TECHNICAL SUPPORT DOCUMENT: ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS: ENERGY CONSERVATION STANDARDS FOR HEARTH PRODUCTS

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CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses and results supporting the information presented in the notice of proposed rulemaking (NOPR) for hearth products.

1.2 SUMMARY OF THE NATIONAL BENEFITS

The U.S. Department of Energy's (DOE) analyses indicate that the proposed energy conservation standard to disallow the use of continuously burning pilots (*i.e.*, standing pilots) for hearth products would save a significant amount of energy. The lifetime energy savings for hearth products purchased in the 30-year period that begins in the first full year of compliance with new standards (2021–2050) amount to .69 quads[a] of full-fuel-cycle energy. This represents a savings of about 77 percent relative to the energy use of the ignition systems in the base case, *i.e.*, without the proposed energy conservation standards.

The cumulative net present value (NPV) of total consumer costs and savings for the proposed hearth products energy conservation standard ranges from $1.03 billion to $3.12 billion at 7-percent and 3-percent discount rates, respectively. This NPV expresses the estimated total value of future operating-cost savings minus the estimated increased product costs for hearth products purchased in 2021–2050.

In addition, the proposed hearth products pilot standard would have significant environmental benefits. The energy savings described above are expected to result in cumulative full-fuel cycle emission reductions of 37.0 million metric tons (Mt)[b] of carbon dioxide (CO_2), 486 thousand tons of methane (CH_4), .01 thousand tons of nitrous oxide (N_2O), .26 thousand tons of sulfur dioxide (SO_2), 125 thousand tons of nitrogen oxides (NOx), and 0.01 tons of mercury (Hg).[c] The cumulative reduction in CO_2 emissions through 2030 amounts to 11.1 Mt.

The value of the CO_2 reductions is calculated using a range of values per metric ton of CO_2 (otherwise known as the social cost of carbon, or SCC) developed by a recent federal interagency process.[d] The derivation of the SCC values is discussed in chapter 14 of the NOPR

[a] A quad is equal to 10^{15} British thermal units (Btu).

[b] A metric ton is equivalent to 1.1 short tons. Results for emissions other than CO_2 are presented in short tons.

[c] DOE calculated emissions reductions relative to the Annual Energy Outlook 2013 (AEO 2013) Reference case, which generally represents current legislation and environmental regulations for which implementing regulations were available as of December 31, 2012.

[d] Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon, U. S. Government (May 2013; revised November 2013) (Available at: http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf).

TSD. Using discount rates appropriate for each set of SCC values, DOE estimates the present monetary value of the CO_2 emissions reduction is between $0.2 billion and $3.4 billion, with the value of $1.1 billion using the central SCC case represented by $40.5 per ton in 2015. Additionally, DOE estimates the present monetary value of the NOx emissions reduction to be $0.06 billion to $0.15 billion at 7-percent and 3-percent discount rates, respectively.[e]

Table 1.2.1 summarizes the national economic benefits and costs expected to result from the proposed pilot standards for hearth products.

[e] DOE is currently investigating valuation of avoided Hg and SO_2 emissions.

Table 1.2.1 Summary of National Economic Benefits and Costs of Proposed Pilot Energy Conservation Standards for Hearth Products (Trial Standard Level 1)*

Category	Present Value <u>Billion 2013$</u>	Discount Rate <u>%</u>
Benefits		
Consumer Operating Cost Savings	1.5	7
	4.1	3
CO_2 reduction monetized value ($12.0/t case)**	0.2	5
CO_2 reduction monetized value ($40.5/t case)**	1.1	3
CO_2 deduction monetized value ($62.4/t case)**	1.8	2.5
CO_2 reduction monetized value ($119/t case)**	3.4	3
NOx reduction monetized value (at $2,684/ton)**	0.1	7
	0.1	3
Total benefits†	2.7	7
	5.4	3
Costs		
Consumer incremental installed costs	0. 5	7
	1.0	3
Total Net Benefits		
Including emissions reduction monetized value†	2.2	7
	4.4	3

* This table presents the costs and benefits associated with hearth products shipped in 2021−2050. These results include benefits to consumers which accrue after 2050 from the products purchased in 2021−2050. The results account for the incremental variable and fixed costs incurred by manufacturers due to the standard, some of which may be incurred in preparation for the rule.
** The CO_2 values represent global monetized values of the SCC, in 2013$, in 2015 under several scenarios of the updated SCC values. The first three cases use the averages of SCC distributions calculated using 5%, 3%, and 2.5% discount rates, respectively. The fourth case represents the 95th percentile of the SCC distribution calculated using a 3% discount rate. The SCC time series used by DOE incorporate an escalation factor. The value for NOx is the average of the low and high values used in DOE's analysis.
† Total benefits for both the 3% and 7% cases are derived using the series corresponding to average SCC with a 3-percent discount rate ($40.5/t in 2015).

The benefits and costs of the proposed energy conservation standards for hearth products sold in 2021–2050, can also be expressed in terms of annualized values. The annualized monetary values are the sum of: (1) the annualized national economic value of the benefits from consumer operation of products that meet the proposed new or amended standards (consisting primarily of operating cost savings from using less energy, minus increases in product purchase and installation costs, which is another way of representing consumer NPV), and (2) the annualized monetary value of the benefits of emission reductions, including CO_2 emission reductions.[f]

Although combining the values of operating savings and CO_2 emission reductions provides a useful perspective, two issues should be considered. First, the national operating savings are domestic U.S. consumer monetary savings that occur as a result of market transactions, whereas the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use different timeframes for analysis. The national operating cost savings is measured for the lifetime of hearth products shipped in 2021–2050. The SCC values, on the other hand, reflect the present value of some future climate-related impacts resulting from the emission of one ton of carbon dioxide in each year. These impacts continue well beyond 2100.

Estimates of annualized benefits and costs of the proposed pilot standards are shown in Table 1.2.2. The results under the primary estimate are as follows. Using a 7-percent discount rate for benefits and costs other than CO_2 reduction (for which DOE used a 3-percent discount rate along with the average SCC series that uses a 3-percent discount rate ($40.5 per ton in 2015)), cost of the hearth standards proposed in today's rule is $61.1 million per year in increased equipment costs, while the estimated benefits are $186 million per year in reduced equipment operating costs, $67 million in CO_2 reductions, and $7.0 million in reduced NOx emissions. In this case, the net benefit would amount to $199 million per year. Using a 3-percent discount rate for all benefits and costs and the average SCC series that uses a 3-percent discount rate ($40.5 per ton in 2015), the estimated cost of the hearth products standards proposed in today's rule is $61.2 million per year in increased equipment costs, while the estimated benefits are $251 million per year in reduced equipment operating costs, $67 million in CO_2 reductions, and $9.0 million in reduced NOx emissions. In this case, the net benefit would amount to $266 million per year.

[f] DOE used a two-step calculation process to convert the time-series of costs and benefits into annualized values. First, DOE calculated a present value in 2014, the year used for discounting the NPV of total consumer costs and savings, for the time-series of costs and benefits using discount rates of 3 and 7 percent for all costs and benefits except for the value of CO_2 reductions. For the latter, DOE used a range of discount rates, as shown in Table I.7. From the present value, DOE then calculated the fixed annual payment over a 30-year period (2021 through 2050) that yields the same present value. The fixed annual payment is the annualized value. Although DOE calculated annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined is a steady stream of payments.

Table 1.2.2 Annualized Benefits and Costs of Proposed Energy Conservation Standards for Hearth Products (Trial Standard Level1)

	Discount Rate %	Primary Estimate*	Low Net Benefits Estimate*	High Net Benefits Estimate*
		million 2013$/year		
Benefits				
Consumer operating cost savings	7	186	175	195
	3	251	235	265
CO_2 reduction monetized value ($12.0/t case)**	5	20	20	20
CO_2 reduction monetized value ($40.5/t case)**	3	67	67	67
CO_2 reduction monetized value ($62.4/t case)**	2.5	98	98	98
CO_2 reduction monetized value ($119/t case)**	3	207	207	207
NOx reduction monetized value (at $2,684/ton)	7	7.00	7.00	7.00
	3	8.99	8.99	8.99
Total benefits†	7 plus CO_2 range	212 to 400	202 to 389	222 to 410
	7	260	249	269
	3 plus CO_2 range	280 to 468	264 to 452	294 to 482
	3	327	311	341
Costs				
Consumer incremental installed costs	7	61.1	61.1	61.1
	3	61.2	61.2	61.2
Net benefits				
Total†	7 plus CO_2 range	151 to 399	141 to 328	161 to 349
	7	199	188	208
	3 plus CO_2 range	219 to 407	203 to 390	233 to 420
	3	266	250	280

* This table presents the annualized costs and benefits associated with hearth products shipped in 2021-–2050. These results include benefits to consumers which accrue after 2050 from the products purchased in 2021-2050. The results account for the incremental variable and fixed costs incurred by manufacturers due to the standard, some of which may be incurred in preparation for the rule. The primary, low benefits, and high benefits estimates utilize projections of energy prices from the *AEO 2014* Reference case, Low Estimate, and High estimate, respectively. Incremental product costs are the same for each Estimate.
** The CO_2 values represent global monetized values of the SCC, in 2013$, in 2015 under several scenarios of the updated SCC values. The first three cases use the averages of SCC distributions calculated using 5%, 3%, and 2.5% discount rates, respectively. The fourth case represents the 95th percentile of the SCC distribution calculated using a 3% discount rate. The SCC time series used by DOE incorporate an escalation factor. The value for NOx is the average of high and low values found in the literature.
† Total benefits for both the 3% and 7% cases are derived using the series corresponding to the average SCC with a 3-percent discount rate ($40.5/t in 2015). In the rows labeled "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NOx benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

The Energy Policy and Conservation Act of 1975 (EPCA), as amended, requires the U.S. Department of Energy (DOE) to establish energy conservation standards that are technologically feasible and economically justified, and would achieve the maximum improvement in energy efficiency. See 42 U.S.C. 6295(o)(2)(B). DOE has tentatively concluded that the proposed standards represent the maximum improvement in energy efficiency that is technologically feasible and economically justified, and would result in the significant conservation of energy. DOE further notes that for the products covered by this proposal, products achieving these standard levels (*i.e.* hearth products that do not use a standing pilot ignition system) are already commercially available. Based on the analyses described previously, DOE has tentatively concluded that the benefits of the proposed standards to the Nation (energy savings, positive NPV of consumer benefits, consumer LCC savings, and emission reductions) would outweigh the burdens (loss of INPV for manufacturers and LCC increases for some consumers).

Based on consideration of the public comments DOE receives in response to this NOPR and related information collected and analyzed during the course of this rulemaking effort, DOE may adopt the standard proposed in this notice, or some combination of options that incorporate the proposed standards in part.

1.3 OVERVIEW OF STANDARDS FOR HEARTH PRODUCTS

There are currently no federal energy conservation standards for hearth products.

On December 31, 2013, DOE published a notice of proposed determination of coverage to classify hearth products as covered products under EPCA. 78 FR 79638. In the proposed determination of coverage, DOE presented its preliminary findings relating to the energy use of hearth products to determine whether they could be classified as a type of covered product under the requirements of 42 U.S.C. 6292(b)(1)(A) and (B), and whether they would meet the criteria for DOE to prescribe an energy conservation standard under 42 U.S.C. 6295(l)(1)(A)-(D). (See section II.A of the NOPDfor a discussion of these statutory criteria.) DOE also proposed to define a “hearth product” as “a gas-fired appliance that simulates a solid-fueled fireplace or presents a flame pattern (for aesthetics or other purpose) and that may provide space heating directly to the space in which it is installed.” 78 FR 79638, 79640 (Dec. 31, 2013). The proposed determination is still pending, but as discussed in section IV.A of the NOPR, DOE is using that proposed definition to delineate the scope of this proposed rulemaking. In addition, DOE has considered some of the comments submitted in response to the proposed coverage determination, which are relevant to the development of proposed energy conservation standards for hearth products and addresses those comments as applicable in this proposed rulemaking.

1.4 PROCESS FOR SETTING ENERGY CONSERVATION STANDARDS

Under the Energy Policy and Conservation Act of 1975 (EPCA), as amended, when DOE is studying new or amended standards, it must consider, to the greatest extent practicable, the following seven factors (42 U.S.C. 6295 (o)(2)(B)(i)):

1) the economic impact of the standard on the manufacturers and consumers of the affected products;
2) the savings in operating costs throughout the estimated average life of the product compared to any increases in the initial cost or maintenance expense;
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 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.

Other statutory requirements are set forth in 42 U.S.C. 6295 (o)(1)–(2)(A), (2)(B)(ii)–(iii), and (3)–(4) and 42 U.S.C. 6316(e).

DOE considers interested party participation to be a very important part of the process for setting energy conservation standards. Through formal public notifications (*i.e.*, *Federal Register* notices), DOE actively encourages the participation and interaction of all interested parties during each stage of the rulemaking.

Before DOE determines whether to adopt a proposed energy conservation standard, it must first solicit comments on the proposed standard. (42 U.S.C. 6295(p)(2)) Any new or amended standard must be designed to achieve the maximum improvement in energy efficiency and be technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A)) To determine whether economic justification exists, DOE 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 seven factors listed above. (42 U.S.C. 6295 (o)(2)(B)(i))

The energy conservation standards rulemaking process usually involves three formal public notices, which DOE publishes in the *Federal Register*. The first of the rulemaking notices is typically a notice of public meeting (NOPM), which is designed to publicly vet the models and tools used in the rulemaking and to facilitate public participation before the NOPR stage. The second notice is usually the NOPR, which presents a discussion of: (1) comments received in response to the NOPM analyses; (2) analyses of the impacts of potential amended energy conservation standards on consumers, manufacturers, and the Nation; (3) DOE's weighting of these impacts of amended energy conservation standards; and (4) the proposed energy conservation standards for each product. The third notice is usually the final rule, which presents a discussion of: (1) the comments received in response to the NOPR; (2) the revised analyses; (3) DOE's weighting of these impacts; (4) the amended energy conservation standards DOE is adopting for each product; and (5) the effective dates of the amended energy conservation standards. However, due to the close proximity between this NOPR and prior rulemaking activities for some hearth products, this energy conservation standards rulemaking did not include a publication of a notice of public meeting (NOPM) or preliminary analysis. Instead, the NOPR analysis included all analyses typically included in the preliminary analysis. Table 1.4.1 shows the analyses that typically occur during each phase of the rulemaking process.

Table 1.4.1 Rulemaking Analysis Stages

Preliminary Analyses*	NOPR	Final Rule
Market and technology assessment	Revised analyses	Revised NOPR analyses
Screening analysis	Life-cycle cost sub-group analysis	
Engineering analysis	Manufacturer impact analysis	
Energy use determination	Utility impact analysis	
Markups for equipment price determination	Emissions analysis	
Life-cycle cost and payback period analyses	Employment impact analysis	
Shipments analysis	Regulatory impact analysis	
National impact analysis		
Preliminary manufacturer impact analysis		

* The analyses typically performed for the preliminary analysis were performed at the NOPR stage for this rulemaking.

1.5 STRUCTURE OF THE DOCUMENT

This document outlines the analytical approaches used in this rulemaking. This document consists of 17 chapters and 15 appendices.

Chapter 1 Introduction: provides an overview of this rulemaking and outlines the structure of the document.

Chapter 2 Analytical Framework: describes an overview of the rulemaking process, methodology, analytical tools, and relationships among the various analyses.

Chapter 3 Market and Technology Assessment: characterizes the market for the considered products and the technologies available for increasing product efficiency.

Chapter 4 Screening Analysis: identifies all the design options that improve efficiency of the considered products and determines which technology options are viable for consideration in the engineering analysis.

Chapter 5 Engineering Analysis: discusses the methods used for developing the relationship between manufacturer production cost and increased product efficiency.

Chapter 6	Markups Analysis: discusses the methods used for establishing markups for converting manufacturer prices to customer product costs.
Chapter 7	Energy Use Analysis: discusses the process used for generating energy-use estimates for the considered products as a function of standard levels.
Chapter 8	Life-Cycle Cost and Payback Period Analyses: discusses the methods used to analyze 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	Shipments Analysis: estimates shipments of the products over the 30-year analysis period that is used in performing the national impact analysis (NIA), including how shipments may vary under alternative standard levels.
Chapter 10	National Impact Analysis: assesses the national energy savings and the national net present value of total consumer costs and savings expected to result from specific, potential energy conservation standards.
Chapter 11	Consumer Subgroup Analysis: discusses the effects of standards on subgroups of hearth products consumers and compares the LCC and PBP of products with and without higher efficiency standards for these consumers.
Chapter 12	Manufacturer Impact Analysis: discusses the effects of amended standards on the finances and profitability of manufacturers.
Chapter 13	Emissions Impact Analysis: discusses the effects of standards on air-borne emissions, including the impact of emissions of six pollutants or greenhouse gases: sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon dioxide (CO_2), mercury (Hg), methane (CH_4), and nitrous oxide (N_2O).
Chapter 14	Monetization of Emission Reduction Benefits: discusses the monetization of reductions in CO_2 and NOx emissions.
Chapter 15	Utility Impact Analysis: discusses the effects of standards on the installed generation capacity of electric utilities.
Chapter 16	Employment Impact Analysis: discusses the effects of standards on national employment.

Chapter 17 Regulatory Impact Analysis: discusses the present regulatory actions as well as the impact of non-regulatory alternatives to setting energy conservation standards.

Appendix 6A Detailed Data for Equipment Price Markups

Appendix 7A Building Variables

Appendix 7B Mapping of Weather Station Data to RECS Households

Appendix 8A User Instructions for Life-Cycle Cost Analysis Spreadsheet for Hearth Products

Appendix 8B Uncertainty and Variability in the LCC Analysis

Appendix 8C Energy Price Calculations for Hearth Products

Appendix 8D Distributions Used for Discount Rates

Appendix 8E Life-Cycle Cost Analysis Using Alternative Economic Growth Scenarios for Hearth Products

Appendix 9A Relative Price Elasticity of Demand for Appliances

Appendix 10A User Instructions National Impact Analysis Spreadsheet Model

Appendix 10B Full-Fuel-Cycle Multipliers

Appendix 10C National Impact Analysis Using Alternative Economic Growth Scenarios for Hearth Products

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CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

The Energy Policy and Conservation Act (EPCA), as amended (42 USC 6291 et. seq.), requires that when prescribing new or amended energy conservation standards for covered products, the U.S. Department of Energy (DOE) must promulgate standards that achieve the maximum improvements in energy efficiency that are technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A)) This chapter provides a description of the analytical framework that DOE is using to evaluate amended energy conservation standards for hearth products. This chapter sets forth the methodology, analytical tools, and relationships among the various analyses that are part of this rulemaking.

Figure 2.1.1 summarizes the analytical components of the standards-setting process. The focus of this figure is the center column, identified as “Analyses.” The columns labeled “Key Inputs” and “Key Outputs” show how the analyses fit into the rulemaking process, and how the analyses relate to each other. Key inputs are the types of data and information that the analyses require. Some key inputs exist in public databases; DOE collects other inputs from interested parties or persons with special knowledge. Key outputs are analytical results that feed directly into the standards-setting process. Arrows connecting analyses show types of information that feed from one analysis to another.

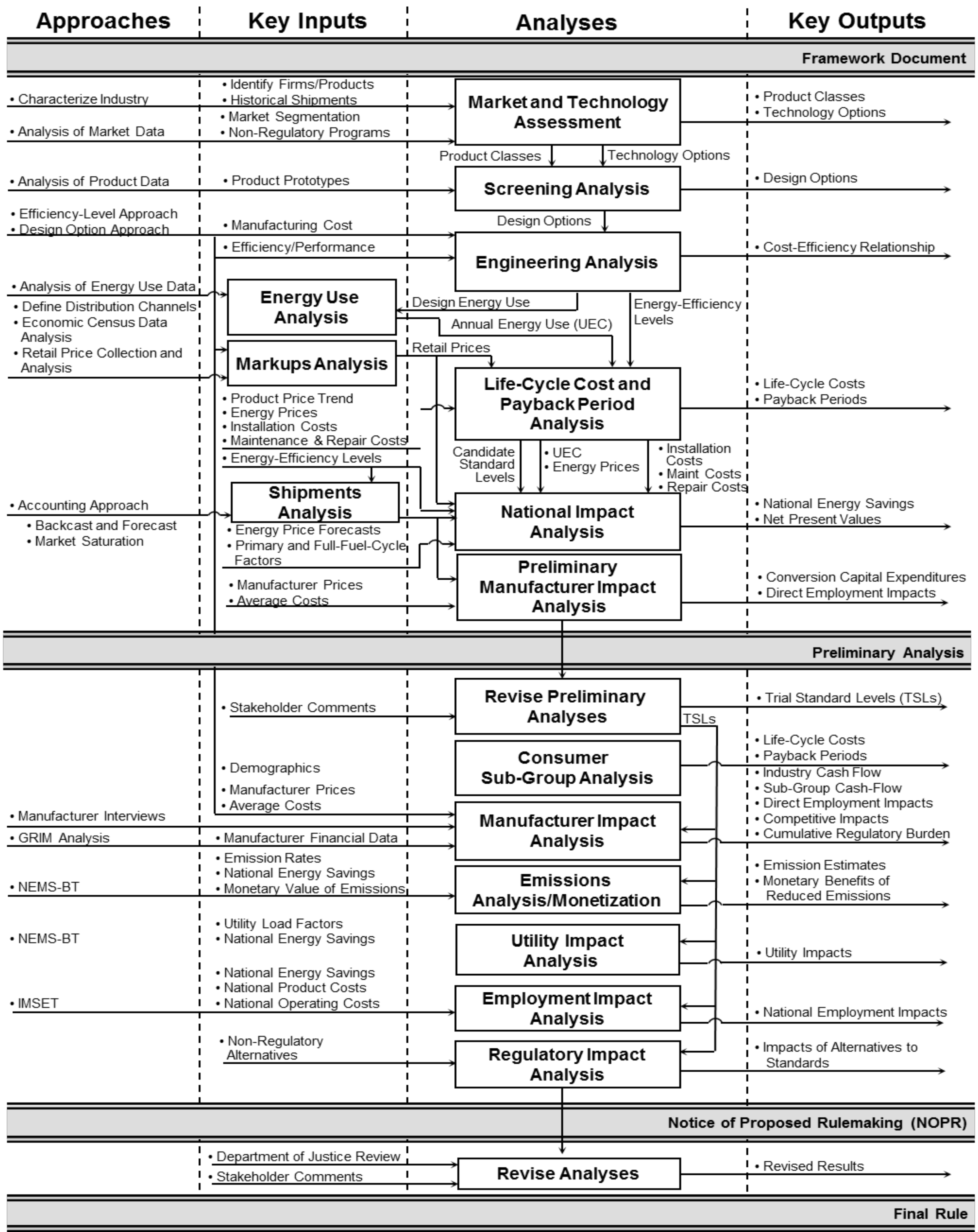

Figure 2.1.1 Flow Diagram of Analyses for the Rulemaking Process[a]

[a] Note: This rulemaking did not include a preliminary analysis, and all analyses typically performed for the preliminary analysis were performed at the NOPR stage of the rulemaking.

In this technical support document (TSD), DOE presents results of the following analyses, which were performed for the development of this NOPR for hearth products:

- A market and technology assessment to characterize the relevant products, their markets, and technology options for reducing their energy consumption.
- A screening analysis to review technology options and determine if they are technologically feasible; are practicable to manufacture, install, and service; would adversely affect product utility or product availability; or would have adverse impacts on health and safety.
- An engineering analysis to develop the cost difference between the manufacturer selling price (MSP) of standing pilot and electronic ignition systems.
- A markups analysis to develop distribution channel markups that relate the MSP to the cost to the consumer.
- An energy use analysis to determine the annual energy use of the considered products in a representative set of users.
- Life-cycle cost (LCC) and payback period (PBP) analyses to calculate the savings in operating costs at the consumer level throughout the life of the covered products compared with any increase in the installed cost for the products likely to result directly from imposition of a standard.
- A shipments analysis to forecast product shipments, which are then used to calculate the national impacts of standards on energy, net present value (NPV), and future manufacturer cash flows.
- A national impact analysis (NIA) to assess the aggregate impacts at the national level of potential energy conservation standards for the considered products, as measured by the NPV of total consumer economic impacts and the national energy savings (NES).
- An LCC subgroup analysis to evaluate variations in consumer characteristics that might cause a standard to disproportionately affect particular consumer subpopulations.
- A manufacturer impact analysis (MIA) to assess the potential impact of energy conservation standards on manufacturers' capital conversion expenditures, marketing costs, shipments, and research and development costs.
- A utility impact analysis to estimate the effects of potential standards on electric, gas, or oil utilities.
- An employment impact analysis to assess the aggregate impacts on national employment.
- An emissions analysis to assess the impacts of amended energy conservation standards on the environment.

- An emissions monetization to assess the benefits associated with emissions reductions.
- A regulatory impact analysis to examine major alternatives to amended energy conservation standards that potentially could achieve substantially the same regulatory goal at a lower cost.

2.2 BACKGROUND

Amendments to Title III of EPCA have given DOE the authority to set forth various provisions designed to improve energy efficiency for residential products. In addition to specifying a list of covered residential and commercial products, EPCA contains provisions that enable the Secretary of Energy to classify additional types of consumer products as covered products. DOE previously published a proposed determination of coverage to classify hearth products as covered consumer products under the provisions outlined in EPCA. There are currently no federal energy conservation standards for hearth products.

On December 31, 2013, DOE published a notice of proposed determination (NOPD) of coverage to classify hearth products as covered products under EPCA. 78 FR 79638. In that proposed determination of coverage, DOE presented its preliminary findings relating to the energy use of hearth products to determine whether they could be classified as a type of covered product under the requirements of 42 U.S.C. 6292(b)(1)(A) and (B), and whether they would meet the criteria for DOE to prescribe an energy conservation standard under 42 U.S.C. 6295(l)(1)(A)-(D). (See section II.A of the NOPR for a discussion of these statutory criteria.) DOE also proposed to define a "hearth product" as "a gas-fired appliance that simulates a solid-fueled fireplace or presents a flame pattern (for aesthetics or other purpose) and that may provide space heating directly to the space in which it is installed." 78 FR 79638, 79640 (Dec. 31, 2013). The proposed determination is still pending, but as discussed in section IV.A of the NOPR, DOE is using the proposed definition to delineate the scope of this NOPR. In addition, DOE has considered some of the comments submitted in response to the proposed coverage determination, which are relevant to the development of proposed energy conservation standards for hearth products and addresses those comments as applicable in this NOPR.

The following sections provide a general description of the different analytical components of the rulemaking analytical framework. DOE has used the most reliable and accurate data available at the time of each analysis in this rulemaking. DOE welcomes and will consider any submissions of additional data during the rulemaking process.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

When DOE begins an energy conservation standards rulemaking, it develops information that provides an overall picture of the market for the products considered, including the nature of the products, market characteristics, and industry structure. This activity consists of both quantitative and qualitative efforts based primarily on publicly available information. The market assessment examines manufacturers, trade associations, and the quantities and types of products offered for sale.

DOE recognizes that there may be limited public information on national shipments, manufacturing costs, channels of distribution, and manufacturer market shares of hearth products. This type of data is an important input for analyses that determine if energy conservation standards are economically justified and will result in significant energy savings. Therefore, DOE encourages interested parties to submit data that will improve DOE's understanding of the hearth products market. These data may be provided under a confidentiality agreement with DOE's contractor responsible for this part of the rulemaking analysis, Navigant Consulting, Inc. (NCI). As in other rulemakings, NCI works with confidential data provided by manufacturers and other organizations in preparing aggregated results for DOE's analysis. These aggregated results do not divulge the sensitive, individual raw data, but enable other interested parties to comment on the aggregated dataset.

Alternatively, interested parties may submit confidential data to DOE, indicating in writing which data should remain confidential. Interested parties must submit confidential information to DOE according to the procedures outlined in 10 CFR 1004.11. Pursuant to 10 CFR 1004.11, any person submitting information that he or she believes to be confidential and exempt by law from public disclosure should submit two copies. One copy of the document shall include all the information believed to be confidential, and the other copy shall have the information believed to be confidential deleted. DOE will make its own determination about the confidential status of the information and treat it accordingly.[b]

DOE reviewed relevant literature and interviewed manufacturers to develop an overall picture of the hearth products industry in the United States. Industry publications and trade journals, government agencies, and trade organizations provided the bulk of the information, including: (1) manufacturers and their approximate market shares; (2) shipments by product type; (3) product information; and (4) industry trends.

The analyses developed as part of the market and technology assessment are described in chapter 3 of this TSD.

[b] Factors that DOE considers when evaluating requests to treat submitted information as confidential include: (1) a description of the items; (2) whether and why such items are customarily treated as confidential within the industry; (3) whether the information is generally known by or available from other public sources; (4) whether the information has previously been made available to others without obligation concerning its confidentiality; (5) an explanation of the competitive injury to the submitting person which would result from public disclosure; (6) a date after which such information might lose its confidential character; and (7) why disclosure of the information would be contrary to the public interest.

2.3.1 Definition and Scope of Coverage

There is currently no statutory definition of hearth products as hearth products are not covered consumer products. In the December 2013 NOPD, DOE proposed to adopt a definition of "hearth product" that was used to define the scope of this rulemaking. In the December 2013 NOPD, DOE suggested several common hearth product types that would be covered under the proposed definition, including vented decorative hearth products, vented heater hearth products, vented gas logs, gas stoves, outdoor hearth products, and ventless hearth products. DOE used the definition proposed in the December 2013 NOPD (as stated above) to determine the scope of this proposed rulemaking.

As described in section III.B of the NOPR, DOE has tentatively determined to focus the current rulemaking on reducing standby mode energy consumption. Whereas an energy conservation standard could fractionally reduce the energy use of hearth products in active mode, DOE found that all standby mode fossil fuel consumption could be eliminated with a prescriptive design requirement.

In some instances, hearth products may have standby mode and/or off mode electrical energy consumption. However, DOE has tentatively determined that the standby and off mode electrical energy consumption of the ignition module is *de minimis*, and did not analyze energy conservation standards to regulate electrical standby mode and off mode energy consumption.[c]

2.3.2 Product Classes

As described in III.C of the NOPR, DOE has tentatively determined not to establish separate product classes for a standby mode energy conservation standard. The criteria for separation into different product classes are: (1) energy source and (2) capacity or other performance-related features such as those that provide utility to the consumer or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 U.S.C. 6295 (q) and 6316(a)) DOE found substantial similarity in the function, components used, and energy use of hearth products with regard to standby mode. By reviewing manufacturer product literature, conducting teardown analyses, and interviewing manufacturers, DOE found that the same or similar ignition system components, including manual, millivolt, and electronic gas control valves, pilot assemblies, and electronic control modules for electronic ignitions, were used across a wide range of hearth products. DOE has tentatively determined should standing pilot ignitions be disallowed, most hearth products styles will switch to similar electronic ignition components. See section III.C of the NOPR for further detail regarding DOE's tentative determination that product classes do not need to be established for hearth products in light of the focus on standby energy mode.

[c] See section III.I of the NOPR for more details regarding the tentative determination that standby electrical consumption for hearth products is *de minimis*.

2.3.3 Market Assessment

As part of the market and technology assessment, DOE developed information that provides an overall picture of the market for the products considered, including the nature of the products, market characteristics, and industry structure. DOE collected quantitative and qualitative information, primarily from publicly available sources. The market assessment examined manufacturers, trade associations, and the quantities and types of products sold and offered for sale. DOE reviewed relevant literature and interviewed manufacturers to develop an overall picture of the hearth products industry in the United States. Industry publications, government agencies, and trade organizations provided the bulk of the information, including: (1) manufacturers and their estimated market shares; (2) shipments by product type; (3) product information; and (4) industry trends. The analyses developed as part of the market assessment are described in chapter 3 of this TSD.

2.3.4 Technology Assessment

DOE typically uses information relating to existing and past technology options and prototype designs as inputs to determine what technologies manufacturers use to attain higher performance levels. In consultation with interested parties, DOE develops a list of technologies for consideration. Initially, these technologies encompass all those DOE believes are technologically feasible.

DOE developed its list of technologically feasible design options for the considered products through consultation with manufacturers of components and systems. Product literature and direct examination provided additional information. The technologies examined in the technology assessment are described in detail in chapter 3 of this TSD.

2.4 SCREENING ANALYSIS

The purpose of the screening analysis is to evaluate the technologies identified in the technology assessment to determine which technologies to consider further and which technologies to screen out. DOE consulted with industry, technical experts, and other interested parties in developing a list of energy-saving technologies for the technology assessment. DOE then applied the screening criteria to determine which technologies were unsuitable for further consideration in this rulemaking. Chapter 4 of this TSD, the screening analysis, contains details about DOE's screening criteria.

As presented in further detail below, the screening analysis examines whether various technologies: (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on product utility or availability; and (4) have adverse impacts on health and safety. In consultation with interested parties, DOE reviewed the list of hearth products technologies according to these criteria. In the engineering analysis, DOE further considers the efficiency-enhancement technologies that it did not eliminate in the screening analysis.

1. *Technological feasibility.* DOE screens out technologies that are not incorporated in commercially available products or working prototypes.

2. *Practicability to manufacture, install, and service.* If DOE determines that mass production of a technology in commercial products and reliable installation and servicing of the technology cannot be achieved on the scale necessary to serve the relevant market by the time of the compliance date of the standard, it will not consider that technology further.

3. *Adverse impacts on product or equipment utility or availability.* If DOE determines a technology has a significant adverse impact on the utility of the product for significant consumer subgroups or results in the unavailability of any covered product type with performance characteristics (including reliability), features, size, capacities, and volumes that are substantially the same as products generally available in the United States at the time, it will not consider that technology further.

4. *Adverse impacts on health or safety.* If DOE determines that a technology will have significant adverse impacts on health or safety, it will not consider that technology further.

Chapter 4 contains additional details about the screening analysis and the justification for screening out certain technologies.

2.5 ENGINEERING ANALYSIS

The engineering analysis (chapter 5 of this TSD) establishes the difference in manufacturing production cost between standing pilot and electronic ignition systems. This cost difference serves as the basis for cost-benefit calculations in terms of individual consumers, manufacturers, and the nation. Chapter 5 discusses the representative units analyzed, methodology used to develop manufacturing production costs and manufacturer markups, and results of the analysis. To determine the cost to consumers of hearth products with different types of ignition systems, DOE estimated manufacturing costs, markups in the distribution chain, installation costs, and maintenance costs product teardowns and manufacturer interviews.

In the engineering analysis, DOE evaluated the different ignition systems found in hearth products and the associated manufacturing costs. The purpose of the analysis is to estimate the incremental increase to selling prices that would result from disallowing the use of standing pilot ignition systems and replacing them with electronic ignition systems. The engineering analysis considers the electronic ignition system since it was not eliminated in the screening analysis. Certain other technologies were not analyzed due to other reasons, such as negligible incremental efficiency improvements, lack of information on efficiency improvement, or inapplicability to certain hearth categories (*e.g.*, gas log sets). DOE considers the remaining technologies (i.e. the electronic ignition system) in developing the cost-efficiency relationship, which is subsequently used for the LCC and PBP analyses.

DOE typically structures its engineering analysis around one of three methodologies: (1) the design-option approach, which calculates the incremental costs of adding specific design options to a baseline model; (2) the efficiency-level approach, which calculates the relative costs of achieving increases in energy efficiency levels without regard to the particular design options used to achieve such increases; and/or (3) the reverse-engineering or cost-assessment approach, which involves a "bottom-up" manufacturing cost assessment based on a detailed bill of materials derived from tear-downs of the product being analyzed.

For this analysis, DOE conducted the engineering analysis for hearth products using a combination of the design option and cost-assessment approaches. DOE selected for teardown hearth models that represent a range of hearth configurations (*e.g.*, vented fireplaces, vented fireplace inserts, unvented fireplace inserts, vented gas log sets, unvented gas log sets). In light of the analytical focus on standby mode energy consumption, DOE examined the implementation of an electronic ignition system as a design option and chose representative models for analysis that would allow a direct comparison between standing pilot and electronic ignition systems. DOE gathered information using reverse-engineering methodologies, product information from manufacturer catalogs and manuals, and discussions with manufacturers and other experts on hearth products.

DOE generated bills of materials (BOMs) by disassembling products representing a range of hearth configurations, including vented and unvented fireplaces, inserts, and stoves, vented and unvented gas log sets, and outdoor products. The BOMs describe each unit analyzed in detail, including all manufacturing steps required to make and/or assemble each part. Subsequently, DOE developed a cost model that converted the BOMs into manufacturer production costs (MPCs). By applying derived manufacturer markups to the MPCs, DOE calculated the manufacturer selling prices.

More information regarding the engineering analysis can be found in chapter 5 of the TSD.

2.6 MARKUPS ANALYSIS

DOE uses manufacturer-to-customer markups to convert the manufacturer selling price estimates in the engineering analysis to customer prices, which include markups throughout the distribution chain (wholesalers, retailers, etc.) These are then used in the LCC and PBP analyses and in the manufacturer impact analysis. Retail prices are necessary for the baseline efficiency level (standing pilot) and the energy conservation standard case being considered (electronic ignition system).

Before developing markups, DOE defines key market participants and identifies distribution channels. Generally, the hearth products distribution chain includes five market participants: (1) manufacturer; (2) wholesaler; (3) mechanical contractors; (4) general contractors; and (5) consumers. For the markups analysis, DOE used two types of distribution channels to describe how most hearth products pass from the manufacturer to the consumer: (1) replacement/new owner market; and (2) new construction. These channels are explained in detail in chapter 6 of this TSD.

After defining the participants and channels, DOE develops baseline and incremental markups to transform the manufacturer selling price into a consumer product price. DOE uses the baseline markups, which cover all of a distributor's costs, to determine the sales price of baseline models. Incremental markups are coefficients that DOE applies to the incremental cost of models of electronic ignition systems. Because companies mark up the price at each point in the distribution channel, both baseline and incremental markups are dependent on the particular distribution channel.

2.7 ENERGY USE ANALYSIS

The purpose of the energy use analysis is to determine the annual energy consumption of hearth products used in representative U.S. single-family homes and multi-family residences. Additionally, the energy use analysis assesses the energy savings potential of increased hearth product efficiency. DOE estimated the annual energy consumption of residential hearth products across a range of climate zones. The annual energy consumption includes the natural gas, liquid petroleum gas, oil fuel, and/or electricity use by the hearth products. The annual energy consumption of hearth products is used in subsequent analyses, including the LCC and PBP analyses and the national impact analysis.

DOE used Residential Energy Consumption Survey (RECS) 2009 data and weather data from NOAA to estimate weather-normalized energy use. The RECS 2009 data provide information on the home characteristics, as well as heating energy use in each household. The survey includes household information such as the physical characteristics of housing units, household demographics, information about other heating and cooling products installed in the household, fuel types used, energy consumption and expenditures, and other relevant data.

To estimate the annual energy consumption of hearth products meeting higher efficiency levels, DOE calculated the heating load based on the RECS estimates of the annual energy consumption of the hearth products for each household.

Chapter 7 of this TSD details the energy use analysis methodology.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

In determining whether an energy conservation standard is economically justified, DOE considers the economic impact of potential standards on consumers. The effect of new or amended standards on individual consumers usually includes a reduction in operating cost and an increase in purchase cost. DOE used the following two metrics to measure consumer impacts:

- *Life-cycle cost (LCC)* is the total consumer cost of an appliance or product, generally over the life of the appliance or product, including purchase and operating costs. The latter consist of maintenance, repair, and energy costs. Future operating costs are discounted to the time of purchase and summed over the lifetime of the appliance or product.
- *Payback period (PBP)* measures the amount of time it takes consumers to recover the assumed higher purchase price of a more energy-efficient product through reduced operating costs.

DOE analyzed the net effect of potential hearth products standards on consumers by determining the LCC and PBP using engineering performance data, energy-use data, and markup data. Inputs to the LCC calculation include the installed cost to the consumer (purchase price plus installation cost), operating expenses (energy expenses, repair costs, and maintenance costs), the lifetime of the product, and a discount rate. Inputs to the payback period calculation include the installed cost to the consumer and first-year operating costs.

DOE generated LCC and PBP results as probability distributions using a simulation approach based on Monte Carlo analysis methods, in which certain key inputs to the analysis consist of probability distributions rather than single-point values. Therefore, the outcomes of the Monte Carlo analysis can also be expressed as probability distributions. As a result, the analysis produces a range of LCC and PBP results that allow DOE to identify the fraction of customers achieving LCC savings or incurring net cost at the considered efficiency levels.

DOE examined expected maintenance, repair, and installation costs for the products covered in this rulemaking. DOE used the most recent *RS Means Facilities Maintenance & Repair Cost Data*[d] to develop appropriate repair and maintenance costs for baseline units (standing pilot models) and units including electronic ignition systems. DOE concluded that while repair costs are likely to increase in proportion to the initial size and cost of hearth products, maintenance costs for more-efficient products were not likely to be significantly higher than those for baseline units.

DOE estimated all the installation costs associated with installing a hearth product in a new housing unit or as a replacement for an existing hearth product using *RS Means*

[d] RS Means, 2013 Facilities Maintenance & Repair Cost Data (Available at: http://rsmeans.reedconstructiondata.com/60303.aspx) (Last accessed April 10, 2013).

2013 Residential Cost Data,[e] manufacturer literature, and information from expert consultants. This includes any additional costs, such as venting modifications that would be required to install various hearth products.

Based on a search of industry studies and literature, DOE concluded that hearth products typically have an approximate average lifetime of 15 years.

DOE used discount rates to determine the present value of lifetime operating expenses. The discount rate used in the LCC analysis represents the rate from an individual consumer's perspective.[f] Much of the data used for determining consumer discount rates comes from the Federal Reserve Board's triennial Survey of Consumer Finances.[g]

To estimate the share of consumers affected by a standard, DOE's LCC and PBP analyses consider the projected distribution (*i.e.*, market shares) of products with electronic ignition systems that consumers will purchase in the first compliance year under the base case (the case without amended energy conservation standards disallowing use of standing pilots).

Chapter 8 of this TSD provides more details on the LCC and PBP analyses methodology.

2.9 SHIPMENTS ANALYSIS

DOE used forecasts of product shipments to calculate the national impacts of standards on energy use, NPV, and future manufacturer cash flows. DOE developed these shipment forecasts based on an analysis of key market drivers for each product.

DOE estimated hearth product shipments by projecting shipments in three market segments: (1) replacements; (2) new housing; and (3) new owners in buildings that did not previously have a hearth product. DOE also considered whether standards that disallow standing pilot ignitions would have an impact on hearth product shipments.

To project hearth product replacement shipments, DOE developed retirement functions for hearth products 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 project shipments to the new housing market, DOE utilized a forecast of new housing construction and historic saturation rates of hearth product types in new housing.

[e] RS Means Company Inc., *RS Means Residential Cost Data*. 32nd Annual Edition ed. 2013: Kingston, MA
[f] The consumer discount rate differs from the discount rates used in the national impact analysis, which are intended to represent the rate of return on capital in the U.S. economy, as well as the societal rate of return on private consumption.
[g] Available at www.federalreserve.gov/econresdata/scf/scfindex.htm.

DOE used the *Annual Energy Outlook* (*AEO) 2014* for forecasts of new housing. Hearth product saturation rates in new housing are provided by the U.S. Census Bureau's *Characteristics of New Housing*.[h]

See chapter 9 of this TSD for more details regarding the projection of hearth product shipments.

Because the standards-case projections take into account the increase in purchase price and the decrease in operating costs caused by amended standards, projected shipments for a standards case typically deviate from those for the base case. Because purchase price tends to have a larger impact than operating cost on appliance purchase decisions, standards-case projections typically show a decrease in product shipments relative to the base case.

Consistent with economic theory, it is reasonable to expect that standards that result in higher hearth product prices will have some dampening effect on sales. To estimate the impact of the projected price increase for the considered efficiency levels, DOE modeled developed a price elasticity model. This approach gives some weight to the operating cost savings from higher efficiency products. The impact of higher hearth products prices is expressed as a percentage drop in market share for each year during the analysis period.

2.10 NATIONAL IMPACT ANALYSIS

The NIA assesses the NES and the NPV from a national perspective of total consumer costs and savings expected to result from new energy conservation standards. DOE determined the NPV and NES for the standard level considered (disallowing standing pilot ignitions) for the hearth products analyzed. To make the analysis more accessible and transparent to all interested parties, DOE prepared a Microsoft Excel spreadsheet that uses typical values (as opposed to probability distributions) as inputs. To assess the effect of input uncertainty on NES and NPV results, DOE has developed its spreadsheet model to conduct sensitivity analyses by running scenarios on specific input variables.

Analyzing impacts of potential energy conservation standards for hearth products requires comparing projections of U.S. energy consumption with new energy conservation standards against projections of energy consumption without new standards. The forecasts include projections of annual product shipments, the annual energy consumption of new products, and the purchase price of new products.

A key component of DOE's NIA is the energy efficiencies forecasted over time for the base case (without new standards) and the standards case (disallowing standing pilot use). The forecasted efficiencies represent the annual shipment-weighted energy efficiency

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

of the products under consideration during the forecast period (*i.e.*, from the assumed compliance date of a new standard to 30 years after compliance is required).

DOE developed a distribution of standing pilot and electronic ignition systems in the base-case for 2021 (the assumed compliance date for new standards). In the standards case, all hearths were assumed to include an electronic ignition system for 2021. DOE assumed: (1) products in the base case that would have their standing pilot ignition systems replaced with an electronic ignition system to meet the new standard; and (2) products that are match lit or already include an electronic ignition system would not be affected.

Chapter 10 of this TSD provides additional details on the national impact analysis.

2.10.1 National Energy Savings Analysis

The inputs for determining the national energy savings for each product analyzed are: (1) annual energy consumption per unit; (2) shipments; (3) product stock; (4) national energy consumption; and (5) site-to-source conversion factors. DOE calculated the national energy consumption by multiplying the number of units (stock) of each product (by vintage or age) by the unit energy consumption (also by vintage). Vintage represents the age of the product. DOE calculated annual NES based on the difference in national energy consumption for the base case and for the standard case (disallowing standing pilots). DOE estimated energy consumption and savings based on site energy and converted the electricity consumption and savings to source (primary) energy using annual conversion factors derived from the most recent version of the National Energy Modeling System (NEMS). Cumulative energy savings are the sum of the NES for each year over the timeframe of the analysis.

DOE has historically presented NES in terms of primary energy savings. DOE published a Statement of Policy regarding its intent to incorporate full-fuel-cycle (FFC) metrics into its analyses, and outlining a proposed approach. DOE stated that it intends to calculate FFC energy and emission impacts by applying conversion factors generated by the greenhouse 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 energy conservation standards rulemaking. For this analysis, DOE calculated FFC energy savings using the NEMS-based methodology described in appendix 10-B of this TSD. Chapter 10 of this TSD presents both the primary NES and the FFC energy savings for the analyzed efficiency levels.

2.10.2 Net Present Value Analysis

The inputs for determining NPV are: (1) total annual installed cost; (2) total annual savings in operating costs; (3) a discount factor to calculate the present value of costs and savings; (4) present value of costs; and (5) present value of savings. DOE determined the net savings for each year as the difference between the base case and standards case in terms of total savings in operating costs versus total increases in installed costs. DOE calculated savings over the lifetime of products shipped in the forecast period. DOE calculated NPV as the difference between the present value of operating cost savings and the present value of total installed costs. DOE used a discount factor based on real discount rates of 3 and 7 percent to discount future costs and savings to present values.

