves are described by the efficiency levels DOE analyzed and the increase in manufacturer selling price (MSP) associated with achieving each of these efficiency levels. MSP is the MPC estimated from teardowns multiplied by a manufacturer markup (see section ES.3.4). DOE chose efficiency levels in its analysis that are aligned with specific technology options (*e.g.*, EL 4 represents use of an electronically-commutated motor (ECM)). The cost-efficiency curves that result for non-hydronic product classes are all similar because DOE anticipates that manufacturers of these products will consider similar technology paths to increase furnace fan efficiency. The incremental costs for each efficiency level are different for oil furnaces compared to other non-hydronic product classes because manufacturers of oil furnaces typically have lower annual production volumes. As a result, their buying power is limited and purchased parts cost more for these low-volume manufacturers. Table ES.3.3 and Table ES.3.4 describe the cost-efficiency relationships for a furnace fan used in a non-hydronic HVAC product rated to provide 1,200 cfm in the maximum default airflow-control setting (*i.e.*, with an input capacity of approximately 70,000 kBtu/hr and a cooling capacity of approximately 3 tons).

Table ES.3.3 Incremental Manufacturer Production Cost Results for Furnace Fans Used in HVAC Products Other than Oil Furnaces and Hydronic Air Handlers

Efficiency Level (EL)	Technology Option	Percent Reduction in FER	Incremental Cost
EL0	Baseline (PSC)	-	-
EL1	Improved PSC	2%	$2.00
EL2	PSC w/ Controls	10%	$11.52
EL3	X13	45%	$22.73
EL4	ECM and Multi-staging	59%	$91.95
EL5	Premium ECM and Multi-staging + Backward-Inclined Impeller	63%*	$107.20

* DOE estimates that implementing a backward inclined impeller at EL 5 results in a 10% reduction in FER from EL4. This is equivalent to a 4% percent reduction in FER from baseline. The total percent reduction in FER from baseline for EL5 includes the 59% reduction from EL4 and the 4% net reduction from the backward-inclined impeller for a total percent reduction of 63% from baseline.

Table ES.3.4 Incremental Manufacturer Production Cost Results for Furnace Fans Used in Oil Furnaces

Efficiency Level (EL)	Technology Option	Percent Reduction in FER	Incremental Cost
EL0	Baseline (PSC)	-	-
EL1	Improved PSC	2%	$6.98
EL2	PSC w/ Controls	10%	$16.24
EL3	X13	45%	$37.25
EL4	ECM and Multi-staging	59%	$106.62
EL5	Premium ECM and Multi-stating + Backward-Inclined Impeller	63%*	$122.01

* DOE estimates that implementing a backward inclined impeller at EL 5 results in a 10% reduction in FER from EL4. This is equivalent to a 4% percent reduction in FER from baseline. The total percent reduction in FER from baseline for EL5 includes the 59% reduction from EL4 and the 4% net reduction from the backward-inclined impeller for a total percent reduction of 63% from baseline.

The cost-efficiency curve for furnace fans used in hydronic air handlers (heat/cool) differs from those for furnace fans used in non-hydronic air handler products, because standby mode and off mode energy consumption are integrated in the rating metric, the integrated fan efficiency rating (IFER), for hydronic air handlers. As a result, DOE identified two additional efficiency levels for hydronic air handlers that are associated with technology options that reduce the standby mode energy consumption of hydronic air handlers. As described in the DOE furnace fan test procedure, DOE estimates that hydronic air handlers off mode operating hours and off mode energy consumption are equal to zero. In addition, manufacturers of hydronic air handlers are low-volume manufacturers, increasing the MPC of purchased parts. Table ES.3.5 presents the cost-efficiency curves for furnace fans used in hydronic air handlers.

Table ES.3.5 Incremental Manufacturer Production Cost Results for Furnace Fans Used in Hydronic Air Handlers

Efficiency Level	Technology Option	Percent Reduction in IFER	Incremental Cost
EL0	Baseline (PSC)	-	-
EL1	Improved PSC	2%	$6.98
EL2	PSC w/ Controls	10%	$16.24
EL3	X13	45%	$37.25
EL4	ECM and Multi-staging	59%	$106.62
EL5	Premium ECM and Multi-staging + Backward-Inclined Impeller	63%*	$122.01
EL6	Switching Mode Power Supply	64%**	$129.26
EL7	Toroidal Transformer	65%**	$140.21

* DOE estimates that implementing a backward inclined impeller at EL 5 results in a 10% reduction in FER from EL4. This is equivalent to a 4% percent reduction in FER from baseline. The total percent reduction in FER from baseline for EL5 includes the 59% reduction from EL4 and the 4% net reduction from the backward-inclined impeller for a total percent reduction of 63% from baseline.
** DOE estimates that implementing a switching mode power supply at EL 6 and a toroidal transformer at EL7 each results in a 2% reduction in IFER from the respective previous EL (EL 5 and 6, respectively). In both cases, this is equivalent to a 1% percent reduction in IFER from baseline. The total percent reduction in FER from baseline for EL6 includes the 63% reduction from EL5 and the 1% net reduction from the switching mode power supply for a total percent reduction of 64% from baseline. The total percent reduction in FER from baseline for EL7 includes the 64% reduction from EL6 and the 1% net reduction from the toroidal transformer for a total percent reduction of 65% from baseline.

