CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF DOCUMENT

This Technical Support Document (TSD) is a "stand-alone" report that provides technical analyses and results in support of the information presented in the Advance Notice of Proposed Rulemaking (ANOPR) for residential furnaces and boilers.

1.2 OVERVIEW OF APPLIANCE STANDARDS

Part B of Title III of the Energy Policy and Conservation Act (EPCA or Act), Public Law 94–163—as amended by the National Energy Conservation Policy Act (NECPA), Public Law 95–619; the National Appliance Energy Conservation Act (NAECA) of 1987, Public Law 100–12; the National Appliance Energy Conservation Amendments of 1988 (NAECA 1988), Public Law 100–357; and the Energy Policy Act of 1992 (EPACT), Public Law 102–486—created the Energy Conservation Program for Consumer Products other than Automobiles. The consumer products subject to this Program (referred to hereafter as ''covered products'') include residential furnaces and boilers. (42 U.S.C. 6295(f))

Before the Department determines whether to adopt a proposed energy conservation standard, it must first solicit comments on the proposed standard. (42 U.S.C. 6295 (p)) Any new or amended standard must be designed so as to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. (42 U.S.C. 6295 (o)(2)(A)) If a proposed standard is not designed to achieve the maximum improvement in energy efficiency or the maximum reduction in energy use that is technologically feasible, the Secretary must state the reasons for this in the proposed rule. (42 U.S.C. 6295 (p)(2)) To determine whether economic justification exists, the Department must review comments on the proposal and determine that the benefits of the proposed standard exceed its burdens to the greatest extent practicable, weighing the following seven factors:

1. The economic impact of the standard on the manufacturers and on the consumers of the products subject to such standard;
2. The savings in operating costs throughout the estimated average life of the covered product in the type (or class) compared to any increase in the price of, or in the initial charges for maintenance expenses of, the covered products which are likely to result from the imposition of the standard;
3. The total projected amount of energy savings likely to result directly from the imposition of the standard;
4. Any lessening of the utility or the performance of the covered products likely to result from the imposition of the standard;
5. The impact of any lessening of competition, as determined in writing by the Attorney General, that is likely to result from the imposition of the standard;

6. The need for national energy conservation; and
7. Other factors the Secretary considers relevant.

1.3 OVERVIEW OF RESIDENTIAL FURNACES AND BOILERS STANDARDS

The EPCA, as amended, requires the Department of Energy (DOE or Department) to consider amending the energy conservation standards for certain major appliances. The NAECA legislation of 1987 established efficiency standards for residential furnaces and boilers.[a] It set the standards in terms of the annual fuel utilization efficiency (AFUE) descriptor at a minimum value of 78 percent for most furnaces. For boilers, it set the minimum AFUE at 75 percent for gas steam boilers and 80 percent for other boilers. For mobile home furnaces, it set the minimum AFUE at 75 percent. The effective date for these standards was January 1, 1992.

For ''small'' furnaces (those having an input rate of less than 45,000 British thermal units per hour), the Act required the Department to publish a final rule by January 1, 1989, and to set a minimum AFUE at a specific level not less than 71 percent and not more than 78 percent. (EPCA 325(f)(1)(B)(ii)) For these products, the Department published an ANOPR (52 FR 46367, December 7, 1987), followed by a Notice of Proposed Rulemaking (NOPR) (53 FR 48798, December 2, 1988), in which the Department proposed to establish an energy conservation standard of 78 percent AFUE for small gas furnaces. In a final rule (54 FR 47916, November 17, 1989), the Department set the minimum AFUE for these products at 78 percent, with an effective date of January 1, 1992.

For mobile home furnaces, the Act directed the Department to publish a final rule no later than January 1, 1992, to determine whether the standard should be amended. The Act required the effective date for amendments to be January 1, 1994. The Department started this activity and issued an ANOPR (55 FR 39624, September 28, 1990), followed by a NOPR. 59 FR 10464, March 4, 1994. The Department did not release a final rule for mobile home furnace standards. As part of this activity, the Department proposed a new energy descriptor that accounts for both natural gas and electricity used by a furnace. The Department rejected this approach because of the difficulty of accounting for source energy associated with electricity use. Further activities on this rulemaking were interrupted by several events, including a fiscal year 1996 moratorium on proposing or issuing new or amended appliance energy conservation standards, and the development of an improved process for the Department's energy efficiency standards rulemakings. No final rule for mobile home furnace standards was published.