For the NPV analysis, DOE calculates increases in total installed costs as the difference in total installed cost between the base case and standards case (*i.e.*, once the standards take effect). Because the products bought in the standards case usually cost more than products bought in the base case (due to the presence of electronic ignition), cost increases appear as negative values in the NPV.

DOE expresses savings in operating costs as decreases associated with the lower energy consumption of products bought in the standards case compared to the base case. Total savings in operating costs are the product of savings per unit and the number of units of each vintage that survive in a given year.

DOE used the *AEO 2014* as the source of projections for future energy prices.

DOE estimates the NPV of consumer benefits using both a 3-percent and a 7-percent real discount rate. DOE uses these discount rates in accordance with guidance provided by the Office of Management and Budget (OMB) to federal agencies on the development of regulatory analysis. (OMB Circular A-4 (Sept. 17, 2003), section E, "Identifying and Measuring Benefits and Costs")

2.11 CONSUMER SUBGROUP ANALYSIS

In analyzing the potential impacts of new standards on consumers, DOE evaluates the potential impact of new standards on identifiable groups of consumers (*i.e.*, subgroups), such as small businesses, that may be disproportionately affected by a national standard. Accordingly, DOE evaluated impacts on low-income households and senior-only households using the LCC and PBP spreadsheet model, using inputs appropriate to these subgroups to the extent possible. The hearth products subgroup analysis is discussed in detail in chapter 11 of this TSD.

2.12 MANUACTURER IMPACT ANALYSIS

The MIA assesses the impacts of new energy conservation standards on manufacturers of the considered product. Potential impacts include financial effects, both quantitative and qualitative, that might lead to changes in the manufacturing practices for these products. DOE identified these potential impacts through interviews with manufacturers and other interested parties.

DOE conducted the MIA in three phases. In Phase I, DOE created an industry profile to characterize the industry, and conducted a preliminary MIA to identify important issues that required consideration. In Phase II, DOE prepared an industry cash flow model and an interview questionnaire to guide subsequent discussions. In Phase III, DOE interviewed manufacturers, and the impacts of standards were assessed both quantitatively and qualitatively. Industry and subgroup cash flow and NPV were assessed through use of the Government Regulatory Impact Model (GRIM). Then impacts on competition, manufacturing capacity, employment, and cumulative regulatory burden were assessed based on manufacturer interview feedback and discussions. DOE discusses its findings from the MIA in chapter 12 of this TSD.

2.13 EMISSIONS IMPACT ANALYSIS

In the emissions analysis, DOE estimated the reduction in power sector emissions of carbon dioxide (CO_2), nitrogen oxides (NOx), sulfur dioxide (SO_2) and mercury (Hg) from potential energy conservation standards for the considered products. In addition, DOE estimated emissions impacts in production activities (extracting, processing, and transporting fuels) that provide the energy inputs to power plants. These are referred to as "upstream" emissions. Together, these emissions account for the FFC. In accordance with DOE's FFC Statement of Policy (76 FR 51282 (Aug. 18, 2011)), the FFC analysis includes impacts on emissions of methane and nitrous oxide, both of which are recognized as greenhouse gases.

DOE primarily conducted the emissions analysis using emissions factors for CO_2 and most of the other gases derived from data in the latest version of *AEO*. Combustion emissions of CH_4 and N_2O were estimated using emissions intensity factors published by the Environmental Protection Agency (EPA) GHG Emissions Factors Hub.[i]

The Energy Information Administration (EIA) prepares the *AEO* using NEMS. Each annual version of NEMS incorporates the projected impacts of existing air quality regulations on emissions. This discussion refers to *AEO 2014*, which generally represents current legislation and environmental regulations, including recent government actions, for which implementing regulations were available as of December 31, 2013.

Because the on-site operation of hearth products requires use of fossil fuels and results in emissions of CO_2, NO_X, and SO_2 at the sites where these appliances are used, DOE also accounted for the reduction in these site emissions and the associated upstream emissions due to potential standards.

SO_2 emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap and trading programs. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for affected EGUs in the 48 contiguous states and the District of Columbia (D.C.). SO_2 emissions from 28 eastern states and D.C. were

[i] http://www.epa.gov/climateleadership/guidance/ghg-emissions.html

also limited under the Clean Air Interstate Rule (CAIR), which created an allowance-based trading program that operates along with the Title IV program in those States and D.C. 70 FR 25162 (May 12, 2005). CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit), but it remained in effect.[j] On July 6, 2011, EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule (CSAPR). 76 FR 48208 (August 8, 2011). On August 21, 2012, the D.C. Circuit issued a decision to vacate CSAPR.[k] The court ordered EPA to continue administering CAIR. *AEO 2014* assumes that CAIR remains a binding regulation through 2040.[l]

The attainment of emissions caps is typically flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the adoption of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. In past rulemakings, DOE recognized that there was uncertainty about the effects of conservation standards on SO_2 emissions covered by the existing cap-and-trade system, but it concluded that no reductions in power sector emissions would occur for SO_2 as a result of standards.

Beginning in 2016, however, SO_2 emissions will fall as a result of the Mercury and Air Toxics Standards (MATS) for power plants. 77 FR 9304 (Feb. 16, 2012). In the final MATS rule, EPA established a standard for hydrochloric acid as a surrogate for acid gas hazardous air pollutants (HAP), and also established a standard for SO_2 (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, SO_2 emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO 2013* assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2016. Both technologies, which are used to reduce acid gas emissions, also reduce SO_2 emissions. Under the MATS, emissions will be far below the cap that would be established by CAIR, so it is unlikely that excess SO_2 emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in SO_2 emissions by any regulated EGU. Therefore, energy conservation standards will reduce SO_2 emissions in 2016 and beyond.

[j] See North Carolina v. EPA, 550 F.3d 1176 (D.C. Cir. 2008); North Carolina v. EPA, 531 F.3d 896 (D.C. Cir. 2008).

[k] See EME Homer City Generation, LP v. EPA, 696 F.3d 7, 38 (D.C. Cir. 2012).

[l] On April 29, 2014, the U.S. Supreme Court reversed the judgment of the D.C. Circuit. and remanded the case for further proceedings consistent with the Supreme Court's opinion. The Supreme Court held in part that EPA's methodology for quantifying emissions that must be eliminated in certain states due to their impacts in other downwind states was based on a permissible, workable, and equitable interpretation of the Clean Air Act provision that provides statutory authority for CSAPR. See *EPA v. EME Homer City Generation,* No 12-1182, slip op. at 32 (U.S. April 29, 2014). Because DOE is using emissions factors based on AEO 2013, the analysis assumes that CAIR, not CSAPR, is the regulation in force. The difference between CAIR and CSAPR is not relevant for the purpose of DOE's analysis of SO_2 emissions.

CAIR established a cap on NOx emissions in eastern states and the District of Columbia. Energy conservation standards are expected to have little or no physical effect on these emissions in those states covered by CAIR because excess NOx emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in NOx emissions. However, standards would be expected to reduce NOx emissions in the States not affected by the caps, so DOE estimated NOx emissions reductions from potential standards in the states where emissions are not capped.

The MATS limit mercury emissions from power plants, but they do not include emissions caps and, as such, DOE's energy conservation standards would likely reduce Hg emissions. DOE estimated mercury emissions reduction using emissions factors based on *AEO 2014*, which incorporates the MATS.

Power plants may emit particulates from the smoke stack, which are known as direct particulate matter (PM) emissions. NEMS does not account for direct PM emissions from power plants. DOE is investigating the possibility of using other methods to estimate reduction in PM emissions due to standards. The great majority of ambient PM associated with power plants is in the form of secondary sulfates and nitrates, which are produced at a significant distance from power plants by complex atmospheric chemical reactions that often involve the gaseous emissions of power plants, mainly SO_2 and NOx. The monetary benefits that DOE estimated for reductions in SO_2 and NOx emissions resulting from standards are in fact primarily related to the health benefits of reduced ambient PM.

Further detail is provided in chapter 13 of the TSD.

2.14 MONETIZING REDUCED CO2 AND OTHER EMISSIONS

DOE considered the estimated monetary benefits likely to result from the reduced emissions of CO_2 and NOx that are expected to result from each of the standard levels considered.

To estimate the monetary value of benefits resulting from reduced emissions of CO_2, DOE used the most current SCC values developed and/or agreed to by an interagency process. The SCC is intended to be a monetary measure of the incremental damage resulting from GHG emissions, including, but not limited to, net agricultural productivity loss, human health effects, property damage from sea level rise, and changes in ecosystem services. Any effort to quantify and to monetize the harms associated with climate change will raise serious questions of science, economics, and ethics. But with full regard for the limits of both quantification and monetization, the SCC can be used to provide estimates of the social benefits of reductions in GHG emissions.

The Interagency Working Group on Social Cost of Carbon released in 2013 an update of its previous report.[m] The most recent estimates of the SCC in 2015, expressed in 2013$, are $12.0, $40.5, $62.4, and $119 per metric ton of CO_2 avoided. For emissions reductions that occur in later years, these values grow in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although DOE gives preference to consideration of the global benefits of reducing CO_2 emissions.

DOE multiplied the CO_2 emissions reduction estimated for each year by the SCC value for that year in each of the four cases. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the discount rates that had been used to obtain the SCC values in each case.

DOE recognizes that scientific and economic knowledge continues to evolve rapidly as to the contribution of CO_2 and other GHG to changes in the future global climate and the potential resulting damages to the world economy. Thus, these values are subject to change.

DOE also estimated the potential monetary benefit of reduced NOx emissions resulting from the standard levels it considers. Estimates of monetary value for reducing NOx from stationary sources range from $476 to $4,893 per ton in 2013$.[n] DOE calculated monetary benefits using a medium value for NOx emissions of $2,684 per short ton (2013$), and real discount rates of 3 percent and 7 percent.

DOE is investigating appropriate valuation of Hg and SO_2 emissions. DOE has not monetized estimates of SO_2 and Hg reduction in this rulemaking.

Further detail on the emissions monetization is provided in chapter 14 of this TSD.

2.15 UTILITY IMPACT ANALYSIS

In the utility impact analysis, DOE analyzes the changes in electric installed capacity and generation that result for each trial standard level (TSL). DOE uses a variant of NEMS, referred to as NEMS-BT,[o] to account for these impacts. NEMS-BT has several

[m] *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Interagency Working Group on Social Cost of Carbon, United States Government; revised November 2013.
http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

[n] U.S. Office of Management and Budget, Office of Information and Regulatory Affairs, *2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities*, Washington, DC.

[o] DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on DOE/EIA assumptions, DOE refers to it by the

advantages that have led to its use in the analysis of energy conservation standards. NEMS-BT uses a set of assumptions that are well known and fairly transparent, due to the exposure and scrutiny each *AEO* receives. In addition, the comprehensiveness of NEMS-BT permits the modeling of interactions among the various energy supply and demand sectors.

The utility impact analysis is a comparison between the NEMS-BT model results for the base case and standard cases. The utility impact analysis reports the changes in installed capacity and generation that result from each standard level by plant type. DOE models the anticipated energy savings impacts from potential amended energy conservation standards using NEMS-BT to generate forecasts that deviate from the *AEO* reference case.

Further detail is provided in chapter 15 of this TSD.

2.16 EMPLOYMENT IMPACT ANALYSIS

The adoption of energy conservation standards can affect employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the plants that produce the covered products. DOE evaluates direct employment impacts in the MIA.

Indirect employment impacts may result from expenditures shifting between goods (the substitution effect) and changes in income and overall expenditure levels (the income effect) that occur due to standards. DOE defines indirect employment impacts from standards as net jobs eliminated or created in the general economy as a result of increased spending driven by increased product prices and reduced spending on energy.

Indirect employment impacts are investigated in the employment impact analysis using the Pacific Northwest National Laboratory's "Impact of Sector Energy Technologies" (ImSET) model.[p] The ImSET model was developed for DOE's Office of Planning, Budget, and Analysis to estimate the employment and income effects of energy-saving technologies in buildings, industry, and transportation. Compared with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy conservation investments. Further detail is provided in chapter 16 of this TSD.

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name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed).

[p] M.J. Scott, O.V. Livingston, P.J. Balducci, J.M. Roop, and R.W. Schultz, ImSET 3.1: Impact of Sector Energy Technologies, PNNL-18412, Pacific Northwest National Laboratory (2009) (Available at: www.pnl.gov/main/publications/external/technical_reports/PNNL-18412.pdf).

2.17 REGULATORY IMPACT ANALYSIS

DOE prepared a regulatory impact analysis (RIA) pursuant to Executive Order 12866, Regulatory Planning and Review, 58 FR 51735, October 4, 1993, which is subject to review by the Office of Information and Regulatory Affairs at the Office of Management and Budget. The RIA addresses the potential for non-regulatory approaches to supplant or augment energy conservation standards in order to improve the energy efficiency or reduce the energy consumption of the product covered under this rulemaking.

DOE recognizes that voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties can substantially affect energy efficiency or reduce energy consumption. DOE bases its assessment on the actual impacts of any such initiatives to date, but also considers information presented by interested parties regarding the impacts existing initiatives might have in the future. Further detail is provided in chapter 17 of this TSD.

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter details the market and technology assessment that the U.S. Department of Energy (DOE) conducted in support of the energy conservation standards rulemaking for hearth products.

This chapter consists of the market assessment and the technology assessment. The goal of the market assessment is to develop a qualitative and quantitative characterization of hearth industry and market structures based on publicly available data and other information that DOE received directly from manufacturers and other interested parties. The market and technology assessment addresses manufacturer characteristics and market shares, existing regulatory and non-regulatory efficiency improvement initiatives, product classes, and trends in product markets and characteristics. DOE performs the technology assessment to develop a preliminary list of technologies (referred to as technology options) that could be used to improve the efficiency or reduce the fuel consumption of hearth products.

3.1.1 Description of Products

Gas-fired hearth products present a visible flame that typically provides aesthetic appeal and may also provide supplemental space heating. Gas-fired hearth products are often designed to simulate wood-burning hearth products, but come in a variety of designs, including “modern” styles consisting of only a flame pattern, or a flame surrounded by glass, stones, or other media. Consumers of gas-fired hearth products may select a product for décor, ambiance, heat, or some combination thereof. Hearth product consumers are typically homeowners or contractors purchasing a hearth product for installation in a new home or for replacement or upgrade in an existing home. Some consumers purchase a gas-fired hearth product to retrofit a wood-burning fireplace.

Hearth products covered by this rulemaking use natural gas or propane, can be vented or unvented, and may be designed for indoor or outdoor use. Hearth products take a variety of forms, including but not limited to fireplaces, fireplace inserts, freestanding stoves, and gas log sets. Outdoor hearths may take the form of a fireplace, fire pit or patio heater. Section 3.3.1 describes these hearth products and the components that typically comprise them.

There are three general types of ignition types for hearth products: match lit, constant burning or “standing” pilot, and electronic ignition. Match-lit burners do not use a pilot-type ignition system. The user manually turns on the gas valve and lights gas flowing to the main burner, typically with a match although sometimes a piezo-electric spark igniter is provided. DOE notes that match-lit hearth products would be unaffected by the proposed prescriptive requirement disallowing use of a constant burning pilot (see the notice of proposed rulemaking for further details on the proposal).

The most common form of electronic ignition system found in hearth products is the intermittent pilot ignition. Both standing pilot and intermittent pilot ignitions use a pilot light to ignite the main burner. In both ignition systems, a small pilot light is first lit and proven before gas can flow to the main burner. A “constant burning pilot” system is so called because when gas flow to the main burner is discontinued, the pilot light continues to consume fuel unless it is extinguished by the user. In such systems, the pilot is not designed to extinguish automatically, and in many cases the user will leave the pilot on either year ’round or during an entire heating season. In an intermittent pilot ignition, the pilot light is only lit when there is a call for heat, and the pilot light is automatically extinguished after the burner is turned off. In order to ignite the pilot light, these systems require an outside power source, often supplied by either a battery or an electrical connection.

3.1.2 Definitions

Currently, there is no statutory definition of hearth products, and hearth products are not covered consumer products under the Energy Policy and Conservation Act *et seq*. (EPCA). In December 2013, DOE published a notice of proposed determination (NOPD) that proposed a definition of hearth products for coverage. 78 FR 79638. In the December 2013 NOPD, DOE proposed the following definition of hearth product:

Hearth product means a gas-fired appliance that simulates a solid-fueled fireplace or presents a flame pattern (for aesthetics or other purpose) and that may provide space heating directly to the space in which it is installed. 78 FR 79638, 79640.

DOE tentatively determined that, according to the proposed definition, hearth products would meet the relevant statutory criteria so as to justify coverage as a consumer product under EPCA, and provided the relevant justifications in the December 2013 NOPD. Specifically, DOE estimated that hearth products exceeded the 100 kilowatt -hour average household annual energy consumption threshold established by EPCA to define product coverage. 78 FR 79638. Also in the December 2013 NOPD, DOE suggested several common styles of hearth products that would be covered under the proposed definition, including vented decorative hearth products, vented heater hearth products, vented gas logs, gas stoves, outdoor hearth products, and ventless hearth products. DOE used the definition proposed in the December 2013 NOPD (as stated above) for determining the scope of the analysis contained in this technical support document (TSD). If the proposed determination process results in coverage of hearth products, this rulemaking process would form the basis for establishing energy conservation standards for them.

3.1.3 Product Classes

The criteria for separation of a product type into different classes are the type of energy used, capacity, and other performance-related features, such as those that provide utility to the consumer or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard (42 U.S.C. 6295(q)). For hearth products, DOE has tentatively determined that product classes do not need to be established for a prescriptive requirement for hearth products to disallow the use of continuously burning pilots, as discussed in section III.C of the notice of proposed rulemaking (NOPR).

Although DOE tentatively determined that product classes do not need to be established, DOE acknowledges the wide variety of hearth products styles available. Accordingly DOE also recognizes that the impacts of the proposed prescriptive requirement could depend on the types of hearth products a manufacturer produces. For instance, the impact of disallowing constant burning pilots on the manufacturer of vented fireplaces may differ from the impact on a gas log set or outdoor patio heater manufacturer. Additionally, DOE received information during manufacturer interviews and from the Hearth, Patio and Barbecue Association (HPBA) that often pertained to particular groups of hearth products rather than all products. To assess the differences in impact according to type of hearths produced and to provide the most accurate analysis possible using available information, DOE opted to maintain some level of disaggregation by hearth product type in its analysis of the hearth industry.

The analysis examined the five hearth product groups shown in Table 3.1.1. Based on information from manufacturers obtained during interviews, data provided by HPBA (described further in section 3.2.6.2), and the research presented in this TSD, these hearth product groups adequately capture the differences among hearth product styles and configurations. Section 3.3.1 and chapter 5 of this TSD provide descriptions of the hearth products found in each of these analysis groups.

Table 3.1.1 Hearth Product Groups for DOE Analysis

Product Analysis Group	Example Products
Vented Fireplaces/Inserts/Stoves	Vented fireplaces, vented fireplace inserts, vented freestanding stoves
Unvented Fireplaces/Inserts/Stoves	Unvented fireplaces, unvented fireplace inserts, unvented freestanding stoves
Vented Gas Log Sets	Vented gas log sets for installation in existing masonry fireplace
Unvented Gas Log Sets	Unvented gas logs for installation in existing masonry fireplace
Outdoor Products	Outdoor fireplaces, outdoor fireplace inserts, outdoor fire pits, outdoor gas lamps, patio heaters

3.1.4 Test Procedures

Currently, there is no statutory definition of hearth products, and hearth products are not covered consumer products under EPCA. Accordingly, there is no DOE test procedure for measuring the energy efficiency or consumption of hearth products.

EPCA states, in relevant part, that an amended or new standard may not be adopted if a test procedure has not been established for the relevant product type or class (42 U.S.C. 6295(o)(3)(A)) However, later sections of EPCA acknowledge that DOE may establish prescriptive design requirements that by nature would not require a test procedure. For determining compliance with standards, EPCA requires use of the test procedures and criteria prescribed in 42 U.S.C. 6293, except for design standards. (42 U.S.C. 6295(s)) EPCA also states that a test procedure need not be prescribed if one cannot be designed to reasonably measure energy efficiency, energy use, water use, or annual operating cost, and not be unduly burdensome to conduct. (42 U.S.C. 6293(d)(1)) EPCA requires that a determination be published in the *Federal Register* providing justification for such case. Id.

Because the NOPR proposes to adopt a prescriptive design requirement for hearth products, in the NOPR DOE tentatively concluded that a test procedure is unnecessary, and thus, DOE is not developing a test method for these products. See section III.D of the NOPR for more information regarding test procedures for hearth products.

3.2 MARKET ASSESSMENT

The following market assessment identifies the manufacturer trade associations, domestic and international manufacturers of products, and regulatory and non-regulatory programs. The market assessment also provides historical shipment data, describes the cost structure for the hearth industry, and summarizes relevant market performance data for each product type.

3.2.1 Trade Associations

DOE recognizes the importance of trade groups in disseminating information and providing growth to the industry they support. To gain insight into hearth industry, DOE researched various associations available to manufacturers, suppliers, and users of hearth products. DOE also used the member lists of these groups to construct a database of domestic manufacturers.

DOE identified two trade groups that support or have an interest in the hearth industry: the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and the HPBA.

3.2.1.1 Hearth, Patio and Barbecue Association

HPBA is an international trade association that promotes the hearth industry through marketing and education, administers surveys and compiles statistics, and serves its members through government relations and advocacy. HPBA has approximately 2,700 members[1] including “manufacturers, retailers, distributors, manufacturers’ representatives, service and installation firms, and other companies and individuals, all having business interests in and related to the hearth, patio, and barbecue products industries."[2]

3.2.1.2 Air-Conditioning, Heating, and Refrigeration Institute

AHRI[a] is a national trade association representing manufacturers of air conditioning, heating, ventilation and commercial refrigeration equipment and components. AHRI was established in January 2008, when the Air-Conditioning and Refrigeration Institute (ARI) merged with the Gas Appliance Manufacturers Association (GAMA). AHRI has more than 300 member companies that account for more than 90 percent of the residential and commercial air-conditioning, space heating, water heating, and commercial refrigeration equipment manufactured and sold in North America.[3] AHRI serves many functions, including advocating for the heating, ventilation, air-conditioning and refrigeration (HVACR) industry; certifying product performance; developing performance standards for equipment; compiling statistical reports of industry data; sponsoring HVACR research programs; and supporting HVACR technician education programs.[4]

AHRI maintains the AHRI Efficiency Certification Program. AHRI also maintains on its website a database of products and equipment tested under its certification program. While the directory lists a "vented hearth heater" product type in its direct heating equipment directory, no products are listed under that category.

3.2.2 Manufacturer Information

The following section provides information about manufacturers of hearth products, potential small business impacts, and product distribution channels.

3.2.2.1 Manufacturers

DOE identified 77 domestic manufacturers of hearth products as well as 13 foreign-owned manufacturers of gas hearth products sold in the United States. The majority of the domestic market is controlled by six manufacturers: Hearth and Home Technologies, Innovative Hearth Products, Vermont Castings Group, Travis Industries, Regency, and Napoleon.

Table 3.2.1 lists all identified manufacturers of products potentially affected by this rulemaking. Domestic small business manufacturers, defined as having 500 employees or fewer, are noted in the table.

Table 3.2.1 Hearth Product Manufacturers

Acucraft Fireplace Systems**	Fire Features (Colombo Construction Corp)**	O.W. Lee**

[a] For more information, please visit www.ahrinet.org.

Adobelite LLC**	Firegear LLC**	Ortal Heating Solutions**
American Fireglass**	Firetaiment Inc**	Outdoor Entertainment Designs**
American Gas Log, LLC**	Formation Creation Inc.**	Pacific Energy Fireplace*
American Heating Technologies**	GHP Group, Inc**	Portland Willamette**
Appalachian Stove**	Golden Blount, Inc.**	Pride Family Brands**
Archgard Industries Ltd.*	Hargrove Manufacturing**	Procom
Architectural Pottery**	Hearth & Home Technologies	Pyrotek, Inc.
Big Woods Hearth Products**	Hearth Innovations**	Rasmussen Gas Logs & Grills**
Blaze King Industries**	Hearth Products Controls Co.**	Raw Urth Design**
Blue Rhino	HearthStone Quality Home Heating Products, Inc.**	Regency
Blue Rooster Company, The**	Heatmaster, Inc.**	Robert H. Peterson Company**
Bobe Water & Fire**	Infrared dynamics**	Sherwood Industries Ltd.*
Bond Manufacturing**	Innovative Hearth Products	Sierra Products Inc**
Buck Stove Corporation**	IronHaus**	Skytech Products Group**
Burley Appliances Limited*	J.A. Roby *	Solus Décor*
Cal Flame**	Jotul*	Spark Modern Fires**
California Outdoor Concepts**	Kingsman Fireplaces*	Steelog Artistic Metals**
Camp Chef**	Kozy Heat**	Stone Forest, Inc.**
Cast Classics	Lava Heat**	Sun Star Heaters**
Cooke Furniture**	Louisville Tin and Stove Co.**	Superior Radiant Products*
Crown Verity*	Lynx**	Sure Heat Manufacturing**
Designing Fire**	Malm Fireplace**	Thelin**
Diamond Fire Glass**	Mason-Lite**	Travis Industries, Inc.
Eiklor Flames Inc.**	Mendota Hearth Products	Tropitone
Empire Comfort Systems**	Modern Home Products Corporation**	Valor Fireplaces*
Empire Pre-Cast**	Moderustic Fire**	Vermont Castings
Enerco Group, Inc**	Montigo**	Warming Trends, LLC**
Fire On Glass**	Napoleon Fireplaces*	William Smith**
Fireboulder**	Nibe Stoves*	World Marketing of America, Inc.**

*Foreign-owned
**Small business (500 employees or fewer)

3.2.2.2 Small Business Impacts

Small businesses may be disproportionately affected by the promulgation of energy conservation standards for hearth products. The Small Business Administration (SBA) defines small business manufacturing enterprises for residential hearth products as those having 500 employees or fewer.[5] SBA lists small business size standards for industries as they are described in the North American Industry Classification System (NAICS). The size standard for an industry establishes the largest size that a for-profit entity can be while still qualifying as a small business for federal government programs. These size standards are generally expressed in terms of the average annual receipts or the average employment of a firm. Hearth manufacturing is classified under NAICS 335228, "Other Major Household Appliance Manufacturing," and under NAICS 333414, "Heating Equipment (except warm air furnaces) Manufacturing." The size standard is 500 employees or fewer for both NAICS codes.

DOE identified 66 domestic small business manufacturers of hearth products covered by this rulemaking (denoted in Table 3.2.1 above). DOE studied the potential impacts on these small businesses as a part of the manufacturer impact analysis (chapter 12 of this TSD).

3.2.3 Distribution Channels

Analysis of the distribution channels of products covered by this rulemaking is an important facet of the market assessment. DOE gathered information from publicly available sources and manufacturer interviews regarding the distribution channels for hearth products. DOE uses distribution channel markups (*e.g.*, manufacturer markups, retailer markups, distributor markups, contractor markups) and sales taxes (where appropriate) to convert the manufacturer production cost estimates from the engineering analysis to consumer prices, which are then used in the LCC and PBP analyses and in the manufacturer impact analysis. The markups are multipliers that are applied to the purchase cost at each stage in the distribution channel for hearth products. Before developing markups, DOE defines key market participants and identifies distribution channels.

DOE characterized two distribution channels to describe how hearth products pass from the manufacturer to consumers: (1) replacement market and (2) new construction. The replacement market channel is characterized as follows:

Manufacturer → Wholesaler → Mechanical contractor → Consumer

The new construction distribution channel is characterized as follows:

Manufacturer → Wholesaler → Mechanical contractor → General contractor → Consumer

Chapter 6 of the NOPR TSD provides further detail on the estimation of markups.

3.2.4 Regulatory Programs

The following section details current regulatory programs mandating energy conservation standards for hearth products. Section 3.2.4.1 discusses current federal energy conservation standards, and section 3.2.4.2 provides an overview of existing state standards. Sections 3.2.4.3 reviews standards in Canada that may affect companies servicing the domestic market. No energy conservation standards have been implemented for gas hearth products in Mexico.[6]

3.2.4.1 Current Federal Energy Conservation Standards

As described in section 3.1.1, there are currently no energy conservation standards for hearth products as hearth products are not currently covered products. In the December 2013 NOPD, DOE proposed a definition of coverage for hearth products. Should the December 2013 NOPD result in coverage of hearth products, this rulemaking would establish energy conservation standards, if it is determined that such standards would meet the requirements of EPCA.[b]

3.2.4.2 State Energy Conservation Standards

DOE notes that state and local jurisdictions may require certification to certain safety standards. A sample list of these standards is provided in Table 3.2.2. However, none of the heater standards set forth a minimum efficiency requirement, and none of the standards establish a design requirement intended to reduce fuel consumption. DOE is not aware of any state requirements that regulate the energy use or energy efficiency of hearth products.

Table 3.2.2 List of Sample Hearth Industry Standards

ANSI Z21.50 *Vented Gas Fireplaces*
ANSI Z21.60 *Decorative gas appliances for installation in solid-fuel burning fireplaces*
ANSI Z21.84 *Standard for manually lighted, natural gas, decorative gas appliances for installation in solid-fuel burning fireplaces*
ANSI Z21.88 *Vented gas fireplace heaters*
ANSI Z21.11.1 *Gas-fired room heaters, volume II, unvented room heaters*
RGA #2-72 *Standard for Decorative Log Sets for Installation in Wood-Burning Fireplaces*

[b] Any new or amended standard for a covered product must be designed to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A) and (3)(B))

3.2.4.3 Canadian Standards Association

The Canadian Standards Association (CSA) is an independent standards-setting agency that establishes test procedures and efficiency standards that are typically adopted by the Canadian government.

Canada has product classes for vented gas fireplaces and fireplace heaters. Vented gas fireplaces are primarily used for aesthetic purposes, whereas vented gas fireplace heaters are designed to provide heat to the space where they are installed. Canada has not issued energy conservation standards for either of these products classes.[7]

Since September 2003, all gas fireplaces sold in Canada must be tested and certified to the Canadian test standard CSA P.4.1-02 under the EnerGuide program. This standard determines a fireplace efficiency rating that is used in certification and labeling.[8]

3.2.5 Voluntary Programs

DOE reviewed voluntary programs promoting energy efficient gas hearth products in the United States. Hearth products are not currently covered under the ENERGY STAR® appliance program[9] DOE's Federal Energy Management Program.[10]

Several utilities offer rebate programs for gas fireplaces. A sample of these programs is listed in Table 3.2.3.

Table 3.2.3 Sample Rebate Programs

State	Utility	Product	Requirement	Value
Washington	Puget Sound Energy[11]	Gas Fireplaces	Must meet minimum fireplace efficiency (CSA P.4.1-02 rating) of 70% and have electronic ignition	$200
Minnesota	CenterPoint Energy[12]	Gas Fireplaces, Inserts, Stoves	Must have electronic ignition	$75
Utah, Wyoming, Idaho	City Water Light and Power[13]	Gas Fireplaces (Direct-Vent)	Must have minimum heater efficiency annual fuel utilization efficiency 70%, must be direct-vent, thermostatically controlled, include blower, and electronic ignition	$200

3.2.6 Historical Shipments

Annual product shipment trend data are an important aspect of the market assessment and development of the standards rulemaking. Such data are used in the shipments analysis (chapter 9 of this TSD). The number of unit shipments is expected to follow a trend similar to that of new home starts. This relationship is further detailed in chapter 9 of this TSD.

3.2.6.1 New Home Starts

Figure 3.2.1 presents the total number of new single-family and multifamily housing units started in the United States from 2005 to 2013. Between 2005 and 2009, total housing starts decreased by 73 percent. Since 2009, total housing starts have increased slightly, and as of 2013, were at 45 percent of 2005 total housing starts.[14]

Certain hearth product types, specifically indoor fireplaces, are more strongly tied to housing starts as these products are more often purchased and installed at the time of new home construction. Inserts and gas logs are less directly tied to housing starts as these products are typically purchased for remodeling or upgrading existing homes with wood-burning fireplaces. However, remodeling existing homes can be assumed to correlate with the overall state of the economy, an indicator of which is housing unit starts. The relationship between housing starts and hearth product shipments is discussed further in chapter 9 of this TSD.

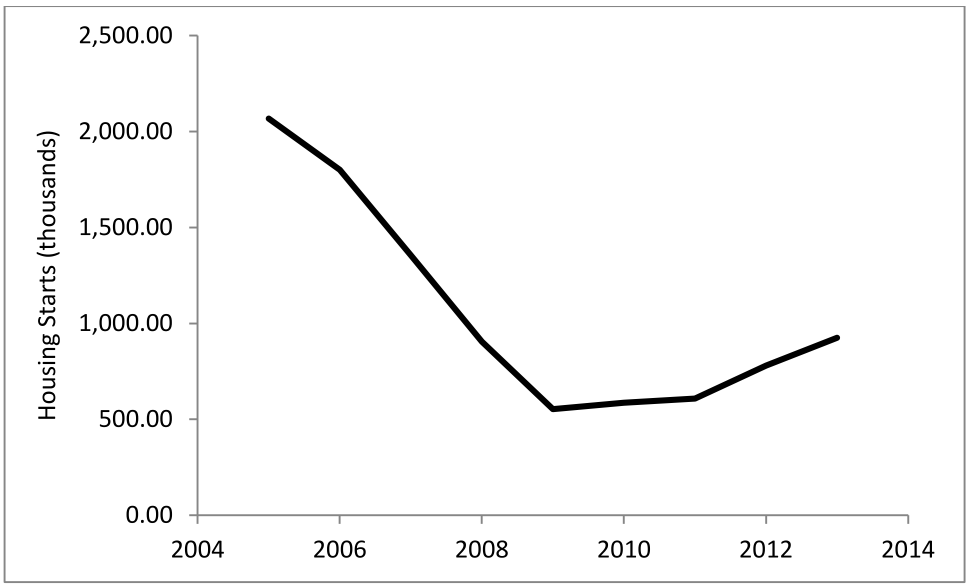

Figure 3.2.1 New Privately Owned Single-Family and Multi-Family Housing Unit Starts from 2005 to 2013[15]

3.2.6.2 Shipments

Information about annual equipment shipment trends allows DOE to estimate the impacts of energy conservation standards on the hearth products industry. DOE has examined unit shipments and value of shipments for various hearth products using data provided by HPBA.

Data for the total number of gas hearth appliances shipped are available on HPBA's website for the years 1998 to 2013.[16] These total shipments include all types of gas hearth products shipped by member manufacturers, including fireplaces, inserts, stoves, fireboxes, and gas logs, among other types. HPBA also provided DOE with additional data for the rulemaking process, [17] including ranges of market shares for each of nine hearth product styles from 2005 to 2013, and the total annual shipments for these nine categories. HPBA did not provide the relative market shares for each year, but rather provided a range of market shares over the corresponding period. Figure 3.2.2 shows the total shipments data from the HPBA website and those provided by HPBA from 2005 to 2014.

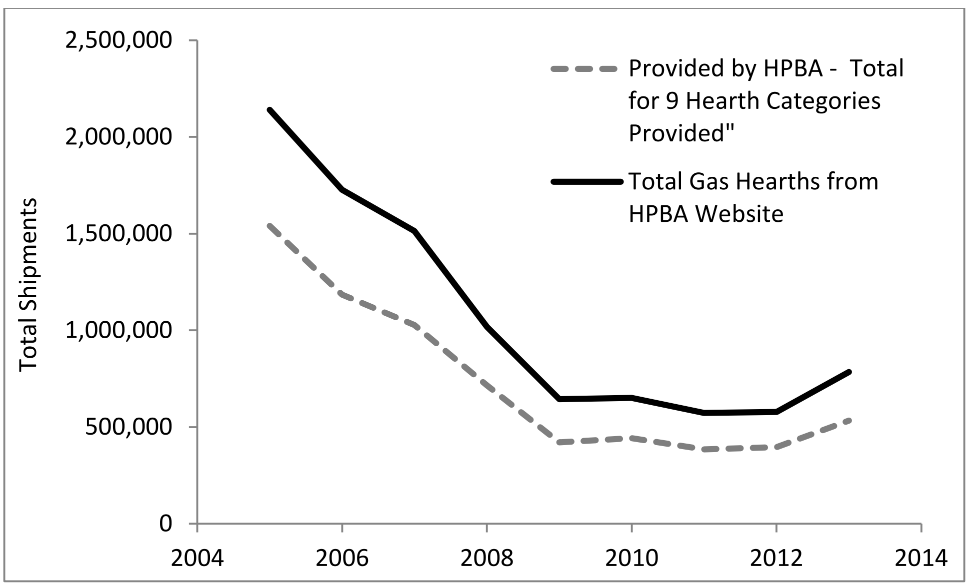

Figure 3.2.2 HPBA Shipments Data

Table 3.2.4 shows the product categories and market shares provided to DOE by HPBA.

Table 3.2.4 HPBA Product Categories and Relative Market Shares[17]

HPBA Product Category	Shipments, 2005-2013 %
Vented Fireplace	40 58
Unvented Fireplace	2 6
Vented Stove	3 5
Unvented Stove	0 1
Vented Fireplace Insert	4 10
Unvented Fireplace Insert	0 0.3
Vented Gas Logs	3 10
Unvented Gas Logs	16 23
Outdoor Fireplaces	0.4 24*

*HPBA subsequently clarified via email that the range 4% to 9% was typical for outdoor fireplaces over the period 2010-2013.

DOE confirmed with HPBA that the difference between the total shipments available on the HPBA website and the total shipments provided for the nine categories is due primarily to fireboxes and patio heaters. HPBA was unable to provide additional data for patio heaters. HPBA also clarified that the outdoor fireplaces category included shipments for fire pits, and that a substantial portion of other outdoor products are from non-HPBA manufacturers and are therefore not captured in these data.

As described in section 3.1.3, DOE elected to use five hearth product groups for analysis. The shipment percentage ranges provided by HPBA were aggregated into the five product groups for the rulemaking analysis. In order to derive a set of five average shipment ratios for its product groups, DOE started by taking the midpoint of the ranges provided and proportionally adjusting so that the total of the resulting percentages equaled 100 percent. DOE used the 4-9 percent range for outdoor fireplaces because HPBA acknowledged that the range initially provided was larger than would be expected in a typical year.

To determine a useful and accurate market share for outdoor products and in light of HPBA's suggestions, DOE deemed it necessary to capture non-HPBA shipments for this product group. Using a product listing database compiled for the rulemaking (discussed in section 3.2.9), DOE found that there were 12 percent as many HPBA patio heater models listed compared to the number of all other outdoor product models listed for HPBA members. DOE used this ratio as a proxy to estimate the number of patio heater shipments from HPBA members. For patio heaters, DOE assumed that non-HPBA shipments were three times those of HPBA members. For all other outdoor products, DOE assumed that the number of non-HPBA shipments was equal to the HPBA shipments. These additional shipments estimates were added to the average number of shipments from 2010 to2013, and the shares for each of the five hearth product groups were then recalculated. These values are provided in Table 3.2.5.

Table 3.2.5 DOE Market Shares for Hearth Product Groups

Product Group	Market Share %*
Vented Fireplace/Insert/Stove	56.2
Unvented Fireplace/Insert/Stove	4.4
Vented Gas Log Sets	6.1
Unvented Gas Log Sets	18.3
Outdoor	15.0

*These shipment weights include match-lit hearth products. These products are later removed becase they would be unaffected by a proposed rule disallowing standing pilot ignitions. See chapter 9 of this TSD for more information regarding the shipments analysis.

3.2.7 Industry Cost Structure

DOE developed the hearth industry cost structure using publicly available information (*e.g.*, Securities and Exchange Commission 10-K reports,[18] corporate annual reports, the U.S. Census Bureau's 2011 Annual Survey of Manufacturers[19]) as well as data obtained directly from manufacturers through interviews. Table 3.2.6presents key industry financial metrics, each of which is estimated as a percentage of total revenue. The manufacturer impact analysis (chapter 12 of this TSD) includes a more detailed discussion of the industry cost structure and the potential financial impacts of an energy conservation standard.

Table 3.2.5 Industry Cost Structure

Parameter	Percent of Total Revenue %
Working Capital	2.2
Net Property, Plant, and Equipment	10.8
Selling, General and Administrative Expenses	25.0
Research and Development	2.3
Depreciation	2.1
Capital Expenditures	2.1

3.2.8 Equipment Lifetime

DOE reviewed available literature and consulted with manufacturers to establish typical equipment lifetimes. (See the life-cycle cost analysis, chapter 8 of this TSD, for additional details and sources used to determine the typical equipment lifetimes.) DOE combined these sources to develop an average estimated lifetime of the equipment covered by this rulemaking. DOE tentatively determined the average lifetime of hearth products to be 15 years.

Chapter 8 of the TSD provides more information about hearth product lifetimes.

3.2.9 Market Performance Data

As previously mentioned, DOE compiled a product listing database by conducting a review of product literature. Fields captured in the database include the hearth product type, fuel type, and ignition type. For gas log sets, DOE found this type of data aggregation was not useful, as model numbers are not used to reflect all possible permutations of burners, log styles, and ignition types.

In conjunction with manufacturer estimates provided during the interview process, DOE also used the product listing database to estimate the portion of shipments that use each of the three general ignition types by product group. These estimates are shown in Table 3.2.7.

Table 3.2.6 Average Market Share of Ignition Types by Analysis Group

Product Group	Match Lit %	Standing Pilot %	Intermittent Pilot Ignition %	Source
Vented Fireplace/Insert/Stove	5	40	55	Manufacturer Interviews
Unvented Fireplace/Insert/Stove	0*	12	88	Product Listing Database
Vented Gas Log Sets	50*	44	6	Manufacturer Interviews
Unvented Gas Log Sets	0	94	6	Manufacturer Interviews
Outdoor	50**	26	24	Product Listing Database

*DOE assumed that there are no shipments of unvented match-lit hearth products because the industry safety standard ANSI Z21.11.2 requires the use of an oxygen depletion sensor and therefore a safety pilot.
**The product listing database showed that the number of match-lit outdoor models was lower, however DOE assumed that 50% of outdoor hearth products are match lit.

DOE found that efficiency data for heater-rated hearth products are inconsistent and frequently not fully specified. Thermal efficiency, annual fuel utilization efficiency (AFUE), and fireplace efficiency (CSA P.4.1-02) are used inconsistently throughout the industry, and efficiency ratings in product literature often do not specify which metric is used or the test procedure by which the rating is obtained.

3.3 TECHNOLOGY ASSESSMENT

The purpose of the technology assessment is to develop a list of technology options manufacturers can use reduce the energy consumption of hearth products. The following assessment provides descriptions of those technology options that apply to all hearth product groups or specific hearth product groups.

In preparation for the screening and engineering analyses, DOE identified several possible technology options for improving the energy efficiency or reducing the energy consumption of hearth products. These options provide insight into the design improvements typically used to reduce the gas consumption of hearth products.

3.3.1 Baseline Equipment Components and Operation

DOE typically defines the baseline model as a product having an efficiency that just meets the existing federal energy conservation standards. DOE also typically defines baseline models as having commonly available features. The baseline models for hearth products serve as a reference points for measuring changes resulting from energy conservation standards.

In the case of hearth products, there are no federal energy conservation standards. For all hearth product groups, DOE assumes the baseline model uses a constant burning pilot ignition system. Because the inclusion of a constant burning pilot ignition would lead to the highest possible standby mode energy use, this ignition type represents the baseline for comparison to other technologies that would reduce standby mode energy use. Hearth products that are match lit were not considered baseline as these consume no energy during standby mode.

Furthermore, DOE's selection of baseline models focused primarily on the types of ignitions typically employed in each hearth product group because the standby mode energy use is mostly attributable to the ignition type (see section III.B of the NOPR for rationale). As noted in section 3.1.3, DOE has tentatively concluded that within each hearth product group and for each ignition type (standing pilot and electronic ignition) the primary ignition components (gas valve, pilot assembly, and control module for electronic ignition models) are largely interchangeable. The paragraphs below describe the baseline model for each hearth product group analyzed.

Vented Fireplace/Insert/Stove. A vented gas fireplace simulates a wood-burning fireplace and may be installed into a wall or other framing structure. An insert is designed for installation into an existing solid fuel burning fireplace. A stove is a free-standing unit that does not require installation into a surrounding structure. Vented units include pipes that carry combustion gases out of the building.

For this product group, the typical constant burning pilot ignition system included a millivolt gas control valve and a pilot assembly. The millivolt valve uses the pilot light to generate a small voltage potential, allowing use with a remote control or thermostat to open the gas valve without requiring an additional source of power. The pilot assembly includes a gas line connecting the gas valve to the pilot, a thermocouple, and a thermopile. The thermocouple is heated by the pilot and used to prove that the pilot is burning gas, while the thermopile provides the voltage potential for use with a remote control or thermostat.

Unvented Fireplace/Insert/Stove. Unvented fireplaces, inserts, and stoves are similar to those found in the vented group, but are not designed to vent combustion gases.

Rather, these products are designed to safely allow the byproducts of combustion into the dwelling. The ignition systems on these products differ from their vented counterparts in their use of an oxygen depletion sensor (ODS). The ODS is a precision pilot light and calibrated thermocouple that shuts the gas control valve when the oxygen in the room is below a threshold. These components are included with the pilot assembly.

Vented Gas Log Sets. Vented gas log sets are designed for installation directly into existing solid fuel burning fireplaces. These products are open flame devices and do not include the metal heat shield or enclosure found in fireplaces, inserts, and stoves. Gas log sets are meant as a replacement for wood as a fuel source in existing fireplaces, and are therefore subject to the physical space constraints of the existing fireplace. Additionally, they rely on the existing chimney or ventilation system to remove the combustion byproducts from the building. Vented gas log sets typically consist of a burner, a grate, and ceramic or cement imitation logs.

In jurisdictions that do not require a safety pilot ignition system, the burner is commonly lit manually with a match or lighter. These types of gas log sets do not maintain a constant burning pilot and are therefore unaffected by the proposed prescriptive requirement contained in the NOPR.

In jurisdictions that require a safety pilot specifically or certification to a safety standard that requires one, manufacturers may offer or include a manual safety pilot system, a millivolt pilot system, or an electronic ignition system. Manual gas valves are typically less expensive and smaller in size than millivolt gas valves or gas valves for electronic ignition systems. DOE selected the manual safety pilot system as the baseline model due to the space and cost constraints consumers of these products often face.

Unvented Gas Log Sets. Unvented gas log sets are similar to their vented counterparts except that the burner is designed so that the byproducts of combustion enter the occupied space rather than being vented outside of the building. Unvented gas log sets also incorporate an ODS for safe operation.

Outdoor Products. Outdoor products may take several forms. DOE identified fireplaces, fire pits or burners, and patio heaters as the most prominent styles of outdoor hearth products. Outdoor fireplaces are similar in design to indoor fireplaces, but are specially designed with materials that make them suitable for installation outdoors. Fire pits and burners are open flame devices that do not incorporate heat shielding or an enclosure. These products are comprised of a burner and an ignition system consisting of a gas valve and pilot.