ES.3.4 Markups Analysis

The markups analysis develops appropriate markups in the distribution chain to convert the estimates of manufacturer cost derived in the engineering analysis to consumer prices. Because a significant majority of the furnace fans covered in this rulemaking are components of furnaces,[2] DOE is using the same distribution channels for furnace fans as it used for furnaces in its 2011 rulemaking for that product.[3] 76 FR 37408 (June 27, 2011). DOE does not expect the distribution chains for furnace fans used in non-furnace HVAC products to differ significantly from furnace distribution chains.

DOE considered three distinct categories of market participants for furnace distribution: (1) distributors; (2) mechanical contractors; and (3) general contractors. DOE combined mechanical contractors, dealers, and installers in a single category labeled "mechanical contractors," because these terms are used interchangeably by the industry. Because builders serve the same function in the HVAC marketplace as general contractors, DOE included the

[2] The term "furnace" as used by DOE in this context includes all of the key product classes being analyzed.
[3] See http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_central_ac_hp_direct_final_rule_tsd.html.

builders in the "general contractors" category. For each type of actor in the distribution channel, DOE developed separate markups for baseline products (baseline markups) and for the cost increase associated with improvements required to produce more-efficient products (incremental markups). DOE also added sales tax. Table ES.3.6 summarizes the markups developed for furnace fans.

Table ES.3.6 Markups for Furnaces Containing Furnace Fans

	Baseline Cost	Incremental Cost
Manufacturer	1.26	
Wholesaler	1.36	1.11
Mechanical Contractor (new construction/replacement)	1.44/1.55	1.15/1.23
General Contractor (new construction only)	1.48	1.34
Sales Tax	1.071	1.071

ES.3.5 Energy Use Analysis

The purpose of the energy use analysis is to determine the annual energy consumption of furnace fans in representative U.S. homes and to assess the energy savings potential of increased furnace fan efficiency. DOE estimated the annual energy consumption of furnace fans at the considered energy efficiency levels across a range of climate zones. The annual energy consumption includes the electricity use by the fan and the change in natural gas, liquid petroleum gas (LPG), electricity, or oil use for heating as a result of a change in the amount of useful heat provided to the conditioned space at an alternative furnace fan efficiency.

To determine the variation in field energy use by products that would meet possible energy efficiency standards, DOE developed a sample from the Energy Information Administration (EIA)'s 2005 Residential Energy Consumption Survey (RECS).[4] RECS is a national sample survey of housing units that collects statistical information on the consumption of and expenditures for energy in housing units along with data on energy-related characteristics of the housing units and occupants.

To determine the energy consumption of furnace fans, DOE is using DOE's proposed fan efficiency rating, along with relevant heating and cooling characteristics for each sample household. The FER is proportional to annual energy consumption for national average operating conditions. It includes a time-weighted sum of the electricity consumed in key modes of operation.

The electricity consumption (and overall efficiency) of a furnace fan depends on the speed at which the motor operates, the external static pressure difference across the fan, and the airflow through the fan. To calculate furnace fan electricity consumption, DOE determined the

[4] Energy Information Administration (EIA), 2005 Residential Energy Consumption Survey (Available at: http://www.eia.doe.gov/emeu/recs).

operating conditions (the pressure and airflow) at which a particular furnace fan will operate in each RECS housing unit when performing heating, cooling, and continuous-circulation functions.

To estimate use of continuous circulation in the sample homes, DOE evaluated the available studies, which include a recent survey in Minnesota,[5] a 2009 program evaluation report from Wisconsin,[6] and 2003 Wisconsin field monitoring of residential furnaces.[7] DOE did not use these data directly, however, because it believes they are not representative of consumer practices for the U.S. as a whole. In these States, many homes have low air infiltration, and there is a high awareness of indoor air quality issues, which leads to significant use of continuous circulation. To develop U.S. average values, DOE modified the data from the upper Midwest using information from manufacturer product literature and consideration of climate conditions in other regions.

Duct pressure affects airflows and motor performance. DOE gathered field data from available studies and research reports to determine an appropriate probability distribution of external static pressure values.

Table ES.3.7 shows the results of the energy use analysis for furnace fans used in non-weatherized gas furnaces, which account for 71 percent of furnace fan shipments. Similar results for the other key product classes are presented in chapter 7 of this TSD, along with details on the methods, data, and assumptions used for the energy use analysis.

The savings in Table ES.3.7 do not account for potential changes in consumer operation of furnace fans if they purchase a more-efficient product. There is evidence that many homeowners who purchase ECM furnaces significantly increase the frequency with which they operate the furnace fan subsequent to the installation of the ECM furnace, thereby negating some or all of the energy savings from the more-efficient fan. After reviewing the available information, DOE concluded that inclusion of such a rebound effect in its analysis is warranted. DOE used the aforementioned report from Wisconsin[8] to estimate the extent to which increased use of continuous circulation under a standard requiring ECM furnace fans is likely to cancel out some of the savings from such a fan. DOE accounts for the rebound effect in the NIA.

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[5] Provided in CEE, No. 22 at pp. 1-2.

[6] State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation Semiannual Report, Final: April 8, 2009.

[7] Pigg, S., "Electricity Use by New Furnaces: A Wisconsin Field Study" (October 2003)(Available at http://www.doa.state.wi.us/docview.asp?docid=1812).

[8] State of Wisconsin, *op. cit*.