[a] EPCA Section 321 (23) states that a "furnace" includes forced-air and gravity central furnaces and low-pressure steam and hot water boilers, and that it must have a heat input rate of less than 225,000 Btu/hr for forced-air and gravity central furnaces, and less than 300,000 Btu/hr for boilers. However, in the current furnace and boiler rulemaking DOE adopted the terminology used in the heating, ventilating, and air-conditioning (HVAC) industry, which considers furnaces and boilers as separate categories.

The Act also required the Department to publish a final rule to determine for all furnaces and boilers whether the standards should be amended. The Act required that DOE publish this final rule no later than January 1, 1994, and, if the Department determined that the standards should be amended, the Act required that those amendments be effective on January 1, 2002. EPCA, section 325(f)(3)(B), 42 U.S.C. 6295(f)(3)(B). The Department started this activity and published an ANOPR in which it presented the product classes for furnaces that it planned to analyze, and a detailed discussion of the analytical methodology and models that it expected to use in this rulemaking. (58 FR 47326, September 8, 1993) The Department invited comments and data on the accuracy and feasibility of the planned methodology and encouraged interested persons to recommend improvements or alternatives to DOE's approach. The rulemaking was not completed by January 1, 1994.

In September 1995, the Department announced a formal effort to consider improvements to the process used to develop appliance efficiency standards, calling on manufacturers, energy-efficiency groups, trade associations, State agencies, utilities, and other interested parties to provide input to guide the Department. On July 15, 1996, the Department published a Final Rule: Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products (Process Rule). 61 FR 36974. The Process Rule outlines the procedural improvements identified by the interested parties. The process improvement effort included a review of the economic models and the analytical tools used in the rulemaking process, as well as the prioritization of future rules.

In its fiscal year 1998 Priority Setting for the Appliance Rulemaking Process, the Department assigned a low priority level to residential furnaces and boilers, which meant it did not plan to actively pursue the rulemaking over the next two years. The Department limited its work on these products to basic technology investigation.

In the fiscal year 2001 Priority Setting for the Appliance Rulemaking Process, DOE assigned a high level of priority to residential furnaces and boilers, which meant the Department planned to pursue the rulemaking actively through meetings, workshops, and published notices.

Table 1.3.1 summarizes the history of the standards for furnaces and boilers.

Table 1.3.1 History of Furnace and Boiler Standards

	Furnaces/boilers	**Small furnaces**	**Mobile home furnaces**
Original standard Source Publication year	78/75% AFUE NAECA 1987	78% AFUE Final Rule 1989	75% AFUE NAECA 1987
Update	Start FY2001	Part of furnaces	NOPR, 1994 (*)

(*) not completed; included as a product class in FY2001 furnace rulemaking

The current rulemaking has followed the requirements for developing efficiency standards, as described in Title 10 Energy, Code of Federal Regulations (CFR), Part 430, Subpart C, Appendix A, Section 4, Process for Developing Efficiency Standards and Factors to be Considered. Throughout the process, DOE reviewed important issues with expert groups and stakeholders.

The Department held a workshop on July 17, 2001, to discuss the analytical framework proposed for this rulemaking. The framework presented at the workshop described the different analyses to be conducted, the methods proposed for conducting them, and the relationships among the various analyses as shown in Table 1.3.2.

Table 1.3.2 Residential Furnace and Boiler Analyses Required by Process Rule

ANOPR	NOPR	Final Rule
Market and technology assessment	Revised ANOPR analyses	Revised analyses
Screening analysis	Life-cycle cost sub-group analysis	
Markups for equipment price determination	Manufacturer impact analysis	
Engineering analysis	Utility impact analysis	
Energy use	Environmental assessment	
Life-cycle cost and payback period analyses	Net national employment impact analysis	
Shipments analysis	Regulatory impact analysis	
National impact analysis		

The Department held a public workshop on May 8, 2002, to receive and discuss comments on issues related to venting for residential furnaces and boilers, and to discuss the Department's research concerning venting systems. As discussed in section 1.3.1, several stakeholders expressed concerns about safety and liability issues associated with condensation problems that may arise with higher-efficiency non-condensing furnaces and boilers.

In June 2002, DOE asked the Gas Appliance Manufacturers Association (GAMA) to review DOE's analysis of manufacturing costs. GAMA provided comments, which DOE considered in its further analysis.