Patio heaters may come in two styles, radiant and pyramid. Radiant patio heaters provide primarily radiant heat to an outdoor space. A steel emitter screen that surrounds the combustion zone glows when heated and provides radiant heat to its surroundings. These patio heaters typically consist of a base or stand, a gas connection and regulator, a post, and a head unit, which contains the gas valve and pilot assembly, a burner, the emitter screen, and a reflector shield. These patio heaters may use natural gas or propane; in the case of propane, the base or stand is often large enough to store a propane tank.

Pyramid style patio heaters create a very large flame through a glass tube. These heaters consist of a base, gas connections and regulator, gas valve and pilot assembly, burner, glass tube, and reflector.

3.3.2 Technology Options

Air-to-Fuel Ratio. The mixture of air and fuel for combustion determines key flame aspects for hearth products, in particular the flame color, height, and heat output from the hearth product. As described previously, gas-fired hearth products are often designed to simulate the burning of wood. In order to achieve flame characteristics that mimic wood-burning flames, gas-fired hearth products utilize a "rich" mixture, that is, the ratio of air to fuel is low. For many natural gas products, primary air is in fact not pre-mixed, and what is burned is nearly 100 percent natural gas. This results in a tall yellow flame. For propane products, air is pre-mixed with fuel prior to combustion. Optimizing the air-to-fuel ratio would improve the active mode energy use of hearth products, but may reduce the flame aesthetic appeal. Manufacturers indicated during interviews that becasue the aesthetic appeal of the flame must be maintained, there would be no room to reduce the fuel consumption by adjusting the air-to-fuel ratio.

Burner port design. Gas burners for hearth products typically comprise tubes with holes or slots through which the gas exits and combusts. The holes or slots are designed with particular sizes and patterns in order to achieve the desired flame pattern or aesthetic. While the primary objective of optimizing gas burner ports is to achieve the desired flame pattern, the ports could also be optimized to deliver an acceptable flame aesthetic while reducing the amount of fuel consumed. This design would have the potential to improve the active mode energy use of hearth products, but may reduce aesthetic appeal. DOE is not aware of any products on the market using advanced burner port designs as a means of reducing energy consumption. During manufacturer interviews, most manufacturers stated that they expected that adjusting the burner port design would insignificantly reduce fuel consumption .

Simulated log design. Many gas hearth products incorporate cement, fiber, or ceramic logs that are designed to simulate the look of wood logs. The log shapes are optimized in conjunction with the burner design. The combination of the burner design and log shape, size, and placement results in the overall aesthetic for the product. Additionally, logs must be designed in conjunction with the burner to ensure that flames do not impinge on the logs themselves, as this causes the flame to cool and form soot. For contemporary style hearth products, simulated logs may be replaced with other shapes or materials or may be removed entirely.

For products that incorporate simulated logs or other objects, the combination of the logs or objects with the flame pattern (burner design) results in the complete design. A key design objective for this log and flame pattern combination is to fill the firebox into which they are installed as much as possible. For a given size, the logs could therefore be optimized to reduce the amount of fuel needed while sufficiently filling the firebox. This design option would potentially improve the active mode energy efficiency of hearth products. However, DOE is not aware of any product designs on the market that have proven to be more efficient methods for arranging the simulated log. Manufacturer indicated during interviews that insignificant reductions in energy use would be achieved by adjusting the simulated log design.

Pan burner media/bead or glowing ember type. Many hearth products include an ember material that glows and radiates when heated. In pan type burners, sand is used to cover the burner and results in a flame pattern. In contemporary hearth products and in outdoor fire pits, glass beads may be used in place of simulated logs for effect. These media could potentially be selected to produce a satisfactory flame pattern while reducing the required gas consumption. This design option would reduce the active mode energy use of hearth products. During manufacturer interviews, DOE inquired about the use of media, beads, or glowing embers for reducing fuel consumption while providing an adequate aesthetic flame. Manufacturers indicated that this technology would not result in measurable energy savings. Additionally, this technology would only apply to the subset of hearth products that use media, glass, or other beads, or glowing embers.

Reflective walls and/or other components in firebox/combustion zone. For hearth products that include a firebox or other enclosure, the interior walls could potentially be painted with a reflective coating. This could potentially give the illusion of more or taller flames, thereby reducing the amount of fuel required to achieve a satisfactory aesthetic. This design option would only apply to fireplaces, inserts, and stoves, as other hearth products do not incorporate a firebox. This design option may reduce the amount of fuel used in active mode. Manufacturers indicated during interviews that reflective walls would not substantially reduce the fuel needed to produce an aesthetic flame, and that the reflective coating would only serve as a supplemental aesthetic effect. Also, this technology would only apply to the subset of hearth products that include an enclosure surrounding the flame.

Air circulating fan. Air circulating fans improve the efficiency of heater hearth products by increasing the air flow rate through the heat exchanger section of a fireplace, insert, or stove. For vented products, this results in more heat being provided to the occupied space rather than lost through the vent. An air circulating fan would only be an option for vented fireplaces, inserts, and stoves. These hearth products already incorporate the heat exchanger for which the circulating fan would be of use, and many are already available with circulating fans as an option. A circulating fan would not be of use to or feasible for products such as gas logs, outdoor fire pits, and patio heaters because these products do not incorporate a heat exchanger and do not have sufficient cabinetry or enclosure to house the fan. A circulating fan would not improve the efficiency of an unvented hearth product, as all of the heat from an unvented hearth already remains in the occupied space. A circulating fan would primarily improve the heating efficiency during the active mode for those hearth products for which a fan could be integrated, namely fireplaces, inserts, and stoves. It would not substantially affect the standby mode energy use of hearth products.

Condensing heat exchanger. For hearth products that provide space heating, the combustion gases can be passed through a larger or improved heat exchanger to extract as much heat as possible. Such a heat exchange can remove sufficient energy from the combustion gases to reduce the combustion gas temperature below its condensing point. This type of heater is typically termed a condensing heater and is highly efficient at converting the energy in combustion gases into space heating.

The flue-gas condensate is often acidic and corrosive. Therefore, special corrosion-resistant heat exchangers and vent linings are required for safe and reliable operation. Corrosion due to condensation of combustion gases limits the heating efficiency of a hearth product with a standard flue and vent system. Using corrosion-resistant heat exchangers or sidewall venting, and lining the vent/masonry systems with corrosion-resistant material can extend the heating efficiency.

Condensing systems require some means to collect and drain the condensate that develops within the heat exchangers. Condensing systems can be designed to use secondary heat exchangers and air circulation fans as well. This technology would only apply to hearth products designed to provide space heating and only improves heating efficiency during active mode operation.

Electronic Ignition. As shown in Table 3.2.7, a substantial portion of the hearth industry uses standing pilot ignition systems. For hearth products, DOE found that there are primarily two types of electronic ignition systems that do not rely on a continuously burning pilot: intermittent pilot ignition and hot surface (or wire) ignition. The intermittent pilot ignition is a device that generates a spark to light a pilot which in turn lights the main burner. The pilot then automatically extinguishes after the main burner is lit. The hot surface or hot wire ignition system lights the main burner directly via a sufficiently hot surface.

Both hot surface and intermittent pilot electronic ignitions require an outside source of electricity to operate. The gas valve for each electronic ignition system typically only consumes power during a call for heat. The control module, which houses the electronic circuitry required to control the entire ignition system, typically only consumes power during a call for heat. Finally, the electronic thermostat, if present, draws power continuously (regardless of whether heat is needed). These power requirements in total are typically much less than the pilot burn rate.

An electronic ignition would eliminate most standby mode energy consumption since these ignitions do not rely on a continuously burning pilot light. This design option would not affect active mode energy use.

3.3.3 Technology Options That Do Not Affect Energy Use

After reviewing the technology options, DOE found that the circulating fan, condensing heat exchanger, and electronic ignition may substantially reduce energy consumption of hearth products. DOE understands that altering the air-to-fuel ratio, burner port design, simulated log design, burner pan media, bead, or ember type, and reflective combustion chamber walls in order to achieve fuel savings would result in negatively impacting the design aesthetic of hearth products. When maintaining an aesthetic flame, these technologies would not be means for achieving significant fuel savings. During manufacturer interviews, DOE found that regulations focused on or requiring any of these five technology options would hinder manufacturers' ability to innovate and produce aesthetic products. However, DOE does not discourage manufacturers from using these design options or strategies since they may reduce annual energy consumption.

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CHAPTER 4. SCREENING ANALYSIS

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CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter discusses the screening analysis conducted by the U.S. Department of Energy (DOE) of the technology options identified in the market and technology assessment for hearth products (chapter 3 of this technical support document; TSD). In the market and technology assessment, DOE presented an initial list of technology options that can be used to improve the energy efficiency and/or reduce energy consumption of hearth products. The goal of the screening analysis is to identify any technology options that will be eliminated from further consideration in the rulemaking analyses.

The candidate technology options are assessed based on information gathered during DOE research, as well as inputs from interested parties. Technology options that are judged to be viable approaches for improving energy efficiency or reducing annual energy consumption are retained as inputs to the subsequent engineering analysis. Technology options that are not incorporated in commercially available products or in working prototypes, that fail to meet certain criteria pertaining to practicability to manufacture, install, and service, that have adverse impacts on product utility or availability, or have adverse impacts on health or safety will be eliminated from consideration, in accordance with 10 CFR 430, subpart C, appendix A, section 4(a)(4)(i-iv).

DOE uses the following four screening criteria to determine which technology options are suitable for further consideration in an energy conservation standards rulemaking:

1. *Technological feasibility*. DOE will consider technologies incorporated in commercially available products or in working prototypes to be technologically feasible.

2. *Practicability to manufacture, install, and service*. If mass production and reliable installation and servicing of a technology in commercial products could be achieved on the scale necessary to serve the relevant market at the time the standard comes into effect, then DOE will consider that technology practicable to manufacture, install, and service.

3. *Adverse impacts on product utility or product availability*. If DOE determines a technology would have a significant adverse impact on the utility of the product to significant subgroups of consumers, or would result in the unavailability of any covered product type with performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as products generally available in the United States at the time, it will not consider this technology further.

4. *Adverse impacts on health or safety*. If DOE determines that a technology will have significant adverse impacts on health or safety, it will not consider this technology further.

4.2 TECHNOLOGY OPTIONS

As described in chapter 3 of this TSD, DOE developed a list of technology options manufacturers could use to reduce the energy consumption of hearth products. The following technology options were considered in the technology assessment.

- Air-to-fuel ratio
- Burner port design
- Simulated log design
- Pan burner media/bead type
- Reflective walls and/or other components inside combustion zone
- Air circulating fan
- Electronic ignition
- Condensing heat exchanger

Several of these technologies were not considered further in the screening analysis (see chapter 3 of this TSD for details). The air circulating fan, condensing heat exchanger, and electronic ignition were considered as part of the screening analysis because DOE concluded that these three options may substantially the reduce energy consumption of hearth products.

4.3 SCREENED OUT TECHNOLOGIES

DOE has tentatively concluded that these three technologies, namely the air circulating fan, the condensing heat exchanger, and the electronic ignition, would not be screened out by any of the four screening criteria listed above. These technologies are currently commercially available for hearth products and do not result in adverse impacts on health or safety. Therefore, they do not fail the first, second or fourth screening criteria. With regard to impact on product utility and availability, DOE notes that an electronic ignition provides the same functionality as a millivolt standing pilot gas valve, specifically the ability to be used with a remote control or thermostat. DOE has also tentatively determined that electronic ignition components are available for a wide range of gas-fired equipment beyond hearth products, and that the ability of hearth manufacturers to comply with the standard will not be restricted for lack of available components.

4.4 REMAINING TECHNOLOGIES

DOE passed the circulating fan, condensing heat exchanger, and electronic ignition to the engineering analysis for further consideration. See chapter 5 of this TSD for the results of that analysis.

CHAPTER 5 ENGINEERING ANALYSIS

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CHAPTER 5. ENGINEERING ANALYSIS

5.1 INTRODUCTION

The U.S. Department of Energy (DOE) performed an engineering analysis to establish the relationship between manufacturer production cost (MPC) and reduced energy consumption in hearth products. Specifically, DOE analyzed the change in MPC resulting from implementation of electronic ignition systems that would replace a constant burning pilot. The change in MPC resulting from this requirement serves as the basis for cost-benefit calculations in terms of individual consumers, manufacturers, and the nation. This chapter provides an overview of the engineering analysis (section 5.1), discusses product classes (section 5.2), establishes baseline unit specifications (section 5.5.2), discusses incremental efficiency levels (section 5.3), explains the methodology used during data gathering (section 5.4), and discusses the analysis and results (section 5.9). DOE completed a separate engineering analysis for each of the hearth product groups identified for analysis: vented fireplaces/inserts/stoves, unvented fireplaces/inserts/stoves, vented gas log sets, unvented gas log sets, and outdoor hearth products.

The primary inputs of the engineering analysis are baseline information from the market and technology assessment (MTA; chapter 3 of this TSD) and the technologies that are passed through the screening analysis (chapter 4 of this TSD). Additional inputs include cost data derived from the physical teardown analysis and interviews with manufacturers. The primary output of the engineering analysis is the estimated change in MPC associated with reduced energy consumption from disallowing constant burning pilots by hearth product group.

DOE typically structures its engineering analysis around one of three methodologies: (1) the design-option approach, which calculates the incremental cost of adding specific design options to the baseline model; (2) the efficiency-level approach, which calculates the relative costs of achieving increases in energy efficiency levels without regard to the particular design options used to achieve such increases; and/or (3) the reverse engineering cost-assessment approach, which involves a “bottom-up” manufacturing cost assessment based on a detailed bill of materials derived from teardowns of products being analyzed. Deciding which methodology to use for the engineering analysis depends on the product, the technologies under study, and any historical data DOE can draw upon.

To establish the industry incremental cost associated with implementing an electronic ignition system, DOE used both the design-option approach and the cost-assessment approach. After identifying hearth products that represent a cross section of the market, DOE gathered additional information using reverse engineering methodologies, product information from manufacturer catalogs, and discussions with experts and manufacturers of hearth products. DOE generated bills of materials (BOMs) by disassembling manufacturers' products. The BOMs describe the product in detail, including all manufacturing steps required to make and/or assemble each part. Subsequently, DOE developed a cost model that converted the BOMs into MPCs. By applying derived manufacturer markups to the MPCs, DOE calculated the manufacturer selling prices (MSPs) and developed the incremental MPCs associated with the prescriptive requirement.

In a subsequent life-cycle cost analysis (chapter 8), DOE used the MPCs and MSPs to determine consumer prices for hearth products by applying the appropriate distribution channel markups.

5.2 PRODUCT CLASSES

As described in section III.C of the NOPR, DOE has tentatively determined not to establish product classes for a standby mode energy conservation standard. The criteria for separation into different product classes are: (1) energy source and (2) capacity or other performance-related features, such as those that provide utility to the consumer, or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 U.S.C. 6295 (q) and 6316(a)) DOE found substantial similarity in the function, components used, and energy use of hearth products with regard to ignition systems and their standby mode energy consumption. By reviewing manufacturer product literature, DOE found that the same or similar ignition system components, including manual, millivolt, and electronic gas control valves; pilot assemblies; and electronic control modules for electronic ignitions; were used across a wide range of hearth products. DOE has tentatively determined that if standing pilot ignitions are ultimately disallowed, most hearth products styles currently using standing pilot ignitions will switch to similar electronic ignition components. However, recognizing the need to account for differences in product design and manufacturing production volumes, DOE analyzed several specific subgroups of hearths separately, to determine the impacts individually. This is explained in more detail in section 5.2.1.

5.2.1 Product Groups Analyzed

While DOE has tentatively concluded that product classes are not necessary to distinguish hearth products as a result of focusing on standby mode operation (see section III.C of the NOPR), DOE acknowledges that the impact on manufacturers and consumers could differ depending on the hearth product. To investigate these differences, DOE selected five hearth product groups for analysis based on product literature review and manufacturer interviews.

Unvented hearth products consume air from the occupied space for combustion, and release all byproducts of combustion into the occupied space. For safety, unvented ignition systems on indoor hearth products use an oxygen depletion sensor that closes the gas control valve when oxygen in the room drops below a threshold. This sensor consists of a precision pilot light and thermocouple connected to the gas control valve. The pilot light heats the thermocouple; as the oxygen in the room decreases, the pilot flame "lifts" farther from the thermocouple to seek out sufficient oxygen for combustion. This cools the thermocouple, and once the thermocouple cools to a certain temperature (corresponding to an unsafe room oxygen level) the gas control valve closes, preventing further depletion of oxygen in the room. To account for this difference in ignition system components, DOE separated unvented from vented products.

DOE also acknowledges differences between gas log sets and other indoor hearth products. In terms of standing ignition systems, DOE tentatively determined that manual safety pilot valves were more likely to be found on gas log sets, rather than using larger, more expensive millivolt valves. Gas log sets also lack the enclosure and integrated heat shielding found in fireplaces, inserts, and stoves that would more readily house and protect the additional components necessary for ignition systems of any kind. DOE therefore used separate analysis groups for gas log sets.

Outdoor fireplaces often use similar ignition system components to indoor hearth products. However, DOE found that certain types of outdoor hearth products, such as patio heaters and fire pits, may use different ignition components than indoor hearth products. For example, patio heaters do not typically use millivolt gas valves, and fire pits often use hot wire igniters to ignite the pilot light. For these reasons, DOE separated outdoor hearth products as well.

Table 5.2.1 presents the product groups used for analysis.

Table 5.2.1 Hearth Product Analysis Groups

Vented Fireplaces, Inserts, and Stoves
Unvented Fireplaces, Inserts, and Stoves
Vented Gas Log Sets
Unvented Gas Logs Sets
Outdoor Hearth Products

5.3 DESIGN OPTIONS

For each of the hearth product groups listed in Table 5.2.1, DOE analyzed representative models and estimated the manufacturer production costs. As described in the market and technology assessment (chapter 3 of this TSD) and the screening analysis (chapter 4 of this TSD), additional design options for hearth products were considered. Because this rulemaking has focused on standby mode energy consumption for the reasons described in section III.B of the NOPR, DOE did not consider technologies affecting active mode energy consumption in the engineering analysis (*i.e.*, condensing heat exchanger and air circulating blower). Rather, DOE focused its analysis on the impacts of removing the standing pilot ignition system and replacing it with a system that does not use a continuously burning pilot.

The following subsections describe the models selected for each product group for comparison between the baseline (standing pilot) and design option (electronic ignition).

5.3.1 Baseline Model

DOE selected baseline units (standing pilot; *i.e.*, without new energy standards) as reference points for each product group, against which DOE measured changes resulting from potential energy conservation standards. The baseline units in each hearth product group use a constant burning pilot ignition system to allow for comparison to the electronic ignition design option. DOE used the baseline units in the engineering analysis and the life-cycle-cost and payback-period analyses. DOE determined the increase in MPC associated with switching to an electronic ignition. DOE notes that less expensive ignition systems are available–namely match lit burner –but those systems would not be affected by this rulemaking because they do not employ a continuously burning pilot light. DOE did not consider match lit burners as a viable alternative to standing pilot ignition systems because many municipalities and product safety standards require an ignition system be present for gas-fired hearth products. However, DOE notes that for cases where match lit burners are permissible, the MPC for the product would be lower for the match lit hearth product than for those with standing pilot ignition systems.

DOE considered that there are two main standing pilot valve types: manual and millivolt. The manual valve requires the user to manually open and close the valve and is therefore smaller, simpler, and cheaper. The millivolt gas valve uses a thermopile to generate a voltage difference such that the valve can be coupled with additional control systems, for example, a remote control or thermostat. Because gas log sets are subject to physical space constraints that fireplaces, inserts, and stoves are not, DOE selected gas log sets with manual valves as representative of gas log sets with standing pilots. DOE selected models with millivolt gas valves as being representative of the fireplace, insert, and stove vented and unvented categories as millivolt gas valves are common for these products.

Table 5.3.1 Gas Control Valve Types Used for Constant Burning Pilot Units in Engineering Analysis

Hearth Product Group	Standing Pilot Valve
Vented Fireplaces, Inserts, and Stoves	Millivolt
Unvented Fireplaces, Inserts, and Stoves	Millivolt
Vented Gas Log Sets	Manual
Unvented Gas Logs Sets	Manual
Outdoor	Manual

The market baseline units identified in the engineering analysis represent the cost of the typical products on the market that utilize a constant burning pilot. DOE used these baseline models for the subsequent analyses (*e.g.*, life-cycle cost (LCC), payback period (PBP), national impact analysis (NIA), manufacturer impact analysis (MIA).

5.3.2 Electronic Ignition

The results of the screening analysis (chapter 4) are used as inputs to the engineering analysis. As described above in section 5.3, three technologies passed the screening analysis (condensing heat exchanger, air circulating blower, and electronic ignition), only the electronic ignition is being considered in the engineering analysis due to the rulemaking focus on standby energy use.

DOE selected models for each hearth product group that represented typical implementations of electronic ignitions. Based on product literature review and confirmation during manufacturer interviews, DOE determined that the intermittent pilot (IPI) is by far the most common type of electronic ignition used for hearth products. DOE also found that in some outdoor products with high-input capacities, a hot wire igniter (HWI) is used to light the pilot intermittently rather than a spark igniter. DOE therefore considered both types of units for its outdoor product analysis.

Table 5.3.2 Electronic Ignition Types Used in Engineering Analysis

Hearth Product Group	**EIS**
Vented Fireplaces, Inserts, and Stoves	IPI
Unvented Fireplaces, Inserts, and Stoves	IPI
Vented Gas Log Sets	IPI
Unvented Gas Logs Sets	IPI
Outdoor	IPI, HWI

5.4 METHODOLOGY

This section describes the analytical methodology used in the engineering analysis.

DOE first identified units with standing pilot ignitions and with electronic ignitions to represent each hearth product group. DOE gathered the information from the physical teardown analysis to create a BOM using reverse engineering methods (see section 5.5). DOE calculated the MPC for both the standing pilot model and the electronic ignition model for each product type.

During the preparation of the MPCs, DOE held interviews with manufacturers to gain insight into hearth product industry and request comments regarding its cost estimations for various components, particularly those associated with the ignition systems. DOE used the information gathered from these interviews to refine assumptions in the cost model. Next, DOE converted the MPCs into MSPs (see section 5.8) using publicly available industry financial data, in addition to manufacturers' feedback.

5.5 TEARDOWN ANALYSIS

To assemble BOMs and calculate the manufacturing costs of the different components in hearth products, DOE disassembled multiple units into their components and estimated the material and labor cost of each individual component. This process is referred to as a "physical teardown."

5.5.1 Selection of Units

Because the engineering analysis is designed to assess the difference in MPC between baseline (standing pilot) and the proposed design option (electronic ignition), DOE was primarily concerned with selecting units for teardown that represented typical implementations of standing pilot ignition systems and electronic ignition systems. DOE determined the typical characteristics of hearth products based on the market analysis done for the market and technology assessment (chapter 3 of this TSD). In order to provide direct comparison between standing pilot and electronic ignition costs, DOE selected models within each hearth product group from the same manufacturer and within the same product line.

To compare only the cost difference between standing pilot and electronic ignition models in each product group, DOE considered only those subassemblies necessary to constitute the baseline unit and both ignition types. Items that were not common between ignition types and necessary to determining the cost difference for the ignition system only were excluded. For example, remote controls and accompanying remote receivers may be found on electronic ignition systems but not with manual safety pilot ignition systems. Because the goal of the analysis is to directly compare the change in MPC related to the ignition system only, remote controls and remote receivers were not included, as they are often included as a premium feature but are not required for implementing an electronic ignition. If, in the case of electronic ignition systems, the electronic control module for the intermittent pilot ignition system was found to also perform remote receiver functions, the components associated with the remote receiver functions were not considered in the analysis.

Using the data gathered from the physical teardowns, DOE characterized each component according to its weight, dimensions, material, quantity, and the manufacturing processes used to fabricate and assemble it. DOE collected additional component information during the manufacturer interviews.

DOE did not explicitly identify the model number or manufacturer of the units it tore down because this could expose sensitive information about individual manufacturers' products.

5.5.2 Baseline Units

DOE selected baseline units for the teardown analysis as a comparison for more efficient designs. Typically, DOE defines baseline products as those with energy efficiencies equal to the current federal energy conservation standards, and which are representative of the minimum technology and lowest costing product that a manufacturer can produce that provides basic functionality and utility to the consumer. In this case, because there is currently no federal energy standard for hearth products, DOE selected as baseline units those with continuously burning pilot designs. DOE then used the baseline units as reference points to compare the technology and cost of products with electronic ignition systems. The characteristics of the baseline units are described further in section 5.3.1.

5.6 COST MODEL

5.6.1 Generation of Bills of Materials

The end result of each teardown is a structured BOM. DOE developed structured BOMs for each of the teardowns. Structured BOMs describe each product part and its relationship to the other parts in the estimated order in which manufacturers assembled them. The BOMs describe each fabrication and assembly operation in detail, including the type of equipment needed (*e.g.*, presses, drills), the process cycle times, and the labor associated with each manufacturing step. The result is a thorough and explicit model of the production process, which includes space, conveyor, and equipment requirements by planned production level.

The BOMs incorporate all materials, components, and fasteners classified as either raw materials or purchased parts and assemblies. The classifications into raw materials or purchased parts were based on DOE's previous industry experience, recent information in trade publications, and discussions with high- and low-volume original equipment manufacturers (OEMs). DOE also visited manufacturing plants to reinforce its understanding of the industry's current manufacturing practices for hearth products.

For purchased parts, the purchase price is estimated based on volume-variable price quotations and detailed discussions with manufacturers and component suppliers. For fabricated parts, the prices of "raw" materials (*e.g.*, tube, sheet metal) are estimated on the basis of 5-year averages (see section 5.6.4.4). The cost of transforming the intermediate materials into finished parts is estimated based on current industry pricing.

5.6.2 Cost Structure of the Spreadsheet Models

The last step was to convert the BOM information into dollar values. To perform this task, DOE collected information on labor rates, tooling costs, raw material prices, and other factors. DOE assumed values for these parameters using internal expertise and confidential information available to DOE contractors. Although most of the assumptions are manufacturer specific and cannot be revealed, section 5.6.4.3 provides a discussion of the values used for each assumption.

In summary, DOE assigned costs of labor, materials, and overhead to each part whether purchased or produced in house. DOE then aggregated single-part costs into major assemblies (*e.g.*, ignition assembly, controls, burner, packaging.) and summarized these costs in a worksheet. During interviews with manufacturers, DOE showed key estimates from the cost model and asked for feedback. Because this engineering analysis is focused on ignition components, DOE was particularly interested in feedback regarding purchase prices for key ignition components. DOE considered any information manufacturers gave that was relevant to the cost model and incorporated it into the analysis as appropriate.

5.6.3 Cost Model and Definitions

Once DOE disassembled selected units, gathered information from manufacturer catalogs on additional products, and identified technologies, DOE created an appropriate manufacturing cost model that could translate physical information into MPCs. The cost model is based on production activities and divides factory costs into the following categories:

- Materials: Purchased parts (*e.g.,*. gas valves, pilot assemblies), raw materials (e.g., cold rolled steel), and indirect materials that are used for processing and fabrication.
- Labor: Fabrication, assembly, indirect, and supervisor labor. Fabrication and assembly labor cost are burdened with benefits and supervisory costs.
- Overhead: Equipment, tooling, and building depreciation, as well as utilities, equipment and tooling maintenance, insurance, and property taxes.

5.6.3.1 Cost Definitions

Because there are many different accounting systems and methods to monitor costs, DOE defined the above terms as follows:

- Direct material: Purchased parts (outsourced) plus manufactured parts (made in house from raw materials).
- Indirect material: Material used during manufacturing (*e.g.*, welding rods, adhesives).
- Fabrication labor: Labor associated with in-house piece manufacturing.
- Assembly labor: Labor associated with final assembly.
- Indirect labor: Labor costs that scaled with fabrication and assembly labor. This included the cost of technicians, manufacturing engineering support, stocking, etc., that were assigned on a span basis.
- Equipment and plant depreciation: Money allocated to pay for initial equipment installation and replacement as the production equipment wears out.
- Tooling depreciation: Cost for initial tooling (including non-recurring engineering and debugging of the tools) and tooling replacement as it wears out.
- Building depreciation: Money allocated to pay for the building space and the conveyors that feed and/or make up the assembly line.

- Utilities: Electricity, gas, telephones, etc.
- Maintenance: Annual money spent on maintaining tooling and equipment.
- Insurance: Appropriated as a function of unit cost.
- Property Tax: Appropriated as a function as unit cost.

5.6.4 Cost Model Assumptions Overview

In converting physical information about the product into cost information, DOE reconstructed manufacturing processes for each component using internal expertise and knowledge of the methods used by the industry. DOE used assumptions regarding the manufacturing process parameters (*e.g.*, equipment use, labor rates, tooling depreciation, and cost of purchased raw materials) to determine the value of each component. DOE then summed the values of the components into assembly costs and, finally, the total product cost. The product cost included the material, labor, and overhead costs associated with the manufacturing facility. The labor costs included fabrication, assembly, indirect, direct, and supervisor labor rates, including the associated overhead. The labor costs were determined by the type of product manufactured at the factory. Overhead costs included equipment depreciation, tooling depreciation, building depreciation, utilities, equipment, tooling maintenance, insurance, property, and taxes.

Using the information gathered during manufacturer interviews, DOE updated the cost model to address manufacturer comments, particularly with respect to purchased parts for ignition assemblies. These changes involved updating component and material pricing and production volumes. DOE used a continuous refinement process to update information. Changes to the cost model were made immediately after interviews so that refined data could be presented to the next manufacturer. Positive feedback from manufacturers presented with refined data confirmed the accuracy of the changes.

The next sections discuss specific assumptions about outsourcing, factory parameters, production volumes, and material prices. When the assumptions are manufacturer specific, they are presented as industry averages to prevent disclosure of confidential information.

5.6.4.1 Fabrication Estimates

DOE characterized parts based on whether manufacturers purchased them from outside suppliers or fabricated them in house. For purchased parts, DOE estimated the purchase price. For fabricated parts, DOE estimated the price of raw materials (*e.g.*, tube, sheet metal) and the cost of transforming them into finished parts. Whenever possible, DOE obtained price quotes directly from the manufacturers’ suppliers.

DOE based the manufacturing operations assumptions on internal expertise, interviews with manufacturers, and manufacturing facilities site visits. The major manufacturer processes identified and developed for the spreadsheet model are listed in Table 5.6.1.

Table 5.6.3 Cost Model In-House Manufacturing Operation Assumptions

Fabrication	Finishing	Assembly/Joining	Quality Control
Fixturing	Painting	Adhesive Bonding	Inspecting and Testing
Stamping/Pressing	Powder Coating	Spot Welding	
Turret Punch		Seam Welding	
Tube Forming		Packaging	
Brake Forming		Clinching	
Cutting and Shearing			
Hand Bending			
Drilling			
Concrete			

5.6.4.2 Production Volumes Assumptions

A manufacturer's production volumes vary depending on several factors, including market share, the type of product produced (*e.g.*, fireplace, gas log set), and if the manufacturer produces other similar products (*e.g.*, direct heating equipment, barbeque grills). For hearth products, DOE based production volume assumptions on data provided by the Hearth, Patio, and Barbecue Association (HPBA) and information obtained during manufacturer interviews.

The data provided by HPBA included ranges of the market share for nine product categories. DOE used these data to determine average market sizes for each of its product groups used in its analysis. Based on these weights, the historical shipments data also provided by HPBA, the number of manufacturers identified for each product group, and feedback from manufacturers, DOE selected representative production volumes. The production volumes are presented in Table 5.6.2

5.6.4.3 Factory Parameters Assumptions

DOE used information gathered from publicly available literature and analysis of common industry practices to formulate factory parameters for each type of manufacturer. Table 5.6.2 lists DOE's assumptions for manufacturers of hearth products.

Table 5.6.4 Hearth Product Production Volumes and Factory Parameter Assumptions

Parameter		Plant Capacity *units /year*	Actual Annual Production Volume *units/year*	Fabrication Labor Wages *$/hr*	Fringe Benefits Ratio
Estimate	**Vented Fireplaces, Inserts, Stoves**	12,000	10,000	16	50%
	Unvented Fireplaces, Inserts, Stoves	2,400	2,000	16	50%
	Vented Gas Log Sets	2,400	2,000	16	50%
	Unvented Gas Log Sets	6,000	5,000	16	50%
	Outdoor	3,600	3,000	16	50%

The main difference among the assumptions for all hearth products is the production volumes. Labor rates were assumed to be the same across hearth products. Approximate labor rates are based on published labor rates for the hearth industry from the U.S. Department of Labor.[1]

5.6.4.4 Material Prices Assumptions

DOE determined the cost of raw materials using publicly available information such as the American Metals Market,[2] interviews with manufacturers, and direct discussions with material suppliers. Common metals used in the fabrication of hearth products include plain cold rolled steel (CRS), CRS tubing, and stainless steel. To account for fluctuations, DOE used a 5-year average of metal prices from the Bureau of Labor Statistics Producer Price Indices (PPIs) spanning 2009 to 2014 with an adjustment to 2014$.[3] DOE used the PPIs for copper rolling, drawing, and extruding and steel mill products, and made the adjustments to 2014$ using the gross domestic product implicit price deflator.[4] DOE also used a 5-year average in material prices from 2009 to 2014 to normalize changes to some extent to better represent long-term material price averages.

Table 5.6.3 shows the 5-year average metal prices DOE used for the analysis.

Table 5.6.5 Five-Year Material Prices (2009 to 2014)

Metals	Cost *$/lb 2014$*
Plain Cold Rolled Steel	0.432
Aluminized CRS	0.528
CRS Tube	0.803
CRS Wire	1.148
Aluminized CRS Tube	0.867
Stainless Steel	1.507
Stainless Steel Tube	2.377
Brass (Sand Cast)	2.111
Concrete	0.028

5.6.5 Manufacturing Production Cost

Once the cost estimate for each teardown unit was finalized, a detailed summary was prepared for relevant components, subassemblies, and processes. The BOM thus details all aspects of unit costs. DOE totaled the cost of materials, labor, and direct overhead used to manufacture a product to calculate the MPC.[a] Figure 5.6.1 shows the general breakdown of costs associated with manufacturing a product.

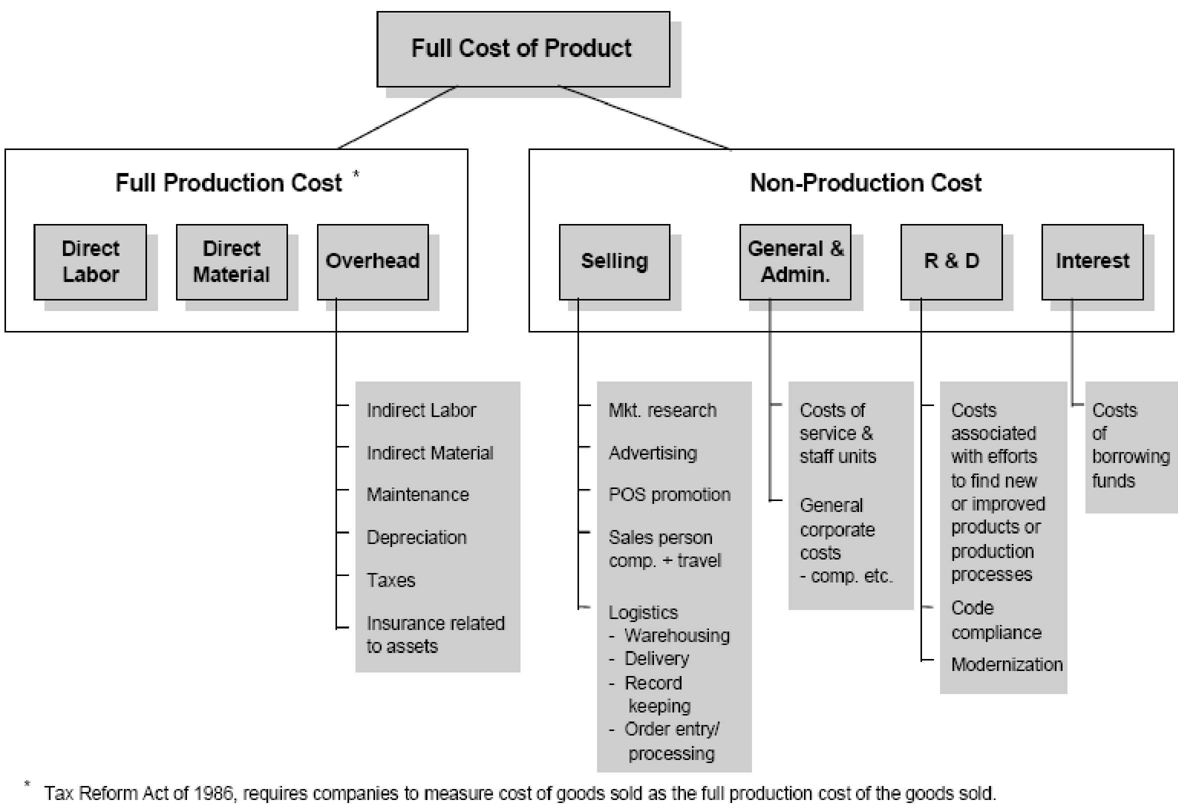

Figure 5.6.1 Full Production Costs

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[a] When viewed from the company-wide perspective, the sum of all material, labor, and overhead costs equals the company's sales cost, also referred to as the cost of goods sold (COGS).

The full cost of product is broken down into two main costs, the full production cost or MPC, and the non-production cost. The non-production cost is equal to the manufacturer markup minus profits.

Following the development of the MPCs, DOE reviewed its major cost estimates by conducting interviews with hearth products manufacturers. DOE presented the data and estimates for purchased ignition components to manufacturers who provided feedback and validation. DOE used a continuous refinement process by incorporating each manufacturer's feedback before each set of interviews. As a result, DOE developed MPCs for use in the engineering analysis and subsequent analyses.

5.7 MPC BREAKDOWN

After DOE incorporated all of the assumptions into the cost model, the different production cost percentages were calculated. The product cost percentages are used to validate the assumptions by comparing them to manufacturers' actual financial data published in annual reports, where possible, along with feedback from manufacturers during interviews. DOE also used these figures in the MIA (see chapter 12 of this TSD). DOE calculated the average product cost percentages by product group due to the variations in production volumes, fabrication and assembly costs, and other assumptions that affect the calculation of a unit's total MPC. Table 5.7.1 shows the different percentages for the production costs that make up the total product MPC.

Table 5.7.1 Total Product Manufacturer Production Cost Breakdown for Hearth Product Groups

	Percentage Cost Breakdown by Hearth Product Group (Baseline)			
	Materials %	**Labor %**	**Depreciation %**	**Overhead %**
Vented Fireplaces, Inserts, and Stoves	43.4%	22.4%	22.1%	12.1%
Unvented Fireplaces, Inserts, and Stoves	38.2%	25.0%	24.8%	12.0%
Vented Gas Log Sets	29.5%	23.5%	32.8%	14.3%
Unvented Gas Log Sets	38.9%	28.9%	21.2%	11.0%
Outdoor Products	55.6%	15.8%	18.7%	9.9%

5.8 MANUFACTURER MARKUP

DOE applies a manufacturer markup to calculated MPCs in order to estimate MSPs. The manufacturer markup is a multiplier that covers both non-production costs (*e.g.*, selling, general and administrative expenses, research and development , interest expenses) and profit. The manufacturer markup can be thought of as:

$$\text{Markup} = \frac{\text{Gross Profit}}{\text{Cost of Goods Sold (COGS)}}$$

Where:

$$\text{Gross Profit} = \text{Revenue} - \text{COGS}$$

The manufacturer markup is distinct from, and greater than, a manufacturer profit margin, or gross margin percentage, which is calculated as:

$$\text{Gross Margin Percentage} = \frac{\text{Gross Profit}}{\text{Revenue}}$$

For the hearth industry, DOE estimated a set of base case manufacturer markups using data developed as part of the 2010 Energy Conservation Standard for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters (75 FR 20112). DOE then solicited feedback on its markup estimates during confidential manufacturer interviews. Based on manufacturer feedback, DOE calculated and applied an average baseline markup of 1.45 percent for all gas hearth products. The MSPs estimated using this markup reflect the price at which manufacturers recover both production and non-production costs and earn a profit. Additional markups across the distribution chain (*e.g.*, distributors, retailers, contractors) account for the final consumer price.

For further discussion of manufacturer markups, see the manufacturer impact analysis (chapter 12 of this TSD). For further discussion of final consumer prices, see the life-cycle cost analysis and payback period analysis (chapter 8 of this TSD), and the national impact analysis (chapter 10 of this TSD).

5.9 ENGINEERING ANALYSIS SUMMARY OF RESULTS

Throughout the rulemaking process, the results from the engineering analysis are used in the LCC analysis to determine consumer prices for hearth products. The manufacturer production costs for the baseline assembly by product group are listed in Table 5.9.1. DOE also determined the incremental cost to each product group associated with the switch to the electronic ignition design; these are also presented in Table 5.9.1.

Table 5.9.2 Baseline Full Assembly Manufacturer Production Costs and Incremental Electronic Ignition System Costs for Hearth Products

Hearth Product Analysis Group	Baseline MPC *$*	Incremental Cost for EIS *$*
Vented Fireplaces, Inserts, and Stoves	322	28
Unvented Fireplaces, Inserts, and Stoves	281	32
Vented Gas Log Sets	190	70
Unvented Gas Log Sets	208	56
Outdoor Products	210	55

5.10 REFERENCES

1 U.S. Department of Labor, Bureau of Labor Statistics, *Wages by Area and Occupation*. Last accessed August 2014. <http://www.bls.gov/bls/blswage.htm>.

2 American Metals Market. Last accessed June 2014. <http://www.amm.com>.

3 U.S. Department of Labor, Bureau of Labor Statistics, *Producer Price Indices*. Last accessed June 2014. <http://www.bls.gov/ppi>.

4 U.S. Department of Commerce, Bureau Economic Analysis, *Gross Domestic Product Implicit Price Deflator*. Last accessed June 2014. <http://www.bea.gov/iTable/iTable.cfm?reqid=9&step=3&isuri=1&903=13#reqid=9&step=3&isuri=1&903=13>.

CHAPTER 6. MARKUPS ANALYSIS

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CHAPTER 6. MARKUPS ANALYSIS

6.1 INTRODUCTION

To carry out its analyses, the U.S. Department of Energy (DOE) needed to determine the cost to the consumer of baseline products and the cost of more efficient units the consumer would purchase under new energy conservation standards. DOE calculated such costs based on engineering estimates of manufacturing product costs (see chapter 5) plus appropriate markups for the various distribution channels for hearth products.

Generally, companies mark up the price of a product to cover their business costs and profit margin. In financial statements, the gross margin is the difference between the company revenue and the company cost of sales or cost of goods sold (*CGS*). The gross margin takes account of the expenses of companies in the distribution channel, including overhead costs (sales, general, and administration); research and development (R&D) and interest expenses; depreciation; and taxes—and company profits. In order for sales of a product to contribute positively to company cash flow, the product's markup must be greater than the corporate gross margin. Products command lower or higher markups, depending on company expenses associated with the product and the degree of market competition.

For wholesalers and contractors, DOE estimated a baseline markup and an incremental markup. DOE defines a baseline markup as a multiplier that converts the manufacturer selling price (MSP) of equipment with baseline efficiency to the consumer purchase price for the equipment at the same baseline efficiency level. An incremental markup is defined as the multiplier to convert the incremental increase in manufacturer selling price of higher efficiency equipment to the consumer purchase price for the same equipment. Because companies mark up the price at each point in the distribution channel, both baseline and incremental markups are dependent on the distribution channel, as described in section 6.2.

The components used to produce a hearth product are usually purchased by hearth product manufacturers who install the ignition device in a hearth product. From this point, the ignition devices are passed along the distribution channels as part of hearth products. Essentially, various markups applied to these products by different market participants are also the markups applied to hearth product ignition devices, whose manufacturing costs account for a portion of the total manufacturing costs of the finished products. Therefore, DOE developed the markup analysis for hearth product ignition devices based on hearth products.

6.2 DISTRIBUTION CHANNELS

The appropriate markups for determining the consumer product price depend on the type of distribution channel through which products move from manufacturers to purchasers. At each point in the distribution channel, companies mark up the price of the product to cover their business costs and profit margin.

There are two primary distribution channels describing the way most products pass from the manufacturer to the consumer, one applying to hearth products installed in replacement markets or by new owners and the other applying to hearth products that are installed in new construction. For replacement applications, most sales go through wholesalers to mechanical contractors, and then to consumers. The new construction distribution channel includes an additional link in the chain—the general contractor. Thus, DOE defined two distribution channels for the purposes of estimating markups for hearth products, as shown in Figure 6.2.1.

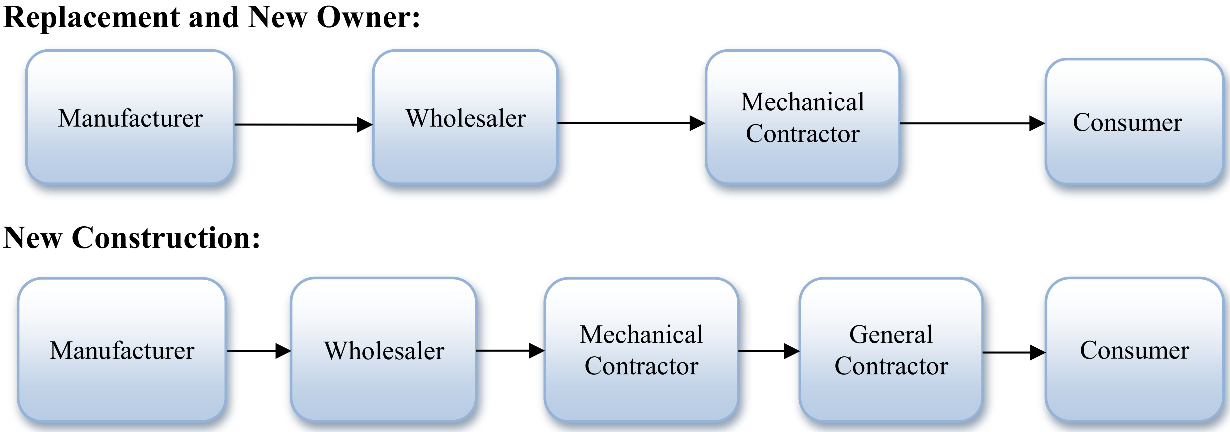

Figure 6.2.1 Distribution Channels for Hearth Products

Based on information provided from manufacturer interviews, there is another possible distribution channel that includes a retail store instead of a wholesaler. In this case, the manufacturer sells the equipment to a retailer, who in turn sells it to a mechanical contractor, who in turn sells it to the consumer. However, DOE does not have enough information at this point to make a separate markup estimation for this distribution channel. DOE assumed that the retailer markup is similar to the wholesaler markup. DOE is also aware that there may be two additional distribution channels for hearth products: (1) an online distribution channel where manufacturers sell the products to online retailers who in turn sell them directly to consumers, and (2) a rebranding distribution channel where wholesalers or retailers negotiate good pricing from the hearth product manufacturer based on high volumes and have the product customized to carry their name, and then send it through their normal distribution channel to the contractors. The former one mainly applies to the do-it-yourself (DIY) installation representing around two percent of the total HVAC shipments, which implies an even smaller fraction of the total hearth product shipments. For the latter one, DOE assumes that it would have the same overall markups as the conventional distribution channels. Although manufacturers may have lower margin, wholesalers and retailers would redistribute the profit throughout the distribution channel to have the final retail price comparable with products sold through conventional distribution channels. Due to the reasons mentioned above, DOE did not consider them in this analysis.