Table ES.3.7 Average Annual Energy Consumption and Savings for Furnace Fans Used in Non-Weatherized Gas Furnaces

Efficiency Level	Non- Condensing Furnace Fan			Condensing Furnace Fan		
	Annual Electricity Use (kWh)	Net Electricity Use Savings (kWh)	Additional Fuel Use (MMBtu)	Annual Electricity Use (kWh)	Electricity Use Savings (kWh)	Additional Fuel Use (MMBtu)
Baseline (PSC)	798	NA	NA	768	NA	0.00
Improved PSC	784	13	0.00	736	32	0.00
PSC w/ Controls	779	19	-0.04	643	125	-0.03
X13	508	290	0.28	421	347	0.39
ECM	532	265	0.33	410	357	0.44
ECM + Backward-inclined Impeller	478	319	0.36	372	396	0.48

ES.3.6 Life-Cycle Cost and Payback Period Analysis

New and amended energy conservation standards for products result in changes in consumer operating expenses—usually a decrease—and changes in consumer price—usually an increase. DOE analyzed the net effect of potential standards on consumers by evaluating the LCC and PBP using the cost-efficiency relationships derived in the engineering analysis, as well as the energy use derived from the energy use analysis. DOE conducted the LCC and PBP analysis using values that reflect use of furnace fans in the field.

DOE performed the LCC and PBP analysis using a spreadsheet model combined with Crystal Ball (a commercially-available software program used to conduct stochastic analysis using Monte Carlo simulation and probability distributions) to account for uncertainty and variability among the input variables. Each Monte Carlo simulation consists of 10,000 LCC and PBP calculations. The model performs each calculation using input values that are either sampled from probability distributions and household samples or characterized with single point values. Inputs to the LCC calculation include the installed cost to the consumer, operating costs (primarily energy expenses), the lifetime of the appliance, and a discount rate.

DOE used recent energy price data from EIA to determine average residential prices of electricity and natural gas in 13 geographic areas. To estimate the future trends in energy prices, DOE used projections from EIA's *Annual Energy Outlook 2011* (*AEO 2011*).[9] Appropriate prices were assigned to each sample household based on its location.

DOE modeled furnace fan lifetime based on the distribution of furnace lifetimes developed for the recent furnace standards rulemaking. By combining survey results from RECS and the U.S. Census's American Housing Survey[10] with the known history of furnace shipments, DOE estimated the fraction of furnaces of a given age still in operation. The survival function provides an average and median appliance lifetime. DOE assumed that the lifetime is the same for furnace fans at different efficiency levels.

DOE included motor replacement as a repair cost for a fraction of furnace fans. To estimate rates of fan failure, DOE developed a distribution of fan motor lifetime (expressed in operating hours) by motor size using data from DOE's analysis for small electric motors.[11] DOE then paired these data with the calculated number of annual operating hours for each sample furnace. Motor costs were based on costs developed in the engineering analysis. The labor time and unit costs were based on RS Means.[12]

The take-back in energy consumption associated with the rebound effect provides consumers with a service of value (*e.g.,* enhanced comfort associated with the indoor environment). DOE used the same discount rates for furnace fans as it used in the recent standards rulemaking for furnaces. DOE assumes that the value of this service is equivalent to the monetary value of the energy savings that would have occurred without the rebound effect. Therefore, the economic impacts on consumers with or without the rebound effect, as measured in the LCC analysis, are the same.

To estimate the share of consumers that would be affected by a standard at a particular efficiency level, DOE projected the distribution (*i.e.*, market shares) of product efficiencies that consumers may purchase under the base case (*i.e.*, the case without new or amended energy efficiency standards). Trends in HVAC system efficiency influence the market shares of different furnace fan efficiency levels. However, DOE found very limited historical data upon which to estimate either current shares or recent trends. To start, DOE considered Rheem's comment stating that the market share for ECM motors has increased from 10 percent to 30 percent within the last five years. (Rheem, No. 29 at p. 3) To estimate the market share for ECM motors in 2018, DOE developed data on the share of models in each product class that are ECM design.[13] The resulting estimate for 2018 is a 45 percent share for ECM fans out of the overall market for furnace fans. The market shares of each ECM fan efficiency level are derived from the data on number of models. No such data were available for the PSC fan efficiency levels, so DOE assumed that half of shipments are at the baseline level and half are improved PSC fans. There are currently no models of PSC with controls design, so DOE assumed a zero market share.

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9 See http://www.eia.gov/oiaf/aeo/overview.html.
10 See http://www.census.gov/housing/ahs/
11 See http://www1.eere.energy.gov/buildings/appliance_standards/commercial/sem_finalrule_tsd.html.
12 RS Means Company Inc., *RS Means Residential Cost Data* (2011).
13 DOE used the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Furnace Equipment as well as manufacturer product literature.

Using the projected distribution of product efficiencies for each product class, DOE assigned a base-case fan efficiency to each sample household. If a household was assigned a product efficiency that is greater than or equal to the efficiency of the standard level under consideration, the LCC calculation would show that this household is not impacted by that standard level.

Table ES.3.8 through Table ES.3.11 show key LCC and PBP results by candidate standard level (CSL) for furnace fans used in non-weatherized gas furnaces, electric furnaces, and weatherized gas furnaces. These product classes account for the majority of furnace shipments. Similar results for the other key product classes are presented in chapter 8 of this TSD, along with details on the methods, data, and assumptions used for the LCC and PBP analysis. The average lifetime operating cost presented in the tables reflects discounting of future costs using the consumer discount rates developed for the LCC analysis.

The LCC savings are relative to the distribution of efficiencies in the base case, not to the baseline technology. All of the considered CSLs show large average LCC savings and have a median PBP well below the average lifetime of furnace fans. Figures presented in chapter 8 show the range of LCC savings and PBPs for all of the efficiency levels considered for each key product class.