The Department's analytical framework described a possible approach to regulating the electricity use of residential furnaces and boilers that would involve specifying a maximum annual electrical consumption based on the E_{AE} parameter (average annual auxiliary electrical consumption as defined in the test procedure), which is already reported in the GAMA directory for each model. The current DOE test procedure (10 CFR430, Subpart B, Appendix N) provides a means to determine this value.

In 1995, the Department considered development of a single descriptor that combines electricity use and a measure of fuel efficiency, AFUE.[1] The approach considered at the time, which involved measuring the source energy input associated with the electricity use of a furnace or boiler, was rejected by the Department in 1997 because the use of source energy is not permitted by EPCA, which specified that efficiency must be determined by energy use at the point of use (site).[2] The Department stated it would continue to explore and to solicit input on various options for the development of a descriptor that accounts separately for fossil fuel and electricity used by furnaces and boilers.

Commenting on DOE's framework document for furnaces and boilers in 2001, the American Council for an Energy-Efficient Economy (ACEEE) suggested defining an electricity use standard in terms of watts of electricity per unit of air moved at specific static pressure in cubic feet per minute (W/cfm).[3] This approach requires a knowledge of furnace operating parameters (power (W), air-flow rate (cfm)) that are not required to be reported currently.

In August 2002, GAMA convened a meeting to discuss the above issues at which the Department, GAMA, and ACEEE presented their ideas. The Department considered whether it has the legal authority to regulate electricity consumption in residential furnaces and boilers. Based on its review of the current statutory language, the Department has decided that it lacks the authority to regulate electricity consumption in residential furnaces and boilers at this time.

While considering the legal interpretation, the Department analyzed all design options that met the screening criteria, including design options specific to saving electricity. The Department presents the analysis of design options specific to saving electricity in residential furnaces and boilers separately (in Appendix 8.5 of this TSD) for the purposes of: (a) full reporting to the public of the complete analysis, and (b) making the information available for use in voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties.

In September 2002, DOE posted the engineering analysis for furnaces and boilers on its website and asked for comments. GAMA, ACEEE, and Natural Resources Canada (NRCan) provided comments, which DOE considered in its further analysis.

In late 2002 and the beginning of 2003, DOE reviewed its preliminary analysis and previous stakeholder comments. In response to stakeholder comment, and in order to apply a more comprehensive and accurate analysis than previously available, DOE created an "Installation Model" in the spring of 2003. In the summer of 2003, DOE completed its preliminary analysis, which is described in this TSD.

According to the rulemaking timeline, DOE plans to issue a Final Rule in June, 2006. The effective date for any new standards for furnaces and boilers would be January, 2012.

1.3.1 Issues Related to Venting of Residential Furnaces and Boilers

1.3.1.1 Background

The Department recognizes that there are potential vent system safety concerns associated with increasing the minimum fuel efficiency standard for "non-condensing" furnaces and boilers. In order to receive and discuss comments related to venting for residential furnaces and boilers, DOE convened a public workshop on May 8, 2002. At this workshop, stakeholders expressed their views and shared their knowledge of venting issues associated with traditional vent systems (i.e., single wall, double wall Type B vent, and masonry chimneys) used on "non-condensing" residential furnaces and boilers. These discussions focused on the potential safety issues and the cost of ensuring safety.

"Non-condensing" furnaces and boilers (which operate at an efficiency range of 78–82 percent AFUE) produce high-temperature flue gases that do not generate significant condensate in normal operation, and use a single wall or Type B vent. While "non-condensing" furnaces and boilers produce some condensate in the vent, they are not designed to utilize the heat from condensing the water vapor necessary to improve the efficiency to about the 90 percent AFUE range. The "condensing" furnaces (usually 90 percent AFUE or higher) achieve high efficiency by reducing flue-gas temperatures to a level at which most of the water vapor in the flue gas is condensed and the latent heat associated with phase change of the water is harnessed. The heat of vaporization of water in the combustion products of natural gas represents about 9 percent of the total energy in the gas. Today's "condensing" technology demonstrates that this energy can be harnessed without concerns for corrosion and safety compromises and, therefore, venting issues concerning "condensing" furnaces and boilers were not a focus of the workshop.