6.3 APPROACH FOR MANUFACTURER MARKUP

DOE uses manufacturer markups to transform a manufacturer's product cost into a manufacturer sales price. Detailed methodology to derive manufacturer markups were described in chapter 5 (Engineering Analysis).

6.4 APPROACH FOR WHOLESALER AND CONTRACTOR MARKUPS

DOE examined the manner in which wholesaler and contractor markups may change in response to changes in hearth product ignition system efficiency and other factors. Using the available data, DOE estimated that there are differences between *incremental* markups on incremental equipment costs of higher efficiency products and the *baseline* markup on direct business costs of products with baseline efficiency.

DOE derived the wholesaler and contractor markups from three key assumptions about the costs associated with hearth products. DOE based the wholesaler and mechanical contractor markups on firm-level income statement data, and based the general contractor markups on U.S. Census Bureau data for the residential building construction industry. DOE obtained the firm income statements from the Heating, Air-conditioning & Refrigeration Distributors International (HARDI) 2013 Profit Report and from the Air Conditioning Contractors of America (ACCA) 2005 Financial Analysis.[1, 2] HARDI and ACCA are trade associations representing wholesalers and mechanical contractors, respectively. DOE used the financial data from the 2007 U.S. Census of Business for developing general contractor markups in the same form as the income statement data for wholesalers and mechanical contractors. These income statements break down the components of all costs incurred by firms that supply and install heating and air-conditioning equipment.[a] The key assumptions used to estimate markups using these financial data are:

1. The firm income statements faithfully represent the various average costs incurred by firms distributing and installing hearth products.

2. These costs can be divided into two categories: 1) costs that vary in proportion to the MSP of hearth products (variant costs); and 2) costs that do not vary with the MSP of hearth products (invariant costs).

3. Overall, wholesale and contractor prices for hearth products vary in proportion to the wholesaler and contractor costs for hearth products included in the income statements.

In support of the first assumption, the income statements itemize firm costs into a number of expense categories, including direct costs to purchase or install the equipment, operating labor and occupancy costs, and other operating costs and profit. Although wholesalers and contractors tend to handle multiple commodity lines, including room air conditioners, furnaces, central air

[a] Wholesalers and mechanical contractors to which these reports refer handle multiple commodity lines.

conditioners and heat pumps, and boilers, the data provide the most accurate available indication of the expenses associated with hearth products.

Information obtained from the trade literature, selected HVAC wholesalers, contractors, and consultants tends to support the second assumption. This information indicates that wholesale and contractor markups vary according to the quantity of labor and materials used to distribute and install appliances. In the following discussion, DOE assumes a division of costs between those that do not scale with the manufacturer price (labor and occupancy expenses) and those that do (operating expenses and profit).

In support of the third assumption, the HVAC wholesaler and contractor industry is competitive, and consumer demand for heating and air conditioning is inelastic, *i.e.,* the demand is not expected to decrease significantly with an increase in the price of equipment. The large number of HVAC firms listed in the 2007 Census indicates the competitive nature of the market. For example, there are more than 700 HVAC manufacturers,[3] 5,300 wholesalers of heat pumps and air-conditioning equipment,[4] more than 170,000 general residential contractors, and 91,000 HVAC contractors[5] listed in the 2007 Census. Following standard economic theory, competitive firms facing inelastic demand either set prices in line with costs or quickly go out of business.[6]

DOE concluded that markups for more-efficient products are unlikely to be proportional to all direct costs. When the wholesaler's purchase price of equipment increases, for example, only a fraction of a business' expenses increases, while the remainder may stay relatively constant. For example, if the unit price of a hearth product unit increases by 30 percent due to improved efficiency of the ignition system, it is unlikely that the cost of secretarial support in an administrative office will increase by 30 percent also. Therefore, DOE assumed that incremental markups cover only those costs that scale with a change in the MSP (variant costs).

6.4.1 Wholesaler Markup

Using the above assumptions, DOE developed baseline and incremental markups for wholesalers using the firm income statement from the HARDI 2013 Profit Report (appendix 6A). The baseline markups cover all of the wholesaler's costs (both *invariant costs* and *variant costs*). Here, variant costs were defined as costs that likely vary in proportion to the change in MSP induced by increased efficiency standards; in contrast, invariant costs were defined as costs that are unlikely to vary in proportion to the change in MSP due to increased efficiency standards. DOE calculated the baseline markup for wholesalers using the following equation:

$$MU_{BASE} = \frac{CGS_{WHOLE} + GM_{WHOLE}}{CGS_{WHOLE}} = \frac{CGS_{WHOLE} + (IVC_{WHOLE} + VC_{WHOLE})}{CGS_{WHOLE}}$$

Eq. 6.1

Where:

MU_{BASE} = baseline wholesaler markup,

CGS_{WHOLE} = wholesaler cost of goods sold,
GM_{WHOLE} = wholesaler gross margin,
IVC_{WHOLE} = wholesaler invariant costs, and
VC_{WHOLE} = wholesaler variant costs.

Incremental markups are coefficients that relate the change in the MSP of more energy-efficient models, or those products that meet the requirements of new energy conservation standards, to the change in the wholesaler sales price. Incremental markups cover only those costs that scale with a change in the MSP (variant costs, *VC*). DOE calculated the incremental markup (MU_{INCR}) for wholesalers using the following equation:

$$MU_{INCR} = \frac{CGS_{WHOLE} + VC_{WHOLE}}{CGS_{WHOLE}}$$

Eq. 6.2

Where:

MU_{INCR} = incremental wholesaler markup,
CGS_{WHOLE} = wholesaler cost of goods sold, and
VC_{WHOLE}= wholesaler variant costs.

6.4.2 Mechanical and General Contractor Markups

The type of financial data used to estimate markups for wholesalers is also available for mechanical contractors and general contractors from the 2007 Economic Census and ACCA 2005 Financial Analysis. To estimate mechanical contractor markups for hearth products, DOE collected financial data from the *Plumbing and HVAC Contractors* (NAICS 23822) series from the 2007 Economic Census and from ACCA 2005 Financial Analysis. To estimate general contractor markups for hearth products, DOE collected data from the Residential Building Construction series from the 2007 Economic Census, which is the aggregation of *New Single-Family General Contractors* (NAICS 236115), *New Multifamily Housing Construction* (NAICS 236116), *New Housing Operative Builders* (NAICS 236117), and *Residential Remodelers* (NAICS 236118).

ACCA financial data provide GM as percent of sales for the mechanical contractor industry. For mechanical contractors, the baseline markup can be derived from the ACCA data with the following equation:

$$MU_{BASE} = \frac{Sales(\%)}{Sales(\%) - GM(\%)}$$

Eq. 6.3

The U.S. Census data include the number of establishments, payroll for construction workers, value of construction, cost of materials, and cost of subcontracted work at both state and national levels. DOE calculated the baseline markup for mechanical contractors and general contractors using the following equation:

$$MU_{BASE} = \frac{V_{CONSTRUCT}}{Pay + MatCost + SubCost}$$

Eq. 6.4

Where:

MU_{BASE} = baseline mechanical contractor or general contractor markup,
$V_{CONSTRUCT}$ = value of construction,
Pay = payroll for construction workers,
$MatCost$ = cost of materials, and
$SubCost$ = cost of subcontracted work.

Analogously, DOE estimated the incremental mechanical contractor and general contractor markups by only marking up those costs that scale with a change in the MSP (variant costs, *VC*) for more energy-efficient products. As stated above, DOE assumes a division of costs between those that do not scale with the manufacturer price (labor and occupancy expenses), and those that do (other operating expenses and profit). Hence, DOE categorized the Census cost data in each major cost category and estimated markups using the following equation:

$$MU_{INCR} = \frac{CGS_{CONT} + VC_{CONT}}{CGS_{CONT}}$$

Eq. 6.5

Where:

MU_{INCR} = incremental contractor markup,
CGS_{CONT} = contractor cost of goods sold, and
VC_{CONT} = contractor variant costs.

6.5 DERIVATION OF MARKUPS

6.5.1 Manufacturer Markup

The methodology DOE used to determine the manufacturer markup for hearth products is similar to the methodology described in chapter 5 of the Residential Furnace and Central Air-Conditioning products Direct Final Rule technical support document (TSD).[b] DOE used U.S. Security and Exchange Commission (SEC) 10-K reports from publicly owned hearth product

[b] The TSD for the direct final rule for HVAC products is available at the following website: www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

manufacturing companies to estimate manufacturer markups. The estimated manufacturer markup for hearth products is 1.42.

6.5.2 Wholesaler Markup

Wholesalers reported median data in a confidential survey that HARDI conducted of member firms. In the survey, HARDI itemized revenues and costs into cost categories, including direct equipment expenses (cost of goods sold), labor expenses, occupancy expenses, other operating expenses, and profit. DOE presents these data in full in appendix 6A. Table 6.5.1 summarizes them at the national aggregated level as cost-per-dollar sales revenue in the first data column. These wholesaler markups are applicable to hearth products.

Table 6.5.1 Wholesaler Expenses and Markups

Descriptions	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Equipment Sales: Cost of goods sold	0.739	1.000
Labor Expenses: Salaries and benefits	0.151	0.204
Occupancy Expense: Rent, maintenance, and utilities	0.035	0.047
Other Operating Expenses: Depreciation, advertising, and insurance.	0.052	0.070
Operating Profit	0.023	0.031
Wholesaler Baseline Markup ($MU_{WHOLE\ BASE}$)		**1.353**
Incremental Markup ($MU_{WHOLE\ INCR}$)		**1.101**

Source: Heating, Air Conditioning & Refrigeration Distributors International. 2013. 2013 Profit Report (2012Data).

In this case, direct equipment expenses (cost of goods sold) represent about $0.74 per dollar sales revenue, so for every $1 wholesalers take in as sales revenue, $0.74 is used to pay the direct equipment costs. Labor expenses represent $0.15 per dollar sales revenue, occupancy expenses represent $0.04, other operating expenses represent $0.05, and profit accounts for $0.02 per dollar sales revenue.

DOE converted the expenses per dollar sales into expenses per dollar cost of goods sold, by dividing each figure in the first data column by $0.74 (*i.e.,* cost of goods sold per dollar of sales revenue). The data in column two show that, for every $1.00 the wholesaler spends on equipment costs, the wholesaler allocates $0.204 to cover labor costs, $0.047 to cover occupancy expenses, $0.070 for other operating expenses, and $0.031 in profits. This totals to $1.353 in sales revenue earned for every $1.00 spent on equipment costs. Therefore, the wholesaler baseline markup ($MU_{WHOLE\ BASE}$) is 1.353 ($1.353 ÷ $1.00).

DOE used the data in column two to estimate the incremental markup. The incremental markup depends on which of the costs in Table 6.5.1 are variant and which are invariant with MSP. For example, for a $1.00 increase in the MSP, if all of the other costs scale with the MSP (*i.e.,* all costs are variant), the increase in wholesale price will be $1.353, implying that the incremental markup is 1.353, or the same as the baseline markup. At the other extreme, if none of the other costs are variant, then a $1.00 increase in the MSP will lead to a $1.00 increase in the wholesale price, for an incremental markup of 1.0. DOE believes that the labor and occupancy costs will be invariant and that the other operating costs and profit will scale with the MSP (*i.e.,* be variant). In this case, for a $1.00 increase in the MSP, the wholesale price will increase to match changes in "other" operating costs and operating profit of $0.075, which when divided by 73.9 cents in cost of goods sold yields an increase of $0.101, giving a wholesaler incremental markup ($MU_{WHOLE\ INCR}$) of 1.101. See appendix 6A for cost details.

6.5.3 Mechanical Contractor Markups

6.5.3.1 Aggregate Markups for Mechanical Contractors

The 2007 Economic Census provides Geographic Area Series for the *Plumbing and HVAC Contractors* (NAICS 23822) sector, which contains national average sales and cost data, including value of construction, cost of subcontract work, cost of materials, and payroll for construction workers. It also provides the cost breakdown of gross margin, including labor expenses, occupancy expenses, other operating expenses, and profit. The gross margin provided by the U.S. Census is disaggregated enough that DOE was able to determine the invariant (labor and occupancy expenses) and variant (other operating expenses and profits) costs for this particular sector. By using the equation mentioned above, baseline and incremental markups were estimated. The markup results representing the plumbing and HVAC contractor industry at the national aggregated level are presented in Table 6.5.2. (Appendix 6A contains the full set of data.)

Table 6.5.2 Mechanical Contractor Expenses and Markups Based on Census Bureau Data

Description	Mechanical Contractor Expenses or Revenue	
	Per Dollar Sales Revenue *$*	**Per Dollar Cost of Goods *$***
Direct Cost of Equipment Sales: Cost of goods sold	0.68	1.00
Labor Expenses: Salaries (indirect) and benefits	0.18	0.26
Occupancy Expense: Rent, maintenance, and utilities	0.02	0.03
Other Operating Expenses: Depreciation, advertising, and insurance.	0.08	0.12
Net Profit Before Taxes	0.04	0.06
Baseline Markup (*MUMECH BASE*): Revenue per dollar cost of goods		**1.48**
Incremental Markup (*MUMECH INCR*): Increased revenue per dollar increase in cost of goods sold		**1.18**

Source: U.S. Census Bureau. 2007. Plumbing, Heating, and Air-Conditioning Contractors. Sector 23: 238220. Construction: Industry Series, Preliminary Detailed Statistics for Establishments, 2007.

The first data column in Table 6.5.2 provides the cost of goods sold and a list of gross margin components as expenses per dollar of sales revenue. As shown in the table, the direct cost of sales represents about $0.68 per dollar sales revenue to the mechanical contractor, and the gross margin totals $0.32 per dollar sales revenue. DOE converted these expenses per dollar sales into revenue per dollar cost of goods sold by dividing each figure in the first data column by $0.68. For every $1.00 the mechanical contractor spends on equipment costs, the mechanical contractor earns $1.00 in sales revenue to cover the equipment cost and $0.48 to cover the other costs. This totals $1.48 in sales revenue earned for every $1.00 spent on equipment costs. This is equivalent to a baseline markup ($MU_{MECH\ CONT\ BASE}$) of 1.48 for mechanical contractors.

DOE used the data in column two in Table 6.5.2 to estimate the incremental markups, after classifying the costs as either invariant or variant. At one extreme, if all of the other costs scale with the equipment price (*i.e.,* all costs are variant), the increase in general contractor price will be $1.48, implying that the incremental markup is 1.48 or the same as the baseline markup. At the other extreme, if none of the other costs are variant, then a $1.00 increase in the equipment price will lead to a $1.00 increase in the general contractor price, for an incremental markup of 1.0. DOE believes the labor and occupancy costs are invariant and the other operating costs and profit scale with the equipment price (*i.e.,* are variant). In this case, for a $1.00 increase in the equipment price, the general contractor price will increase by $1.18, giving a general contractor incremental markup ($MU_{MECH\ CONT\ INCR}$) of 1.18.

6.5.3.2 Markups for Mechanical Contractors in the Replacement and New Construction Markets

DOE derived the baseline and incremental markups for both replacement and new construction markets using the 2007 Economic Census industrial cost data[7] supplemented with the most recent ACCA 2005 financial data.[2] The 2007 Economic Census provides sufficient detailed cost breakdown for the *Plumbing and HVAC Contractors* (NAICS 23822) sector so that DOE was able to estimate baseline and incremental markups for mechanical contractors. However, the 2007 Economic Census does not separate the mechanical contractor market into replacement and new construction markets. In order to calculate markups for these two markets, DOE utilized 2005 ACCA financial data, which reports gross margin data for the entire mechanical contractor market and for both the replacement and new construction markets.

The HVAC contractors, defined here as mechanical contractors, reported median cost data in an ACCA 2005 financial analysis of the HVAC industry. These data are shown in Table 6.5.3.

Table 6.5.3 Baseline Markup, All Mechanical Contractors

Description	Contractor Expenses or Revenue	
	Per Dollar Sales Revenue $	Per Dollar Cost of Goods $
Direct Cost of Equipment Sales: Cost of goods sold	0.7286	1.00
Gross Margin: Labor, occupancy, operating expenses, and profit	0.2714	0.372
Revenue: Baseline revenue earned per dollar cost of goods		**1.372**
Baseline Markup ($MU_{MECH\ CONT\ BASE}$)		**1.372**

Source: Air Conditioning Contractors of America. 2005. Financial Analysis for the HVACR Contracting Industry.

Table 6.5.4 summarizes the gross margin and resulting baseline markup data for all mechanical contractors that serve the replacement and new construction markets.

Table 6.5.4 Baseline Markups for the Replacement and New Construction Markets, All Mechanical Contractors

Description	Contractor Expenses or Revenue by Market Type			
	Replacement		New Construction	
	Per Dollar Sales Revenue $	Per Dollar Cost of Goods $	Per Dollar Sales Revenue $	Per Dollar Cost of Goods $
Direct Cost of Equipment Sales: Cost of goods sold	0.7031	1.000	0.745	1.000
Gross Margin: Labor, occupancy, operating expenses, and profit	0.2969	0.422	0.255	0.342
Baseline Markup (*MUMECH CONT BASE*): Revenue per dollar cost of goods	NA	**1.422**	NA	**1.342**
% Difference from Aggregate Mechanical Contractor Baseline MU	NA	**3.63%**	NA	**-2.20%**

Source: Air Conditioning Contractors of America. 2005. Financial Analysis for the HVACR Contracting Industry.

Using the baseline markup data from Table 6.5.4 and results from Table 6.5.3, DOE calculated that the baseline markups for the replacement and new construction markets are 3.63 percent higher and 2.20 percent lower, respectively, than for all mechanical contractors serving all markets.

The markup deviations (*i.e.,* 3.63 percent higher and 2.20 percent lower for the replacement and new construction markets, respectively) derived for all mechanical contractors were then applied to the baseline markup of 1.48 and the incremental markup of 1.18 estimated for the *Plumbing and HVAC Contractors* (NAICS 23822) sector in Table 6.5.2. DOE assumed that this deviation applies equally to the baseline and incremental markups calculated from the 2007 Economic Census. The results of the baseline and incremental markups for the replacement and new construction markets served by mechanical contractors are shown in Table 6.5.5.

Table 6.5.5 Markups for the Replacement and New Construction Markets

	Baseline Markup	Incremental Markup
Replacement Market	1.53	1.22
New Construction Market	1.44	1.16

6.5.4 General Contractor Markups

DOE derived markups for general contractors from U.S. Census Bureau data for the residential building construction sector to reflect application of hearth products.[8] The residential construction sector includes establishments primarily engaged in construction work, including new construction work, additions, alterations, and repairs of residential buildings.[9] The U.S. Census Bureau data for the construction sector include detailed statistics for establishments with payrolls, similar to the data reported by HARDI for wholesalers. The primary difference is that the U.S. Census Bureau reports itemized revenues and expenses for the construction industry as a whole in total dollars rather than in typical values for an average or representative business. Because of this, DOE assumed that the total dollar values that the U.S. Census Bureau reported, once converted to a percentage basis, represent revenues and expenses for an average or typical contracting business. Similar to the data for wholesalers, Table 6.5.6 summarizes the expenses for general contractors in residential building construction at the national aggregated level as expenses per dollar sales revenue in the first data column. (Appendix 6A contains the full set of data.)

Table 6.5.6 Residential Building General Contractor Expenses and Markups

Description	General Contractor Expenses or Revenue	
	Per Dollar Sales Revenue $	Per Dollar Cost of Goods $
Direct Cost of Equipment Sales: Cost of goods sold	0.68	1.00
Labor Expenses: Salaries (indirect) and benefits	0.08	0.12
Occupancy Expense: Rent, maintenance, and utilities	0.01	0.01
Other Operating Expenses: Depreciation, advertising, and insurance.	0.06	0.09
Net Profit Before Taxes	0.17	0.25
Baseline Markup (*MUGEN CONT BASE*): Revenue per dollar cost of goods		**1.47**
Incremental Markup (*MUGEN CONT INCR*): Increased revenue per dollar increase in cost of goods sold		**1.34**

Source: U.S. Census Bureau. 2007. Residential Building Construction. Sector 23: 236115-236118. Construction: Industry Series: Preliminary Detailed Statistics for Establishments: 2007.

As shown in the first column, the direct cost of sales represents about $0.68 per dollar sales revenue to the general contractor. Labor expenses represent $0.08 per dollar sales revenue, occupancy expenses represent $0.01 per dollar sales revenue, other operating expenses represent $0.03, and profit makes up $0.20 per dollar sales revenue.

DOE converted these expenses per dollar sales into revenue per dollar cost of goods sold, by dividing each figure in the first data column by $0.68. The data in column two show that, for every $1.00 the general contractor spends on equipment costs, the general contractor earns $1.00 in sales revenue to cover the equipment cost, $0.12 to cover labor costs, $0.01 to cover occupancy expenses, $0.09 for other operating expenses, and $0.25 in profits. This totals to $1.47 in sales revenue earned for every $1.00 spent on equipment costs. Thus, the general contractor baseline markup ($MU_{GEN\ CONT\ BASE}$) is 1.47.

DOE used the data in column two in Table 6.5.6 to estimate the incremental markups, after classifying the costs as either invariant or variant. At one extreme, if all of the other costs scale with the equipment price (*i.e.,* all costs are variant), the increase in general contractor price will be $1.47, implying that the incremental markup is 1.47, or the same as the baseline markup. At the other extreme, if none of the other costs are variant, then a $1.00 increase in the equipment price will lead to a $1.00 increase in the general contractor price, for an incremental markup of 1.0. DOE believes the labor and occupancy costs are invariant and the other operating costs and profit scale with the equipment price (*i.e.,* are variant). In this case, for a $1.00 increase in the equipment price, the general contractor price will increase by $1.34, giving a general contractor incremental markup ($MU_{GEN\ CONT\ INCR}$) of 1.34.

6.6 DERIVATION OF CENSUS REGIONS MARKUPS

In this analysis, DOE assumed a market saturation rate for hearth products that varies by geographical region defined by the 2009 Residential Energy Consumption Survey (RECS 2009),[10] based on the housing projections for the year 2021. Therefore, regional markups were calculated for hearth products.

Wholesalers and mechanical and general contractors in the hearth products industry were divided into the 30 regions[c] provided by RECS 2009. Regional baseline and incremental markups were derived using the region/state level data from the 2013 HARDI Profit Report and the 2007 Economic Census.

6.6.1 Estimation of Wholesaler Markups

Based on the regional income statement from the 2013 HARDI Profit Report, DOE estimated baseline and incremental markups for the seven HARDI regions (Northeastern, Mid-Atlantic, Southwestern, Great Lakes, Central, Southwestern, and Western) using the methodology shown in section 6.4.1. Next, each state in each region was assigned the HARDI regional baseline and incremental markups for the region to which it belongs. Then, DOE assigned all states to one of the 30 RECS 2009 regions used in the analysis and then calculated 2021 housing projections-weighted baseline and incremental markup averages for each region. The results are summarized in Table 6.6.1.

[c] RECS 2009 provides 27 regions (also called reportable domains). The 27th region includes Oregon, Washington, Alaska, and Hawaii. DOE subdivided Alaska and Hawaii into separate regions (28 and 29, respectively) based on cooling and heating degree days. In addition, West Virginia, which is in RECS region 14, was disaggregated into region 30 based on cooling and heating degree days. See appendix 7B for more details.

Table 6.6.1 Wholesaler Markups for Hearth Products

RECS Regions	State(s)	Baseline MU	Incremental MU
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	1.366	1.072
2	Massachusetts	1.366	1.072
3	New York	1.366	1.072
4	New Jersey	1.355	1.092
5	Pennsylvania	1.354	1.095
6	Illinois	1.364	1.115
7	Indiana, Ohio	1.353	1.097
8	Michigan	1.353	1.097
9	Wisconsin	1.364	1.115
10	Iowa, Minnesota, North Dakota, South Dakota	1.364	1.115
11	Kansas, Nebraska	1.364	1.115
12	Missouri	1.364	1.115
13	Virginia	1.355	1.092
14	Delaware, District of Columbia, Maryland	1.355	1.092
15	Georgia	1.330	1.097
16	North Carolina, South Carolina	1.330	1.097
17	Florida	1.330	1.097
18	Alabama, Kentucky, Mississippi	1.338	1.097
19	Tennessee	1.330	1.097
20	Arkansas, Louisiana, Oklahoma	1.348	1.112
21	Texas	1.348	1.112
22	Colorado	1.364	1.115
23	Idaho, Montana, Utah, Wyoming	1.400	1.110
24	Arizona	1.404	1.110
25	Nevada, New Mexico	1.380	1.111
26	California	1.404	1.110
27	Oregon, Washington	1.404	1.110
28	Alaska	1.404	1.110
29	Hawaii	1.404	1.110
30	West Virginia	1.353	1.097

6.6.2 Estimation of Mechanical Contractor Markups

The 2007 Economic Census provides Geographic Area Series for the *Plumbing and HVAC Contractors* (NAICS 23822) sector, which contains state-level sale and cost data, including value of construction, cost of subcontract work, cost of materials, and payroll for construction workers. By using the equations in section 6.4.2, DOE was able to estimate baseline markups for each state. Because the Census does not provide more disaggregated cost data, DOE was not able to differentiate between invariant and variant cost.

Alternatively, DOE calculated the national baseline and incremental markups (Table 6.6.2) and found that the incremental markup is around 20 percent lower than the baseline markups. DOE further derived the state-level incremental markups by applying this ratio to the baseline markup in each state, assuming that this deviation applies equally to all states. (Appendix 6A contains the full set of data.)

To estimate the baseline and incremental markups for both replacement and new construction markets for each state, DOE applied the markup deviations (*i.e.,* 3.6 percent higher and 2.2 percent lower for the replacement and new construction markets, respectively) derived in section 6.5.3.2 to the statewide baseline and incremental markups. DOE assumed that this deviation of replacement and new construction markets applies equally to the baseline and incremental markups.

Lastly, DOE divided all states among the 30 RECS 2009 regions and then calculated average baseline and incremental markups for mechanical contractors weighted by housing projections in 2021 for each region, as shown in Table 6.6.2.

Table 6.6.2 Mechanical Contractor Markups Weighted by Housing Projections in 2021 for Hearth Products

RECS Regions	State(s)	Replacement Baseline MU	Replacement Incremental MU	New Construction Baseline MU	New Construction Incremental MU
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	1.557	1.246	1.449	1.159
2	Massachusetts	1.538	1.231	1.431	1.145
3	New York	1.600	1.280	1.488	1.191
4	New Jersey	1.583	1.267	1.473	1.178
5	Pennsylvania	1.479	1.183	1.375	1.100
6	Illinois	1.577	1.262	1.467	1.173
7	Indiana, Ohio	1.563	1.250	1.453	1.163
8	Michigan	1.530	1.224	1.423	1.138
9	Wisconsin	1.510	1.208	1.404	1.123
10	Iowa, Minnesota, North Dakota, South Dakota	1.531	1.224	1.423	1.139
11	Kansas, Nebraska	1.460	1.168	1.358	1.086
12	Missouri	1.479	1.183	1.376	1.101
13	Virginia	1.557	1.246	1.448	1.158
14	Delaware, District of Columbia, Maryland	1.491	1.193	1.386	1.109
15	Georgia	1.474	1.179	1.371	1.096
16	North Carolina, South Carolina	1.501	1.201	1.396	1.117
17	Florida	1.512	1.210	1.407	1.125
18	Alabama, Kentucky, Mississippi	1.526	1.220	1.419	1.135
19	Tennessee	1.477	1.182	1.374	1.099
20	Arkansas, Louisiana, Oklahoma	1.541	1.233	1.434	1.147
21	Texas	1.498	1.198	1.393	1.115
22	Colorado	1.531	1.225	1.424	1.139
23	Idaho, Montana, Utah, Wyoming	1.491	1.193	1.387	1.110
24	Arizona	1.580	1.264	1.470	1.176
25	Nevada, New Mexico	1.537	1.230	1.430	1.144
26	California	1.607	1.286	1.495	1.196
27	Oregon, Washington	1.579	1.263	1.469	1.175
28	Alaska	1.766	1.413	1.642	1.314
29	Hawaii	1.835	1.468	1.707	1.366
30	West Virginia	1.528	1.222	1.421	1.137

6.6.3 Estimation of General Contractor Markups

To derive regional general contractor markups for hearth products from the 2007

Economic Census, DOE combined four Geographic Area Series: (1) *New Single-Family General Contractors* (NAICS 236115), (2) *New Multifamily Housing Construction* (NAICS 236116), (3) *New Housing Operative Builders* (NAICS 236117), and (4) *Residential Remodelers* (NAICS 236118).

Each series consists of statewide cost data required to calculate baseline markups for each state, as illustrated in section 6.4.2. Although there is only a new construction (no replacement) channel for general contractors, the same technique shown for mechanical contractors can still be employed to estimate regional baseline and incremental markups. First, DOE estimated the statewide incremental markups by applying the ratio of national baseline and incremental markups (*i.e.,* the national incremental markup is around 8.84 percent lower than the national baseline markup) to the baseline markups for each state. Lastly, DOE divided all states among the 30 RECS regions; then calculated average baseline and incremental markups for general contractors weighted by 2021 housing projections for each region. The final results are summarized in Table 6.6.3 (Appendix 6A contains the full set of data.)

Table 6.6.3 General Contractor Markups Weighted by Housing Projections in 2021 for Hearth Products

RECS Regions	State(s)	Baseline MU	Incremental MU
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	1.404	1.278
2	Massachusetts	1.343	1.222
3	New York	1.393	1.267
4	New Jersey	1.503	1.368
5	Pennsylvania	1.362	1.239
6	Illinois	1.589	1.446
7	Indiana, Ohio	1.378	1.254
8	Michigan	1.537	1.399
9	Wisconsin	1.340	1.219
10	Iowa, Minnesota, North Dakota, South Dakota	1.368	1.244
11	Kansas, Nebraska	1.351	1.229
12	Missouri	1.325	1.206
13	Virginia	1.450	1.320
14	Delaware, District of Columbia, Maryland	1.419	1.291
15	Georgia	1.428	1.300
16	North Carolina, South Carolina	1.390	1.265
17	Florida	1.528	1.391
18	Alabama, Kentucky, Mississippi	1.355	1.233
19	Tennessee	1.353	1.231
20	Arkansas, Louisiana, Oklahoma	1.372	1.248
21	Texas	1.499	1.364
22	Colorado	1.499	1.364
23	Idaho, Montana, Utah, Wyoming	1.303	1.186
24	Arizona	1.707	1.553
25	Nevada, New Mexico	1.637	1.490
26	California	1.717	1.562
27	Oregon, Washington	1.465	1.333
28	Alaska	1.854	1.687
29	Hawaii	1.417	1.289
30	West Virginia	1.545	1.406

6.7 SALES TAX

The sales tax represents state and local sales taxes that are applied to the consumer price of the product. The sales tax is a multiplicative factor that increases the consumer product price. DOE only applied the sales tax to the consumer price of the products in the replacement market, not the new construction market. The common practice for selling larger residential appliances like hearth products in the new construction market is that general contractors (or builders) bear the added sales tax for product, in addition to the cost of product, and then mark up the entire cost in the final listing price to consumers. Therefore, no additional sales tax is necessary to calculate the consumer product price for the new construction market.

DOE derived state and local taxes from data provided by the Sales Tax Clearinghouse.[11] These data represent weighted averages that include county and city rates. DOE then derived average tax values weighted by housing projections in 2021 for each RECS 2009 region to match the regional markups for wholesalers and mechanical and general contractors, as shown in Table 6.6.4. Detailed sales tax data by each state can be found in appendix 6A.

Table 6.6.4 Average Sales Tax Rates by RECS 2009 Region

RECS Regions	State(s)	Fraction of Housing Projections in 2021 %	Tax Rate (2014) %
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.17	5.16
2	Massachusetts	0.69	6.25
3	New York	2.96	8.40
4	New Jersey	1.87	6.95
5	Pennsylvania	3.38	6.40
6	Illinois	6.24	8.05
7	Indiana, Ohio	5.00	7.06
8	Michigan	5.06	6.00
9	Wisconsin	3.17	5.45
10	Iowa, Minnesota, North Dakota, South Dakota	1.84	6.83
11	Kansas, Nebraska	1.29	7.12
12	Missouri	3.44	7.45
13	Virginia	1.85	5.60
14	Delaware, District of Columbia, Maryland	2.03	5.19
15	Georgia	4.49	7.05
16	North Carolina, South Carolina	1.91	7.00
17	Florida	0.74	6.65
18	Alabama, Kentucky, Mississippi	1.22	7.27
19	Tennessee	1.92	9.45
20	Arkansas, Louisiana, Oklahoma	1.77	8.65
21	Texas	9.88	7.90
22	Colorado	2.19	6.05
23	Idaho, Montana, Utah, Wyoming	0.90	5.12
24	Arizona	1.18	7.15
25	Nevada, New Mexico	0.81	7.31
26	California	10.52	8.45
27	Oregon, Washington	1.65	5.72
28	Alaska	0.07	1.30
29	Hawaii	0.03	4.40
30	West Virginia	0.37	6.10
2021 Housing Projection-Weighted National Average			**7.13**

6.7 OVERALL MARKUPS

The overall markup for each distribution channel is the product of the appropriate markups, as well as sales tax in the case of replacement applications.

DOE used the overall baseline markup to estimate the consumer product price of baseline models, given the manufacturer cost of the baseline models. As stated above, DOE considers baseline models to be product sold under existing market conditions (*i.e.*, without new energy conservation standards). The following equation shows how DOE used the overall baseline markup to determine the product price for baseline models.

$$CPP_{BASE} = COST_{MFG} \times \left(MU_{MFG} \times MU_{BASE} \times Tax_{SALES} \right) = COST_{MFG} \times MU_{OVERALL\_BASE}$$

Eq. 6.6

Where:

CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
MU_{MFG} = manufacturer markup,
MU_{BASE} = baseline replacement or new home channel markup,
Tax_{SALES} = sales tax (replacement applications only), and
$MU_{OVERALL\_BASE}$ = baseline overall markup.

Similarly, DOE used the overall incremental markup to estimate changes in the consumer product price, given changes in the manufacturer cost above the baseline model cost resulting from an energy conservation standard to raise product energy efficiency. The total consumer product price for higher energy efficient models is composed of two components: the consumer product price of the baseline model and the change in consumer product price associated with the increase in manufacturer cost to meet the new energy conservation standard. The following equation shows how DOE used the overall incremental markup to determine the consumer product price for higher energy efficient models (*i.e.*, models meeting new energy conservation standards).

$$\begin{aligned} CPP_{STD} &= COST_{MFG} \times MU_{OVERALL\_BASE} + \Delta COST_{MFG} \times \left(MU_{MFG} \times MU_{INCR} \times Tax_{SALES} \right) \\ &= CPP_{BASE} + \Delta COST_{MFG} \times MU_{OVERALL\_INCR} \end{aligned}$$

Eq. 6.7

Where:

CPP_{STD} = consumer product price for models meeting new energy conservation standards,
CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
$\Delta COST_{MFG}$ = change in manufacturer cost for more energy-efficient models,
MU_{MFG} = manufacturer markup,
MU_{INCR} = incremental replacement or new home channel markup,
Tax_{SALES} = sales tax (replacement applications only),
$MU_{OVERALL\_BASE}$ = baseline overall markup (product of manufacturer markup, baseline replacement or new home channel markup, and sales tax), and
$MU_{OVERALL\_INCR}$ = incremental overall markup.

National weighted-average baseline and incremental markups for each market participant are summarized in Table 6.7.2 for hearth products. These values represent the weighted average markups based on the state-level markup values and 2021 housing projections by state. Based on hearth product shipment forecasts for the year 2021 (see chapter 9), DOE estimated that 25 percent of hearth products go to new construction and 75 percent go to the replacement market. By weighting the markups by the market shares for each type of hearth product and market, overall markups are listed in Table 6.7.3.

Table 6.7.2 Markups for Hearth Products

	Replacement		New Construction	
	Baseline	**Incremental**	**Baseline**	**Incremental**
Manufacturer	1.45		1.45	
Wholesaler	1.36	1.10	1.36	1.10
Mechanical Contractor	1.53	1.23	1.43	1.14
General Contractor	-		1.46	1.33
Sales Tax	1.07			-
Total	3.25	2.10	4.11	2.43

Table 6.7.3 Summary of Overall Markup by Hearth Product Class

Product Class	Baseline Markup	Incremental Markup
Hearth Products	3.43	2.17

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CHAPTER 7. ENERGY USE ANALYSIS

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CHAPTER 7. ENERGY USE ANALYSIS

7.1 INTRODUCTION

The purpose of the energy use analysis is to determine the annual energy consumption of hearth product ignition devices in use in the United States and to assess the energy savings potential in switching from standing pilot lights to intermittent pilot ignition. DOE used survey data, tear downs, manufacturer literature, and consultant input to establish representative energy consumption for each hearth product group and pilot light option (see chapter 5). DOE estimated the annual energy consumption of hearth product ignition systems across a range of climate zones, building characteristics, and heating applications.

DOE developed energy consumption estimates for the key product groups listed in Table 7.1.1. The hearth products analyzed utilize gas for a standing pilot or electricity to power an intermittent pilot ignition.

Table 7.1.1 Hearth Product Groups Analyzed

Product Group	Description
1	Vented Fireplace (Fireplace/Insert/Stove)
2	Unvented Fireplace (Fireplace/Insert/Stove)
3	Vented Gas Logs
4	Unvented Gas Logs
5	Outdoor

DOE estimated the energy consumption of hearth products by developing a building sample for each of the five product groups based on the Energy Information Administration's (EIA) 2009 Residential Energy Consumption Survey (RECS 2009).[1] This is the latest available survey for residential households.[a] This sample is further described in section 7.2.

DOE used RECS 2009 reported hearth product heating energy consumption and household characteristics to calculate the energy use of the hearth product ignition system for each household. RECS 2009 also provided weather data for the sample households, which was used to characterize the heating season for each household. In addition, DOE made adjustments based on historical weather data, projections of building shell efficiency and building square footage, and for household's primary heating equipment type. To complete the analysis, DOE calculated the energy consumption of alternative (more energy-efficient) ignition systems if they replaced existing ignition system in each housing unit.

7.2 HOUSEHOLD SAMPLE

DOE's calculation of the annual energy use of residential[b] hearth products relied on data from RECS 2009. RECS 2009 included energy-related data from 12,083 housing units that

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[a] EIA is currently working on the 2015 version of RECS, which is not expected to be available until 2017.
[b] DOE did not consider hearth products in commercial applications for this analysis

represent almost 113.6 million households. Of these units, 712 of them contained gas fireplaces, representing 6.49 million households. For this analysis, DOE assumed that, on average, the characteristics of households with gas fireplaces do not significantly differ from those of households with other types of hearth products.

DOE divided the hearth product subset into further subsets that include households that use either vented or ventless hearth products. For vented gas fireplaces, the subset of RECS 2009 records used in the analysis met all of the following criteria:

- used a fireplace for secondary or primary space heating,
- used a heating fuel that is natural gas or liquefied petroleum gas (LPG), and
- had a flue on the gas fireplace to the outside.

To identify households with ventless gas fireplaces, DOE used the same criteria as for vented gas fireplaces except for criterion (3), which was replaced with:

- did not have a flue on the gas fireplace to the outside.

DOE used the vented and ventless sample to more accurately assign hearth products to households. In DOE's product groups listed in Table 7.1.1, groups 1 and 3 include only vented hearth products, and groups 2, 4, and 5 include only ventless hearth products. DOE assigned vented hearth products to the households in RECS 2009 listed as having vented gas fireplaces. Similarly, DOE assigned ventless hearth products from groups 2, 4, and 5 to households listed as having ventless gas fireplaces. This sampling method takes into account that ventless hearth products are not allowed to be installed in some states.

The RECS 2009 weighting indicates how commonly each household configuration occurs in the general population in 2009. Appendix 7A presents the variables included in the analysis and their definitions. Table 7.2.1 lists the number of records and representative population of households in the RECS 2009 selected for the hearth products replacement and new construction samples. Based on hearth product shipment forecasts for the year 2021 (see chapter 9), DOE estimated that 25 percent of hearth products go to new construction and 75 percent go to the replacement market. For the new construction sample, DOE only selected homes built on or after 2000 that would better represent the new construction market.

Table 7.2.1 Selection of RECS 2009 Records for Hearth Products

Product Class	**Replacements Sample** *(All homes in RECS2009)*		**New Construction Sample** *(Homes built on or after 2000)*	
	No. of Records	**Number of Households** ***million***	**No. of Records**	**Number of Households** ***million***
Vented Gas Fireplaces	541	4.67	182	1.56
Ventless Gas Fireplaces	171	1.83	70	0.72

7.3 HEARTH PRODUCT IGNITION ENERGY CONSUMPTION

To calculate the energy use of hearth product ignition devices in each of the product groups, DOE determined either the annual natural gas or LPG consumption associated with a standing pilot light or the annual electricity use of an intermittent pilot ignition. DOE estimated the input capacity and operating hours of both the existing hearth product and hearth product ignition device using household and hearth product characteristics. In addition, because hearth products (excluding outdoor units) are installed in conditioned spaces, a portion of the standing pilot fuel input is useful heat that slightly reduces the load of the primary heating appliance during the heating season. Conversely, if the pilot light is left on during the cooling season, this heat increases the cooling load, resulting in additional electricity consumption by the primary cooling appliance.

To calculate the natural gas or LPG consumption of a standing pilot light, DOE determined the standing pilot operating hours, the input capacity of the standing pilot, and the secondary space conditioning effects of heat from the standing pilot entering the conditioned space. The electrical consumption of intermittent pilot ignitions was calculated from the operating hours and input capacity of the intermittent pilot ignition.

The sum of the fuel and electrical energy consumption (when applicable) represents the estimated annual energy use of a sampled ignition device. Additional details used for determining the total energy use can be found in the following sections.

The calculation used for the determination of the total annual energy use for hearth product ignition devices ($EnergyUse_{Total}$) is:

$$EnergyUse_{Total} = EnergyUse_{Pilot,Type} + SecondaryEffects$$

Eq. 7.1

Where:

$EnergyUse_{Pilot,Type}$ = total annual fuel consumption as a result of standing pilot light operation or the total annual electrical consumption as a result of intermittent pilot ignition operation, and

$SecondaryEffects$ = total annual energy consumed by the primary heating or cooling appliance as a result of the heat input from the standing pilot into the conditioned space (when applicable).

7.3.1 Determination of Standing Pilot Energy Consumption

DOE calculated the annual fuel consumption ($EnergyUse_{Pilot,Standing}$) for each standing pilot light using the following formula:

$$EnergyUse_{Pilot,Standing} = OH_{Pilot,Standing} \times Q_P$$

Eq. 7.2

Where:

$OH_{Pilot,Standing}$ = annual standing pilot operating hours (hr/yr), and
Q_P = input capacity of hearth product standing pilot light (kBtu/hr).

DOE derived a range of possible operating hours from field studies.[2, 3] The operating hours for each household were determined based on typical behavior patterns and the household's characteristics, such as heating load, length of heating season, and primary heating appliance. These ranges correspond to three modes of behavior:

1. Mode 1: consumers closely monitor the standing pilot light operation and only use it when starting the hearth product; therefore, their standing pilot operating hours are almost zero;
2. Mode 2: consumers leave the standing pilot light on for the entirety of the heating season but turn it off for the remaining part of the year; or
3. Mode 3: consumers leave the standing pilot light on for the entire year.

DOE represented each of these three scenarios with a continuous distribution of standing pilot operating hours, not including the pilot operating hours when the burner is also operating. These distributions are shown in Figure 7.3.1 through Figure 7.3.3. Note that Figure 7.3.3 shows the number of hours the standing pilot light is off.