Table ES.3.8 Non-Weatherized, Non-Condensing Gas Furnace Fan: LCC and PBP Results

CSL	Technology Option	Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
						% Households with			
		Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	Net Cost	No Impact	Net Benefit	Median
0	Baseline (PSC)	236	1,354	1,590	N/A	0	100	0	N/A
1	Improved PSC	240	1,333	1,573	6	33	63	4	1.2
2	PSC w/ Controls	261	1,312	1,573	7	61	26	13	8.8
3	X13	293	967	1,260	240	24	26	50	3.7
4	ECM	448	1,056	1,503	31	64	15	21	20.5
5	ECM + Backward-Inclined Impeller	480	984	1,463	71	67	0	33	15.9

Table ES.3.9 Non-Weatherized, Condensing Gas Furnace Fan: LCC and PBP Results

CSL	Technology Option	Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	% Households with Net Cost	% Households with No Impact	% Households with Net Benefit	Median
0	Baseline (PSC)	241	1,292	1,533	N/A	0	100	0	N/A
1	Improved PSC	246	1,242	1,488	10	20	76	4	0.8
2	PSC w/ Controls	265	1,095	1,361	65	35	53	12	5.3
3	X13	306	840	1,146	169	13	53	33	5.2
4	ECM	459	884	1,344	34	54	33	13	22.8
5	ECM + Backward-Inclined Impeller	491	836	1,327	51	71	0	29	17.3

Table ES.3.10 Electric Furnace/ Modular Blower Fan: LCC and PBP Results

CSL	Technology Option	Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	% Households with Net Cost	% Households with No Impact	% Households with Net Benefit	Median
0	Baseline (PSC)	207	827	1,034	N/A	0	100	0	N/A
1	Improved PSC	211	817	1,028	1	23	74	3	3.8
2	PSC w/ Controls	231	829	1,060	-17	44	48	7	4.5
3	X13	235	629	864	88	16	48	35	1.9
4	ECM	388	680	1,069	-53	56	33	11	18.5
5	ECM + Backward-Inclined Impeller	420	635	1,054	-38	71	0	29	14.3

Table ES.3.11 Weatherized Gas Furnace Fan: LCC and PBP Results

CSL	Technology Option	Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	% Households with Net Cost	% Households with No Impact	% Households with Net Benefit	Median
0	Baseline (PSC)	237	1,243	1,480	N/A	0	100	0	N/A
1	Improved PSC	241	1,233	1,474	1	25	72	3	1.9
2	PSC w/ Controls	261	1,180	1,441	18	37	44	19	4.0
3	X13	297	820	1,117	203	7	44	49	2.6
4	ECM	451	814	1,264	102	37	32	30	10.1
5	ECM + Backward-Inclined Impeller	483	751	1,234	133	48	0	51	9.4

ES.3.7 Shipments Analysis

Shipment forecasts are needed to calculate the national impacts of standards on energy use, NPV, and future manufacturer cash flows. The vast majority of furnace fans are shipped installed in furnaces, so DOE estimated furnace fan shipments by projecting furnace shipments in three market segments: (1) replacements; (2) new housing; and (3) new owners in buildings that did not previously have a gas furnace.

To forecast furnace replacement shipments, DOE developed retirement functions for furnaces from the lifetime estimates and applied them to the existing products in the housing stock. The existing stock of products is tracked by vintage and developed from historical shipments data. To forecast shipments to the new housing market, DOE utilized forecasted new housing construction and historic saturation rates of various furnace and cooling product types in new housing. DOE used *AEO 2011* for forecasts of new housing. Furnace saturation rates in new housing are provided by the U.S. Census Bureau's *Characteristics of New Housing*.[14]

Figure ES.3.3 illustrates the forecasted base-case shipments by product class.

DOE believes that, consistent with economic theory and its past practice, it is reasonable to expect that standards that result in higher furnace prices will have some dampening effect on sales. To estimate the impact of the price increase for the considered efficiency levels, DOE used the relative price elasticity approach that was applied in the 2011 furnace standards rulemaking.

[14] Available at: http://www.census.gov/const/www/charindex.html.

This approach gives some weight to the operating cost savings from higher-efficiency products. The impact of higher furnace prices (due to more-efficient fans) is expressed as a percentage drop in market share for each year during the analysis period.