Vent systems, such as Type B vent or masonry chimneys, discharge hot flue gases to the exterior of a building. While a breach in any vent system can allow toxic combustion compounds, such as carbon monoxide (CO), to mix with the interior air, fire is also a hazard that can result from a failed vent system. A vent failure commonly results from corrosion precipitated by excessive condensation inside the vent. Condensation occurs when the water vapor created in the combustion process of hydrocarbon fuels, such as natural gas, liquified petroleum (LP) gas, and fuel oil, cools below the dew point and becomes a liquid. As the water vapor condenses and liquefies, it combines with other combustion byproducts to form an acidic solution. The resulting acid eventually corrodes and destroys any metal vent system not designed for handling the corrosive compounds generated during condensing operation. While condensate problems more commonly affect vent system components, the Department recognizes that the heat exchangers of furnaces and boilers can also be subject to corrosion stemming from condensate build-up and result in the aforementioned safety hazards.

How is this important in the case of furnace and boiler energy efficiency standards? The higher the efficiency, the more likely the production of condensate. This relationship exists because lower flue gas temperatures may not allow the vent system to dryout during the on-cycle period and thus excess condensate accumulates in greater quantity. More-efficient furnaces and boilers produce lower-temperature flue gases since they better harness the heat energy from the fuel. A sufficiently high flue gas temperature keeps the water vapor from condensing inside the venting system.

The National Fuel Gas Code (NFGC) (American National Standards Institute (ANSI) Z223.1-2202, National Fire Protection Association (NFPA) 54-2002)[4] establishes venting guidelines to help ensure safety and preclude the production of excessive condensation inside vent systems. The ANSI Standard for Gas-fired Central Furnaces (ANSI Z21.47-2001)[5] specifies the furnace categories for the guidelines. These guidelines establish minimum and maximum vent capacities for furnaces whose efficiencies do not exceed 83 percent steady-state efficiency (SSE). These guidelines are based on wet time limits (wet time is defined as that period of time when vent wall temperature is lower than the dew point) and 83 percent SSE. 83 percent SSE is a baseline condition used to generate venting tables for Category I fan-assisted appliances and is the generally accepted threshold above which potentially excessive quantities of condensation are produced. The wet time limits for the vent connectors are significantly shorter than the wet time limits for the vertical vents. Therefore, if the venting system design ensures no condensation in the vent connector, the entire venting system (including the vertical vent) will operate without risk of condensation damage.

Modulation technology is used for non-condensing and condensing furnaces. Manufacturers of non-condensing modulating furnaces employ appropriate controls to regulate the flow of air outside the furnace heat exchanger and the flow of flue gases inside the heat exchanger to prevent the formation of excessive condensate during the heat-up cycle on cold heat exchanger and vent system surfaces.[6] According to the American Gas Association (AGA) handbook, if the furnace control system maintains the flue flow rates in the proper proportions of the furnace input rate, the furnace will operate at SSE not higher than 83 percent (the limit used for developing the venting tables in the NFGC to safeguard against excessive condensate) throughout the entire designed turndown range[b] and maintain the designed air flow temperature rise. To ensure safety, the manufacturers' installation manuals specify the use of Type B double-wall vent connectors[7] for modulating furnaces that operate at the 80–81 percent AFUE range. The Department believes that, because of the incorporation of effective controls and Type B double-wall vent systems, modulating furnaces and boilers at this efficiency level would not pose a safety concern.

1.3.1.2 Summary of Stakeholder Comments

For non-weatherized gas furnaces, manufacturers commented that furnaces with efficiencies between 81 percent and 90 percent AFUE would present safety and liability risks if not vented appropriately. GAMA stated that 83 percent SSE, which corresponds to an AFUE of

[b] "Turndown range" for modulating furnaces is defined as the ratio of the furnace maximum input rate to the furnace minimum input rate.

80–82.5 percent, is recognized as the threshold above which potentially hazardous condensation may occur. (GAMA, No. 25JJ at p. 162) However, ACEEE maintained that 83 percent AFUE is technically feasible without significant risk of corroding the heat exchanger. (ACEEE, No. 25JJ at p. 20)

For condensing furnaces, GAMA recommended that the Department consider in its analyses regional and local building code requirements concerning venting materials and practices. GAMA also mentioned the problems with less expensive plastic materials, such as high temperature plastic vents (HTPV), to vent exhaust gases, which resulted in a recall by the US Consumer Product Safety Commission, and cautioned DOE about the appropriate use of materials and approaches to reduce condensation problems (e.g., vent coating, vent pre-heating, new materials, improved vent-connectors). (GAMA, No. 25JJ at p. 174)