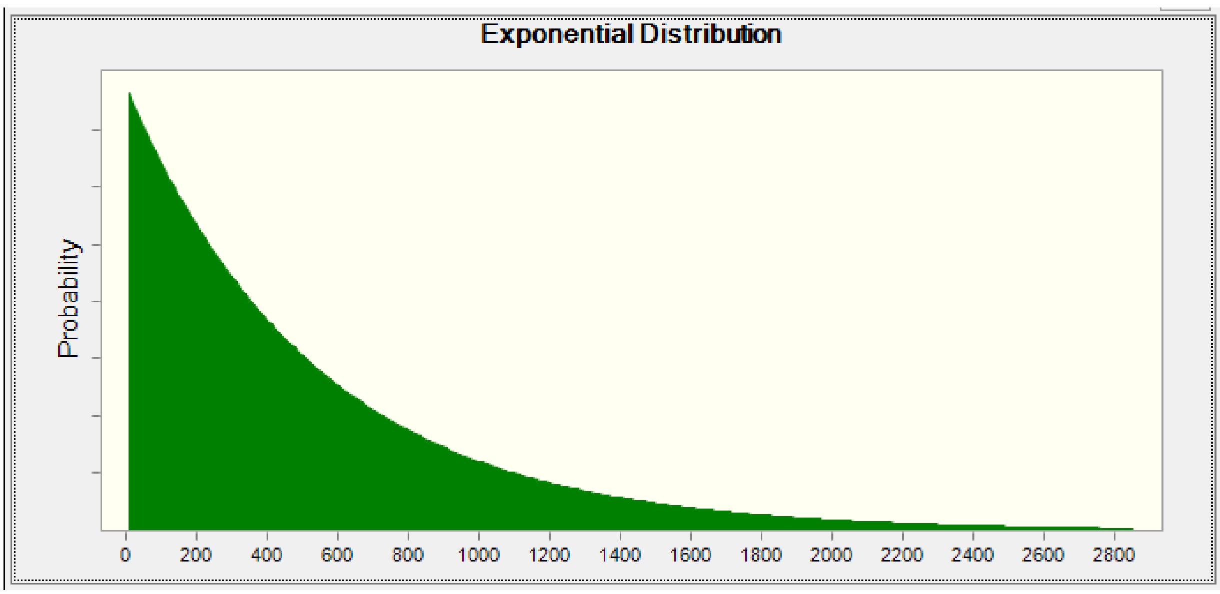

Figure 7.3.1 Distribution of Standing Pilot Light Operating Hours for Mode 1

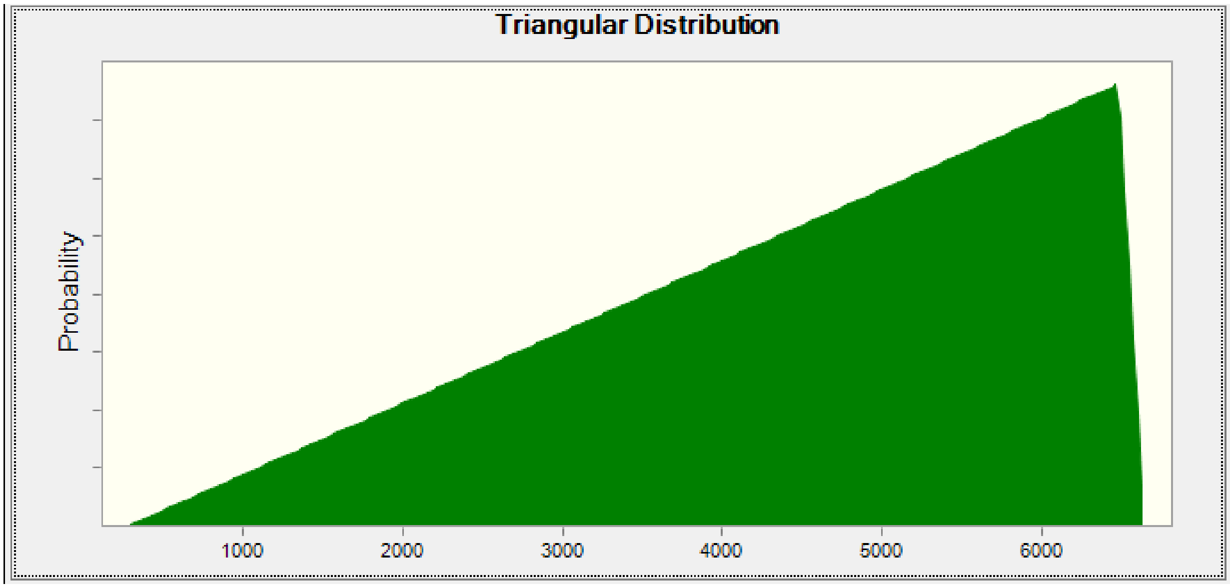

Figure 7.3.2 Distribution of Standing Pilot Light Operating Hours for Mode 2

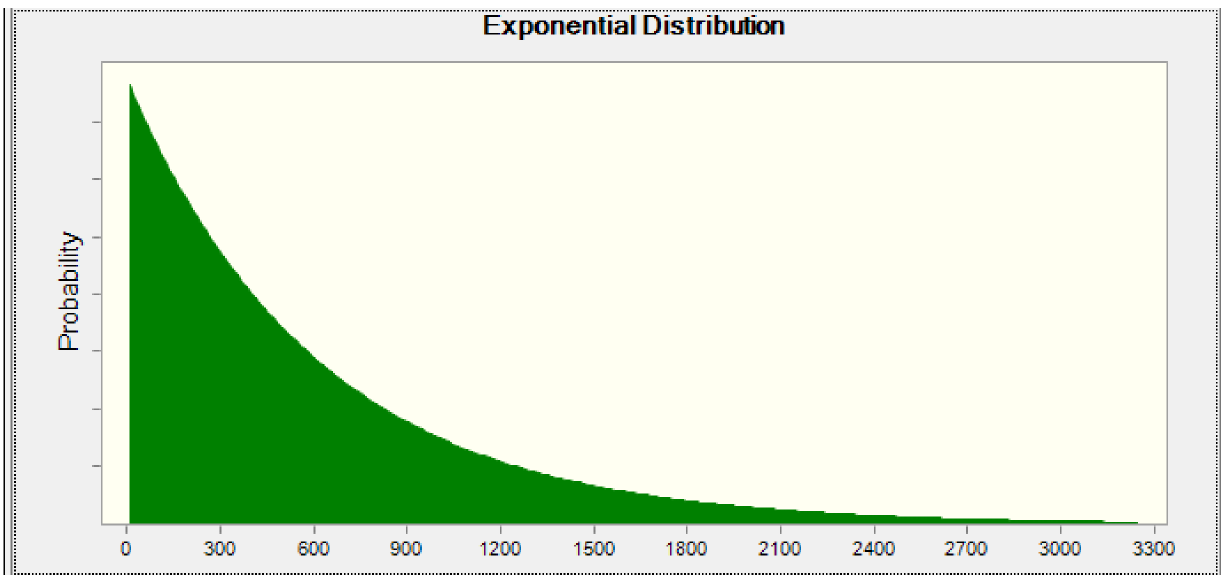

Figure 7.3.3 Distribution of Hours when the Standing Pilot Light is not Operating for Mode 3

DOE then weighted these probability distributions by the likelihood that a consumer would adopt them. The likelihood was determined from a field study of fireplace standing pilot light gas usage.[2] The study found that 30 of 68 households (44 percent) left the pilot on year-round, while 14 of 68 (21 percent) had almost no pilot light usage. These households were represented with the exponential distributions in Figure 7.3.1 and Figure 7.3.3. The remaining households are represented by a distribution of behavior when the standing pilot light is on only during the heating season, which DOE represented as a triangular distribution, as shown in Figure 7.3.2.

For all LPG units, it was assumed that consumers do not leave the standing pilot light on for the entire heating season, but rather operate the pilot light proportionally to the main burner of the hearth product because of the high cost of LPG fuel. From the RECS 2009 household sample, DOE determined that 23 percent of all gas fireplaces use LPG.

The percentages of households operating their standing pilot light in each mode are listed in Table 7.3.1. These probabilities are derived from a field study.[2]

Table 7.3.1 Distribution of Hearth Product Standing Pilot Operation Behavior

Behavior Mode	Description	Percentage
1	Closely Monitored	40%
2	Heating Season	40%
3	Year-Round	20%

Table 7.3.2 shows the resulting range of hearth product standing pilot light operating hours among sample households.

Table 7.3.2 Overall Range of Standing Pilot Light Operating Hours

Min	Max	Average	Percentiles				
			5%	25%	50%	75%	95%
18.8	8760	3708	156	544	2691	7718	8760

Table 7.3.3 shows the representative pilot light inputs that DOE determined from the tear-down analysis (chapter 5). These values are used to calculate the fuel used by the standing pilot as in Eq. 7.2.

Table 7.3.3 Hearth Product Standing Pilot Representative Inputs

Hearth Product Group	Input Capacity *kBtu/h*
Vented Fireplace (fireplace/insert/stove)	1
Unvented Fireplace (fireplace/insert/stove)	1.2
Vented Gas Log Sets	0.7
Unvented Gas Log Sets	0.8
Outdoor	1

7.3.1.1 Determination of Hearth Product Main Burner Operating Hours

In creating the ranges of standing pilot operating hours, DOE also determined the main burner operating hours (*BOH*) of the hearth product. This allowed DOE to establish the minimum of the range of standing pilot operating hours (*i.e.*, the hours that the hearth product is operating). To calculate the BOH for hearth products used for heating, DOE used the building heating load met by the hearth product (BHL_{Hearth}), and the representative main burner input. The

BHL_{Hearth} is determined from the annual space heating energy consumption provided by RECS 2009 for vented and unvented gas fireplaces (fireplace/insert/stove).

The BOH of the hearth product (BOH_{Hearth}) is calculated as:

$$BOH_{Hearth} = \frac{BHL_{Hearth}}{Q_{IN,Hearth} \times \eta_{Hearth}}$$

Eq. 7.3

Where:

BHL_{Hearth} = building heating load served by a single hearth product (kBtu/yr),
$Q_{IN,Hearth}$ = representative input capacity of the hearth product main burner (kBtu/h), and
η_{Hearth} = average efficiency of newly installed gas hearth product.

DOE assumed that the resulting BOH_{Hearth} value for vented and unvented fireplaces (fireplace/insert/stove) would be similar for the other hearth product groups.

Table 7.3.4 shows the representative input capacity ($Q_{IN,Hearth}$) that DOE determined from the tear-down analysis (chapter 5).

Table 7.3.4 Hearth Product Representative Input Capacities

Hearth Product Group	**Input Capacity** *kbtu/h*
Vented Fireplaces (fireplace/insert/stove)	35
Unvented Fireplaces(fireplace/insert/stove)	30
Vented Gas Log Sets	35
Unvented Gas Log Sets	25
Outdoor	50

The annual BHL is the total amount of heat output from the hearth product that the house needs during the heating season. This includes heat from the burner. DOE determined projected BHL_{Hearth} in 2021 for each sampled housing unit based on the input capacity of the assigned existing hearth product, using the following calculation:

$$BHL_{Hearth} = Q_{YR} \times \eta_{Hearth} \times HeatingLoadFraction \times Adj_{Factor}$$

Eq. 7.4

Where:

Q_{YR} = annual total space heating fuel consumption reported by RECS 2009 (kBtu/yr),
$\eta_{Hearth,ex}$ = average efficiency of existing gas hearth product, assumed to be 64 percent for vented and 100 percent for ventless,
HeatingLoadFraction = fraction of the total building heating load met by the hearth product, and
Adj_{Factor} = adjustment factor (discussed below).

RECS 2009 reports space heating energy use (Q_{YR}) for each of the sampled households. RECS 2009 also reports the fraction of heat provided by the main heating equipment. DOE assumed that the remainder of the heat not provided by the main heating equipment was provided by the hearth product.

DOE adjusted the BHL to reflect the expectation that the houses in 2021 will have a somewhat different BHL than the households in the RECS 2009 hearth product sample. The adjustment involves multiplying the calculated BHL for each RECS 2009 household by the building shell efficiency index[c] based on information from the National Energy Modeling System (NEMS) simulation associated with EIA's Annual Energy Outlook (*AEO 2014)*.[4] This factor differs for new construction and replacement buildings. The factor applied in the analysis is 0.91 for replacements and 0.92 for new construction. This means that households on average will have lower space heating load compared to households in 2009.

DOE also adjusted BHL to reflect historical average climate conditions using heating degree days (HDD) reported in RECS 2009 for each household and NOAA HDD data by region.[5] The adjustment factors are calculated using the following equation:

$$Adj_{Factor_{average_{climate}}} = \frac{HDD_{10_{yr_{avg}}}}{HDD_{bldg_{2009}}}$$

Eq. 7.5

Where:

HDD_{bldg_2009} = HDD in 2009 for the specific region where the housing unit is located, and
$HDD_{10\_yr\_avg}$ = 10-year average HDD (2004–2013) based on NOAA data for the specific region where the housing unit is located.

The adjustment factors range from 0.91 to 1.02 and on average 0.95 for the hearth product household sample (*i.e.*, 2009 was in general colder than the 10-year average).

DOE also account for future climate trends based on *AEO 2014* HDD projections, which show a decline in HDD, leading to lower projected BHL_{Hearth} in 2021 relative to the non-climate-trend-adjusted BHL_{Hearth} values. On average, this decreases the heating load by 7.25% in 2021.

Table 7.3.5 presents the calculated hearth product burner operating hours among sample households.

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[c] The building shell efficiency index sets the heating load value at 1.00 for an average home in 2009 (by type) in each census division. The values listed below represent the change in heating load based on the difference in physical size and shell attributes for homes in the future (which takes into account physical size difference and efficiency gains from better insulation and windows).

Table 7.3.5 Range of Burner Operating Hours for Hearth Products

Min	Max	Average	Percentiles				
			5%	25%	50%	75%	95%
1.95	3518	157	21.02	54.04	106.3	194.1	443.7

7.3.1.2 Determination of Secondary Effects

DOE included the seasonal secondary effects of the operation of a standing pilot light on space conditioning energy use. During the heating season, a fraction of the standing pilot light heat input ($HeatInput_{Pilot,HeatingSeason}$) contributes to space heating that would otherwise be provided by a main heating appliance, such as a furnace. Therefore, DOE added a fraction of the standing pilot light energy consumption that contributes to space heating to the intermittent pilot fuel energy consumption. Based on the results of a field study that quantified the percentage of fireplace standing pilot fuel energy converted into useful heat in a home, DOE estimated the fraction of the heat output from the hearth product standing pilot light that contributes to space heating for each hearth product group as listed in Table 7.3.6.[6] For the decorative vented fireplaces and vented gas logs, which are not intended for space heating, DOE assumed that the fraction of the heat transferred to the space is half of the fraction for the vented fireplaces. For the ventless hearth products, DOE assumed that the fraction of the heat transferred to the space is double the fraction for the vented fireplaces. The large range in the ventless hearth products fraction accounts for increased heat transfer to the space due to the combustion products going into the room for a fraction of installations, as well as for units installed in space without a thermostat, where the heat input from the hearth product has no impact on the operation of the main heating equipment (see Table 7.3.6).

Table 7.3.6 Hearth Product Standing Pilot Representative Secondary Effect Fraction

Hearth Product Group	Fraction *%*
Vented Fireplace (fireplace/insert/stove)	1 to 47
Vented Fireplaces (Decorative)	0 to 23
Unvented Fireplace (fireplace/insert/stove)	2 to 94
Vented Gas Log Sets	0 to 23
Unvented Gas Log Sets	2 to 94
Outdoor	Not Applicable

The operation of standing pilot lights during the cooling season contributes some heat to the conditioned space ($HeatInput_{Pilot,CoolingSeason}$) , resulting in an additional cooling load and increased electrical energy consumption. To account for the increased cooling energy use, DOE subtracted the additional electrical energy consumption of the cooling appliance from the electricity consumption of the intermittent pilot ignition.

Eq. 7.6 through Eq. 7.8 describe the calculation approach of the effects (*SecondaryEffects*) of the heat input of the pilot during the heating and cooling season.

$$HeatInput_{Pilot,HeatingSeason} = \frac{BOH_{Pilot,HeatingSeason} Q_P \eta_{Pilot}}{\eta_{MainHeat}}$$

Eq. 7.6

$$HeatInput_{Pilot,CoolingSeason} = \frac{BOH_{Pilot,HeatingSeason} Q_P \eta_{Pilot}}{COP_{Cool}}$$

Eq. 7.7

$$Secondary\ Effects = HeatInput_{Pilot,CoolingSeason} - HeatInput_{Pilot,HeatingSeason}$$

Eq. 7.8

Where:

$HeatInput_{Pilot,HeatingSeason}$ = annual heat input of the pilot light into the space during the heating season (Btu) adjusted for main heating appliance operation,
Q_P = as previously defined,
η_{Pilot} = efficiency of the pilot light, as listed in Table 7.3.6,
$\eta_{MainHeat}$ = national average efficiency of the main heating appliance, as listed in *AEO 2014*,
$HeatInput_{Pilot,CoolingSeason}$ = annual heat input of the pilot light into the space during the cooling season (kWh) adjusted for main cooling appliance operation, and
COP_{Cool} = national average Coefficient of Performance of the main cooling appliance based on *AEO 2014*.

RECS 2009 contains information about several primary heating and cooling appliances. DOE applied the *AEO 2014* projections of the average efficiency ratings of these products in 2021. The listed efficiencies for each type of main heating appliance ($\eta_{MainHeat}$) are listed in Table 7.3.7. The listed efficiencies for each main cooling appliance (COP_{Cool}) are listed Table 7.3.8.

Table 7.3.7 Main Heating Appliance Efficiencies

Main Heating Appliance Description	Efficiency Rating
Natural Gas Furnace (AFUE, %)*	80 or 92
Gas DHE (%)	64
Electric Heat (%)	98
Electric Heat Pumps (HSPF)**	8.01 or 8.52
No Primary Heating Appliance	Not Applicable

* In the replacement hearth market, the average stock AFUE in 2021 from AEO2014 is used, which is 55 percent at 80-percent AFUE and 45 percent at 92-percent AFUE. In the new construction hearth market, the average shipment AFUE in 2021 from DOE's 2011 Direct Final Rule[7] is used, which is 43 percent at 80-percent AFUE and 57 percent at 92-percent AFUE.
** In replacement hearth market, the average stock HSPF in 2021 from AEO2014 is used (8.01 HSPF). In new construction hearth market, the average shipment HSPF in 2021 from DOE's 2011 Direct Final Rule is used (8.52 HSPF).

Table 7.3.8 Main Cooling Appliance Efficiencies

Main Cooling Appliance Description	Efficiency Rating
Central Air Conditions (SEER)	14.2
Electric Heat Pump (SEER)	13.7
Room Air Conditioner (EER)	11.0
No Primary Cooling Appliance	Not Applicable

7.3.2 Intermittent Pilot Ignition Electricity Consumption

DOE calculated intermittent pilot ignition energy consumption with a similar methodology as for standing pilot lights (section 7.3.1). The annual energy consumption of the hearth product intermittent pilot ignition ($EnergyUse_{Pilot,Intermittent}$) is:

$$EnergyUse_{Pilot,Intermittent} = OH_{Pilot,Intermittent} \times PE_{IG}$$

Eq. 7.9

Where:

$OH_{Pilot,Intermittent}$ = operating hours of the intermittent pilot ignition, and
PE_{IG} = input capacity of the intermittent pilot ignition, conservatively determined to be 50 watts (see chapter 5).[d]

The distribution of BOH of hearth products with intermittent pilot ignitions was assumed to be the same as for hearth products with standing pilots, as listed in Table 7.3.2. Because hearth products are a secondary heating appliance similar to direct heating equipment, DOE applied the average on-time per cycle used in the DHE test procedure to hearth products, which is 20 minutes.[11] DOE assumed a 30-second operating time per cycle for the intermittent pilot ignition. The operating hours of intermittent pilot ignitions ($OH_{Pilot,Intermittent}$) is determined by:

$$OH_{Pilot,Intermittent} = BOH_{Hearth} \frac{T_{ON}}{T_{Cycle}}$$

Eq. 7.10

Where:

BOH_{Hearth} = hearth product burner operating hours (Eq. 7.3),
T_{ON} = on-time per cycle of the intermittent pilot ignition, assumed to be 30 seconds, and
T_{Cycle} = on-time per cycle of the hearth product, assumed to be 20 minutes.

Table 7.3.9 lists the resulting annual national average intermittent pilot operating hours.

[d] DOE surveyed several intermittent ignition systems and found the typical electrical requirements of the largest of these units was approximately 24 volts, 2 amps, or 48 watts.[8, 9, 10]

Table 7.3.9 Range of Intermittent Pilot Ignition Hours

Min	Max	Average	Percentiles				
			5%	25%	50%	75%	95%
0.05	87.95	3.94	0.53	1.35	2.66	4.85	11.09

7.4 SUMMARY OF ENERGY USE RESULTS

This section presents the average annual energy use and the average energy savings for each considered energy efficiency level (EL 1) compared to the baseline energy efficiency (EL 0) for each hearth product ignition device.[e] The LCC and PBP analysis uses the results calculated as the national average from all sampled households. Table 7.4.1 lists the average annual energy use for hearth product ignition devices and the average energy savings for each considered energy efficiency level compared to the baseline standing pilot light for each hearth product group.

[e] The derivation of the base case energy consumption, which represents the energy consumption without the standard, includes households that already include EL1 products as explained in chapter 8.

Table 7.4.1 Average Annual Energy Consumption and Savings for Hearth Products

EL	Hearth Product Group	Annual Fuel Use		Annual Electricity Consumption		Overall Energy Savings**
		Total *MMBtu/yr*	Savings *MMBtu/yr*	Total *kWh/yr*	Savings *kWh/yr*	Savings *MMBtu/yr*
0	Vented Fireplace	3.99	--	0.000	--	--
1	Vented Fireplace	0.499	3.49	13.60	(13.60)	3.44
0	Unvented Fireplace	3.52	--	0.000	--	--
1	Unvented Fireplace	1.30	2.22	99.38	(99.38)	1.88
0	Vented Gas Logs	3.13	--	0.000	--	--
1	Vented Gas Logs	0.289	2.84	5.79	(5.79)	2.82
0	Unvented Gas Logs	2.29	--	0.000	--	--
1	Unvented Gas Logs	0.924	1.36	70.61	(70.61)	1.12
0	Outdoor	3.91	--	0.000	--	--
1	Outdoor	0.000	3.91	0.175	(0.175)	3.91
0	All Hearth Products	3.58	--	0.000	--	--
1	All Hearth Products	0.58	3.00	28.54	(28.54)	2.90

* Parentheses () indicate negative values
** Savings include both fuel and electrical energy consumption, reported in MMBtu/yr.

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CHAPTER 8. LIFE-CYCLE COST AND PAYPACK PERIOD ANALYSIS

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CHAPTER 8. LIFE-CYCLE COST AND PAYPACK PERIOD ANALYSIS

8.1 INTRODUCTION

The effect of amended standards on individual consumers usually includes a reduction in operating cost and an increase in purchase cost. This chapter describes two metrics used in the analysis to determine the economic impact of standards on individual consumers.

- Life-cycle cost (LCC) is the total consumer cost over the life of an appliance or product, including purchase costs and operating costs (which in turn include maintenance, repair, and energy costs). Future operating costs are discounted to the time of purchase and summed over the lifetime of the appliance or product.
- Payback period (PBP) measures the amount of time it takes consumers to recover the assumed higher purchase price of more energy-efficient products through reduced operating costs.

The U.S. Department of Energy (DOE) conducted the LCC and PBP analysis using a spreadsheet model developed in Microsoft Excel. When combined with Crystal Ball (a commercially available software program), the LCC and PBP model generates a Monte Carlo simulation to perform the analysis by incorporating uncertainty and variability considerations in certain of the key parameters as discussed further in section 8.1.1.

Inputs to the LCC and PBP analysis of hearth product ignition devices are discussed in sections 8.2 and 8.3, respectively. Results for each metric are presented in sections 8.4 and 8.5. Key variables and calculations are presented for each metric. The calculations discussed here were performed with a series of Microsoft Excel spreadsheets that are accessible over the Internet (www1.eere.energy.gov/buildings/appliance_standards/product.aspx?productid=83).

Details of the spreadsheets and instructions for using them are discussed in appendix 8A.

8.1.1 General Approach for Life-Cycle Cost and Payback Period Analysis

In recognition of the fact that each residential building using hearth products is unique, variability and uncertainty are analyzed by performing the LCC and PBP calculations detailed here for a representative sample of individual households. The results are expressed as the number of buildings experiencing economic impacts of different magnitudes. The LCC and PBP model was developed using Microsoft Excel spreadsheets combined with Crystal Ball. The LCC and PBP analysis explicitly model both the uncertainty and the variability in the model's inputs using Monte Carlo simulation and probability distributions (see appendix 8B).

The LCC analysis used the estimated energy use for each hearth product unit as described in the energy use analysis in chapter 7. Energy use of hearth products is sensitive to climate and therefore varies by location within the United States. Aside from energy use, other important factors influencing the LCC and PBP analysis include energy prices, installation costs, product distribution markups, and sales taxes.

As mentioned previously, DOE generated LCC and PBP results as probability distributions using a simulation based on Monte Carlo analysis methods, in which certain key inputs to the analysis consist of probability distributions rather than single-point values. Therefore, the outcomes of the Monte Carlo analysis can also be expressed as probability distributions. As a result, the Monte Carlo analysis produces a range of LCC and PBP results. A distinct advantage of this type of approach is that DOE can identify the percentage of consumers achieving LCC savings or attaining certain PBP values due to an increased efficiency level, in addition to the average LCC savings or average PBP for that efficiency level.

The LCC results are displayed as distributions of impacts compared to a base case. The base case efficiency is for 2021 and reflects the expected distribution of efficiency levels by product class. The PBP results are displayed compared to the baseline efficiency level.

8.1.2 Overview of Life-Cycle Cost and Payback Period Analysis Inputs

The LCC is the total consumer cost over the life of the product, including purchase price (including retail markups, sales taxes, and installation costs) and operating cost (including repair costs, maintenance costs, and energy cost). Future operating costs are discounted to the time of purchase and summed over the lifetime of the product. The PBP is the increase in purchase cost of a higher efficiency product divided by the change in annual operating cost of the product. It represents the number of years that it will take the consumer to recover the increased purchase cost through decreased operating costs. In the PBP calculation, future costs are not discounted.

Inputs to the LCC and PBP analysis are categorized as: (1) inputs for establishing the purchase cost, otherwise known as the total installed cost; and (2) inputs for calculating the operating cost (*i.e.*, energy, maintenance, and repair costs).

The primary inputs for establishing the total installed cost are:

- *Baseline manufacturer selling price*: The baseline manufacturer selling price (MSP) is the price charged by the manufacturer to a wholesaler for product meeting existing minimum efficiency (or baseline) standards. The MSP includes a markup that converts the cost of production (*i.e.*, the manufacturer cost) to an MSP.
- *Standard-level manufacturer selling price increase*: The standard-level MSP is the incremental change in MSP associated with producing product at each of the higher efficiency standard levels.
- *Markups and sales tax*: Markups and sales tax are the wholesaler and contractor margins and state and local retail sales taxes associated with converting the MSP to a consumer price.

- *Installation cost*: Installation cost is the cost to the consumer of installing the product. The installation cost represents all costs required to install the product but does not include the marked-up consumer product price. The installation cost includes labor, overhead, and any miscellaneous materials and parts.

The primary inputs for calculating the operating cost are:

- *Product energy consumption*: The product energy consumption is the site energy use associated with the use of the hearth product ignition device to start the hearth product.
- *Energy Prices*: Electricity, natural gas, and liquid petroleum gas (LPG) prices are determined using average and marginal monthly energy prices.
- *Electricity, LPG and natural gas price trends*: The Energy Information Administration's (EIA's) *Annual Energy Outlook 2014* (*AEO 2014*)[1] is used to forecast energy prices into the future. For the results presented in this chapter, DOE used the *AEO 2014* Reference case to forecast future energy prices.
- *Maintenance costs*: The labor and material costs associated with maintaining the operation of the product.
- *Repair costs*: The labor and material costs associated with repairing or replacing components that have failed.
- *Lifetime*: The age at which the hearth product is retired from service.
- *Discount rate*: The rate at which future costs and savings are discounted to establish their present value.

Figure 8.1.1 graphically depicts the relationships between the installed cost and operating cost inputs for the calculation of the LCC and PBP.

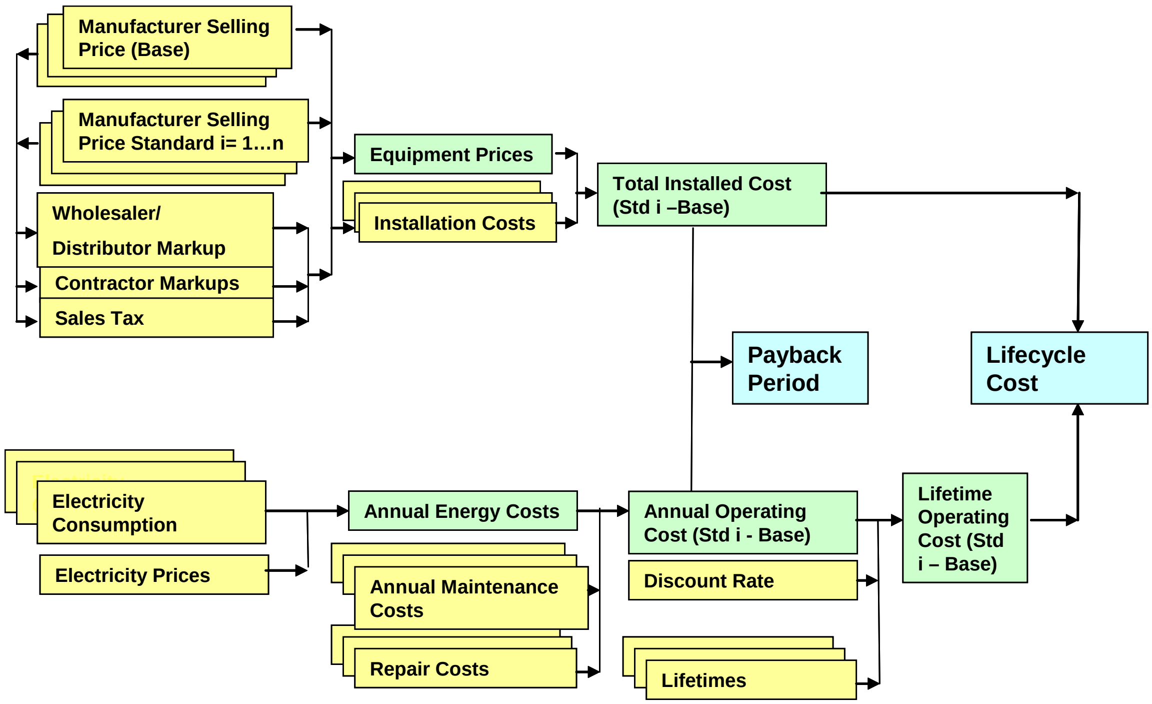

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

Table 8.1.1 provides descriptions of the various inputs to the calculation of the LCC and PBP. As noted earlier, most of the inputs are characterized by probability distributions that capture variability in the input variables.

Table 8.1.1 Summary of Inputs and Key Assumptions Used in the LCC and PBP Analysis

Inputs	Description
Affecting Installed Costs	
Product Price	Derived from MSP for hearth product groups (from the engineering analysis, chapter 5) multiplied by wholesaler markups and contractor markups plus sales tax (from markups analysis). Used the probability distribution for the different markups to describe their variability.
Installation Cost	Includes installation labor derived from *RS Means Residential Cost Data 2013*.[2] Overhead and materials costs and profits are assumed to be included in the contractor's markup. Thus, the total installed cost equals the consumer product price (manufacturer cost multiplied by the various markups plus sales tax) plus the installation cost.
Affecting Operating Costs	
Energy Use	Determined from the input capacity and operating hours of the hearth product ignition system. See chapter 7.
Energy Prices	Costs were calculated for RECS 2009 households from monthly marginal average electricity and natural gas or LPG prices in each of 30 states and groups of states in RECS 2009.[a] Residential prices were escalated by the *AEO 2014* forecasts to estimate future electricity prices. Escalation was performed at the census division level and aggregated to the regions used in the study.
Maintenance Cost	No maintenance cost is applied in this analysis.
Repair Cost	Estimated the annualized repair cost for hearth product ignition systems based on the cost of replacement.
Affecting Present Value of Annual Operating Cost Savings	
Product Lifetime	Used the probability distribution of lifetimes developed for hearth products.
Discount Rate	Mean real discount rates ranging from 3.57 percent to 5.12 percent for various classes of residential consumers based on Federal Reserve Board's *Survey of Consumer Finances*. Probability distributions are used for the discount rates.
Date Standard Becomes Effective	2021 (5 years after expected publication of the final rule)

All of the inputs depicted in Figure 8.1.1 and summarized in Table 8.1.1 are discussed in section 8.2.

8.1.3 Use of Residential Energy Consumption Survey in Life-Cycle Cost and Payback Period Analysis

The LCC and PBP calculations detailed here are for a representative sample of individual hearth product users. As explained in chapter 7, the Energy Information Administration (EIA)'s 2009 Residential Energy Consumption Survey (RECS 2009)[3] serves as the basis for determining

[a] RECS 2009 provides 27 regions (also called reportable domains). The 27th region includes Oregon, Washington, Alaska, and Hawaii. DOE subdivided Alaska and Hawaii into separate regions (28 and 29, respectively) based on cooling and heating degree days. In addition, West Virginia, which is in RECS region 14, was disaggregated into region 30 based on cooling and heating degree days. See appendix 7A for more details.

the representative residential sample. RECS collects energy-related data for occupied primary housing units in the United States. RECS 2009 included data from 12,083 housing units that represent almost 113.6 million households.

Appendix 7A presents the variables used and their definitions, as well as further information about the derivation of the household samples.

8.2 LIFE-CYCLE COST ANALYSIS INPUTS

Life-cycle cost is the total consumer cost over the life of a product, including purchase cost and operating costs (which are composed of energy costs, maintenance costs, and repair costs). Future operating costs are discounted to the time of purchase and summed over the lifetime of the product. Life-cycle cost is defined by the following equation:

$$LCC = IC + \sum_{t=1}^{N} OC_t / (1+r)^t$$

Eq. 8.1

Where:

LCC = life-cycle cost ($),
IC = total installed cost ($),
∑ = sum over the lifetime, from year 1 to year N,
where N = lifetime of product (years),
OC = operating cost ($),
r = discount rate, and
t = year for which operating cost is being determined.

DOE expressed all the costs in 2013$. Total installed cost, operating cost, lifetime, and discount rate are discussed in the following sections. In the LCC analysis, the year of product purchase is assumed to be 2021, the assumed effective date of energy conservation standards for hearth products.

8.2.1 Total Installed Cost Inputs

The total installed cost to the consumer is defined by the following equation:

$$IC = EQP + INST$$

Eq. 8.2

Where:

EQP = product price ($) (*i.e.*, consumer price for the product only), and
INST = installation cost ($) (*i.e.*, the cost for labor and materials).

The product price is based on the distribution channel through which the consumer purchases the product. As discussed in chapter 6, DOE defined two major distribution channels for new units to describe how a hearth product passes from the manufacturer to the consumer, one applying to hearth products installed in replacement markets or by new owners and the other applying to hearth products that are installed in new construction. In the new construction channel, the manufacturer sells the product to a wholesaler or distributor, who sells to a mechanical contractor hired by a general contractor. The general contractor purchases and installs the product on behalf of the consumer and adds its markup to the mechanical contractor's price. Replacement products follow the same distribution channel, except that there is no general contractor. Instead, the mechanical contractor takes on the general contractor's function.

The remainder of this section provides information about the variables DOE used to calculate the total installed cost for hearth products.

8.2.1.1 Manufacturer Costs

DOE developed the manufacturer costs for hearth products ignition systems as described in chapter 5, Engineering Analysis. The manufacturer costs for a baseline ignition system (*i.e.*, standing pilot light) for each product group and the incremental cost of an intermittent pilot ignition system are shown in Table 8.2.1.

Table 8.2.1 Manufacturer Production Cost for Hearth Product Ignitions Systems by Hearth Product Group

Product Group	Description	Standing Pilot MPC	Intermittent Pilot MPC
1	Vented Fireplaces/Stoves/Inserts	\$49.13	\$76.83
2	Unvented Fireplaces/Stoves/Inserts	\$69.17	\$101.44
3	Vented Log Sets	\$30.79	\$100.63
4	Unvented Log Sets	\$29.04	\$85.46
5	Outdoor	\$84.83	\$139.96

8.2.1.2 Markups

For a given distribution channel, the overall markup is the value determined by multiplying all the associated markups and the applicable sales tax together to arrive at a single overall distribution chain markup value. The overall markup is multiplied by the baseline or standard-compliant manufacturer cost to arrive at the price paid by the consumer. Because there are baseline and incremental markups associated with the wholesaler and mechanical contractor, the overall markup is also divided into a baseline markup (*i.e.*, a markup used to convert the baseline manufacturer price into a consumer price) and an incremental markup (*i.e.*, a markup used to convert a standard-compliant manufacturer cost increase due to an efficiency increase into an incremental consumer price). Markups can differ depending on whether the product is being purchased for a new construction installation or is being purchased to replace an existing product. DOE developed the overall baseline markups and incremental markups for both new construction and replacement applications as a part of the markups analysis (chapter 6).

Table 8.2.2 displays the average markups and their associated components weighted by housing projections in 2021,[16,17,18] for the baseline and incremental markups for hearth product ignition devices, respectively. DOE calculated the projected number of houses in 2021 by state by accounting for the growth in population by region from 2008 to 2012 based on historical U.S. census population numbers by state and the number of people per house in each state based on historical U.S. census population and housing numbers.

Table 8.2.2 Summary of National Average Markups on Hearth Product Ignition Devices

	Replacement		New Construction	
	Baseline Markup	**Incremental Markup**	**Baseline Markup**	**Incremental Markup**
Manufacturer	1.45		1.45	
Wholesaler	1.36	1.10	1.36	1.10
Mechanical Contractor	1.53	1.23	1.43	1.14
General Contractor	-		1.46	1.33
Sales Tax	1.07		-	
Total Markup	3.25	2.10	4.11	2.43

Note: Components may not multiply to the overall markup due to rounding.

Table 8.2.3 presents the total markup for hearth product ignition devices based on the percentage of the market attributed to each distribution channel.

Table 8.2.3 Overall Markup for Hearth Product Ignition Devices

Product Class	Baseline Markup	Incremental Markup
Hearth Products	3.43	2.17

8.2.1.3 Total Consumer Price

DOE derived the consumer product price for the baseline product by multiplying the baseline manufacturer cost by the baseline overall markup (including the sales tax). For each efficiency level above the baseline, DOE derived the consumer product price by taking baseline product consumer price and adding to it the product of the incremental manufacturer cost and the incremental overall markup (including the sales tax). Markups and sales tax can take on a variety of values depending on location, so the resulting total installed cost for a particular efficiency level is represented by a distribution of values.

Table 8.2.4 presents the average consumer product price for hearth product ignition devices at each efficiency level examined.

Table 8.2.4 Average Consumer Price for Hearth Product Ignition Devices (2013$)

Product Class	Efficiency Level	Average Consumer Price 2013$	Incremental Cost 2013$
Hearth Products	Standing Pilot	$166.46	-
	Intermittent Pilot	$248.14	$81.68

8.2.1.4 Future Product Prices

DOE examined the historical price trend of hearth products by looking at the producer price index (PPI) data for floor and wall furnaces from 1999-2013 from the Bureau of Labor Statistics' (BLS).[b] The PPI for floor and wall furnaces is the most representative price index for hearth products, as the products in this PPI index are generally similar to hearth products. The PPI data reflect nominal prices, adjusted for product quality changes. The inflation-adjusted (deflated) price index for floor and wall furnaces is calculated by dividing the PPI series by the Gross Domestic Product Chained Price Index (see Figure 8.2.1).

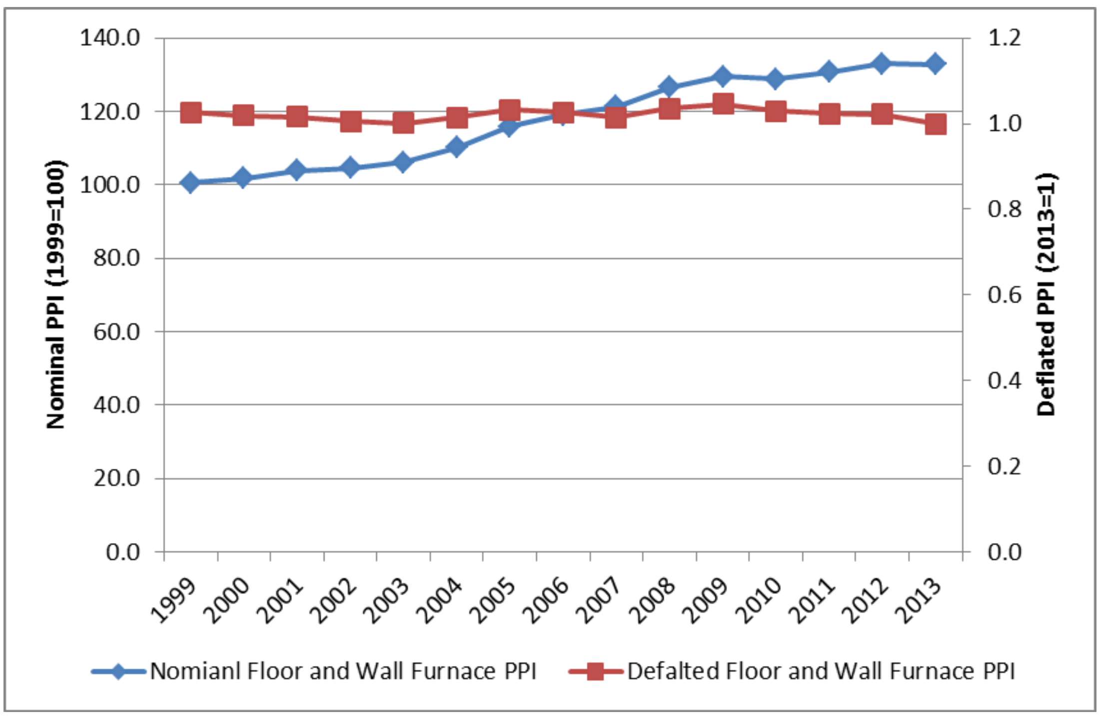

Figure 8.2.2 Historical Deflated Producer Price Indexes for Floor and Wall Furnaces

In Figure 8.2.1, the deflated PPI for floor and wall furnaces has remained relatively constant throughout the past decade. Even though there is a sign of downward trend beginning in 2012, DOE does not have sufficient evidence that the downward trend will continue in the future. Given the uncertainty, DOE chose to apply a constant price trend (in real dollars) to the manufacturer selling price of hearth products.

[b] Floor and wall furnaces PPI series ID: PCU 3334143334147; www.bls.gov/ppi/

8.2.1.5 Installation Cost

The installation cost is the cost to the consumer of installing a hearth product ignition device. Because the ignition device is a component of the hearth product, the only installation costs considered in the analysis were the labor and material costs associated with electrical retrofits for the fraction of households for which this is necessary. DOE assumed that in new construction there would be no additional installation cost of the intermittent pilot compared to the standing pilot. DOE estimated the cost of installing a new electrical connection or installing electrical grounding when applicable for each sample household based the age of the household given in RECS 2009. In addition, DOE assumed that the cost of electrical retrofits for ventless gas logs, which are easier to move closer to the location of the electrical outlet, is half of the cost applied to the other hearth product groups. Table 8.2.5 presents the assumptions DOE used to determine the households that require electrical retrofits.

Table 8.2.5 Installation Cost Household Sample Assumptions

Criteria	Fraction of Households that Require	
	Electrical Outlet	Electrical Grounding
Household built before 1960	50%	50%
Household built before 1990	25%	0%
Household built after 1990	10%	0%
New construction	0%	0%

Table 8.2.6 presents the national average basic installation cost based on RS Means 2013 Residential Cost Data.[2]

Table 8.2.6 RS Means National Installation Labor and Material Costs (2013$)

	Labor Hours	Bare Material Cost*
Electricity Connection (Retrofit)		
Trip Charge	0.5	$0.00
Receptacle Devices (Duplex Outlet,15 amp recpt., EMT & wire) (20' avg. runs and #14/2 wiring included)	1.501	$29.50
Electricity Grounding (Retrofit)		
Clamp, bronze,1/2" diameter	0.25	$5.20
Bare copper wire, #14 solid	0.571	$7.80

*Does not include sales tax or RS Means markups by trade.

RS Means provides average national labor costs for different trade groups as shown in Table 8.2.7. Labor costs including overhead and profit (O&P) are the bare costs provided by RS Means multiplied by the RS Means markups by trade shown in Table 8.2.8.

Table 8.2.7 RS Means 2013 National Average Residential Labor Costs by Crew

Crew Type	Crew Description	Laborers per Crew	Cost per Labor-Hour	
			Bare Costs	Incl. O&P*
1 Elec	1 Electrician	1	35.10	57.42

* O&P includes markups in Table 8.2.8.

Table 8.2.8 RS Means Labor Costs Markups by Trade (Residential)

Trade	Workers Comp.	Avg. Fixed Overhead	Overhead	Profit	Total
Electrician	5.7%	17.9%	30.0%	10.0%	63.6%

DOE's analysis of installation costs accounts for regional differences in labor and material costs. RS Means provides material and labor cost factors for 295 cities and towns in the U.S. To derive average installation labor cost values by state, DOE weighted these price factors by housing projections in 2021. DOE used the average material and labor cost factors for costs associated with electrical labor. Table 8.2.9 shows the final regional material and labor price factors used in the analysis by geographical area.

Table 8.2.9 Material and Labor Cost Factors by Geographical Area (for RECS 2009 Sample)

Geographical Area	Electrical	
	Material	Labor
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	1.01	0.97
Massachusetts	1.02	1.16
New York	1.02	1.68
New Jersey	1.02	1.37
Pennsylvania	0.96	1.25
Illinois	0.95	1.27
Indiana, Ohio	0.98	0.89
Michigan	0.97	0.99
Wisconsin	1.02	0.95
Iowa, Minnesota, North Dakota, South Dakota	1.01	0.91
Kansas, Nebraska	0.99	0.77
Missouri	1.01	0.95
Virginia	0.97	0.71
Delaware, District of Columbia, Maryland	0.98	0.97
Georgia	0.99	0.69
North Carolina, South Carolina	0.97	0.48
Florida	0.99	0.68
Alabama, Kentucky, Mississippi	0.99	0.69
Tennessee	1.00	0.63
Arkansas, Louisiana, Oklahoma	1.00	0.62
Texas	0.95	0.61
Colorado	1.01	0.84
Idaho, Montana, Utah, Wyoming	0.96	0.70
Arizona	0.98	0.66
Nevada, New Mexico	0.94	0.93
California	1.00	1.21
Oregon, Washington	1.02	0.97
Alaska	1.34	1.17
Hawaii	1.06	1.27
West Virginia	0.96	0.90

Table 8.2.10 presents the average installation cost for all hearth product ignition systems.

Table 8.2.10 Average Installation Cost for Hearth Product Ignition Systems (2013$)

Product Class	Efficiency Level	Average Installation Cost 2013$	Incremental Cost 2013$
Hearth Products	Standing Pilot	$0.00	-
	Intermittent Pilot	$19.53	$19.53

8.2.1.6 Total Installed Cost

The total installed cost is the sum of the product price and the installation cost. Markups, sales taxes, and labor and material costs all can take on a variety of values, depending on location, so the resulting total installed cost for a particular efficiency level will not be a single-point value, but rather a distribution of values. Table 8.2.11 presents the average total installed cost for hearth products ignition devices.

Table 8.2.11 Average Total Installed Cost for Hearth Product Ignition Devices (2013$)

Product Class	Efficiency Level	Total Installed Cost 2013$	Incremental Cost 2013$
Hearth Products	Standing Pilot	$166.46	-
	Intermittent Pilot	$267.67	$101.21

8.2.2 Operating Cost Inputs

DOE defined the operating cost by the following equation:

$$OC = EC + RC + MC \qquad \textbf{Eq. 8.3}$$

Where:

OC = operating cost ($),
EC = energy cost associated with operating the product ($),
RC = repair cost associated with component failure ($), and
MC = annual maintenance cost for maintaining product operation ($).

The remainder of this section provides information about the variables that DOE used to calculate the operating cost for hearth products. The annual energy costs of the product are computed from energy consumption per unit for the baseline and standard-compliant cases, combined with the energy prices. Product lifetime, discount rate, and compliance date of the standard are required for determining the operating cost and for establishing the operating cost present value.

8.2.2.1 Annual Energy Use Savings

DOE calculated the annual energy use savings for each sample household at each efficiency level as described in chapter 7. DOE believes that consumers will not use a hearth product with an intermittent pilot more frequently than a hearth product with a standing pilot light, and did not include a rebound effect in the energy use calculations.

8.2.2.2 Energy Prices

DOE derived average and marginal monthly energy prices for a number of geographic areas in the United States using the latest data from EIA and monthly energy price factors that it developed. Average energy prices are applied to the base case energy use, while marginal prices are applied to the differential energy use from the other efficiency options. DOE then assigned an appropriate energy price to each household in the sample, depending on its location.

Derivation of Average and Marginal Monthly Prices

Derivation of Average Annual Energy Prices using EIA data. DOE obtained the data for natural gas prices from EIA's Natural Gas Navigator,[4] which includes monthly natural gas prices by state for residential, commercial, and industrial consumers. DOE derived 2012 annual electricity prices from EIA Form 826 data,[5] which includes electricity prices by state for residential, commercial, and industrial consumers. DOE calculated annual state electricity and natural gas prices by averaging monthly energy prices by state.

DOE collected 2012 average LPG prices from EIA's 2012 State Energy Consumption, Price, and Expenditures Estimates (SEDS).[6] SEDS includes annual LPG prices for residential, commercial, industrial, and transportation consumers by state.

For a RECS region with more than one state, DOE weighted each state's average energy price by its number of homes in 2021. See appendix 8C for the calculated annual energy prices in 2012.

Derivation of Average Monthly Energy Factors using EIA data. To determine monthly prices for use in the analysis, DOE developed monthly energy price factors for each fuel based on long-term price data. See appendix 8C for a description of the method. DOE multiplied the average 2012 annual prices by the monthly price factors for each fuel to derive prices for each month.