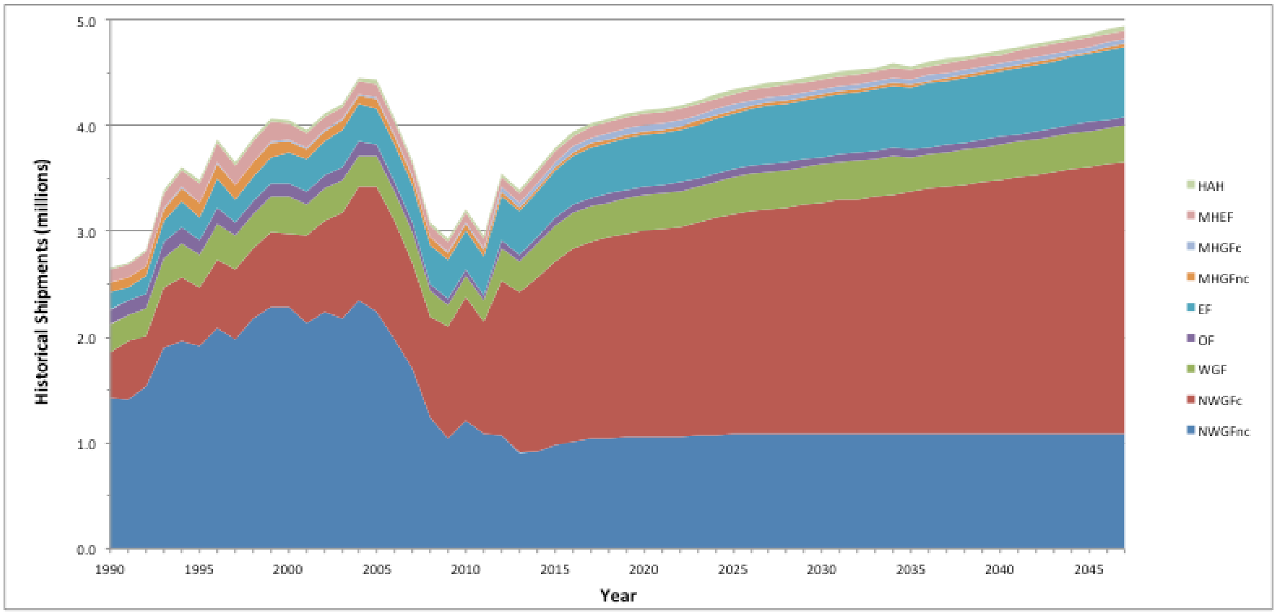

Figure ES.3.3 Forecasted Shipments for Furnaces Containing Furnace Fans (Base Case)

ES.3.8 National Impact Analysis

The NIA estimates the following national impacts from possible CSLs for furnace fans: (1) national energy savings; (2) monetary value of the energy savings due to standards; (3) increased total installed costs of the considered products due to standards; and (4) the NPV of the difference between the value of energy savings and increased total installed costs. DOE prepared a spreadsheet model to forecast energy savings and national consumer economic costs and savings resulting from new standards. In contrast to the LCC and PBP analysis, which uses probability distributions for the inputs, the NIA uses average or typical values for inputs.

A key component of DOE's NIA is the energy efficiencies forecasted for the base case (without new standards) and each of the standards cases. To forecast the efficiency trend in the base case (*i.e.*, no new standards for furnace fans), DOE derived a growth rate in the market share of ECM fans by extrapolating the trend from 2000, when the ECM share was near zero, to 2010, when it was approximately 30 percent. In so doing, DOE considered the favorable cost-effectiveness of ECM fans and assumed that their market share would peak and level off at 75 percent.

For the standards-case efficiency distributions, DOE used a "roll-up" scenario to establish the distribution of efficiencies for the year that standards are assumed to become effective (*i.e.*, 2018). DOE assumed that product efficiencies in the base case that did not meet the standard level under consideration would "roll up" to meet the new standard level in 2018. Market shares that were above a given standard level before 2018 would be unaffected.

The NES account for the energy savings foregone because of the rebound effect. For the calculation of consumer NPV, however, DOE assumes that the value of the service provided by increased product utilization is equivalent to the monetary value of the energy savings that would have occurred without the rebound effect. Therefore, the economic impacts on consumers with or without the rebound effect would be the same.

Chapter 10 provides additional details on the NIA.

ES.3.8.1 National Energy Savings

DOE calculated annual NES as the difference between national energy consumption in the base case (without new efficiency standards) and under each CSL. Cumulative energy savings are the sum of the annual NES, which DOE determined for 2018−2047.

DOE estimated energy consumption and savings based on site energy and converted the site energy values to primary (source) energy using factors that account for losses in transmission and distribution and in electricity generation. These site-to-source factors are derived from the National Energy Modeling System (NEMS). DOE also estimated full-fuel-cycle (FFC) energy savings for each CSL. The full-fuel-cycle measure includes the energy consumed in extracting, processing, and transporting primary fuels.

The NES results shown in Table ES.3.12 and Table ES.3.13 are shown as primary energy savings in quadrillion Btus (quads). Because DOE included a rebound effect for ECM furnace fans, the savings at CSLs 3 through 5 (which require an ECM fan) reflect adjustments for the rebound effect. The FFC energy savings are presented in chapter 10 of the TSD.

Table ES.3.12 National Energy Savings for Furnace Fans Used in HVAC Products Other than Hydronic Air Handlers (quads)

Key Product Class	Candidate Standard Level				
	1 Improved PSC	2 PSC w/ Controls	3 X13	4 ECM and Multi-staging	5 Premium ECM and Multi-staging + Backward -inclined Impeller
Non-Weatherized, Non-Condensing Gas Furnace Fan	0.022	0.061	0.725	0.624	0.850
Non-Weatherized, Condensing Gas Furnace Fan	0.041	0.265	0.623	0.611	0.911
Weatherized Gas Furnace Fan	0.002	0.019	0.122	0.143	0.200
Oil Furnace Fan	0.004	0.032	0.042	0.045	0.051
Electric Furnace / Modular Blower Fan	0.003	-0.005	0.102	0.085	0.162
Manufactured Home Non-Weatherized, Non-Condensing Gas Furnace Fan	0.001	0.010	0.018	0.024	0.026
Manufactured Home Non-Weatherized, Condensing Gas Furnace Fan	0.001	0.008	0.010	0.017	0.019
Manufactured Home Electric Furnace / Modular Blower Fan	0.000	0.007	0.013	0.023	0.031

Table ES.3.13 National Energy Savings for Furnace Fans Used in Hydronic Air Handlers (quads)