Battelle Memorial Institute (Battelle) urged DOE to take into account the increased liabilities that may arise with higher efficiency. (Battelle, No. 25JJ at p. 215) GAMA stated that DOE must consider the risks and costs associated with venting and corrosion problems. (GAMA, No. 25JJ at p. 85) Trane stated that increasing the AFUE above 81 percent would place an undue burden on manufacturers to preserve customer safety.[8]

Several stakeholders commented on including in DOE's analysis the cost of upgrading the venting system due to increased efficiency. GAMA commented that costs must reflect installation in complete compliance with all manufacturer instructions and code requirements, including extra installation costs for relining or resizing non-compliant venting systems for orphaned water heaters. GAMA also said that DOE needs to consider the costs of upgrade or repair when the furnace is no longer vented using a Category I venting system. (GAMA, No. 25JJ at p. 87) York stated DOE should consider that a large percentage of replacement furnaces are installed where masonry chimneys are used (thereby requiring a chimney upgrade), and another large segment of installations use common venting with water heaters.[9] GAMA and the National Propane Gas Association (NPGA) commented that the new efficiency standards for water heaters will contribute to the condensation problem because many furnaces and water heaters are commonly vented. (GAMA, No. 25JJ at p. 174; and NPGA, No. 35 at p. 2)

Controls and sensors exist that are able to prevent the development of condensation in the venting system. In response to the DOE's presentation on controls and sensors that exist, GAMA stated that by the time a sensor or CO detector works, it is too late to prevent condensation. (GAMA, No. 25JJ at p. 171) The AGA commented that some control strategies (CO detectors and water-activated switches) would have adverse safety and health impacts (potential CO exposure resulting from corroded vents). (AGA, No. 25JJ at p. 177)

York stated that venting systems for mobile housing heating equipment have their own special requirements and standards, which must be considered when determining the impact of efficiency requirements on venting issues. (York, No. 25JJ at p. 148) The GAMA said DOE should investigate corrosion related to boiler efficiency apart from furnace efficiency.[10]

1.3.1.3 Department of Energy Analysis Considerations

The Department considered the comments received during and after the workshop in its analysis of installation costs for furnaces and boilers, as described in Chapter 6 of this TSD. The Department recognizes the concerns about the equipment having an SSE above 83 percent. However, DOE believes that the corrosion issue can be solved through the use of the proper materials for the furnace heat exchanger and venting system. The Department addressed the safety issue in the analysis by assigning a specialized venting system to an appropriate fraction of installations (the specialized venting systems incorporate corrosion resistant materials and are applicable to furnaces and boilers having an SSE above 83 percent). This approach captures the added costs associated with ensuring safe operation of higher-efficiency furnaces. The Department included all costs for installations that are in complete compliance with manufacturer instructions and code requirements. This includes upgrades when the furnace is no longer vented using a Category I system, as well as changes to common venting systems, including vent changes for orphaned water heaters.

For furnaces at 80 percent and 81 percent AFUE that utilize modulating technology, the analysis assigned the cost for Type B double-wall vent connectors, as recommended in the manufacturer installation manuals. The Department is unaware of a study that indicates that condensation problems exist with furnaces and boilers having modulating capabilities for these efficiency levels.

The Department applied in its analysis the appropriate venting practices for condensing furnaces, and included the cost of venting higher-efficiency equipment for all product classes, including oil equipment and boilers. The Department is analyses did not consider controls and sensors to prevent condensation.

1.4 STRUCTURE OF THE DOCUMENT

This ANOPR TSD consists of 14 chapters, 23 appendices, and an environmental assessment and regulatory impact analysis.

Chapter 1 Introduction: provides an overview of the appliance standards program and how it applies to the residential furnaces and boilers rulemaking, and outlines the structure of the document.

Chapter 2 Analytical Framework: describes the furnace/boiler analytical process.

Chapter 3 Market and Technology Assessment: characterizes the relevant product markets and existing technologies.

Chapter 4 Screening Analysis: describes the technology options for efficiency improvement and evaluates them against specific criteria.