Seasonal Electricity and Natural Gas Marginal Price Factors using EIA data. Monthly electricity and natural gas prices were adjusted using seasonal marginal price factors to determine monthly marginal electricity and natural gas prices. These marginal energy prices were used to determine the cost to the consumer of the change in energy consumed. Because marginal price data is only available for electricity and natural gas, DOE only developed marginal monthly prices for these fuels. For LPG, DOE used average monthly prices. For a detailed discussion of the development of marginal energy price factors, see appendix 8C.

Table 8.2.12, Table 8.2.13, Table 8.2.14, and Table 8.2.15 show the average and marginal monthly natural gas and electricity prices. Average LPG prices are shown in appendix 8C.

Table 8.2.12 Residential Average Monthly Natural Gas Prices for 2012 Using Monthly Price Factors (2013$/MMBtu)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	14.4	14.5	14.6	14.9	15.6	16.9	18.4	18.7	18.2	16.3	15.5	15.1
Massachusetts	12.9	12.9	12.8	13.1	12.3	12.6	13.9	14.7	14.2	12.3	13.3	13.2
New York	12.8	12.6	12.8	13.3	14.8	16.9	17.8	16.8	16.4	14.4	12.9	12.1
New Jersey	10.9	10.7	10.7	11.0	11.7	12.9	13.4	13.4	13.2	12.1	11.5	11.2
Pennsylvania	11.4	11.6	11.8	12.3	13.8	15.9	17.6	18.1	17.2	14.0	12.4	11.8
Illinois	8.1	8.2	8.2	8.7	10.6	12.2	13.1	13.3	12.3	9.7	8.6	8.1
Indiana, Ohio	11.3	11.4	11.8	12.6	14.1	16.2	17.7	17.9	16.6	13.3	11.8	11.5
Michigan	10.1	10.1	10.3	10.8	12.0	13.7	15.2	15.7	14.5	12.1	10.9	10.5
Wisconsin	9.6	9.3	9.5	9.6	9.7	11.1	11.5	11.7	10.7	8.8	9.8	9.6
Iowa, Minnesota, North Dakota, South Dakota	8.3	8.1	8.2	8.4	9.6	11.2	12.1	12.5	11.6	9.2	8.6	8.2
Kansas, Nebraska	9.5	9.5	9.5	10.4	11.7	13.7	14.7	15.4	15.0	12.9	10.4	9.8
Missouri	12.2	12.2	12.3	13.8	15.9	19.4	22.2	23.5	21.9	18.6	14.6	13.0
Virginia	12.1	11.6	11.5	12.8	15.1	17.6	18.9	18.6	18.6	15.1	12.4	12.0
Delaware, District of Columbia, Maryland	11.9	11.8	12.1	13.2	15.0	16.9	18.0	17.9	17.6	14.6	12.8	12.2
Georgia	13.4	14.2	14.9	16.5	20.5	22.8	24.0	23.8	23.1	19.9	15.3	14.3
North Carolina, South Carolina	12.6	12.5	12.9	13.9	15.9	18.8	19.9	20.7	19.8	16.5	13.8	13.3
Florida	15.4	15.7	16.7	17.7	19.3	20.5	21.2	21.6	21.3	20.9	19.2	17.0
Alabama, Kentucky, Mississippi	11.7	11.7	12.1	13.3	15.2	16.9	17.3	17.7	17.3	15.7	13.4	12.4
Tennessee	9.9	10.0	10.0	10.9	12.0	13.7	14.6	15.0	14.3	13.0	11.0	10.4
Arkansas, Louisiana, Oklahoma	10.6	10.5	10.8	11.9	14.1	15.6	16.6	17.1	16.6	15.5	13.1	11.2
Texas	9.5	9.5	9.8	11.2	12.9	14.4	14.8	15.2	15.1	13.6	11.2	9.9
Colorado	7.8	7.9	8.2	8.4	9.3	11.8	11.9	12.6	11.7	9.3	8.4	8.0
Idaho, Montana, Utah, Wyoming	8.2	8.2	8.4	8.2	8.5	9.2	10.0	10.5	9.8	8.6	8.5	8.3
Arizona	13.5	14.0	14.5	15.8	17.7	19.6	21.4	22.1	21.4	20.0	16.9	14.6
Nevada, New Mexico	8.7	8.9	9.1	9.8	11.3	13.1	12.8	13.3	12.8	11.3	9.6	8.7
California	9.2	9.1	8.8	8.8	9.2	9.6	9.7	9.6	9.3	9.4	9.0	9.0
Oregon, Washington	11.0	11.2	11.2	11.5	12.0	12.6	13.9	14.4	14.0	12.7	11.7	11.4
Alaska	8.1	8.2	8.3	8.4	8.8	9.1	9.8	9.6	8.9	8.4	8.2	8.4
Hawaii	49.6	50.7	50.8	51.0	51.8	52.3	53.6	54.9	54.8	54.5	53.7	52.6
West Virginia	10.8	10.8	10.9	11.3	12.5	15.1	16.9	16.6	15.3	12.5	11.5	11.1
United States	10.5	10.5	10.6	11.2	12.3	13.8	14.6	14.9	14.3	12.3	11.2	10.7

Table 8.2.13 Residential Marginal Monthly Natural Gas Prices for 2012 Using Monthly Price Factors (2013$/MMBtu)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	13.21	13.32	13.42	12.40	12.97	14.03	15.26	15.52	15.11	13.52	14.27	13.84
Massachusetts	13.30	13.29	13.19	11.75	10.98	11.30	12.45	13.13	12.71	11.00	13.66	13.60
New York	11.44	11.24	11.38	10.01	11.12	12.67	13.38	12.61	12.35	10.85	11.47	10.81
New Jersey	10.33	10.20	10.22	9.23	9.82	10.78	11.23	11.18	11.03	10.13	10.89	10.64
Pennsylvania	10.58	10.70	10.90	8.93	10.02	11.55	12.78	13.11	12.45	10.16	11.50	10.91
Illinois	7.93	7.96	8.01	5.91	7.17	8.26	8.88	8.99	8.33	6.58	8.40	7.91
Indiana, Ohio	10.43	10.53	10.88	9.17	10.20	11.78	12.82	12.99	12.08	9.65	10.91	10.65
Michigan	9.40	9.41	9.55	8.38	9.33	10.68	11.82	12.25	11.30	9.41	10.19	9.81
Wisconsin	9.37	9.16	9.33	7.66	7.67	8.78	9.11	9.26	8.48	7.02	9.64	9.39
Iowa, Minnesota, North Dakota, South Dakota	8.04	7.89	8.03	6.03	6.83	8.01	8.65	8.92	8.30	6.59	8.39	8.02
Kansas, Nebraska	8.81	8.86	8.87	7.21	8.12	9.51	10.18	10.69	10.39	8.92	9.70	9.08
Missouri	9.98	9.98	10.11	8.20	9.50	11.59	13.25	14.03	13.07	11.08	12.00	10.67
Virginia	11.23	10.82	10.69	8.65	10.23	11.95	12.83	12.63	12.59	10.21	11.53	11.20
Delaware, District of Columbia, Maryland	11.03	10.94	11.20	9.32	10.59	11.89	12.65	12.64	12.38	10.28	11.83	11.25
Georgia	11.58	12.31	12.86	9.19	11.42	12.74	13.40	13.30	12.88	11.08	13.22	12.39
North Carolina, South Carolina	11.26	11.22	11.53	9.20	10.56	12.46	13.22	13.70	13.15	10.93	12.31	11.94
Florida	12.65	12.90	13.78	11.41	12.42	13.21	13.62	13.91	13.71	13.48	15.83	14.05
Alabama, Kentucky, Mississippi	10.15	10.13	10.46	9.95	11.33	12.59	12.92	13.19	12.89	11.69	11.61	10.76
Tennessee	9.31	9.44	9.44	8.04	8.84	10.11	10.78	11.12	10.61	9.63	10.39	9.80
Arkansas, Louisiana, Oklahoma	8.88	8.84	9.07	7.70	9.16	10.09	10.74	11.08	10.78	10.05	10.96	9.43
Texas	8.01	8.06	8.28	6.68	7.66	8.54	8.80	9.02	8.97	8.10	9.45	8.35
Colorado	7.09	7.18	7.43	5.78	6.41	8.12	8.17	8.67	8.02	6.42	7.66	7.28
Idaho, Montana, Utah, Wyoming	7.84	7.87	8.01	6.82	7.13	7.71	8.38	8.76	8.18	7.22	8.13	7.97
Arizona	11.51	11.87	12.29	10.04	11.27	12.47	13.57	14.08	13.62	12.72	14.33	12.39
Nevada, New Mexico	7.69	7.88	8.08	7.10	8.13	9.46	9.20	9.56	9.24	8.15	8.50	7.77
California	9.94	9.84	9.48	7.45	7.77	8.17	8.22	8.10	7.89	7.95	9.75	9.77
Oregon, Washington	10.35	10.47	10.52	9.67	10.05	10.56	11.64	12.11	11.77	10.65	11.01	10.72
Alaska	7.82	7.89	7.95	7.20	7.55	7.81	8.41	8.25	7.63	7.25	7.87	8.12
Hawaii	45.38	46.34	46.42	39.47	40.05	40.49	41.44	42.49	42.37	42.15	49.08	48.09
West Virginia	10.26	10.30	10.42	9.02	9.99	12.08	13.44	13.28	12.20	9.95	10.91	10.59
United States	9.80	9.85	9.97	8.31	9.14	10.24	10.86	11.09	10.61	9.14	10.47	10.03

Table 8.2.14 Residential Average Electricity Prices for 2012 Using Monthly Price Factors (2013$/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16
Massachusetts	0.15	0.15	0.15	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.15	0.15
New York	0.17	0.17	0.17	0.17	0.18	0.18	0.19	0.19	0.19	0.18	0.18	0.17
New Jersey	0.15	0.15	0.15	0.15	0.16	0.17	0.17	0.17	0.17	0.16	0.16	0.16
Pennsylvania	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.14	0.13	0.13	0.13	0.12
Illinois	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11
Indiana, Ohio	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11
Michigan	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.14	0.14	0.14
Wisconsin	0.13	0.13	0.13	0.13	0.14	0.14	0.13	0.13	0.14	0.14	0.13	0.13
Iowa, Minnesota, North Dakota, South Dakota	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.11	0.11	0.10
Kansas, Nebraska	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.11	0.10	0.10
Missouri	0.09	0.09	0.09	0.10	0.11	0.12	0.12	0.12	0.11	0.10	0.10	0.09
Virginia	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.10
Delaware, District of Columbia, Maryland	0.12	0.12	0.12	0.12	0.14	0.15	0.15	0.15	0.14	0.13	0.12	0.12
Georgia	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.13	0.12	0.11	0.11	0.10
North Carolina, South Carolina	0.11	0.11	0.11	0.11	0.12	0.11	0.12	0.12	0.12	0.12	0.11	0.11
Florida	0.11	0.11	0.12	0.12	0.12	0.11	0.12	0.12	0.12	0.12	0.12	0.12
Alabama, Kentucky, Mississippi	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10
Tennessee	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.10
Arkansas, Louisiana, Oklahoma	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.09	0.09
Texas	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.11	0.11
Colorado	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11
Idaho, Montana, Utah, Wyoming	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Arizona	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11
Nevada, New Mexico	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
California	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.16
Oregon, Washington	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Alaska	0.17	0.17	0.18	0.18	0.19	0.19	0.19	0.19	0.18	0.18	0.18	0.18
Hawaii	0.36	0.37	0.37	0.37	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.39
West Virginia	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.10
United States	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11

Table 8.2.15 Residential Marginal Electricity Prices for 2012 Using Monthly Price Factors (2013$/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Massachusetts	0.15	0.16	0.16	0.14	0.15	0.15	0.14	0.15	0.15	0.15	0.16	0.16
New York	0.15	0.15	0.15	0.20	0.20	0.21	0.21	0.21	0.21	0.20	0.15	0.15
New Jersey	0.15	0.15	0.15	0.19	0.19	0.20	0.21	0.21	0.21	0.19	0.15	0.15
Pennsylvania	0.10	0.10	0.10	0.14	0.14	0.15	0.15	0.15	0.15	0.14	0.11	0.10
Illinois	0.07	0.08	0.08	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.08	0.08
Indiana, Ohio	0.08	0.08	0.08	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.09	0.08
Michigan	0.13	0.14	0.13	0.16	0.16	0.17	0.17	0.17	0.17	0.16	0.14	0.14
Wisconsin	0.11	0.12	0.12	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.12	0.12
Iowa, Minnesota, North Dakota, South Dakota	0.09	0.09	0.09	0.12	0.12	0.13	0.13	0.13	0.12	0.12	0.09	0.09
Kansas, Nebraska	0.07	0.07	0.07	0.12	0.13	0.14	0.14	0.14	0.14	0.13	0.08	0.07
Missouri	0.07	0.07	0.07	0.12	0.13	0.15	0.14	0.14	0.13	0.12	0.07	0.07
Virginia	0.09	0.09	0.09	0.12	0.13	0.13	0.13	0.13	0.13	0.12	0.09	0.09
Delaware, District of Columbia, Maryland	0.11	0.11	0.11	0.14	0.16	0.17	0.17	0.17	0.16	0.15	0.11	0.11
Georgia	0.09	0.09	0.09	0.13	0.13	0.14	0.14	0.15	0.14	0.13	0.09	0.09
North Carolina, South Carolina	0.09	0.09	0.09	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.09	0.09
Florida	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11
Alabama, Kentucky, Mississippi	0.08	0.08	0.08	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.09	0.08
Tennessee	0.08	0.08	0.08	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.09	0.09
Arkansas, Louisiana, Oklahoma	0.06	0.06	0.06	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.07	0.06
Texas	0.09	0.09	0.10	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.10	0.10
Colorado	0.09	0.09	0.09	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.09	0.09
Idaho, Montana, Utah, Wyoming	0.09	0.09	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.09	0.09
Arizona	0.08	0.09	0.09	0.12	0.13	0.13	0.13	0.13	0.13	0.12	0.09	0.09
Nevada, New Mexico	0.10	0.10	0.10	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.11	0.10
California	0.17	0.17	0.17	0.18	0.19	0.19	0.20	0.20	0.19	0.18	0.18	0.18
Oregon, Washington	0.08	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09
Alaska	0.16	0.16	0.16	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.16
Hawaii	0.33	0.33	0.33	0.54	0.55	0.55	0.56	0.56	0.56	0.57	0.35	0.35
West Virginia	0.08	0.08	0.08	0.09	0.10	0.09	0.09	0.09	0.09	0.10	0.09	0.08
United States	0.09	0.09	0.09	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.10	0.09

<u>Household Energy Price Adjustment Factor</u>

RECS 2009 reports the total annual consumption and expenditure of each energy use type. To take into account that household energy prices may vary inside a geographical area, DOE developed an adjustment factor based on the reported average RECS 2009 energy price for each household divided by the average energy price in the RECS 2009 geographical region. This factor was then multiplied by the monthly price developed above to determine the household energy price. Appendix 8C includes more details.

Energy Price Trends by Census Division

To arrive at prices in future years, DOE multiplied the prices described in the preceding section by the forecasts of annual average price changes in *AEO 2014*.[1] Figure 8.2.2 shows the national residential energy price factors with a 2012 base year (2012=1). To estimate the trend after 2040, DOE used the average rate of change during 2030–2040.

DOE applied the projected energy price for each of the nine census divisions to each building in the sample based on the building's location. Appendix 8C includes more details.

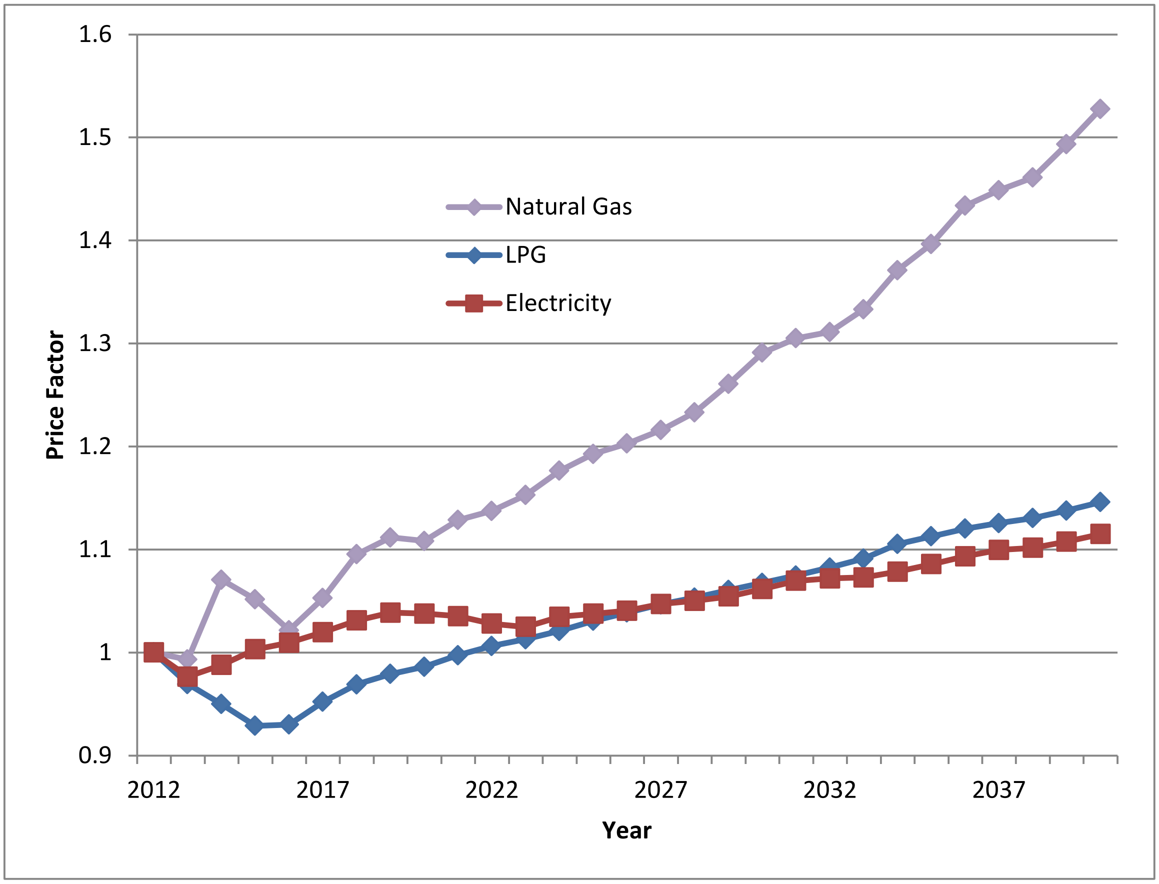

Figure 8.2.3 Projected National Commercial Energy Price Factors, AEO 2014 (Reference Case)

8.2.2.1 Maintenance Cost

The maintenance cost is the routine cost to the consumer of maintaining equipment operation. DOE assumed that hearth product ignition systems do not require any maintenance.

8.2.2.2 Repair Cost

The repair cost is the cost of materials and labor to the consumer for replacing an ignition device that has failed. Repair occurs if the ignition system fails before the end of the hearth product life. The repair costs are assumed to be equal to the retail price for replacement applications. DOE accounts for regional differences in labor and material costs.

The failure year distribution of the hearth product ignition device is assumed to be a Weibull function (see section 8.2.3.3). DOE estimated that the ignition system in 14 percent of all hearth products would fail and be repaired over the course of the product lifetime. DOE observed that typical warranties for hearth products cover the ignition system parts for 5 years. If the ignition system failed before the warranty period expired, it was assumed that the consumer only incurred the cost of labor for the repair; otherwise, the consumer incurred the cost of both parts and repair for the repair. The ignition system lifetime is determined as described in section 8.2.3.3.

Table 8.2.16 presents the repair cost components that DOE derived from RS Means and the repair cost of hearth product ignition devices.

Table 8.2.16 Hearth Product Average Repair Cost Components (2013$)

Repair Description	Bare Material Cost (2013$)*	Total Labor Hours
Repair Standing Pilot Ignition	$43.72	1.50
Repair Intermittent Pilot Ignition	$142.89	1.50

*Does not include sales tax or RS Means markups by trade.

RS Means provides average national labor costs for different trade groups as shown in Table 8.2.17. Labor costs including overhead and profit (O&P) are the bare costs provided by RS Means multiplied by the RS Means markups by trade shown in Table 8.2.18.

Table 8.2.17 RS Means 2013 National Average Residential Labor Costs by Crew

Crew Type	Crew Description	Laborers per Crew	Cost per Labor-Hour	
			Bare Costs	Incl. O&P*
Q1	1 Plumber, 1 Plumber Apprentice	2	33.18	54.61

* O&P includes markups in Table 8.2.8.

Table 8.2.18 RS Means Labor Costs Markups by Trade (Residential)

Trade	Workers Comp.	Avg. Fixed Overhead	Overhead	Profit	Total
Plumber	6.7%	17.9%	30.0%	10.0%	63.6%

DOE's analysis of repair costs accounts for regional differences in labor and material costs. RS Means provides material and labor cost factors for 295 cities and towns in the U.S. To derive average repair labor cost values by state, DOE weighted these price factors by housing projections in 2021. DOE used the average material and labor cost factors for costs associated with plumbing and heating, ventilation, and air conditioning (HVAC). Table 8.2.9 shows the final regional material and labor price factors used in the analysis by geographical area.

Table 8.2.19 shows the annualized repair cost estimates for hearth product ignition devices.

Table 8.2.19 Annualized Repair Cost for Hearth Product Ignition Devices (2013$)

Product Class	Efficiency Level	Annualized Repair Cost 2013$	Incremental Cost 2013$
Hearth Products	Standing Pilot	$1.83	-
	Intermittent Pilot	$2.40	$0.57

8.2.2.3 Lifetime

DOE defines lifetime as the age when a product is retired from service. DOE used warranty information and the lifetimes of similar appliances to estimate the distribution of both hearth product and hearth product ignition system lifetimes.

Hearth product warranties typically cover the hearth product for 5 years and the ignition system for 1 year for both labor and parts. Therefore, because any repairs performed during the warranty period would be free to the consumer, DOE assumed that the minimum lifetime of both the hearth product and the ignition system corresponded to the end of the respective warranty period. In the analysis, a unit was only repaired if the ignition system failed before the overall hearth product did.

A Weibull distribution is a probability distribution function commonly used to measure failure rates.[7] Its form is similar to an exponential distribution, which would model a fixed failure rate, except that it allows for a failure rate that changes over time in a particular fashion. The cumulative distribution takes the form:

$$P(x) = e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}} \text{ for } x > \theta \text{ and } P(x) = 1 \text{ for } x \leq \theta,$$

Eq. 8-1

Where:

$P(x)$ = probability that the appliance is still in use at age x,
x = appliance age,
α = the scale parameter, which is the decay length in an exponential distribution,
β = the shape parameter, which determines the way in which the failure rate changes in time, and
θ = the delay parameter, which allows for a delay before any failures occur.

When $\beta = 1$, the failure rate is constant over time, and this distribution takes the form of a cumulative exponential distribution. For the case of appliances, β is commonly greater than 1, which results from a rising failure rate as the appliance ages. A plot of a Weibull distribution (DOE's calculated hearth product survival function) is shown as Figure 8.2.1.

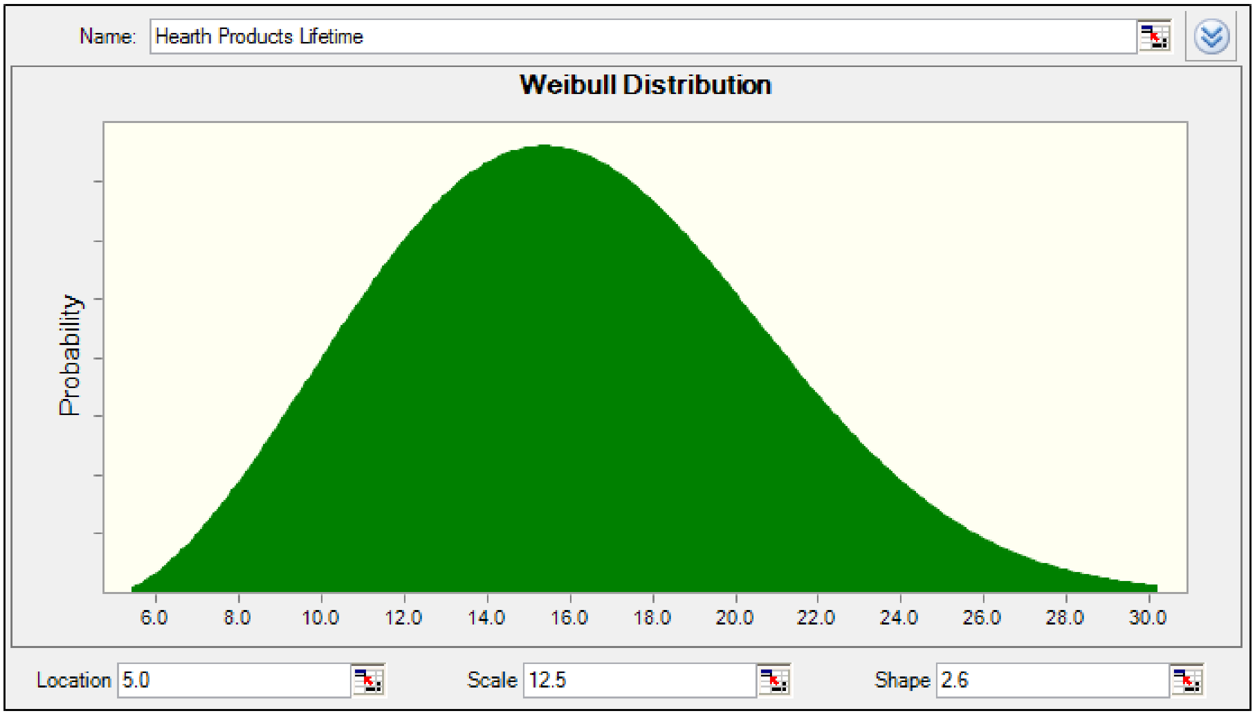

Figure 8.2.1 Lifetime Distribution of Hearth Products (whole unit)

Table 8.2.20 shows the average and minimum lifetime of both the hearth product and hearth product ignition system.

Table 8.2.20 Lifetime Parameters for Hearth Products

Product Class	Lifetime	
	Minimum	Average
Hearth Product (Whole Unit)	5	15.0
Hearth Product (Ignition System Only)	1	7.3

8.2.2.4 Discount Rates

The discount rate is the rate at which future savings and expenditures are discounted to establish their present value. DOE uses publicly available data (the Federal Reserve Board's *Survey of Consumer Finance*s (*SCF*)[8]) to estimate a consumer's opportunity cost of funds related to appliance energy cost savings and maintenance costs. The discount rate value is applied in the LCC to future year energy cost savings and non-energy operations and maintenance costs in order to present the estimated net life-cycle cost and life-cycle cost savings. DOE notes that the discount rate used in the LCC analysis is distinct from an implicit discount rate, as it is not used to model consumer purchase decisions. The opportunity cost of funds in this case may include interest payments on debt and interest returns on assets.

DOE estimated separate discount rate distributions for six income groups, divided based on income percentile as reported in the Federal Reserve Board's *SCF*. This disaggregation reflects the fact that low and high income consumers tend to have substantially different shares of debt and asset types, as well as facing different rates on debts and assets. Summaries of shares and rates presented in this chapter are averages across the entire population.

Table 8.2.21 Definitions of Income Groups

Income Group	Percentile of Income
1	1st to 20th
2	21st to 40th
3	41st to 60th
4	61st to 80th
5	81st to 90th
6	91th to 99th

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, and 2010.

Shares of Debt and Asset Classes

DOE's approach involved identifying all relevant household debt or asset classes in order to approximate a consumer's opportunity cost of funds related to appliance energy cost savings and maintenance costs. The approach assumes that in the long term, consumers are likely to draw from or add to their collection of debt and asset holdings approximately in proportion to their current holdings when future expenditures are required or future savings accumulate. DOE has included several previously excluded debt types (*i.e.*, vehicle and education loans, mortgages, all forms of home equity loan) in order to better account for all of the options available to consumers.

The average share of total debt plus equity and the associated rate of each asset and debt type are used to calculate a weighted average discount rate for each SCF household (Table 8.2.22). The household-level discount rates are then aggregated to form discount rate distributions for each of the six income groups. Note that previously DOE performed aggregation of asset and debt types over households by summing the dollar value across all households and then calculating shares. Weighting by dollar value gave disproportionate influence to the asset and debt shares and rates of higher income consumers. DOE has shifted to a household-level weighting to more accurately reflect the average consumer in each income group.

DOE estimated the average percentage shares of the various types of debt and equity using data from the Federal Reserve Board's *SCF* for 1995, 1998, 2001, 2004, 2007, and 2010.[c] DOE derived the household-weighted mean percentages of each source of financing throughout the 5 years surveyed. DOE posits that these long-term averages are most appropriate to use in its analysis.

[c] Note that although two older versions of the SCF are also available (1989 and 1992); these surveys are not used in this analysis because they do not provide all of the necessary types of data (*e.g.*, credit card interest rates, *etc.*). DOE feels that the 15-year span covered by the six surveys included is sufficiently representative of recent debt and equity shares and interest rates.

Table 8.2.22 Types of Household Debt and Equity by Percentage Shares (%)

Type of Debt or Equity	Income Group					
	1	**2**	**3**	**4**	**5**	**6**
Debt:						
Mortgage	18.9%	24.1%	33.1%	38.1%	39.3%	25.0%
Home equity loan	3.1%	3.3%	2.6%	3.6%	4.5%	7.2%
Credit card	15.3%	13.0%	11.8%	8.7%	6.0%	2.7%
Other installment loan	25.1%	20.6%	17.3%	13.2%	9.6%	4.7%
Other residential loan	0.7%	0.6%	0.6%	0.7%	1.0%	1.2%
Other line of credit	1.6%	1.5%	1.3%	1.5%	2.1%	1.8%
Equity:						
Savings account	18.5%	16.0%	12.7%	10.6%	10.4%	7.9%
Money market account	3.6%	4.5%	4.0%	4.5%	5.0%	8.6%
Certificate of deposit	7.0%	7.8%	5.5%	5.0%	4.4%	4.2%
Savings bond	1.8%	1.7%	1.9%	2.2%	1.7%	1.1%
Bonds	0.2%	0.4%	0.5%	0.7%	0.8%	3.8%
Stocks	2.3%	3.1%	4.4%	5.7%	7.6%	15.8%
Mutual funds	2.1%	3.5%	4.3%	5.7%	7.6%	15.9%
Total	100.0	100.0	100.0	100.0	100.0	100.0

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, and 2010.

Rates for Types of Debt

DOE estimated interest rates associated with each type of debt. The source for interest rates for mortgages, loans, credit cards, and lines of credit was the Federal Reserve Board's *SCF* for 1995, 1998, 2001, 2004, 2007, and 2010, which associates an interest rate with each type of debt for each household in the survey.

In calculating effective interest rates for home equity loans and mortgages, DOE accounted for the fact that interest on both such loans is tax deductible (Table 8.2.23). This rate corresponds to the interest rate after deduction of mortgage interest for income tax purposes and after adjusting for inflation (using the Fisher formula).[d] For example, a 6 percent nominal mortgage rate has an effective nominal rate of 5.5 percent for a household at the 25 percent marginal tax rate. When adjusted for an inflation rate of 2 percent, the effective real rate becomes 2.45 percent.

[d] Fisher formula is given by: Real Interest Rate = [(1 + Nominal Interest Rate) / (1 + Inflation Rate)] – 1.

Table 8.2.23 Data Used to Calculate Real Effective Mortgage Rates

Year	Mortgage Interest Rates in Selected Years *(%)*			
	Average Nominal Interest Rate	**Inflation Rate**[9]	**Applicable Marginal Tax Rate**[10]	**Average Real Effective Interest Rate**
1995	8.2	2.83	24.2	3.3
1998	7.9	1.56	25.0	4.3
2001	7.6	2.85	24.2	2.8
2004	6.2	2.66	20.9	2.2
2007	6.3	2.85	20.6	2.1
2010	5.7	1.64	20.0	2.9

Table 8.2.24 shows the household-weighted average effective real rates in each year and the mean rate across years. Because the interest rates for each type of household debt reflect economic conditions throughout numerous years and various phases of economic growth and recession, they are expected to be representative of rates in effect in 2021.

Table 8.2.24 Average Real Effective Interest Rates for Household Debt

Type of Debt	Income Group					
	1	**2**	**3**	**4**	**5**	**6**
Mortgage	6.6%	6.2%	6.1%	5.2%	5.0%	4.0%
Home equity loan	7.0%	6.9%	6.7%	5.9%	5.7%	4.3%
Credit card	15.2%	15.0%	14.5%	14.2%	14.0%	14.5%
Other installment loan	10.8%	10.3%	9.9%	9.4%	8.7%	8.6%
Other residential loan	9.8%	10.2%	8.9%	8.2%	7.7%	7.4%
Other line of credit	9.1%	10.9%	9.6%	8.8%	7.4%	6.1%

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, and 2010.

Rates for Types of Assets

No similar rate data are available from the *SCF* for classes of assets, so DOE derived asset interest rates from various sources of national historical data (1983-2013). The interest rates associated with certificates of deposit,[11] savings bonds,[12] and bonds (AAA corporate bonds)[13] were collected from Federal Reserve Board time-series data. Rates on money market accounts came from Cost of Savings Index data.[14] Rates on savings accounts were estimated as one half of the rate for money market accounts, based on recent differentials between the return to each of these assets. The rates for stocks are the annual returns on the Standard and Poor's.[15] Rates for mutual funds are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year. DOE assumed rates on checking accounts to be zero.

DOE adjusted the nominal rates to real rates using the annual inflation rate for each year. Average nominal and real interest rates for the classes of household assets are listed in Table 8.2.25. Because the interest and return rates for each type of asset reflect economic conditions throughout numerous years, they are expected to be representative of rates that may be in effect in 2021. For each type, DOE developed a distribution of rates, as shown in appendix 8D.

Table 8.2.25 Average Nominal and Real Interest Rates for Household Equity

Type of Equity	Average Real Rate %
Savings accounts	1.0
Money market accounts	1.9
Certificates of deposit	1.9
Savings bonds	3.4
Bonds	4.2
Stocks	9.4
Mutual funds	7.4

Discount Rate Calculation and Summary

Using the asset and debt data discussed above, DOE calculated discount rate distributions for each income group as follows. First, DOE calculated the discount rate for each consumer in each of the six versions of the *SCF*, using the following formula:

$$DR_i = \sum_j Share_{i,j} \times Rate_{i,j}$$

Eq. 8.4

Where:

DR_i = discount rate for consumer *i*,
$Share_{i,j}$ = share of asset or debt type *j* for consumer *i*, and
$Rate_{i,j}$ = real interest rate or rate of return of asset or debt type *j* for consumer *i*.

The rate for each debt type is drawn from the SCF data for each household. The rate for each asset type is drawn from the distributions described above.

Once the real discount rate was estimated for each consumer, DOE compiled the distribution of discount rates in each survey by income group by calculating the proportion of consumers with discount rates in bins of 1 percent increments, ranging from 0-1 percent to greater than 30 percent. Giving equal weight to each survey, DOE compiled the six-survey distribution of discount rates.

Table 8.2.26 presents the average real effective discount rate and its standard deviation for each of the six income groups. To account for variation among households, DOE sampled a rate for each RECS household from the distributions for the appropriate income group. (RECS provides household income data.) Appendix 8D presents the full probability distributions for each income group that DOE used in the LCC and PBP analysis.

Table 8.2.26 Average Real Effective Discount

Income Group	Discount Rate (%)
1	4.85
2	5.12
3	4.75
4	4.04
5	3.80
6	3.57
Overall Average	4.49

8.2.2.5 Compliance Date of Standard

Pursuant to 42 U.S.C. 6295(m), the compliance date of any new energy efficiency standard for hearth products is 5 years after the final rule is published. Consistent with its published regulatory agenda, DOE assumed that the final rule would be issued by the end of 2015 and that, therefore, the new standards would require compliance beginning in 2021. DOE calculated the LCC and PBP for all consumers considered as if they each would purchase a new hearth product with an intermittent pilot light in 2021.

8.2.2.6 Base Case Distribution of Efficiency Levels

DOE estimated the market share of standing pilots and intermittent pilots in each hearth product group using information from the tear-down analysis (see chapter 5) and consultant input. There is currently not enough publically available data to establish a trend in the adoption of intermittent pilots in hearth products, so the base case market share of each ignition system is projected to be the same through 2021. Table 8.2.27 lists the estimated percentage of intermittent pilot ignition systems by product group. In addition, DOE recognizes that match-lit hearth products comprise a third potential ignition system. These units were excluded from DOE’s analysis as they are not covered in this rulemaking, and provide different functionality than the other systems. However, because they are included in HPBA shipment information, these units were separated by product group to isolate covered products. Table 8.2.28 presents the market shares of match-lit units. The match-lit percentage shown in Table 8.2.28 and the initial disaggregation shown in Table 8.2.27 were used to determine the final base case pilot system distributions, as shown in Table 8.2.29.

Table 8.2.27 Market Shares of Intermittent Ignition in 2021 by Product Group

Product Group	Fraction of Models
Vented Heater	55%
Vented Decorative	55%
Unvented	12%
Vented Gas Log Sets	6%
Unvented Gas Log Sets	6%
Outdoor	24%

Table 8.2.28 Market Shares of Match-Lit Units in 2021 by Product Group

Product Group	Fraction of Models
Vented Heater	5%
Vented Decorative	5%
Unvented	-
Vented Gas Log Sets	50%
Unvented Gas Log Sets	-
Outdoor	50%

Table 8.2.29 Market Shares of Hearth Products Ignition in 2021 by Product Group

Product Group	Intermittent Pilot	Standing Pilot
Vented Heater	58%	42%
Vented Decorative	58%	42%
Unvented	12%	88%
Vented Gas Log Sets	12%	88%
Unvented Gas Log Sets	6%	94%
Outdoor	48%	52%

8.3 PAYBACK PERIOD INPUTS

The PBP is the amount of time it takes the consumer to recover the assumed higher purchase cost of more energy-efficient equipment as a result of lower operating costs. Numerically, the PBP is the ratio of the increase in purchase cost (*i.e.*, from a less efficient design to a more efficient design) to the decrease in first year annual operating expenditures.

The equation for PBP is:

$$PBP = \Delta IC / \Delta OC$$

Eq. 8.5

Where:

PBP = payback period in years,
Δ IC = difference in the total installed cost between the more efficient standard-level equipment and the baseline efficiency equipment, and

ΔOC = difference in first year annual operating costs.

Payback periods are expressed in years. Payback periods can be greater than the life of the equipment if the increased total installed cost of the more efficient equipment is not recovered fast enough in reduced operating costs.

The data inputs to PBP are the total installed cost of the equipment to the consumer for each efficiency level and the annual (first year) operating costs for each efficiency level. The inputs to the total installed cost are the equipment price and the installation cost. The inputs to the operating costs are the annual energy cost, the annualized repair cost, and the annualized maintenance cost (or, in the case of rebuttable PBP, only the annual energy cost). The PBP uses the same inputs as the LCC analysis, except that electricity price trends are not required. Because the PBP is a "simple" payback, the required electricity cost is only for the year in which a new efficient standard is to take effect—in this case, 2021.

8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

As discussed previously, DOE's approach for conducting the LCC and PBP analysis relied on developing samples of households that use each of the considered products. DOE also used probability distributions to characterize the uncertainty in many of the inputs to the analysis. DOE used a Monte Carlo simulation technique to perform the LCC and PBP calculations on the households in the sample.

LCC and PBP calculations were performed 10,000 times on the sample of households established for each residential product. Each LCC and PBP calculation was performed on a single household that was selected from the sample of the residential users. The selection of a household was based on its sample weight (*i.e.*, how representative a particular household is of other households in the distribution—either regionally or nationally), as described in chapter 7. Each LCC and PBP calculation also sampled from the probability distributions that DOE developed to characterize many of the inputs to the analysis.

DOE calculated LCC savings relative to the base case product it assigned to the households. DOE accounted for households that already have intermittent ignition pilots in the base case. For this reason, the average LCC impacts are not equal to the difference between the LCC of the new standard level and the LCC of the baseline product. The calculation of average LCC savings includes households with zero LCC savings (no impact from a standard). DOE considered a household to receive no impact at a given efficiency level if DOE assigned it a base-case product having an efficiency equal to or greater than the efficiency level in question.

Table 8.4.1 and Table 8.4.2 show the LCC and PBP results for all efficiency levels considered for hearth product ignition devices. In Table 8.4.1, the simple payback is measured relative to the baseline product. In Table 8.4.2, the LCC savings are measured relative to the base case efficiency distribution in the compliance year. No impacts occur when the base case efficiency for a specific consumer equals or exceeds the efficiency at a given EL; a standard would have no effect on the individual consumer because the product installed would already have intermittent pilot ignition without amended standards.

Table 8.4.1 Average LCC and PBP Results by Efficiency Level for Hearth Product Ignition Devices

TSL	Efficiency Level	Average Costs 2013$				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	0	$166	$50	$602	$769	--	15.0
1	1	$268	$15	$174	$442	2.9	15.0

Note: The results for each TSL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8.4.2 Average LCC Savings Relative to the Base Case Efficiency Distribution for Hearth Product Ignition Devices

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings* 2013$
1	1	23%	$165

* The calculation includes households with zero LCC savings (no impact).

Figure 8.4.2 shows the range of LCC savings for the efficiency level considered for hearth product ignition devices. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have lifecycle cost savings above this value. The "whiskers" at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for the new standard level.

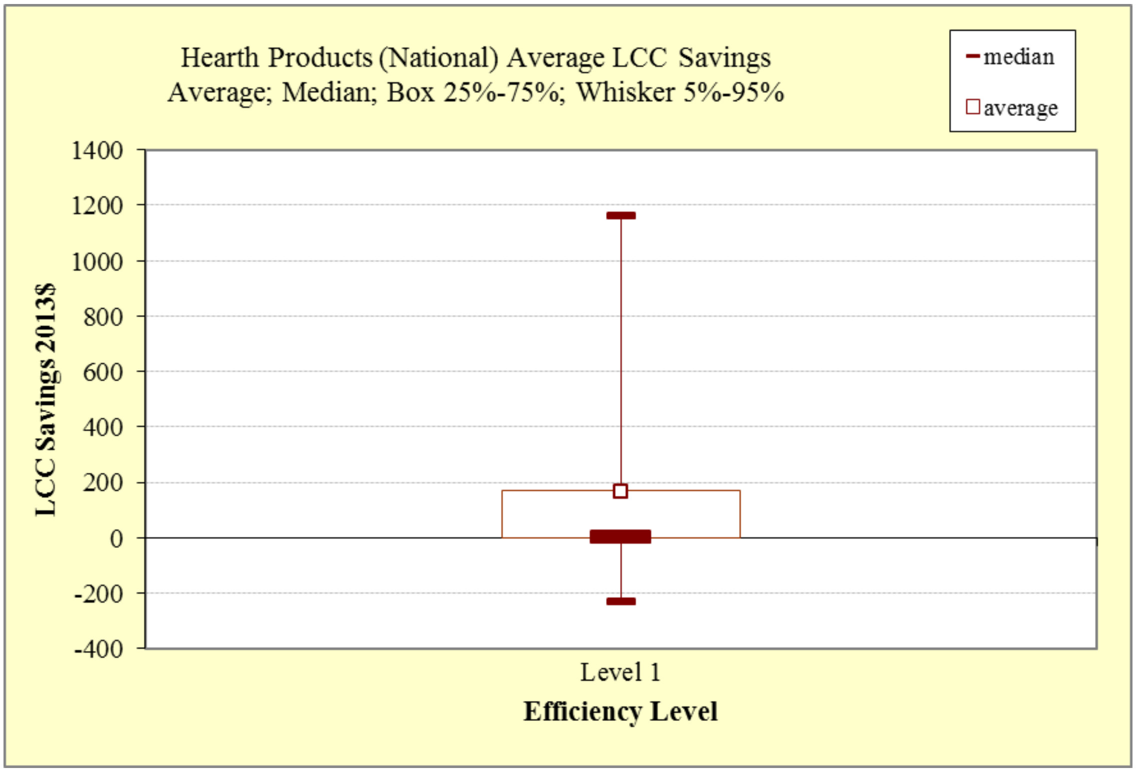

Figure 8.4.2 Distribution of LCC Savings for Hearth Product Ignition Devices

8.5 REBUTTABLE PAYBACK PERIOD

DOE presents rebuttable PBPs to provide the legally established rebuttable presumption that an energy efficiency standard is economically justified if the additional product costs attributed to the standard are less than three times the value of the first-year energy cost savings. (42 U.S.C. §6295 (o)(2)(B)(iii))

The basic equation for rebuttable PBP is the same as that shown for the PBP in section 8.3. Unlike the analyses described in section 8.3, however, the rebuttable PBP is not based on the use of household samples and probability distributions, and it is based not on distributions but on discrete single-point values. For example, whereas DOE uses a probability distribution of energy prices in the distributional PBP analysis, it uses only the national average energy price to determine the rebuttable PBP.

Numerically, the rebuttable PBP is the ratio of the increase in purchase cost (*i.e.*, from a less-efficient design to a more-efficient design) to the decrease in annual energy expenditures; that is, the difference in first year annual energy cost as calculated from the DOE test procedure. Because no DOE test procedure exists for hearth products, the test procedure direct heating equipment (10 CFR 430, subpart B, appendix O) was used to calculate energy use because direct heating equipment are similar secondary heating appliances to hearth products, and in the past the two products shared the same test procedure. The calculation excludes repair costs and maintenance costs.

8.5.1 Inputs

Inputs for the rebuttable PBP differ from the distribution PBP in that the calculation uses discrete values, rather than distributions. Note that for the calculation of distribution PBP, because inputs for the determination of total installed cost were based on single-point values, only the variability and/or uncertainty in the inputs for determining operating cost contributed to variability in the distribution PBPs. The following summarizes the single-point values that DOE used in determining the rebuttable PBP:

- Manufacturing costs, markups, sales taxes, and installation costs were all based on the single-point values used in the distributional LCC and PBP analysis.
- Energy prices were based on national average values for the year that new standards will take effect.
- An average discount rate or lifetime is not required in the rebuttable PBP calculation.
- The effective date of the standard is assumed to be 2021.

8.5.2 Results

DOE calculated rebuttable PBPs for each standard level relative to the distribution of product energy efficiencies estimated for the base case. Table 8.5.1 presents the rebuttable PBPs for hearth product ignition devices.

Table 8.5.1 Rebuttable Payback Period for Hearth Product Ignition Devices

EL	Technology Option	Rebuttable Payback Period *years*
1	Intermittent Pilot	2.31

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CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

Estimates of future product shipments are a necessary input to calculations of the national energy savings (NES) and net present value (NPV), as well as to the manufacturer impact analysis (MIA). This chapter describes the data and methods the U.S. Department of Energy (DOE) used to project annual product shipments and presents results for hearth product types considered in this analysis.