Key Product Class	Candidate Standard Level						
	1 Improved PSC	2 PSC w/ Controls	3 X13	4 ECM and Multi-staging	5 Premium ECM and Multi-staging + Backward-inclined Impeller	6 Switching Mode Power Supply	7 Toroidal Transformer
Hydronic Air Handler Fan (Heat/Cool)	0.000	0.000	0.016	0.030	0.034	0.037	0.039

ES.3.8.2 Net Present Value of Consumer Benefits

DOE calculated net monetary savings in each year as the difference between total savings in operating costs and increases in total equipment costs in the base case and standards cases. DOE calculated savings over the life of the products purchased in the forecast period. The NPV is the difference between the present value of operating cost savings and the present value of increased total installed costs. In accordance with guidance provided by the Office of Management and Budget (OMB) to Federal agencies on regulatory analysis, DOE used discount rates of 7 percent and 3 percent to discount future costs and savings to the present. The NPV results by key product class are shown in Table ES.3.14 through Table ES.3.17. A negative NPV indicates that the costs of a standard at a given efficiency level exceed the savings.

Table ES.3.14 Net Present Value, Discounted at 3 Percent, for Furnace Fans Used in HVAC Products Other than Hydronic Air Handlers (billion 2011$)

Key Product Class	**Candidate Standard Level**				
	1	**2**	**3**	**4**	**5**
	Improved PSC	PSC w/ Controls	X13	ECM and Multi-staging	Premium ECM and Multi-staging + Backward -Inclined Impeller
Non-Weatherized, Non-Condensing Gas Furnace Fan	0.110	0.048	4.462	0.551	1.395
Non-Weatherized, Condensing Gas Furnace Fan	0.254	1.559	4.449	0.089	0.944
Weatherized Gas Furnace Fan	0.006	0.083	0.842	0.382	0.581
Oil Furnace Fan	0.023	0.204	0.135	-0.038	-0.058
Electric Furnace / Modular Blower Fan	0.010	-0.118	0.601	-0.558	-0.406
Manufactured Home Non-Weatherized, Non-Condensing Gas Furnace Fan	0.003	0.021	0.044	-0.060	-0.066
Manufactured Home Non-Weatherized, Condensing Gas Furnace Fan	0.005	0.035	0.046	-0.103	-0.124
Manufactured Home Electric Furnace / Modular Blower Fan	-0.001	0.009	0.038	-0.093	-0.046

Table ES.3.15 Net Present Value, Discounted at 3 Percent, for Furnace Fans Used in Hydronic Air Handlers (billion 2011$)

Key Product Class	**Candidate Standard Level**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
	Improved PSC	PSC w/ Controls	X13	ECM and Multi-staging	Premium ECM and Multi-staging + Backward -Inclined Impeller	Switching Mode Power Supply	Toroidal Transformer
Hydronic Air Handler Fan (Heat/Cool)	0.000	-0.023	0.091	0.112	0.132	0.149	0.144

Table ES.3.16 Net Present Value, Discounted at 7 Percent, for Furnace Fans Used in HVAC Products Other than Hydronic Air Handlers (billion 2011$)

Key Product Class	Candidate Standard Level				
	1	2	3	4	5
	Improved PSC	PSC w/ Controls	X13	ECM and Multi-staging	Premium ECM and Multi-staging + Backward -Inclined Impeller
Non-Weatherized, Non-Condensing Gas Furnace Fan	0.036	-0.034	1.553	-0.278	-0.077
Non-Weatherized, Condensing Gas Furnace Fan	0.095	0.564	1.618	-0.505	-0.392
Weatherized Gas Furnace Fan	0.002	0.027	0.340	0.081	0.131
Oil Furnace Fan	0.007	0.070	0.035	-0.049	-0.063
Electric Furnace / Modular Blower Fan	0.003	-0.059	0.229	-0.343	-0.329
Manufactured Home Non-Weatherized, Non-Condensing Gas Furnace Fan	0.001	0.004	0.011	-0.049	-0.054
Manufactured Home Non-Weatherized, Condensing Gas Furnace Fan	0.002	0.013	0.016	-0.067	-0.080
Manufactured Home Electric Furnace / Modular Blower Fan	-0.001	-0.001	0.009	-0.072	-0.055

Table ES.3.17 Net Present Value, Discounted at 7 Percent, for Furnace Fans Used in Hydronic Air Handlers (billion 2011$)

Key Product Class	Candidate Standard Level						
	1	2	3	4	5	6	7
	Improved PSC	PSC w/ Controls	X13	ECM and Multi-staging	Premium ECM and Multi-staging + Backward -Inclined Impeller	Switching Mode Power Supply	Toroidal Transformer
Hydronic Air Handler Fan (Heat/Cool)	0.000	-0.012	0.031	0.028	0.034	0.040	0.036

ES.3.9 Preliminary Manufacturer Impact Analysis

The preliminary MIA focuses on manufacturers of the residential HVAC products in which furnace fans are used (*i.e.,* furnaces, modular blowers, and hydronic air handlers). Potential impacts include financial effects, both quantitative and qualitative, that might result from new energy conservation standards and consequently lead to changes in manufacturing practices for residential furnace fans. DOE identified potential impacts through interviews with manufacturers and other interested parties. Chapter 12 of the preliminary TSD includes details on the key issues DOE identified during the preliminary MIA, which include the following:

- Regulation of components, as opposed to the overall system;
- Certification and reporting requirements;
- Impacts on consumers;
- Impacts on the PSC market; and
- Cumulative regulatory burden.