Chapter 5	Markups for Equipment Price Determination: describes how manufacturing costs are marked up to obtain retail prices.
Chapter 6	Engineering Analysis: describes the derivation of product costs, including manufacturing, installation, and maintenance costs. It describes the calculation of energy use according to the DOE test procedure.
Chapter 7	Energy Consumption of Furnaces and Boilers: describes the calculation of field energy use by furnaces and boilers for use in the life-cycle cost analysis.
Chapter 8	Life-Cycle Cost and Payback Period Analysis: describes the effects of potential candidate standards on individual purchasers and users of the appliances. This analysis compares the life-cycle cost of appliances with possible new standards against no change in standards.
Chapter 9	Shipments: describes the methodology for forecasting shipments by product class, in the absence or presence of new regulations.
Chapter 10	National Impact Analysis: describes national forecasts of energy use and net present value in the absence or presence of new regulations.
Chapter 11	Life-cycle Cost Sub-group Analysis: describes the approach for estimating LCC impacts on any identifiable groups or customers who may be disproportionately affected by any proposed change in standard levels of residential furnace and boiler users (NOPR stage).
Chapter 12	Manufacturer Impact Analysis: describes the approach for estimating the financial impact of new efficiency standards on manufacturers (NOPR stage).
Chapter 13	Utility Impact Analysis: describes the approach for estimating the impact of proposed standard levels on the electric utility industry due to new efficiency standards (NOPR stage).
Chapter 14	Employment Impacts Analysis: describes the approach for estimating the impact of new efficiency standards on national employment (NOPR stage).

Environmental Assessment: describes the approach for estimating the changes in air-borne emissions due to new efficiency standards (NOPR stage).

Regulatory Impact Analysis: describes the approach for estimating the impact of non-regulatory alternatives to new efficiency standards (NOPR stage).

Appendix 5.1: Detailed Data for Equipment Price Markups: provides further details on the wholesaler, builder, and contractor markups presented in Chapter 5, *Markups for Equipment Price Determination*.

Appendix 6.1: Technical Description of the Reverse Engineering Cost Estimation Methodology: describes the technical aspects of the approach as applied to residential furnaces and boilers. Refer to Chapter 6 of the Technical Support Document (TSD) for more information on assumptions and context.

Appendix 6.2: Installation Cost Model: describes installation cost model called the "Installation Model" based on RS Means, a well-known and respected construction cost estimation method. The model encompasses a broad array of product classes, installation sizes, and venting configurations.

Appendix 6.3: Determination of Furnace and Boiler Energy Use: describes the approach requiring the calculation of the average annual fuel energy consumption (E_F), the average annual electrical energy consumption (E_{AE}), and the national average number of burner operating hours (BOH_{SS}) of furnaces and boilers.

Appendix 6.4: Engineering Analysis Cost and Efficiency Tables: contains the cost and efficiency tables described in Chapter 6, section 6.7.4 of the Furnace/Boiler Technical Support Document (TSD).

Appendix 6.5: Engineering Analysis Payback Results: contains tables and charts of the Engineering Analysis Payback results.

Appendix 7.1: Reduced Set of Furnace Models Database: describes the Reduced Set of Furnace Models Database that was developed to created to identify furnace models. The models represent units with different design characteristics, and expand the Gas Appliance Manufacturers Association (GAMA) directory data for each furnace model by adding information provided in the manufacturers' product literature.

Appendix 7.2: Decoding of Manufacturer Model Numbers: illuminates the furnace specifications from manufacturer model numbers.

Appendix 7.3: Determination of Basic Furnace Models: describes the determination of basic furnace models characteristics.

Appendix 7.4: Furnace Fan Curves: describes fan curves which are graphical representations of the pressure rise, called static pressure, compared to the airflow through the fan or blower.

Appendix 7.5: Blower Fan Curves: describes the selection of blower fan curves for both pressure and shaft power as functions of airflow.

Appendix 7.6: Overall Air-Moving Efficiency: describes overall air-moving efficiency as a variable in the calculation of blower motor electricity consumption. The overall air-moving efficiency is a ratio of the air power divided by the electric power used by the blower motor.

Appendix 7.7: Gas and Electricity Use for Modulating Furnaces: describes how DOE calculated the gas consumed by the burner and electricity consumed by the circulating air blower motor at the two firing rates. This calculation method is based on the procedure in the ASHRAE Standard 103.

Appendix 8.1: Glossary of Variables and Their Values From EIA's RECS97: contains RECS variable name abbreviations and provides definitions of the variable values.