The shipments model divides the shipments of hearth products into specific market segments. The model starts from a historical base year and calculates retirements and shipments by market segment for each year of the analysis period. This approach produces an estimate of the total product stock, broken down by age or vintage, in each year of the analysis period. In addition, the product stock efficiency distribution is calculated for the base case and for each standards case for each product class. The stock distribution is used in the national impact analysis (NIA) to estimate the total costs and benefits associated with each efficiency level.

The shipments model was developed as a Microsoft Excel spreadsheet that is accessible on DOE's Appliance and Commercial Equipment Standards website (www1.eere.energy.gov/buildings/appliance_standards/product.aspx?productid=83). Appendix 10A discusses how to access and utilize the shipments model spreadsheet, which is integrated into the spreadsheet for the NIA. This chapter explains how the shipments model is constructed and provides some summary output. Sections 9.2 through 9.5 describe the methodological approach.

9.2 FUNDAMENTAL MODEL EQUATIONS

The fundamental dependent variable in the shipments model is the product stock, which is represented as a function of analysis year (indexed by *j)*, and product vintage or age (the product age is noted as *a*, and is equal to the analysis year minus the vintage). The stock function is adjusted in each year of the analysis period by new shipments coming in and broken or demolished products being taken out.

For existing stock:

$$Stock(j,a) = Stock(j-1,a-1) - Rem(j,a) + Ship(j-1,a-1)$$

Eq. 9.1

and for new shipments:

$$Stock(j,a=1) = Ship(j-1)$$

Eq. 9.2

Where:

Stock (j, a) = number of units of age *a* in analysis year *j*,
Rem (j, a) = number of units of age *a* removed in analysis year *j*, and
Ship(j) = number of units of shipped in year *j*.

Removals due to product failure contain a survival function $f_p(a)$ that is used to represent the probability that a unit of age *a* will survive in a given year; equivalently, the probability that this unit will fail is 1- $f_p(a)$.

Total removals in the base case are then:

$$Rem(j,a) = \lfloor 1 - f_p(a) \rfloor \times Stock(j,a)$$

Eq. 9.3

9.3 DATA INPUTS

The primary data inputs to the hearth products shipments model are the historical hearth products shipments data, and historical and projected housing starts.

9.3.1 Historical Shipments

DOE used historical shipments data to populate its shipments model for hearth products. DOE used historical shipment data provided by the Hearth, Patio and Barbecue Association (HPBA)[1] for all hearth products between 2005 and 2013. Table 9.3.1 shows the initial shipments data provided by HPBA, which includes all hearth products.

Table 9.3.1 HPBA Shipments Data

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Shipments(millions)	1.54	1.184	1.027	0.715	0.421	0.443	0.385	0.397	0.534

DOE also estimated additional shipments from non-HPBA members. The magnitude of these non-HPBA shipments was determined to be equal to the HPBA shipments for outdoor units. However, the HPBA shipments do not include patio heaters, which are a type of outdoor hearth product. To account for all patio heaters shipments, DOE determined the number of patio heater models based on the HPBA-member hearth product model data and comments received from manufacturers during manufacturer interviews. DOE then applied a three-to-one ratio between non-HPBA and HPBA shipments to develop the total patio heater shipments. In total, patio heater shipments account for an additional 9 percent of hearth product shipments relative to the HPBA member hearth products shipments. DOE added these shipments to the data HPBA provided to determine final shipment values. Finally, through manufacturer interviews and analysis of the HPBA model database, DOE determined the fraction of match-lit units for each hearth product group, which was subtracted from the hearth product shipments. HPBA also provided market shares of each hearth product group relative to all hearth products. Because HPBA provided a range for the market shares, DOE used the midpoint of this range. Table 9.3.2 lists the disaggregated shipments data provided by HPBA, the value DOE determined, the match-lit units by product group, and the final base case market share relative to all hearth products.

Table 9.3.2 Hearth Products Shipments Disaggregated by Product Group

Product Group	HPBA-only Shipment Data (%)	All Hearth Products Shipments* (%)	Match-Lit Shipments (%)	Final Base Case Disaggregation (%)
Vented Fireplace	47 to 73	56.2	5	62
Unvented Fireplace	2 to 7	4.4	0	5
Vented Gas Logs	3 to 10	6.1	50	4
Unvented Gas Logs	16 to 23	18.3	0	21
Outdoor	4 to 9	15.0	50	9

* Includes match-lit units and non-HPBA hearth product shipments

The base case market shares are used to determine the yearly shipments for each hearth product group. In the analysis period (2021-2050), these market shares by product group are assumed to remain constant in the base case, as DOE does not have evidence of a change in the trend of market shares. Figure 9.3.1 and Table 9.3.3 show the historical hearth products shipments used in the analysis, including non-HPBA shipments and excluding match-lit shipments.

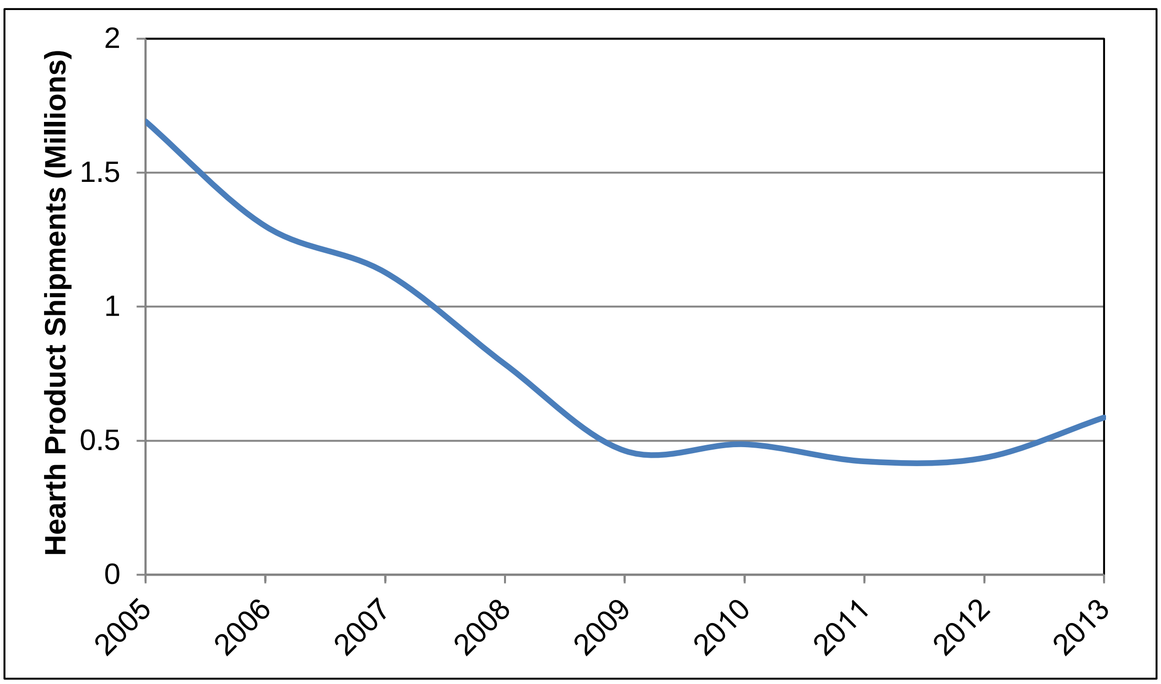

Figure 9.3.1 Historical Shipments of Hearth Products, 2005-2013

Table 9.3.3 Historical Hearth Product Shipments

	2005	2006	2007	2008	2009	2010	2011	2012	2013
Shipments (millions)	1.69	1.30	1.13	0.785	0.462	0.487	0.423	0.436	0.586

9.3.2 Historical and Projected Housing Starts

DOE used projected housing starts to estimate the shipments of hearth products. DOE determined new residential housing starts by using Census data through 2013[2] and projections from the Energy Information Administration's (EIA) *Annual Energy Outlook 2014* (*AEO 2014*).[3] Figure 9.3.2 shows *AEO 2014* historical data as well as projections of housing starts through 2040.

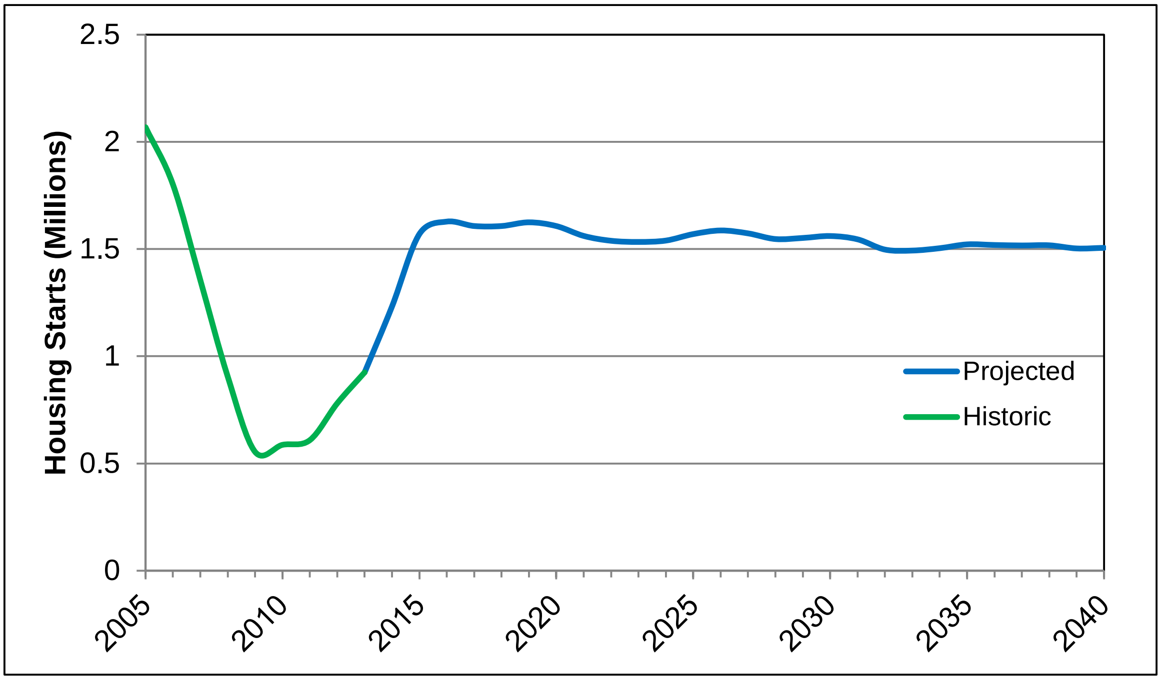

Figure 9.3.2 Historical and Projected Housing Starts

9.3.3 Calculation of the Fraction of New Construction Homes with Hearth Products

DOE estimated the new construction fraction by using historical hearth products shipments data and the number of gas fireplaces in newer homes from EIA's 2009 Residential Energy Consumption Survey (RECS 2009) data.[4] RECS 2009 data shows that there are 1.068 million homes built from 2005-2009 with vented and ventless gas fireplaces, which are the hearth products most likely to be installed in a new construction home. DOE assumed that these households would on average have 1.2 gas fireplaces per home[5] and that only half of the homes built in 2009 were surveyed in RECS 2009. This resulted in 1.335 million gas fireplaces in homes built between 2005 and 2009. During this same period there were 5.367 million hearth products shipped (see Table 9.3.3). This resulted in 25 percent market share for hearth products in new construction.

9.4 IMPACT OF STANDARDS ON SHIPMENTS

Consumer purchase decisions are influenced by the purchase price and operating cost of the product, and therefore may be different in the base case and under the standard case. These decisions are modeled by estimating the purchase price elasticity for hearth products. The purchase price elasticity is defined as the change in the percentage of consumers acquiring a hearth product divided by a change in the *relative price* (defined below) for that product. This elasticity, along with information obtained from the life-cycle cost (LCC) and payback period (PBP) analysis on the change in purchase price and operating costs at different ELs, are used in the shipments model to estimate the change in shipments under standards at different ELs.

9.4.1 Purchase Price Elasticity

DOE conducted a literature review and an analysis of appliance price and efficiency data to estimate the combined effects on product shipments from increases in product purchase price, decreases in product operating costs, and changes to household income. Appendix 9A provides a detailed explanation of the methodology DOE used to quantify the impacts from these variables.

Existing studies of appliance markets suggest that the demand for appliances is price-inelastic. Other information in the literature suggests that appliances are a normal good, so that rising incomes increase the demand for appliances, and that consumer behavior reflects relatively high implicit discount rates[a] when comparing appliance prices and appliance operating costs.

DOE used the available data for the period 1980-2002 on large appliance purchases to evaluate broad market trends and conduct simple regression analyses. These data indicate that there has been a rise in appliance shipments and a decline in appliance purchase price and operating costs over the time period. Household income has also risen during this time. Because purchase decisions are sensitive to income, as well as to potential savings in the operating cost of the appliance, DOE combined the available economic information into one variable, termed the *relative price*. This variable was used in a regression analysis to parameterize historical market trends. The relative price is defined with the following expression:

$$RP = \frac{TP}{Income} = \frac{PP + PVOC}{Income}$$

Eq. 9.4

Where:

RP = relative price,
TP = total price,

Income = household income,
PP = appliance purchase price, and
PVOC = present value of operating cost.

In Eq. 9.4, DOE used real prices, as opposed to nominal, and an implicit discount rate of 37 percent to estimate the present value of operating costs. The rate of 37 percent is based on a survey of several studies of different appliances that suggests that the consumer implicit discount rate has a broad range and averages about 37 percent.[6]

DOE's regression analysis suggests that the relative price elasticity of demand is -0.34. This implies that a relative price increase of 10 percent results in a 3.4 percent decrease in shipments. Note that the relative price elasticity incorporates the impacts from purchase price, operating cost, and household income, so the impact from any single effect can be mitigated by changes in the other two effects.

The relative price elasticity of -0.34 is consistent with estimates in the literature. Nevertheless, DOE stresses that the measure is based on a small data set, using simple statistical analysis. More importantly, the measure is based on an assumption that economic variables, including purchase price, operating costs, and household income, explain most of the trend in appliances per household in the United States since 1980. Changes in appliance quality and consumer preferences may have occurred during this period, but DOE did not account for them in this analysis. Despite these uncertainties, DOE believes that its estimate of the relative price elasticity of demand provides a reasonable assessment of the impact that purchase price, operating cost, and household income have on product shipments.

Because projections of shipments and national impacts attributable to standards are calculated for a lengthy time period, DOE needed to consider how the *relative price* elasticity is affected after a new standard takes effect. DOE considered the *relative price* elasticity, described above, to be a short-term value. It was unable to identify sources specific to household durable goods, such as appliances, to indicate how short-run and long-run price elasticities differ. Therefore, to estimate how the *relative price* elasticity changes over time, DOE relied on a study pertaining to automobiles.[7] This study shows that the automobile price elasticity of demand changes in the years following a purchase price change, becoming smaller (more inelastic) until it reaches a terminal value around the tenth year after the price change. Table 9.4.1 shows the relative change in the price elasticity of demand for automobiles over time. DOE developed a time series of relative price elasticities based on the relative change in the automobile price elasticity of demand. For years not shown in Table 9.4.1, DOE performed a linear interpolation to obtain the relative price elasticity.

Table 9.4.1 Change in Relative Price Elasticity Following a Purchase Price Change

	Years Following Price Change					
	1	**2**	**3**	**5**	**10**	**20**
Relative Change in Elasticity to 1st year	1.00	0.78	0.63	0.46	0.35	0.33
Relative Price Elasticity	-0.34	-0.26	-0.21	-0.16	-0.12	-0.11

9.4.2 Impact from Increase in Relative Price

Using the relative price elasticity, DOE was able to estimate the impact of the increase in relative price from a particular standard level. The impact, as shown in the equation below, is expressed as a percentage drop in market share for each year, dMS^p_j.

$$dMS_j^p = \left[1 - \left(\frac{RP\_std_p(j)}{RP\_base_p(j)}\right)\right] \times e_{RP}(j)$$

Eq. 9.5

Where:

dMS^p_j = percentage market share drop for class p, year j,
$RP\_std_p(j)$= relative price in the standards case for product group p, year j,
$RP_p(j)$= relative price in the base case for product group p, year j, and
$e_{RP}(j)$ = relative price elasticity in year j.

The model calculates the relative percentage market drop, dMS^p_j, due to the product price increase from a particular standard level.

9.5 MODELING APPROACH

For the years where hearth product shipments data are available (2005-2013), DOE found that historical shipments and new housing starts were highly correlated.[b] DOE believes this correlation reflects the relationship between hearth product installations in new homes, and is also because housing starts and hearth products shipments are both sensitive to the broader housing market and general economic activity. DOE applied this correlation to all hearth products shipments. The correlation coefficient (*Correl*) is determined as in the equation below. Figure 9.5.2 shows the historical correlation of hearth product shipments and housing starts, normalized for the average magnitude differences.[c] The correlation factor is calculated as:

[b] Historical shipments and new housing starts had a correlation factor of 0.98 (where 1 indicates perfect correlation).

[c] Because the graph in Figure 9.5.2 is a normalized representation of the relationship between hearth product shipments and housing starts, it contains unit-less quantities.

$$Correl(X,Y) = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sum(x-\bar{x})^2(y-\bar{y})^2}$$

Eq. 9.6

Where:

Correl(X,Y) = the correlation factor between *X* and *Y*,
X = a set of data being correlated,
Y = a set of data being correlated,
x = an element of set *X*,
y = an element of set *Y*,
$\bar{x}$ = the global average of set *X*, and
$\bar{y}$ = the global average of set *Y*.

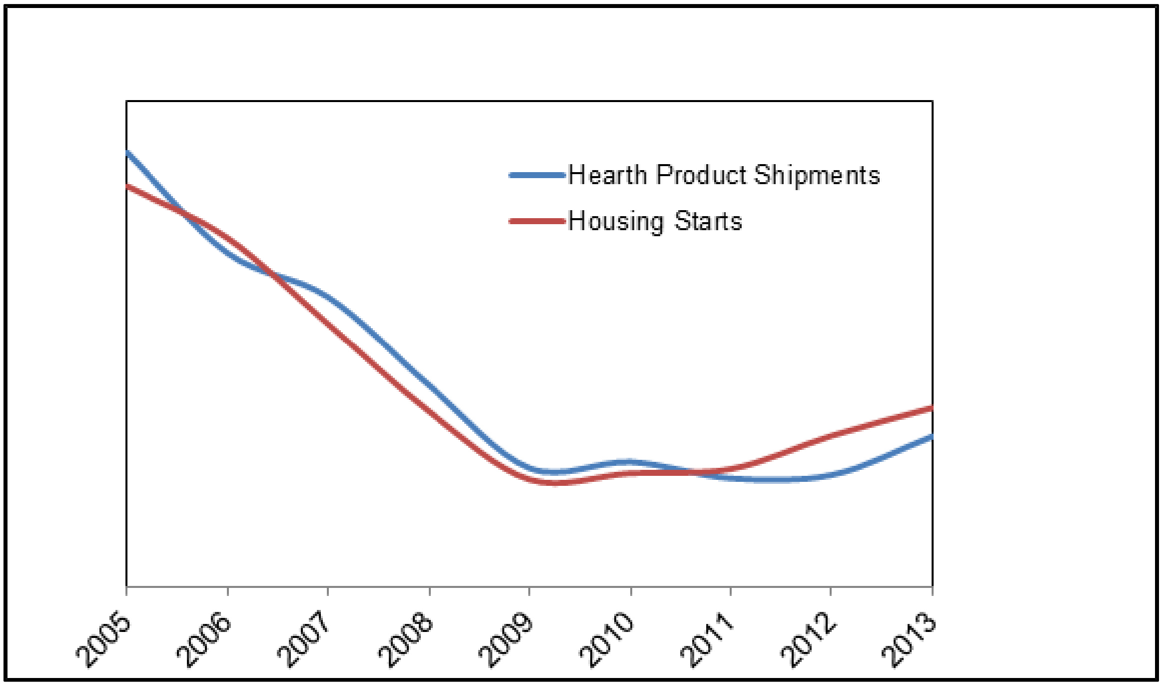

Figure 9.5.2 Normalized Historical Data of Hearth Product Shipments and Housing Starts

For the years between 2040 and 2050, for which *AEO 2014* does not provide projected housing start data, DOE used a trailing 10-year average of housing starts to estimate housing starts during this period. This approach emphasizes more recent values and preserves the cyclical nature observed in historical trends.

The average ratio of hearth product shipments to housing starts from 2005-2013 is 0.754 (see Table 9.5.1). This ratio is multiplied by the yearly projected housing starts in the years 2014-2050, as shown in Figure 9.3.2, and the overall fraction of non-match-lit shipments to obtain the total projected hearth products shipments for these years ($SHP_{Proj,total}(j)$):

$$SHP_{Proj,total}(j) = 0.754 * HS_{Proj}(j) * ML$$

Eq. 9.7

Where:

0.754 = historical ratio of housing starts to hearth products shipments,
HS_{Proj} = projected housing starts in year (j), and
ML = historical Fraction of non-match-lit hearth products shipments, determined to be 86.64 percent.

Table 9.5.2 Calculation of Fraction of Hearth Product Shipments to Housing Starts

Year	Housing Starts*	Hearth Product Shipments**	Calculated Fraction
2005	2.068	1.691	0.818
2006	1.801	1.300	0.722
2007	1.355	1.128	0.832
2008	0.906	0.785	0.867
2009	0.554	0.462	0.835
2010	0.587	0.487	0.829
2011	0.609	0.423	0.695
2012	0.781	0.436	0.559
2013	0.925	0.586	0.634
		Average	**0.754**

* Based on Census data through 2013.[2] See section 9.3.2.
** Based on HPBA shipments data.[1] See section 9.3.1.

To calculate the yearly projected shipments for each hearth product group, $SHP_{Proj,total}$ is multiplied by the market share of that group and the yearly price elasticity value in the standards case, as below:

$$SHP_{Proj,group}(i,j) = SHP_{Proj,total}(j) * MS(i,j) * PE(i,j)$$

Eq. 9.1

Where:

$SHP_{Proj,group}(i,j)$ = projected hearth products shipments for product group *i* in year *j*,
MS(j,i) = market share as a percent of product group *i* of the total hearth product shipments in year *j*, and
PE(j,i) = price elasticity of product group *i* in year *j*. *PE* = 1 in the base case, and is equal to (1-dMS_j^p) in the standard case as calculated in Eq. 9.5.

9.6 RESULTS

As detailed in chapter 10, DOE created a trial standard level (TSL) that adopts intermittent pilot ignition for all product groups. Table 9.6.1 shows the analyzed TSL.

Table 9.6.1 Trial Standard Levels for Hearth Product Ignition Devices

Product Class	TSL	Description
Hearth Products	1	Adoption of Intermittent Pilot Ignition

Figure 9.6.1 shows the historical and projected shipments for hearth products. The shipments of hearth products decline after 2005 due to the economic recession. Shipments bottom in 2011- 2012, and recovery begins in 2013, when shipments increased by 36 percent compared to 2012. The increase in shipments correlates directly with an increase in housing starts and is expected to continue the trend as the economy continues to recover. Hearth product shipments are projected to recover to near pre-recession levels by 2021, which is the compliance year of the standard, and are expected to continue to closely correlate with the relatively stable housing start projections through 2050. The shipments data and the market shares of each product group are primary inputs into the NIA analysis, which is described in chapter 10. Figure 9.6.2 shows each hearth product group's projected market share under the proposed standard. Figure 9.6.3 shows each hearth product group's total shipments in the base case and in the standards case.

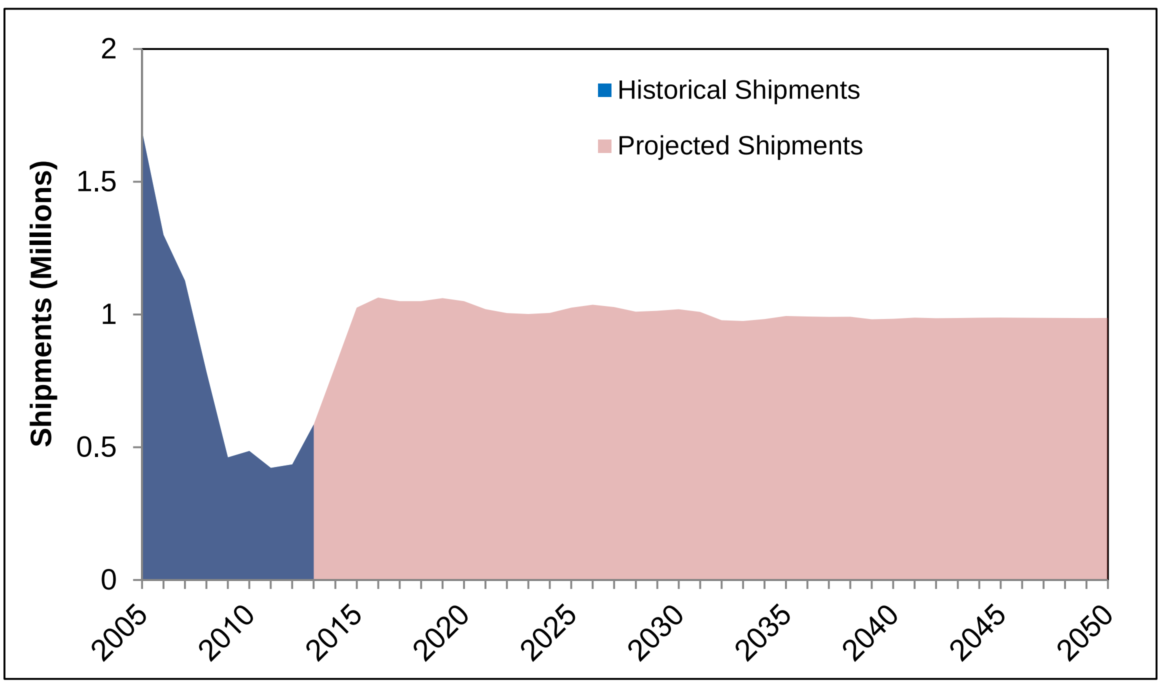

Figure 9.6.1 Historical and Projected Base Case Shipments of Hearth Products

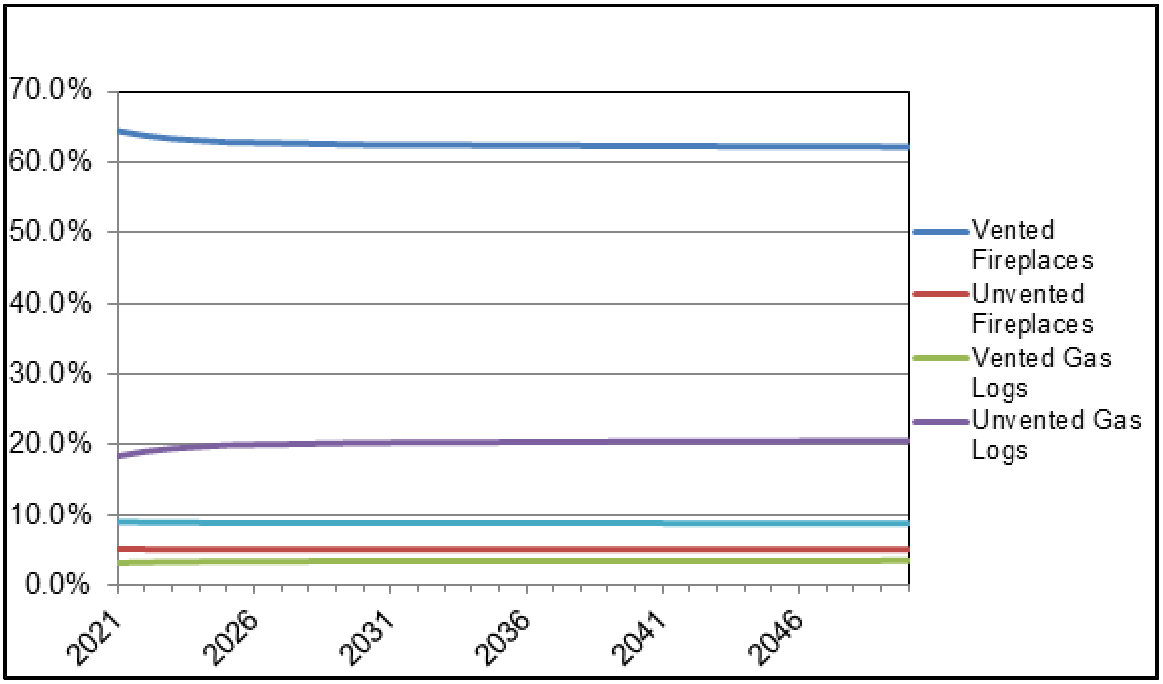

Figure 9.6.2 Projected Hearth Products Groups Market Shares, 2021-2050

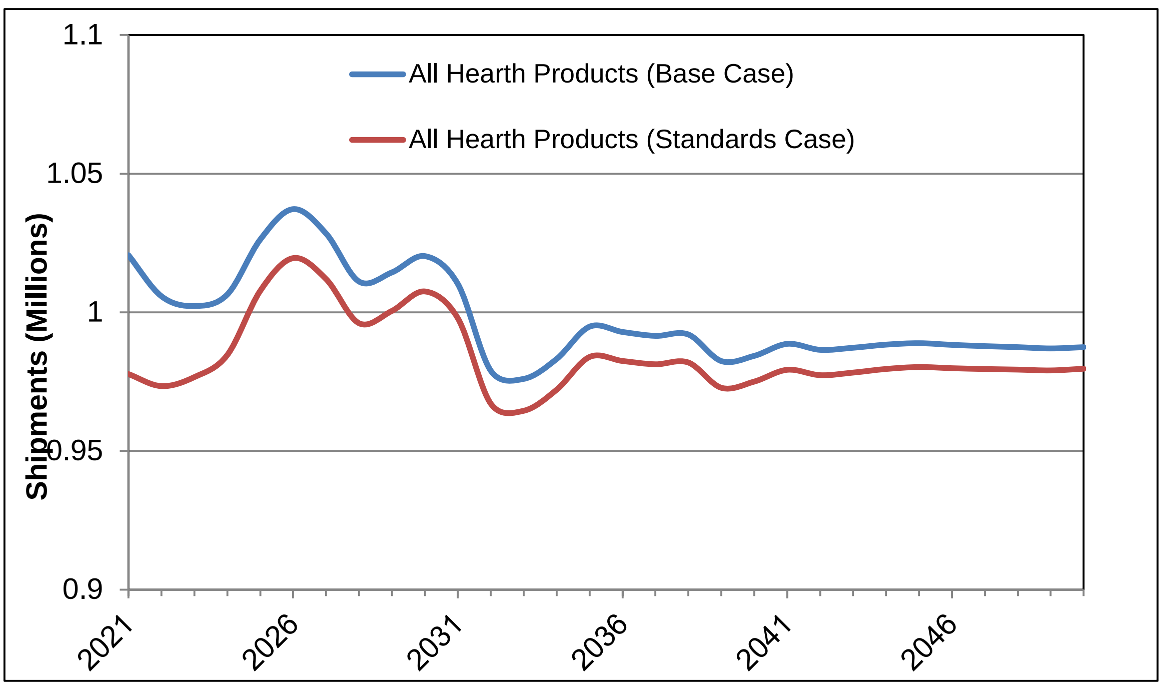

Figure 9.6.3 Hearth Products Shipments in Base Case and Standards Case, 2021-2050

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CHAPTER 10. NATIONAL IMPACT ANALYSES

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CHAPTER 10. NATIONAL IMPACT ANALYSES

10.1 INTRODUCTION

This chapter examines selected national impacts attributable to each trial standard level (TSL) considered for hearth product ignition systems. The results presented here include: (1) national energy savings (NES); (2) operating cost savings; (3) increased total installed costs; and (4) the net present value (NPV) of the difference between the value of operating cost savings and increased total installed costs.

The calculations were performed using a Microsoft Excel spreadsheet model, which is accessible on the Internet (www1.eere.energy.gov/buildings/appliance_standards/product.aspx?productid=83). The spreadsheet model, termed the National Impact Analysis (NIA) model, calculates energy savings and NPV for the nation. Details regarding and instructions for using the NIA model are provided in appendix 10A.

The NIA model incorporates the shipments model that DOE used to project future purchases of hearth products.

10.2 TRIAL STANDARD LEVELS

For hearth products, there are currently two dominant ignition systems on the market, standing pilots and intermittent pilot ignitions. Standing pilot ignitions are the baseline technology for hearth product ignition devices. Trial standard level (TSL) 1 consists of the technology option of intermittent pilot ignitions for all hearth product groups (Table 10.2.1).

Table 10.2.1 Trial Standard Levels for Hearth Product Ignition Systems

Product Class	TSL 1
Hearth Product	Adoption of Intermittent Pilot

10.3 OVERVIEW OF THE NATIONAL IMPACTS ANALYSIS

10.3.1 National Energy Savings

DOE calculates annual national energy savings (NES) as the difference between two projections: the base case (without new standards) and a standard case (with a new standard). The calculation of annual nation energy savings (NES_y) are represented by the following expression:

$$NES_y = AEC_{natl-base} - AEC_{natl-std}$$

Eq. 10.1

Cumulative energy savings are the sum of each annual *NES* over the lifetime of products shipped in the period that extends from a standard's assumed compliance date for 30 years. This calculation is represented by the following equation:

$$NES_{cum} = \sum NES_y$$

Eq. 10.2

DOE calculated *AEC* by multiplying the number or stock of a given product (by vintage) by its unit energy consumption (also by vintage). The calculation of the national and each regional *AEC* is represented by the following equation:

$$AEC = \sum STOCK_V \times UEC_V$$

Eq. 10.3

Where:

AEC = annual energy consumption each year for the Nation in quadrillion British thermal units (Btus), or quads, summed over vintages of the product stock, $STOCK_V$,
NES_y = national annual energy savings (quads),
NES_{cum} = national cumulative energy savings (quads),
$STOCK_V$ = stock of product (millions of units) of vintage *V* that survive in the year for which DOE calculated annual energy consumption,
UEC_V = annual energy consumption per product in kilowatt-hours (kWh); electricity consumption is converted from site energy to power plant energy (quads) by applying a time-dependent conversion factor,
natl = designates the quantity corresponding to the Nation,
base = designates the quantity corresponding to the base case,
std = designates the quantity corresponding to the standard case,
y = year in the projection,
cum = cumulative over the projection period, and
V = year in which the product was purchased as a new unit.

The stock of products depends on annual shipments and the lifetime of the given product. As described in chapter 9, DOE projected shipments for the base case and the standard case.

10.3.2 Net Present Value of Consumer Benefit

The NPV is the value in the present of a time-series of costs and savings. The NPV is described by the equation:

$$\boldsymbol{NPV = PVS - PVC}$$

Eq. 10.4

Where:

PVS = present value of savings in operating cost (including costs for energy, repair, and maintenance), and
PVC = present value of increase in total installed cost (including costs for product and installation).

DOE determined the PVS and PVC according to the following expressions:

$$PVS = \sum OCS_y \times DF_y$$

Eq. 10.5

$$PVC = \sum TIC_y \times DF_y$$

Eq. 10.6

DOE calculated the total annual savings in operating cost by multiplying the number or stock of a given product (by vintage) by its per-unit operating cost savings (also by vintage). DOE calculated the total annual increase in installed cost by multiplying the number or stock of a given product (by vintage) by its per-unit total installed cost increase (also by vintage). Total annual savings in operating cost and increases in installed cost are calculated using the following equations.

$$OCS_y = \sum STOCK_V \times UOCS_V$$

Eq. 10.7

$$TIC_y = \sum STOCK_V \times UTIC_V$$

Eq. 10.8

Where:

OCS = total annual savings in operating cost each year summed over vintages of the product stock, $STOCK_V$,
TIC = total annual increase in installed cost each year summed over vintages of the product stock, $STOCK_V$,
DF =discount factor in each year,
$STOCK_V$ = stock of product (millions of units) of vintage V that survive in the year for which DOE calculated annual energy consumption,
$UOCS_V$ = annual per-unit savings in operating cost,
$UTIC_V$ = annual total per-unit increase in installed cost,
V = year in which the product was purchased as a new unit, and
y = year in the projection.

DOE determined the *PVC* for each year from the compliance date of the standard through 2050. DOE determined the *PVS* for each year from the compliance date of the standard until the year when units purchased in 2021−2050 retire. DOE calculated costs and savings as the difference between the standard case and the base case.

DOE calculated a discount factor from the discount rate and the number of years between the "present" (2014, the year to which the sum is being discounted) and the year in which the costs and savings occur. The NPV is the sum over time of the discounted net savings.

10.4 PROJECTED EFFICIENCY TRENDS

A key component of the NIA is the distribution of hearth product ignition systems projected over time for the base case (without the new standard) and for the standard case (with the potential new standard).

DOE developed a distribution of ignition system technologies in the base case for 2021 (the assumed compliance date for the new standard), as described in chapter 8. DOE did not have sufficient data to establish a trend of adoption of intermittent pilot units. Therefore, DOE assumed constant distributions for the ignition systems in the base case.

In the standard case, DOE assumed a "roll-up" scenario to establish the distribution for 2021. Products in the base case that did not meet the standard under consideration would "roll up" to meet the new standard level (Table 10.4.1). After the compliance year, the distribution remains constant.

Table 10.4.1 Hearth Products: Ignition System Distributions for the Base and Standards Cases in 2021

Product Group	Market Share (percent)			
	Base Case		TSL 1	
	Standing Pilot	Intermittent Ignition	Standing Pilot	Intermittent Ignition
Vented Fireplaces	42	58	0	100
Unvented Fireplaces	88	12	0	100
Vented Gas Logs	87	13	0	100
Unvented Gas Logs	94	6	0	100
Outdoor	52	48	0	100
All Hearth Products	58	42	0	100

10.5 NATIONAL ENERGY SAVINGS

The inputs for calculating national energy savings are:

- average annual energy consumption per unit (*UEC*),

- shipments,
- product stock ($STOCK_V$),
- annual energy consumption for the Nation (*AEC*), and
- power plant primary energy use factor (*src_conv*).

10.5.1 Annual Energy Consumption per Unit

For hearth product ignition devices, DOE presented the per-unit annual energy consumption as a function of product efficiency in chapter 7, Energy Use Analysis. DOE used the shipments-weighted energy consumption of the base and standard cases presented in section 10.4, along with the annual energy use data presented in chapter 7, to estimate the shipment-weighted average annual per-unit energy consumption (UEC) under the base and standard cases.

Table 10.5.1 presents the base case and standard case shipment-weighted annual UECs for hearth product ignition devices in 2021. Due to the constant product group market shares and ignition system distribution in each case, the annual energy use remains the same throughout the analysis period.

Table 10.5.1 Average Annual Hearth Product Ignition System Energy Use for the Base and Standard Cases in 2021

Product Group	Standing Pilot		Intermittent Pilot	
	Fuel Use (MMBtu/yr)	**Elec Use** (kWh/yr)	**Fuel Use** (MMBtu/yr)	**Elec Use** (kWh/yr)
Vented Fireplaces	3.99	0.000	0.499	13.60
Unvented Fireplaces	3.52	0.000	1.30	99.38
Vented Gas Logs	3.13	0.000	0.289	5.79
Unvented Gas Logs	2.29	0.000	0.924	70.61
Outdoor	3.91	0.000	0.000	0.175
All Hearth Products	3.58	0.000	0.579	28.54

DOE also considered the effects of changes in climate and building shell efficiency on the building heating load (BHL) of the hearth product, which determines the operating hours of the hearth product and ignition system and consequent energy use of the hearth product ignition system. The climate adjustment factor, which is based on the forecast of heating degree days (HDD) by region from *Annual Energy Outlook 2014* (*AEO 2014*),[1] shows a declining trend due to warmer weather. Regional building shell efficiency factors are also from *AEO 2014.* For both factors, DOE applied regional weights to make the factors specific to users of hearth products. Figure 10.5.1 shows the adjustment factor for hearth product ignition system energy use.

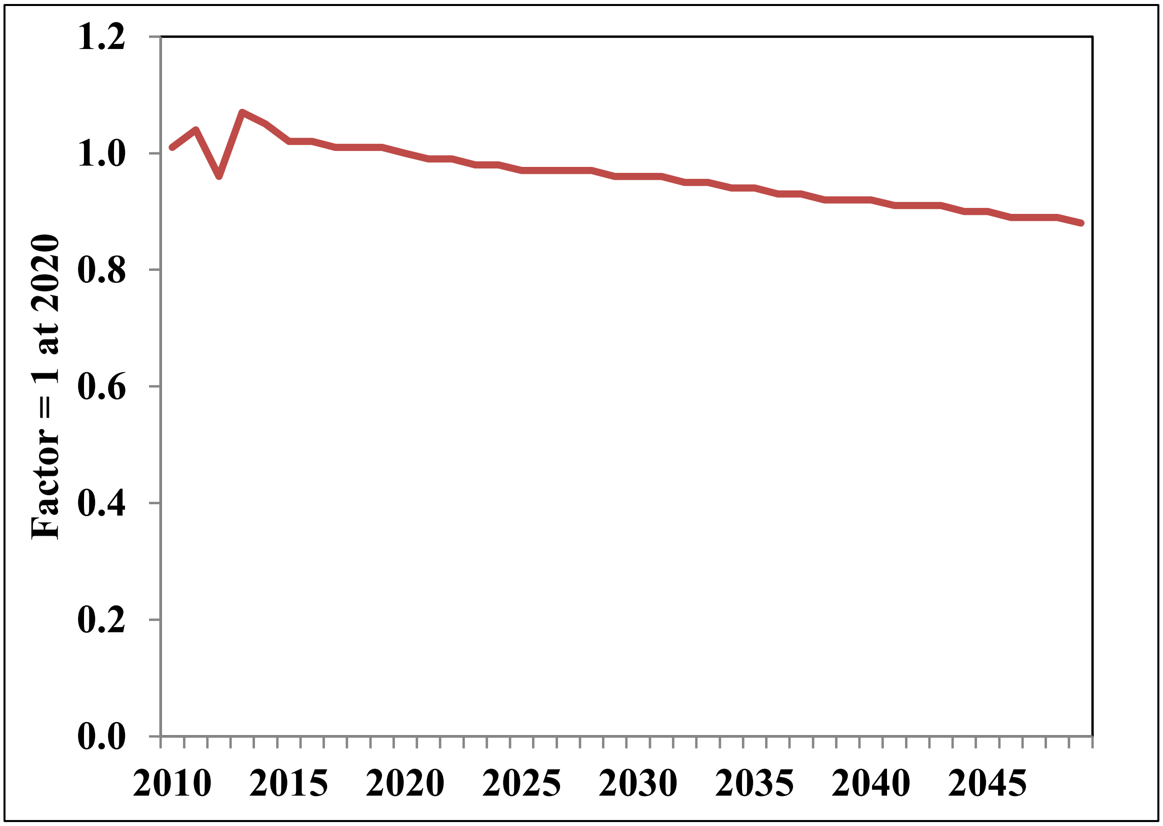

Figure 10.5.1 Combined Adjustment Factor for Hearth Products Energy Use

10.5.2 Shipments

DOE projected shipments for each product group under the base case and standard case (see chapter 9). These shipments are used in conjunction with the LCC results to calculate national impacts from the standard, such as the NES and the NPV. Several factors impact projected shipments, including total installed costs, operating cost, household income, and equipment lifetime. As noted earlier, the increased total installed cost of more-efficient products is expected to cause some consumers to forgo product purchases. Consequently, shipments projected under the standard case are lower than under the base case. DOE believes it would be inappropriate to count energy savings that result from reduced shipments due to a standard. Therefore, DOE did not calculate annual energy consumption for the base case using the base case shipments projection. Instead, for each comparison of a standard case with the base case, DOE used shipments associated with that particular standard case. As a result, all of the calculated energy savings are due to lower energy consumption in the standard case.

10.5.3 Product Stock

The stock of product in any given year depends on annual shipments and the lifetime of a given product class. The NIA model keeps track of the number of units shipped each year. The lifetime of a unit determines how many units shipped in previous years survive in the given year.

DOE assumes that products have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is termed the survival function. Refer to chapter 8 for further details on the survival functions that DOE used in its analysis.

10.5.4 Annual Energy Consumption

For each product group, DOE calculated the total national site (*i.e.*, the energy consumed at the household or establishment) annual energy consumption (AEC). Total annual energy consumption is the product of the AEC per unit (also termed the unit energy consumption (UEC)) and the number of units of each vintage. This method accounts for differences in UEC from year to year.

10.5.5 Site-to-Power Plant Energy Use Factor

For hearth products, the considered TSL increases electricity use. DOE calculated primary energy use (power plant consumption) from site electricity use by applying a factor to account for losses associated with the generation, transmission, and distribution of electricity. DOE derived annual average site-to-power plant factors based on the version of the National Energy Modeling System (NEMS) that corresponds to *AEO 2014*. The factors change over time in response to projected changes in the types of power plants projected to provide electricity to the country. Figure 10.5.2 shows the site-to-power plant factors from 2021 to 2040. For years after 2040 (the last year in the AEO), DOE maintained the 2040 value.

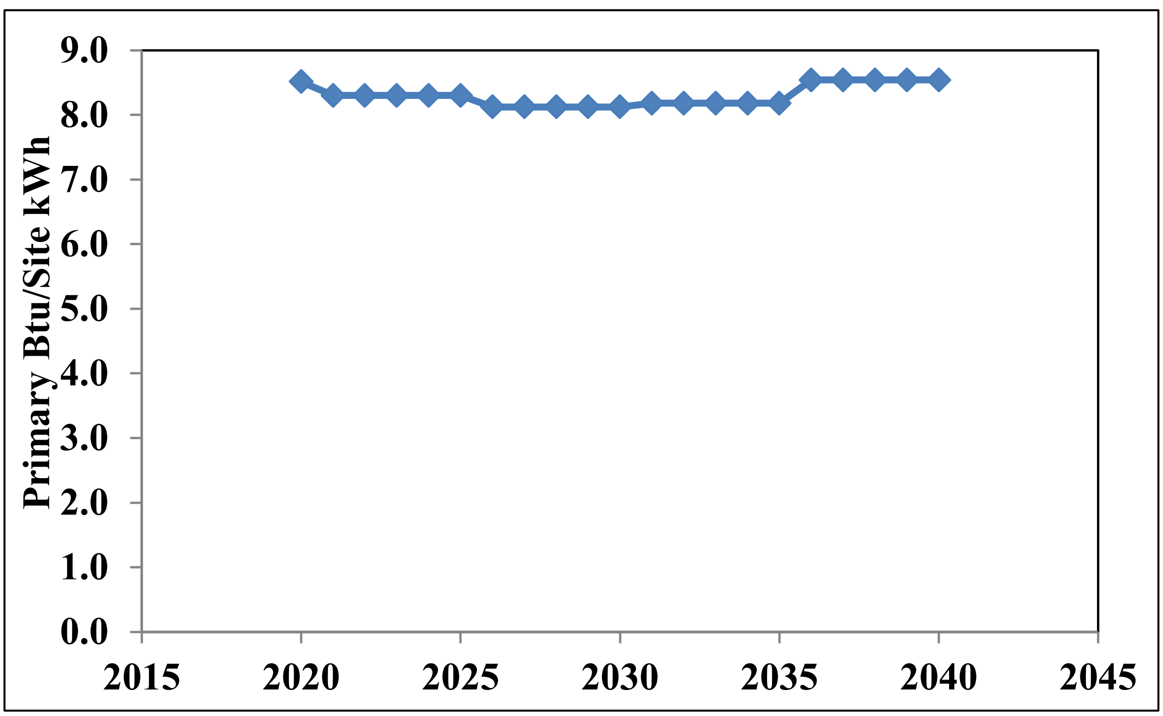

Figure 10.5.2 Primary to Site Energy Use Factor for Hearth Product Electricity Use

10.5.6 Full-Fuel-Cycle Energy Factors

The full-fuel-cycle (FFC) measure includes point-of-use (site) energy, the energy losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels. To complete the full-fuel-cycle by encompassing the energy consumed in extracting, processing, and transporting or distributing primary fuels, which are referred to as "upstream" activities, DOE developed multipliers using the data and projections generated by the National Energy Modeling System (NEMS) used for *AEO 2014*. The AEO provides extensive information about the energy system, including projections of future oil, natural gas and coal supply, energy use for oil and gas field and refinery operations, and fuel consumption and emissions related to electric power production. This information can be used to define a set of parameters representing the energy intensity of energy production. The method used to calculate FFC energy multipliers is described in appendix 10B.