During the preliminary analysis stage, DOE conducted the preliminary MIA by first identifying products, methods, and practices used in the residential furnace fan industries. Next, DOE interviewed manufacturers for feedback. DOE developed and distributed a questionnaire for use during the interviews. In the interviews, DOE gathered information to help determine how energy efficiency improvements affect cost, production, and various other manufacturing metrics. DOE also examined any additional effects on competition, manufacturing capacity, direct employment, and the cumulative burden of other regulations affecting manufacturers, as well as several issues raised by individual manufacturers. DOE considered feedback received during interviews in its analysis.

ES.4 ISSUES ON WHICH DOE SEEKS PUBLIC COMMENT

DOE is interested in receiving comments on all aspects of this preliminary analysis. DOE especially invites comments or data to improve DOE's analysis, including data or information that will respond to the following questions or concerns that were raised in response to the Framework Document and in preparation of the preliminary TSD.

ES.4.1 Market and Energy Performance Data for Non-Key Product Classes

DOE identified 21 product classes for this rulemaking, which are listed in section ES.3.3.1. For those product classes not among the nine key product classes, DOE was unable to find sufficient market and energy performance data to estimate cost and FER or IFER. DOE requests comments and data regarding the market for these products and their expected energy performance. Specifically, DOE requests market data regarding historical and future shipments and energy performance data to estimate FER or IFER (*i.e.,* measurements of airflow and electrical energy consumption in each airflow-control setting from 0 in.w.c. to 0.7 in.w.c. ESP).

ES.4.2 Efficiency as a Function of Capacity

DOE recognizes that furnace fans used in higher-capacity HVAC products consume more energy annually. DOE expects that the proposed rating metrics, FER and IFER, will not be dependent on capacity because they are normalized by airflow in the maximum airflow-capacity setting, which is dictated by the heating or cooling capacity of the HVAC product. DOE requests comments on the validity of these assumptions.

ES.4.3 Inverter-Driven PSC Fan Motors

DOE identified and used in its analyses a technology option that was once commercially available in a product but that is no longer for sale. This technology constitutes use of an inverter to drive a PSC motor. DOE's analysis shows that this technology can save energy, so DOE included it in the engineering analysis. DOE seeks comment on this technology and requests data regarding its energy performance and costs.

ES.4.4 Fan Motor Turndown Ratio

DOE recognizes that significant power reduction potentially occurs when the fan is operating in its lowest airflow-control setting. Consequently, DOE expects that furnace fans that can achieve a high turndown ratio will consume significantly less energy over a typical operating period. DOE seeks comment on the typical turndown ratios that can be achieved technically and in practice by each motor technology (*i.e.*, baseline PSC, improved PSC, inverter-driven PSC, constant-torque ECM, and constant-airflow ECM).

ES.4.5 Proprietary Electronically-Commutated Motor Technology

DOE recognizes that Regal Beloit possesses a number of patents in the brushless direct-current motor space. However, DOE is aware that other motor manufacturers, such as Broad Ocean, also offer brushless DC models. DOE also expects that manufacturers have the ability to use alternative designs to achieve the identified efficiency levels without using Regal Beloit's patented technology, such as ECMs with controls designed in-house. DOE seeks comment on the validity of its premise that alternative motor technologies can achieve comparable performance (turndown ratios and efficiency) at comparable cost to the Regal Beloit technology and that they will become increasingly available.

ES.4.6 High-Efficiency Fan Motor Control Costs

DOE recognizes that higher-efficiency motors require more sophisticated controls. DOE requests comments on whether more costly primary control boards are required to be paired with higher-efficiency motors.

ES.4.7 Backward-Inclined Impellers

DOE is including backward-inclined impellers as a technology option for the preliminary analysis. 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 a backward-inclined impellers.[15] The results of these tests show that backward-inclined impellers can improve furnace fan efficiency considerably, but the designs appear to reduce energy use for some operating conditions, but not for others. A proper evaluation of the technology will require a more careful review of the data

[15] Wiegman, Herman (2003). Final Report for the Variable Speed Integrated Intelligent HVAC Blower.

and the range of furnace fan operating requirements. However, for the preliminary analysis, DOE used a fixed 10-percent reduction in FER to evaluate the technology. According to feedback from manufacturers, the efficiency improvement of backward-inclined impellers may be much lower, less than 5 percent. DOE seeks comment on the expected efficiency improvements across the range of operating conditions in residential applications. DOE also seeks comment on which operating conditions result in favorable and unfavorable performance for furnace fans that use backward-inclined impellers. Manufacturers also mention a number of technical issues and design constraints associated with backward-inclined impellers. DOE recognizes that there are a number of technical hurdles to cost-effectively incorporate backward-inclined impellers in furnace fans. DOE seeks comment on whether design modifications or specialized components, such as fan motors with unique specifications (*e.g.*, high RPM), are necessary to implement backward-inclined impellers. DOE seeks comment on whether backward-inclined impellers are incompatible with the designs or components currently used in furnace fans. In addition, DOE seeks comment on whether use of backward-inclined impellers could impact product offerings. DOE seeks comment on the potential costs associated with implementing backward-inclined impellers. Detailed discussions regarding the backward-inclined impeller technology and how DOE is including them in the preliminary analysis can be found in chapters 3 and 5 of this TSD.