Appendix 8.2: Distribution Discount Rates: describes new installation and replacement discount rates.

Appendix 8.3: LCC and PBP Results Using Alternative Installation Cost Scenarios: presents LCC and PBP results using alternative installation costs for non-weatherized gas furnaces and gas boilers. These results are presented as high and low sensitivity cases.

Appendix 8.4: LCC and PBP Results Using Alternative Energy Price Scenarios: presents LCC and payback results using alternative energy price scenarios from EIA's AEO 2003. The Department based the payback periods on the calculation methodology used in Chapter 8: Life-Cycle Cost and Payback Period Analysis.

Appendix 8.5: Analysis of Electricity Efficiency Design Options for Furnaces and Boilers: describes the process used to determine the level of electricity efficiency in particular design options for furnaces and boilers.

Appendix 8.6: Furnace Airflow Capacity Testing: provides a discussion of the task of testing various circulating-air blowers in a common-size furnace to assess the applicability of using the Air Movement and Control Association test standard 210 (AMCA 210) as a method of determining the airflow capacity of a furnace circulating-air blower.

Appendix 8.7: Power Consumption of ECM Blower Motors: describes a series of equations to first calculate the blower speed and shaft power from the furnace static pressure.

Appendix 8.8:	Power Consumption of BC/ECM+ Blower Motors: describes equations to predict blower motor electrical power consumption for the BC/ECM+ design option based on this prototype.
Appendix 8.9:	Air Conditioner Operating Hours: explains how DOE calculated the reduced air conditioner operating hours for a furnace with a more efficient blower and/or blower motor design option.
Appendix 10.1:	National Energy Savings and Net Present Value Using Alternative Installation Costs and Energy Price Scenarios: presents National Energy Savings (NES) and Net Present Value (NPV) results for alternative installation costs (for non-weatherized gas furnaces and gas boilers), and alternative energy price scenarios from AEO 2003 for all product classes.

REFERENCES

1. U.S. Department of Energy-Office of Energy Efficiency and Renewable Energy, *Energy Conservation Program for Consumer Products: Test Procedures for Furnaces/Boilers, Vented Home Heating Equipment, and Pool Heaters; Proposed Rule, 10 CFR Part 430 Part VIII,* January 20, 1995. Washington, DC. Report No. EE-RM-93-501.

2. U.S. Department of Energy-Office of Energy Efficiency and Renewable Energy, *Energy Conservation Program for Consumer Products: Test Procedures for Furnaces/Boilers, Vented Home Heating Equipment, and Pool Heaters; Final Rule, 10 CFR Part 430 Part IV,* May 12, 1997. Washington, DC. Report No. EE-RM-93-501.

3. Sachs, H. M., *Comments on the Energy Conservation Program for Consumer Products: Standards for Furnaces & Boilers, DOE Docket Number EE-RM/STD-01-350, Comment No.15,* August 17, 2001, American Council for an Energy-Efficient Economy.

4. National Fire Protection Association, *National Fuel Gas Code -2002 Edition*, 2002. 1 Batterymarch Park, P.O. Box 9101, Quincy MA.

5. American National Standards Institute, *American National Standard/CSA Standard for Gas-Fired Central Furnaces,* November, 2001. New York, NY. Report No. ANSI Z21.47-2001, CSA 2.3-2001.

6. AGA Research, *Mid-Efficiency Modulating Furnace Handbook,* June, 1997, Gas Research Institute. Cleveland, Ohio. Report No. GRI-97/0325.

7. Carrier Coporation, *58CVA/58CVX: Installation, Start-up, Operating, and Service and Maintenance Instructions,* December 2002, Carrier Coporation. Report No. Catalog No: 535-80103.

8. Kowalski, S., *Comments on the Energy Conservation Program for Consumer Products: Standards for Furnaces & Boilers, DOE Docket Number EE-RM/STD-01-350, Comment No.34,* June 7, 2002, Trane Company.

9. Rocky, B. K., *Comments on the Energy Conservation Program for Consumer Products: Standards for Furnaces & Boilers, DOE Docket Number EE-RM/STD-01-350, Comment No.33,* June 6, 2002, York International.

10. Kendal, M., *Comments on the Energy Conservation Program for Consumer Products: Standards for Furnaces & Boilers, DOE Docket Number EE-RM/STD-01-350, Comment No. 31,* June 7, 2002, Gas Appliance Manufacturers Association.