ES.4.8 Airflow Path Design

DOE recognizes that the airflow path design of the HVAC product in which the furnace fan is used impacts efficiency. DOE also recognizes that alterations to the design and configuration of internal components, such as the heat exchanger, could impact the thermal performance of the HVAC product. DOE plans to conduct its analyses carefully to ensure that tradeoffs between airflow performance and thermal performance are well understood and do not result in reduced overall system efficiency. While DOE did account for the impacts of airflow path design in the proposed test procedure and other aspects of the preliminary analyses (*e.g.*, product class selection), DOE did not consider airflow path design as a technology option. DOE anticipates that the size of the cabinet and the geometry of the heat exchanger(s) would be the primary targets for improvement in airflow path design. DOE did not include modeled cost and efficiency data for modifications to the cabinet size or heat exchanger geometry, because DOE expects that a model that could ensure that tradeoffs between airflow efficiency and thermal efficiency do not reduce the overall system efficiency would be overly complex. In addition, DOE expects that the costs for these improvements could be prohibitive and result in little airflow efficiency improvement compared to the other technology options mentioned in this TSD. Lastly, HVAC products that use furnace fans have space constraints. Any increase in overall size of the product could reduce utility to the consumer by potentially reducing or eliminating product availability for certain applications. DOE seeks comment on airflow path design changes that could result in improved airflow efficiency. DOE also seeks comment on the expected cost and efficiency improvement of these airflow path design improvements. In addition, DOE seeks comment or data on the expected tradeoffs between airflow efficiency and thermal efficiency for these design changes.

ES.4.9 Distribution Channel and Market Share of Replacement Furnace Fans

DOE understands that the market for replacement fans is very small, and it has not included this distribution channel in the preliminary analysis. DOE requests comments regarding whether this channel is large enough to merit inclusion, and, if so, what would be an appropriate assumption for its market share.

ES.4.10 Continuous-Circulation Operation

To estimate use of continuous circulation in the sample homes, DOE evaluated the available studies, as described in section ES.3.5. DOE did not use these data directly, however, because it believes they are not representative of consumer practices for the U.S. as a whole. In these States, many homes have low air infiltration, and there is a high awareness of indoor air quality issues, which leads to significant use of continuous circulation. To develop U.S. average values, DOE modified the data from the upper Midwest using information from manufacturer product literature and consideration of climate conditions in other regions. The continuous-circulation hours that DOE used are described in chapter 7 of this TSD. DOE requests comments on its characterization of use of continuous circulation, and information that would support use of alternative assumptions.

ES.4.11 Rebound Effect on Energy Savings from Higher-Efficiency Furnace Fans

After reviewing the available information, DOE concluded that inclusion of a rebound effect in its analysis is warranted. DOE used the aforementioned evaluation report from Wisconsin to estimate the fraction of households that may change to use of continuous circulation under a standard requiring ECM furnace fans, which would cancel out some of the savings from such a fan. The specific assumptions are described in chapter 7 of this TSD. DOE requests comments on the reasonableness of the values that it used to characterize this rebound effect.

ES.4.12 Base-Case Furnace Fan Efficiency Distribution in 2018 (LCC Analysis)

Trends in HVAC system efficiency influence the market shares of different furnace fan efficiency levels. However, DOE found very limited historical data upon which to estimate either current shares or recent trends. To estimate the market share for ECM motors in 2018, DOE developed data on the share of models in each product class that are ECM design. The resulting estimate for 2018 is a 45 percent share for ECM fans out of the overall market for furnace fans. The market shares of each ECM fan efficiency level are derived from the data on number of models. No such data were available for the PSC fan efficiency levels, so DOE assumed that half of shipments are at the baseline level and half are improved PSC fans. DOE requests comments on its estimate of the base-case efficiency distribution of furnace fans in 2018 and data that might support use of different assumptions.

ES.4.13 Furnace Fan Efficiency Trends in the Absence of Standards (NIA)

Trends in HVAC equipment efficiency are a major factor driving furnace fan efficiency. However, it is uncertain to what extent incentives will play a role after 2018 and to what degree future standards for residential HVAC products will require high-efficiency furnace fans. For this preliminary analysis, DOE derived a growth rate in the market share of ECM fans by extrapolating the trend from 2000, when the ECM share was near zero, to 2010, when it was approximately 30 percent. In so doing, DOE considered the favorable cost-effectiveness of ECM fans and assumed that their market share would peak and level off at 75 percent. DOE requests comments on the reasonableness of its approach and information that would support use of alternative assumptions.

ES.4.14 Full-Fuel-Cycle Energy Savings

DOE has historically presented NES in terms of primary energy savings. DOE recently published a Notice of Policy (NOP) stating its intent to incorporate full-fuel-cycle (FFC) metrics into its analyses and outlining a proposed approach. The methodology is based on the calculation of an FFC multiplier, or conversion factor, for each of the primary fuels used by covered products. The FFC energy savings are obtained by multiplying the energy savings calculated in the NIA by the conversion factor. The NOP states that DOE intends to calculate FFC energy and emission impacts by applying conversion factors generated by the Greenhouse house gases, regulated emissions, and energy use in transportation (GREET) model to the NEMS-based results currently used by DOE. 76 FR 51281 (Aug. 18, 2011). Additionally, DOE will review alternative approaches to estimating these factors and may decide to use a model other than GREET to estimate the FFC energy and emission impacts in any particular future appliance efficiency standards rulemaking. For this preliminary analysis, DOE calculated FFC energy savings using a NEMS-based methodology described in appendix 10-B of the TSD. DOE welcomes comments on its approach to derive FFC conversion factors.