Table 10.5.2 shows the upstream energy multipliers used for hearth products for selected years. The multipliers are applied to site energy. For years after 2040 (the last year in the AEO), DOE maintained the 2040 value.

Table 10.5.2 Upstream Energy Multipliers (Based on AEO 2014)

	2021	2025	2030	2035	2040	2045	2050
Electricity	1.044	1.045	1.046	1.047	1.047	1.047	1.047
Natural Gas	1.110	1.111	1.113	1.114	1.114	1.114	1.114

10.6 NET PRESENT VALUE OF CONSUMER BENEFITS

Listed below are the inputs to DOE's calculation of the NPV of costs and savings.

- Total installed cost per unit,
- annual per-unit savings in operation cost,
- shipments,
- product stock ($STOCK_V$),
- total annual increases in installed cost (*TIC*),
- total annual operating cost (*OCS*),
- discount factor (*DF*),
- present value of costs (*PVC*), and
- present value of savings (*PVS*).

The *total annual increase in installed cost* is equal to the annual change in the total per-unit installed cost (difference between the base case and standard case) multiplied by the shipments projected for each TSL. As with calculating energy savings, DOE did not use base-case shipments to calculate total annual installed costs for all of the product groups. DOE used the projected shipments and stock for each TSL to calculate costs.

The annual operating cost includes energy, repair, and maintenance costs. The *total annual savings in operating cost* are equal to the change in the annual operating costs (difference between the base case and standard case) per unit multiplied by the shipments projected for each candidate standard level. As with calculating total annual installed costs, DOE used standards-case shipments to calculate savings in operating cost.

10.6.1 Total Installed Cost per Unit

DOE described the total per-unit installed cost for each product group as a function of product efficiency in chapter 8, Life-Cycle Cost and Payback Period Analysis. Because the total per-unit annual installed cost depends directly on efficiency, DOE used the shipment-weighted efficiencies for the base and standard cases, combined with the total installed cost presented in chapter 8, to estimate the shipment-weighted total per-unit average annual installed cost under the base and standard cases. Table 10.6.1 shows the average installed cost of hearth product ignition devices in 2021 for the base and standard cases.

For reasons discussed in chapter 8, DOE used a constant product price assumption for the default projection in the NIA. To investigate the impact of different product price projections on the consumer net present value (NPV) for different efficiency levels, DOE also considered two alternative price trends. Details on how these alternative price trends were developed are in appendix 10C, which also presents the results of the sensitivity analysis.

Table 10.6.1 Average Installed Cost of Hearth Product Ignition Systems in 2021 for the Base and Standard Cases (2013$)

Product Group	Base Case	TSL 1
Fireplace (vented)	$218.37	$253.55
Fireplace (ventless)	$244.32	$323.17
Logs (vented)	$128.67	$278.70
Logs (ventless)	$104.02	$225.71
Outdoor	$358.71	$432.34
All Hearth Products	$208.43	$268.82

10.6.2 Annual Operating Cost per Unit

The per-unit annual operating cost includes costs for energy, repair, and maintenance. DOE determined the per-unit annual savings in energy costs by multiplying the per-unit annual savings in energy consumption developed for hearth products by the appropriate energy price.

Estimates of the per-unit annual energy consumption for the base case and the standard case were presented in section 10.5.1. DOE projected the per-unit annual energy consumption for the base case for all product groups by applying a growth trend in efficiency.

Energy prices and trends in energy prices are described in chapter 8. DOE projected energy prices based on annual changes in average residential energy prices in EIA's *AEO 2014* reference case scenario.

DOE described the total per-unit repair and maintenance costs for each product group as a function of product efficiency in chapter 8. Because the per-unit repair costs depend directly on efficiency, DOE used the efficiencies for the base and standard cases presented in section 10.4, combined with the repair costs presented in chapter 8, to estimate the per-unit average repair and maintenance costs under the base and standard cases.

Table 10.6.2 shows the average operating cost of hearth product ignition devices in 2021 for the base and standard cases. The operating costs change over time, depending on change in annual energy use and energy prices.

Table 10.6.2 Average Annual Operating Cost of Hearth Product Ignition Systems in 2021 for the Base and Standard Cases (2013$)

Product Group	Base Case	TSL 1
Fireplace (vented)	$227.04	$72.46
Fireplace (ventless)	$506.44	$305.43
Logs (vented)	$299.19	$39.95
Logs (ventless)	$338.33	$214.81
Outdoor	$246.11	$2.99
All Hearth Products	$267.80	$105.67

10.6.3 Product Stock

The product stock in any given year depends on annual shipments and the lifetime of a given product group. The NIA model keeps track of the number of units shipped each year. The lifetime of a unit determines how many units shipped in previous years survive in the given year. DOE assumes that products have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is termed the survival function. Refer to chapter 8 for further details on the survival functions that DOE used in its analysis.

10.6.4 Increases in Total Annual Installed Cost

The increase in total annual installed cost for a product under the standard case is the product of the increase in total installed cost per unit attributable to the standard and the number of units of each vintage. This method accounts for differences in total installed cost from year to year.

10.6.5 Savings in Total Annual Operating Cost

The savings in total annual operating cost for any given trial standard level is the product of the annual per-unit savings in operating cost attributable to the standard and the number of units of each vintage. This method accounts for the year-to-year differences in annual operating cost savings.

10.6.6 Discount Factor

DOE multiplied monetary values in future years by a discount factor to determine the present value. The discount factor (DF) is described by the equation:

$$\boldsymbol{DF} = \frac{1}{(1+\boldsymbol{r})^{(y-yp)}}$$

Eq. 10.9

Where:
r = discount rate,
y = year of the monetary value, and
y_P = year in which the present value is being determined.

DOE estimated NPV using both a 3-percent and a 7-percent real discount rate, in accordance with the Office of Management and Budget’s guidance to Federal agencies on the development of regulatory analysis, particularly section E therein: Identifying and Measuring Benefits and Costs.[2] DOE defined the present year as 2014.

10.6.7 Present Value of Increased Installed Cost and Savings

The present value of increased installed cost is the difference between installation cost in the standard case and the base case discounted to the present and summed throughout the period over which DOE is considering the installation of units (from the compliance date of standards, 2021, through 2050). DOE calculated annual increases in installed cost as the difference in total installed cost for new product purchased each year, multiplied by the shipments in the standard case.

The present value of annual savings in operating cost is the difference between the base case and the standard case discounted to the present and summed throughout the period from the compliance date, 2021, to the time when the last unit installed in 2021−2050 is retired from service.

Savings represent decreases in operating cost (including electricity, repair, and maintenance) associated with the more energy-efficient product purchased in each standard case compared to the base case. Total annual savings in operating cost are the savings per unit multiplied by the number of units of each vintage that survive in a particular year.

10.7 RESULTS

10.7.1 National Energy Savings

This section provides the national energy savings that DOE calculated for each of the TSLs analyzed for hearth product ignition systems. See Table 10.7.1 for both primary energy savings and FFC energy savings. DOE based the inputs to the NIA model on weighted-average values, producing results that are discrete point values, rather than a distribution of values as is generated by the life-cycle cost and payback period analysis.

Table 10.7.1 Primary and Full-Fuel-Cycle National Energy Savings for Hearth Product Ignition Systems (quads)

Product Class	Energy Savings	Trial Standard Level
		1
		quads
Hearth Products	Primary	0.62
	Full-Fuel-Cycle	0.69

10.7.2 Net Present Value of Consumer Benefit

This section provides results of calculating the NPV for each trial standard level considered for hearth product ignition devices. Results, which are cumulative, are shown as the discounted dollar value of the net savings. See Table 10.7.2 for NPV results with both 3-percent and 7-percent discount rates. DOE based the inputs to the NIA model on weighted-average values, yielding results that are discrete point values, rather than a distribution of values as is produced by the life-cycle cost and payback period analyses.

Table 10.7.2 Net Present Value of Consumer Benefit for Hearth Product Ignition Devices (billion 2013$)

Product Class	Discount Rate %	Trial Standard Level
		1
		billion 2013$
Hearth Products	3%	3.124
	7%	1.031

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1. U.S. Department of Energy-Energy Information Administration, *Annual Energy Outlook 2014 with Projections to 2040*, 2014. Washington, DC. <www.eia.gov/forecasts/aeo/>

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CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

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11.1 INTRODUCTION

The consumer subgroup analysis evaluates impacts on groups or consumers who may be disproportionately affected by any national energy conservation standard. The U.S. Department of Energy (DOE) evaluates impacts on particular subgroups of consumers by analyzing the life-cycle cost (LCC) impacts and payback period (PBP) for those consumers from the considered energy efficiency levels. DOE determined the impact on consumer subgroups using the LCC spreadsheet models for hearth products. Chapter 8 explains in detail the inputs to the models used in determining LCC impacts and PBPs.

DOE evaluated impacts on low-income households and households occupied solely by senior citizens (senior-only households).

11.2 APPROACH

11.2.1 Subgroup Definition

As defined in the RECS 2009 survey, low-income households are those at or below the "poverty line." The poverty line varies with household size, head of household age, and family income and in RECS encompasses a group of households with incomes below the poverty level in 2009 as defined by the U.S. Bureau of the Census[1] (see Table 11.2.1). The RECS 2009 survey classifies approximately 15 percent of U.S. households as low-income.

Table 11.2.1 RECS 2009 Definitions of Low-Income Households by Yearly Income

Household Size	**Weighted Average Threshold** ***2009$***
1	10,956
2	13,991
3	17,098
4	21,954
5	25,991
6	29,405
7	33,372
8	37,252
9+	44,366

Senior-only households have occupants who are all at least 65 years of age. Based on the Energy Information Administration's 2009 Residential Energy Consumption Survey (RECS 2009),[2] senior-only households comprise 17 percent of the country's households.

11.2.2 Distribution of Subgroup Households with Hearth Products

Of the 12,083 households in the 2009 RECS database, 4.7 million have vented hearth heaters and 1.8 million have ventless hearth heaters. Table 11.2.2 shows the household sample sizes for hearth product subgroups. The low-income sample included only 21 households representing approximately 235,000 households, and the senior-only household included 99 households representing approximately 900,000 households.

Table 11.2.2 Household Population Data for Hearth Products

Product Type	General Population		Low-Income Households		Senior-Only Households	
	No. of Records	Number of Houses	No. of Records	Number of Houses	No. of Records	Number of Houses
Vented Hearth Heaters	541	4,666,601	13	124,196	77	662,864
Ventless Hearth Heaters	171	1,825,134	8	96,271	22	237,811
All Hearth Heaters	712	6,491,734	21	220,468	99	900,676

11.2.3 Estimation of Impacts

To calculate the subgroup results, DOE extracted the results of low-income and senior-only households from the national LCC results. Then DOE calculated the LCC and PBP statistics for the subgroups from the individual households.

In the LCC analysis in chapter 8, the national sample is separated into replacement and new construction samples. For the subgroup analysis, because the number of households in each subgroup is small, DOE chose to only use a single sample rather than disaggregating replacement and new construction markets.

11.3 RESULTS

Table 11.3.1 through Table 11.3.4 summarize the LCC and PBP results for low-income and senior-only households. Table 11.3.5 compares average LCC savings and simple PBP for the consumer subgroups with those for all households. For hearth products, the low-income have lower LCC savings but shorter PBP for the intermittent pilot ignition, while senior-only households have higher LCC savings but longer PBP than average. This may be due to both the higher discount rates in these demographics and the smaller sample size, which may include more outliers by percentage than the overall sample.

Table 11.3.1 Average LCC and PBP Results by Efficiency Level for Low-Income Households

EL	Efficiency Level	Average Costs 2013$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
0	Standing Pilot	159	110	1,234	1,393	--
1	Intermittent Pilot	255	31	356	611	1.2

Note: The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 11.3.2 LCC Savings Relative to the Base Case Efficiency Distribution for Low-Income Households

EL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings* 2013$
1	Intermittent Pilot	21%	557

* The calculation includes buildings with zero LCC savings (no impact).

Table 11.3.3 Average LCC and PBP Results by Efficiency Level for Senior-Only Households

EL	Efficiency Level	Average Costs 2013$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
0	Standing Pilot	168	43	505	673	--
1	Intermittent Pilot	270	13	155	425	3.5

Note: The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 11.3.4 LCC Savings Relative to the Base Case Efficiency Distribution for Senior-Only Households

EL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings* 2013$
1	Intermittent Pilot	26%	121

* The calculation includes buildings with zero LCC savings (no impact).

Table 11.3.5 Summary of Average LCC Savings and Simple Payback Period Results for Consumer Subgroups and All Households

Technology Option	Efficiency Level	Average LCC Savings *2013$*			Simple Payback Period *Years*		
		Low-Income	Senior-Only	All	Low-Income	Senior-Only	All
Intermittent Pilot	1	$557	$121	$165	1.2	3.5	2.9

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2. U.S. Department of Energy: Energy Information Administration, *Residential Energy Consumption Survey (RECS): 2009 RECS Survey Data.* 2009. (Last accessed January 7, 2015.) <www.eia.gov/consumption/residential/data/2009/>

CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

12.1 INTRODUCTION

In determining whether a standard is economically justified, the U.S. Department of Energy (DOE) is required to consider "the economic impact of the standard on the manufacturers and on the consumers of the products subject to such a standard." (42 U.S.C. 6313(a)(6)(B)(i)) The law also calls for an assessment of the impact of any lessening of competition as determined in writing by the Attorney General. *Id.* DOE conducted a manufacturer impact analysis (MIA) to estimate the financial impact of an energy conservation standard on manufacturers of hearth products and to assess the impact such standards would have on direct employment and manufacturing capacity.

The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA primarily relies on the Government Regulatory Impact Model (GRIM), an industry cash-flow model adapted for each product in this rulemaking. The GRIM inputs include information on industry cost structure, shipments, and pricing strategies. The GRIM's key output is the industry net present value (INPV). The model estimates the financial impact of more stringent energy conservation standards for each product by comparing changes in INPV between a base case (without new standards) and the various trial standard levels (TSLs) in the standards case. The qualitative part of the MIA addresses product characteristics, manufacturer characteristics, market and product trends, as well as the impact of standards on subgroups of manufacturers.

12.2 METHODOLOGY

DOE conducted the MIA in three phases. Phase I, Industry Profile, consisted of preparing a characterization of the gas hearth industry, including data on sales volumes, pricing, employment, and financial structure. As part of this phase, DOE conducted interviews with a broad cross-section of hearth manufacturers to gather information on the industry as well as the potential impacts of an energy conservation standard. In Phase II, Industry Cash Flow Analysis, DOE used the GRIM to assess the potential impacts of an energy conservation standard on manufacturers. DOE used financial inputs derived from a combination of sources, including manufacturer interviews conducted in Phase I as well as public sources of information. In Phase III, Subgroup Impact Analysis, DOE developed additional analyses for subgroups that required special consideration and incorporated qualitative data from interviews into its analysis.

12.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the gas hearth industry. DOE developed its industry profile using a combination of sources, including: public information, such as Securities and Exchange Commission (SEC) 10-K reports,[1] market research tools (*e.g.*, Hoovers[2]), corporate annual reports, the U.S. Census Bureau's 2011 Annual Survey of Manufacturers (ASM)[3], and the 2010 Energy Conservation Standard Final Rule for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters

(75 FR 20112 (April 16, 2010)); information obtained through DOE's engineering analysis, life-cycle cost analysis, and market and technology assessment prepared for this rulemaking; and information obtained directly from manufacturers through interviews.

The industry profile includes an analysis of overall market and product characteristics (*e.g.*, market structure, sales trends, competition) as well as estimation of financial parameters for the industry (*e.g.*, typical product markups, costs of goods sold (COGS), selling, general and administrative expenses (SG&A), net plant, property, and equipment (PPE), expenditures on research and development (R&D)). The financial parameters developed as part of the industry profile were subsequently used to develop the industry cash flow analysis conducted during Phase II.

12.2.1.1 Manufacturer Interviews

As part of Phase I, DOE conducted structured, detailed interviews with a representative cross-section of manufacturers. During these interviews, DOE discussed engineering, manufacturing, procurement, and financial topics. The interviews were designed to identify manufacturers' key concerns regarding a potential energy conservation standard and to gather information on the potential effects of a standard on manufacturer finances, direct employment, capital assets, and industry competitiveness. The interviews also presented an opportunity to discuss industry structure and market segmentation and to identify subgroups of manufacturers that could be disproportionately affected by an energy conservation standard.

DOE scheduled interviews and distributed interview guides to manufacturers well in advance of conducting interviews. In doing so, DOE sought to provide every opportunity for key individuals to be available for comment and to afford manufacturers sufficient time to prepare. Although a written response to the interview guide was acceptable, DOE requested interactive interviews, which help to clarify responses and identify additional issues. Topics addressed during interviews included: (1) key issues to this rulemaking; (2) engineering analysis; (3) company overview; (4) manufacturer markups and profitability; (5) financial parameters; (6) conversion costs; (7) industry projections; (8) direct employment impact assessment; (9) exports, foreign competition, and outsourcing; (10) consolidation; (11) cumulative regulatory burden; and (12) impacts on small businesses.

Information obtained during interviews is protected by non-disclosure agreements (NDAs) and resides with DOE's contractors. This allows manufacturers to express their views on important issues privately and to share confidential or sensitive information for consideration as part of the rulemaking process. The opportunity to exchange confidential information enables DOE to refine its engineering and manufacturer impact analyses in a manner that would not be possible if relying solely on publicly available information. For instance, confidential financial data obtained under NDA allows DOE to better tailor the GRIM to reflect financial characteristics specific to the gas hearth industry.

12.2.2 Phase II: Industry Cash-Flow Analysis

Phase II of the MIA focused on the financial impacts of potential energy conservation standards on manufacturers of gas hearth products. In general, energy conservation standards can affect manufacturer cash flow in three distinct ways: (1) create a need for increased investment; (2) raise production costs per unit; and (3) alter revenue due to higher per-unit prices and/or possible changes in sales volumes. To quantify these impacts, DOE used the GRIM to perform a cash-flow analysis for the hearth industry. In performing these analyses, DOE used financial values derived during Phase I and shipment projections used in the national impact analysis (NIA).

The GRIM uses several factors to determine a series of annual cash flows from the announcement year of energy conservation standards until 30 years after the standards' compliance date. These factors include annual expected revenues, COGS, SG&A, taxes, and capital expenditures related to the standards. Inputs to the GRIM include manufacturer production costs, markup assumptions, and shipments forecasts developed in other analyses. DOE derived the manufacturing costs from the engineering analysis and information provided by the industry. It estimated typical manufacturer markups from public financial reports and interviews with manufacturers. DOE developed alternative markup scenarios based on discussions with manufacturers. DOE's shipments analysis, presented in chapter 10 of the TSD, provides the basis for the shipment projections used in the GRIM. The financial parameters were developed using publicly available manufacturer data and were revised with information submitted confidentially during manufacturer interviews. The GRIM results for the standards case are compared to results for the base-case scenario for the industry. The financial impact of an energy conservation standard is then evaluated as the difference between the discounted annual cash flows in the base case and the discounted annual cash flows in the standards case.

The results of the industry cash-flow analysis are presented in section 12.5.

12.2.3 Phase III: Manufacturer Subgroup Analysis

For its GRIM analysis, DOE presented impacts on the hearth industry as a whole. However, using average cost assumptions to develop an industry cash-flow estimate may not adequately assess differential impacts of an energy conservation standard among manufacturer subgroups. For example, small manufacturers, niche players, or manufacturers exhibiting a cost structure that largely differs from the industry average could be more negatively affected. To address this possible impact, DOE used the results of the industry characterization analysis in Phase I to group manufacturers that exhibit similar characteristics. DOE identified two subgroups of hearth manufacturers that could be disproportionately affected by an energy conservation standard and therefore warranted a separate impact analysis: (1) manufacturers of gas log sets; and (2) small business manufacturers.

12.2.3.1 Manufacturers of Gas Log Sets Subgroup

During interviews, multiple manufacturers commented that gas log sets represent a distinct market segment within the gas hearth industry. These manufacturers indicated that gas log sets serve a different market niche and face different space constraints than other gas hearth products. Additionally, manufacturers of gas log sets indicated that an energy conservation standard disallowing the use of standing pilot lights could have a proportionally greater impact on the manufacturing costs and, by extension, the retail prices, of gas log sets relative to other gas hearth products. Given the nature of the gas log set market, manufacturers indicated that the proposed energy conservation standard could trigger a decline in demand from price-sensitive consumers and, in turn, negatively affect manufacturer profitability. DOE reports further on the potential impact of this rulemaking on the subgroup of gas log set manufacturers in section 12.6.1.

12.2.3.2 Small Business Manufacturer Subgroup

DOE investigated whether small business manufacturers should be analyzed as a manufacturer subgroup. DOE used the Small Business Administration (SBA) small business size standards effective on January 1, 2012, as amended, and the North American Industry Classification System (NAICS) codes, presented in Table 12.2.1, to determine whether any small entities would be affected by the rulemaking.[4] For the products under review, the SBA bases its small business definition on the total number of employees for a business, its subsidiaries, and its parent companies. An aggregated business entity with fewer employees than the listed limit is considered a small business. Manufacturing of hearth products is classified under NAICS code 333414, “Heating Equipment (Except Warm Air Furnaces) Manufacturing,” and under NAICS code 335228, “Other Major Household Appliance Manufacturing.” For both NAICS codes, the SBA sets a threshold of 500 employees or fewer for an entity to be considered a small business.

Table 12.2.1 Classification of Small Business Manufacturers Potentially Affected by This Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS Code
Heating Equipment (Except Warm Air Furnaces) Manufacturing	N/A	500	333414
Other Major Household Appliance Manufacturing	N/A	500	335228

DOE used publicly available and proprietary information to identify potential small business manufactures of products covered by this rulemaking. DOE’s research involved industry trade association membership directories (*e.g.*, Hearth, Patio & Barbecue Association (HPBA)), individual company websites, and market research tools (*e.g.*, Hoovers.com) to create a list of small companies that manufacture products that would be covered by this rulemaking. In interviews, DOE presented its initial list of identified small business manufacturers and asked interviewees if they were aware of any small manufacturers not included on the list. DOE also reached out to other interested parties and industry representatives for information on small business manufacturers. DOE screened out companies that do not manufacture products potentially covered by this rulemaking, do not meet the definition of a small business, or are foreign owned and operated. Based on this analysis, DOE identified 66 domestic small businesses that manufacture gas hearth products affected by this rulemaking. DOE reports the potential impact of this rulemaking on small businesses in section 12.6.2.

12.2.4 Manufacturing Capacity Impact

One significant outcome of energy conservation standards could be the obsolescence of existing manufacturing assets, including tooling and investment. The manufacturer interview guides include a series of questions to help identify impacts of standards on manufacturing capacity. Specifically, these are: capacity utilization and plant location decisions in the United States, with and without standards; the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new requirements; the nature and value of any stranded assets; and estimates of any one-time changes to existing plant, property, and equipment (PPE). DOE's estimates of the one-time capital changes and stranded assets affect the cash flow estimates in the GRIM. These estimates can be found in section 12.4.6. DOE's discussion of the capacity impact can be found in section 12.7.2.

12.2.5 Employment Impact

The impact of energy conservation standards on employment is an important consideration in the rulemaking process. To assess how domestic direct employment patterns might be affected, the interviewers explored with interested parties the current employment trends in the hearth industry. The interviewers also solicited manufacturer views on changes in employment patterns that may result from an energy conservation standard. The employment impacts section of the interview guide focuses on current employment levels associated with manufacturers at each production facility, expected future employment levels with and without energy conservation standards, and differences in workforce skills and issues related to the retraining of employees. The employment impacts are reported in section 12.7.1.

12.2.6 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects on manufacturers due to energy conservation standards and other regulatory actions affecting the same products. DOE analyzed the impact on manufacturers of multiple, product-specific regulatory actions. Discussion of the cumulative regulatory burden can be found in section 12.7.3.

12.3 MANUFACTURER IMPACT ANALYSIS KEY ISSUES

Each MIA interview starts by asking: "What are the key issues for your company regarding the energy conservation standard rulemaking?" This question prompts manufacturers to identify the issues they consider important for DOE to explore and discuss further during the interviews. The following sections describe the most significant issues identified by manufacturers. These summaries are provided in aggregate to protect manufacturer confidentiality.

12.3.1 Impacts on Profitability

According to manufacturers, units with electronic ignition systems are more expensive to manufacture than units with standing pilot lights. Manufacturers indicated that purchasing components for electronic ignition systems increases per-unit production costs and, by extension, raises the retail price of products. Manufacturers stated that by driving up their cost of goods sold as well as the end-user purchase price, a standard eliminating standing pilot lights could lead to a drop in consumer demand. Because gas hearth products are not typically purchased exclusively for heating purposes but rather are valued by customers for their aesthetic appeal, manufacturers indicated that higher prices could depress demand if customers decide the decorative benefit of gas hearth products does not merit the higher costs. A fall in sales could, in turn, affect industry profitability.

Additionally, manufacturers stated that shipments of gas hearth products declined significantly over the last decade, in part due to the economic recession and a related decline in new-home construction. Several manufacturers forecast steady or declining shipments in future years absent an energy conservation standard. Those interviewed generally argued that if an energy conservation standard raises the price of gas hearth products, depresses demand, and reduces profitability, it could drive manufacturers to exit the market.

12.3.2 Impacts on Industry Competition

Small manufacturers expressed concern that an energy conservation standard for gas hearth products could alter the competitive dynamics of the market, favoring a subset of large manufacturers over their small-business competitors. Based on economies of scale, manufacturers that produce gas hearth products at high volumes are typically able to source components at lower per-unit prices than manufacturers that produce at lower volumes. In general, manufacturers of gas hearth products do not manufacture the components used for electronic ignition systems in house. Rather, they source them from component suppliers. In interviews, manufacturers indicated that large manufacturers with high production volumes are able to source these components at relatively low cost. Small manufacturers with lower production volumes, in contrast, noted that the comparatively high cost they would incur to purchase electronic ignition system components would exacerbate the pricing advantage of large manufacturers and could lead to loss of price competitiveness for smaller players in the market.

12.3.3 Impacts on Product Performance

Multiple manufacturers stated that electronic ignition systems represent a more complicated and less reliable technology than standing pilot lights. These manufacturers indicated that units with electronic ignition systems often require more effort to repair and maintain. One manufacturer stated that electronic ignition systems account for a small fraction of their sales but the vast majority of their service calls, and several manufacturers suggested higher costs of maintaining units with electronic ignition systems compared to standing pilot lights. Additionally, several manufacturers suggested that electronic ignition systems are not as well suited to cold climates, where standing pilot lights may help to maintain buoyancy through the flue and to prevent condensation from building up on glass.

12.4 GRIM INPUTS AND ASSUMPTIONS

The GRIM serves as the main tool for assessing the impacts on industry resulting from energy conservation standards. DOE relies on several sources (as detailed in section 12.4.2) to obtain inputs for the GRIM. DOE then feeds the data and assumptions from these sources into an accounting model that calculates industry cash flows both with and without energy conservation standards.

12.4.1 Overview of the Government Regulatory Impact Model

The GRIM is an annual cash flow model that uses manufacturer production costs, manufacturer selling prices, shipment projections, and industry financial information as inputs to arrive at a series of annual cash flows, beginning with the base year of the analysis, 2014, and continuing to 2050. As illustrated in Figure 12.4.1, the model calculates INPV by summing the stream of annual discounted cash flows during this period and adding a discounted terminal value.[5] Imposing different conditions, such as changes in manufacturing costs, investment requirements, and anticipated markups, enables DOE to analyze the potential effects of an energy conservation standard on industry finances.

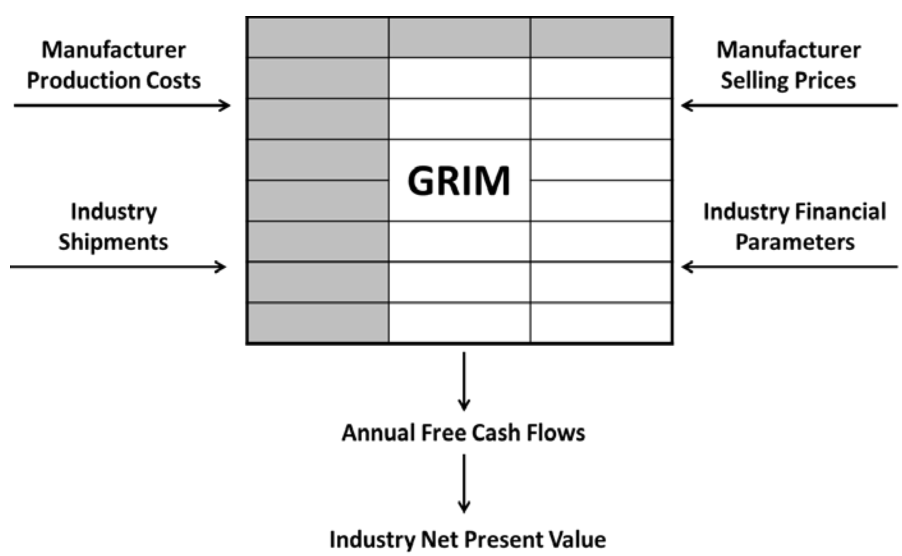


Figure 12.4.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the base case and the standard-case scenarios induced by energy conservation standards. The difference in INPV between the base case and the standard case represents the estimated financial impact of the energy conservation standard on manufacturers. Appendix 12A provides more technical details and user information for the GRIM.

DOE presents MIA results relative to a base case that assumes no energy conservation standard for gas hearth products. Accordingly, when comparing the INPV impacts of the GRIM model, the baseline assumes continued production and sale of hearth products with standing pilot lights, while the standard case assumes the elimination of all standing pilot lights and their replacement with electronic ignition systems.

12.4.2 Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, census data, credit ratings, the shipments model, the engineering analysis, and manufacturer interviews.

12.4.2.1 Final Rule for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters

The 2010 Energy Conservation Standard for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters (75 FR 20112 (April 16, 2010)) provided many of the initial financial inputs to the GRIM. As part of that rule, DOE derived a series of financial parameters for vented gas hearths based on a review of SEC public filings, corporate annual reports, company profiles, credit ratings, and manufacturer interviews. DOE used these parameters as a starting point for analysis, presenting them to manufacturers for review and comment during interviews conducted under Phase I of this rulemaking. Based on manufacturer feedback, DOE then revised its estimated financial parameters to better reflect the current gas hearth industry. Table 12.4.1 presents both the initial estimates and the revised financial parameters used as inputs to the GRIM.

Table 12.4.1 Financial Parameters for Gas Hearth Manufacturers

Parameter	**Initial Estimate %**	**Revised Estimate %**
Tax Rate (% of taxable income)	35	36
Discount Rate	8.5	8.7
Working Capital (% of revenue)	11.4	2.2
Net Property, Plant, and Equipment (% of Revenue)	13	10.8
SG&A (% of revenue)	20.9	25
R&D (% of revenue)	1.5	2.3
Depreciation (% of revenue)	2.2	2.1
Capital Expenditures (% of revenue)	2.4	2.1

12.4.2.2 Shipment Model

The GRIM used shipment projections derived from DOE's shipments model in the national impact analysis (NIA). Chapter 10 of this TSD describes the methodology and analytical model DOE used to forecast shipments.

12.4.2.3 Engineering Analysis

During the engineering analysis, DOE used a manufacturing cost model to develop manufacturing production cost (MPC) estimates. The analysis provided the labor, materials, overhead, and total production costs for different design options for gas hearth products. DOE estimated a manufacturer markup and applied this to the MPC to arrive at the manufacturer selling price (MSP).

12.4.2.4 Manufacturer Interviews

During the course of the MIA, DOE conducted interviews with a representative cross-section of manufacturers. During these discussions, DOE obtained information to determine and verify GRIM input assumptions. Key topics discussed during the interviews and reflected in the GRIM include:

- Capital conversion costs (one-time investments in PPE);
- Product conversion costs (one-time investments in research, product development, testing, and marketing);
- Product cost structure;
- Industry financial parameters; and
- Possible profitability impacts.

12.4.3 Trial Standard Levels

DOE typically considers multiple trial standard levels (TSLs) for a standards rulemaking. However, the hearth products rulemaking is proposing a prescriptive standard that would disallow the use of continuously burning pilots. There is currently only one other established alternative to a standing pilot, which is an intermittent pilot. Other options that are present in other combustion appliances, such as hot surface ignition, are virtually non-existent in the hearth product market primarily due to the increased cost and additional engineering challenges. Therefore, hearth products have only one TSL, which reflects a standard that would disallow the use of a standing pilot. For the purposes of this analysis, TSL1 assumes that all covered hearth products would use an intermittent pilot.

Table 12.4.2 Trial Standard Levels for Analysis of Gas Hearth Products

Ignition Type	TSL 1 %
Standing Pilot	0
Intermittent Pilot	100

12.4.4 NIA Shipments

The GRIM estimates manufacturer revenues based on total-unit-shipment forecasts and the distribution of these values by product group and ignition type. For this analysis, the GRIM applied the NIA shipments forecasts for the period 2014 (the base year of the MIA analysis) to 2050 (the end year of the analysis). As part of the shipments forecasts, DOE estimated the base-case shipment distribution by ignition type. In the standards case, the shipments analysis assumes a roll-up scenario, where all shipments in the base case that do not meet the standard (*i.e.*, use standing pilots) would instead ship at the new standard level (*i.e.*, with electronic ignition systems). The shipments forecasts also assume price elasticity of demand, whereby shipment volumes in the standards case decline relative to the base case as MPCs rise and, in doing so, drive up end-user purchase prices. The key assumptions and methodology used to forecast shipments can be found in chapter 10 of this TSD.

12.4.5 Production Costs

Changes in production costs affect revenues and gross profits. Products that are more efficient typically cost more to produce than baseline products (as shown in chapter 5 of the TSD). For the MIA, DOE used the MPCs derived in the engineering analysis.

The engineering analysis developed MPCs for representative gas hearth units in five product groups: (1) vented fireplaces, inserts, and stoves; (2) unvented fireplaces, inserts, and stoves; (3) vented gas log sets; (4) unvented gas log sets; and (5) outdoor hearth products. The engineering analysis also determined labor, materials, overhead, and depreciation percentages that constitute the full MPC for each product group. DOE uses these MPCs in combination with shipment projections derived as part of the national impact analysis to evaluate industry financials in both the base case and the standards case. DOE also applies a manufacturer markup to the MPCs in order to calculate MSPs for each product group. DOE adjusts this markup under multiple markup scenarios in order to analyze a range of potential financial impacts of an energy conservation standard on manufacturers.

Table 12.4.3 through Table 12.4.5show the manufacture production cost and manufacturer selling price estimates used in the GRIM for each analyzed product group. A baseline markup of 1.45 was applied to all product groups. As explained in section 12.4.7, this markup varies under alternative markup scenarios.

Table 12.4.3 Manufacturer Production Cost Breakdown (2013$) for Vented Fireplaces, Inserts, and Stoves

	Materials $	Labor $	Depreciation $	Overhead $	MPC $	Markup %	MSP $
Standing Pilot	140	72	71	39	322	1.45	468
Intermittent Pilot	167	72	71	40	350	1.45	508

Table 12.4.4 Manufacturer Production Cost Breakdown (2013$) for Unvented Fireplaces, Inserts, and Stoves

	Materials $	Labor $	Depreciation $	Overhead $	MPC $	Markup %	MSP $
Standing Pilot	107	70	70	34	281	1.45	407
Intermittent Pilot	134	75	69	35	313	1.45	454

Table 12.4.5 Manufacturer Production Cost Breakdown (2013$) for Vented Gas Log Sets

	Materials $	Labor $	Depreciation $	Overhead $	MPC $	Markup %	MSP $
Standing Pilot	56	45	62	27	190	1.45	275
Intermittent Pilot	121	47	62	29	260	1.45	376

Table 12.4.6 Manufacturer Production Cost Breakdown (2013$) for Unvented Gas Log Sets

	Materials $	Labor $	Depreciation $	Overhead $	MPC $	Markup %	MSP $
Standing Pilot	81	60	44	23	208	1.45	301
Intermittent Pilot	126	59	52	28	264	1.45	383

Table 12.4.7 Manufacturer Production Cost Breakdown (2013$) for Outdoor Hearth Products

	Materials $	Labor $	Depreciation $	Overhead $	MPC $	Markup %	MSP $
Standing Pilot	117	33	39	21	210	1.45	304
Intermittent Pilot	168	37	37	22	265	1.45	384

12.4.6 Conversion Costs

Energy conservation standards typically cause manufacturers to incur one-time conversion costs to bring their production facilities and product designs into compliance with new regulations. For the MIA, DOE classified these one-time conversion costs into two major groups: capital conversion costs and product conversion costs. Capital conversion costs are one-time investments in plant, property, and equipment to adapt or change existing production facilities in order to fabricate and assemble new product designs that comply with energy conservation standards. Product conversion costs are one-time investments in research, development, testing, marketing, and other costs to make product designs comply with energy conservation standards. DOE based its estimates of the conversion costs for each efficiency level on information obtained from manufacturer interviews and the design pathways analyzed in the engineering analysis.

12.4.6.1 Capital Conversion Costs

To estimate the level of capital conversion costs manufacturers would likely incur to comply with an energy conservation standard, DOE relied on information obtained through manufacturer interviews as well as the engineering analysis.

Based on both the engineering analysis and conversations with manufacturers, DOE has determined that the proposed standard eliminating standing pilot lights would primarily entail a component swap, in which manufacturers would assemble hearth products using a different set of purchased parts for the ignition system. Accordingly, capital investment by manufacturers to re-tool or reconfigure production facilities likely would be limited. Consistent with this expectation, interviewed manufacturers stated that they did not anticipate incurring significant capital conversion costs in order to comply with the proposed standard. As a result, DOE assigned a nominal capital conversion cost per manufacturer, equivalent to $10,000, to account for any one-time capital investments or reorganization of production lines that a standard eliminating standing pilot lights could potentially entail. DOE assigned this capital conversion cost estimate to each of the 90 hearth product manufacturers identified. Table 12.4.8 presents estimated capital conversion costs for the industry resulting from an energy conservation standard.

Table 12.4.8 Industry Cumulative Capital Conversion Costs (2013$ Millions)

TSL	Capital Conversion Costs (2013$ Millions)
1	0.9

12.4.6.2 Product Conversion Costs

As with capital conversion costs, DOE relied on manufacturer interviews and the engineering analysis to evaluate product conversion costs. Because most hearth product manufacturers already offer models with electronic ignition systems, and because the proposed standard would primarily entail a change in purchased parts rather than an entire product redesign, many manufacturers indicated in interviews that they did not expect to incur significant product conversion costs under the proposed standard. DOE based its product conversion cost estimates on the assumption that manufacturers would incur limited costs related to research and development, testing and certification, and development of marketing materials in order to bring into compliance models not currently offered with an electronic ignition system option.

During interviews, some manufacturers expressed concern that an energy conservation standard could entail significant product conversion costs related to labeling requirements. Under Canadian law, manufacturers must test and label gas fireplaces, stoves and inserts with a fireplace efficiency rating. If a federal energy conservation standard mandated an alternative efficiency metric for hearth products (*e.g.*, annual fuel utilization efficiency), manufacturers indicated they could be required to hold separate stock-keeping units (SKUs) for the Canadian and U.S. markets to comply with each jurisdiction's requirements. Because the proposed standard is a prescriptive design requirement and does not establish a minimum efficiency rating or require products to be labeled with a particular efficiency metric, DOE did not factor the cost of holding duplicate SKUs into its estimated product conversion costs.

To analyze potential product conversion costs, DOE reviewed publicly available product literature to estimate an average number of models offered per manufacturer, as well as the average percentage of models offered only with standing pilot lights and without the option of electronic ignition. DOE scaled up these assumptions to arrive at an estimated total of 781 models for the industry that could require product conversion costs in the form design engineering, testing, certification, etc. DOE then assigned a fixed cost per model, equivalent to $10,000, to arrive at total estimated product conversion costs. This methodology assumes all non-compliant models (*i.e.*, models currently offered only with standing pilot lights) would be redesigned to accommodate electronic ignition systems. This represents a conservative assumption, as manufacturers may choose to discontinue some models with standing pilot lights. Models already available with the option of electronic ignition would not require any one-time conversion costs by the manufacturer in order to achieve compliance.

Table 12.4.9 presents estimated product conversion costs for the industry resulting from a design standard eliminating standing pilot lights.

Table 12.4.9 Industry Cumulative Product Conversion Costs (2013$ Millions)

TSL	Product Conversion Costs (2013$ Millions)
1	7.8

12.4.7 Markup Scenarios

DOE modeled multiple standards-case markup scenarios to represent uncertainty surrounding the potential impacts of energy conservation standards on prices and profitability. In the base case, DOE used the same markups applied in the engineering analysis. In the standards case, DOE modeled two markup scenarios to capture a range of potential impacts on manufacturers following implementation of energy conservation standards: (1) a preservation of gross margin percentage scenario; and (2) a preservation of operating profit scenario. These scenarios lead to different markup values that, when applied to the inputted MPCs, resulted in varying revenue and cash flow impacts.

12.4.7.1 Preservation of Gross Margin Percentage Scenario

Under the preservation of gross margin percentage scenario, DOE applied a single uniform gross margin percentage markup, which assumes that manufacturers would be able to maintain the same amount of profit as a percentage of revenues under an energy conservation standard. As production costs increase with implementation of energy conservation standards, this scenario implies that the absolute dollar markup will increase as well. Based on publicly available financial information for manufacturers of hearth products as well as comments from manufacturer interviews, DOE assumed the average markup—which includes SG&A expenses, R&D expenses, interest, and profit—to be 1.45 for all hearth products. Because this markup scenario assumes that manufacturers would be able to maintain their gross margin percentage markups as production costs increase in response to an energy conservation standard, it represents a high bound to industry profitability.

12.4.7.2 Preservation of Operating Profit Scenario

Under the preservation of per unit operating profit scenario, manufacturer markups are set so that operating profit one year after the compliance date of the energy conservation standard is the same as in the base case on a per-unit basis. In this scenario, as production costs increase with implementation of energy conservation standards, manufacturers are generally required to reduce their markups to a level that maintains base-case operating profit per unit. The implicit assumption behind this markup scenario is that the industry can only maintain its operating profit in absolute dollars per unit after compliance with the new standard. Therefore, operating margin in percentage terms is reduced between the base case and standards case. To analyze this markup scenario, DOE adjusted the manufacturer markups in the GRIM to yield approximately the same earnings before interest and taxes in the standards case as in the base case. This markup scenario represents a low bound to industry profitability under the proposed energy conservation standard.

12.5 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, the GRIM estimated indicators of financial impacts on the hearth industry. The following sections detail additional inputs and assumptions for the analysis of industry financial impacts. The main results of the MIA are also reported in this section. The MIA consists of two key financial metrics: INPV and annual cash flows.

12.5.1 Introduction

The INPV measures the industry value and is used in the MIA to compare the economic impacts of an energy conservation standard (the standards case) to a base case that assumes no energy conservation standard. The INPV is different from DOE's NPV, which applies to the U.S. economy. The INPV is the sum of annual net cash flows over the analysis period discounted at the industry's cost of capital, or discount rate. The GRIM for this rulemaking estimates cash flows from 2014 to 2050. This timeframe models both the short-term impacts on the industry from the announcement of the standard until the compliance date (2015 to 2021), and a long-term assessment over the 30-year analysis period used in the NIA (2021 to 2050).

In the MIA, DOE compares the INPV of the base case to that of the standards case. The difference between the base case and the standards case INPV is an estimate of the economic impacts that implementing the standard would have on the industry. While INPV is useful for evaluating the long-term effects of energy conservation standards, short-term changes in cash flow are also important indicators of the industry's financial situation. For example, a large investment over one or two years could strain the industry's access to capital. Consequently, the sharp drop in financial performance could cause investors to flee, even though recovery may be possible. Thus, a short-term disturbance can have long-term effects that the INPV cannot capture. Figure 12.5.1 and Figure 12.5.2 present the expected behavior of annual net cash flows over the analysis period. As the figures illustrate, industry cash flows begin to decline after the publication date of the final rule as companies use their financial resources to prepare for the energy conservation standard. Cash flows between the publication date and the compliance date are driven by the level of conversion costs and by the proportion of these investments made each year. All cash flows are discounted to the base year, 2014.

Free cash flow in the year the energy conservation standards take effect is driven by two competing factors. In addition to capital and product conversion costs, energy conservation standards could create (1) stranded assets, *i.e.*, tooling and equipment that would have enjoyed longer use if the energy conservation standard had not made them obsolete. In this year, manufacturers write down the remaining book value of existing tooling and equipment whose value is affected by the energy conservation standard. This one-time write down acts as a tax shield that alleviates decreases in cash flow from operations in the year of the write down. In this year, there is also (2) an increase in working capital, which reduces cash flow from operations. A large increase in working capital is needed due to more costly production components and materials, higher inventory carrying to sell more expensive products, and higher accounts receivable for more expensive products. Depending on these two competing factors, cash flow can either be positively or negatively affected in the year the standard takes effect.

12.5.2 Hearth Industry Financial Impacts

Table 12.5.1 and Table 12.5.2 provide INPV estimates for the hearth industry under the two markup scenarios analyzed. Figure 12.5.1 and Figure 12.5.2 present annual industry net cash flows under the two markup scenarios. As described in section 12.4.7, the preservation of gross margin percentage scenario presents an upper bound to industry profitability under an energy conservation standard while the preservation of operating profit scenario presents a lower bound to industry profitability**.**

Table 12.5.1 Preservation of Gross Margin Percentage Scenario Changes in INPV for Hearth Products

	Units	Base Case	Standards Case
INPV	2013$M	125.3	125.8
Change in INPV	2013$M	-	0.5
	% Change	-	0.4

Table 12.5.2 Preservation of Operating Profit Scenario Changes in INPV for Hearth Products

	Units	Base Case	Standards Case*
INPV	2013$M	125.3	122.0
Change in INPV	2013$M	-	(3.3)
	% Change	-	(2.6)

*Parentheses indicate negative values

Under an energy conservation standard, DOE estimates impacts on INPV to range from -$3.3 million to $0.5 million, or a change of -2.6 percent to 0.4 percent. See section 12.8 for further discussion of results.

Figure 12.5.1 Annual Industry Net Cash Flows under Preservation of Gross Margin Percentage Markup Scenario

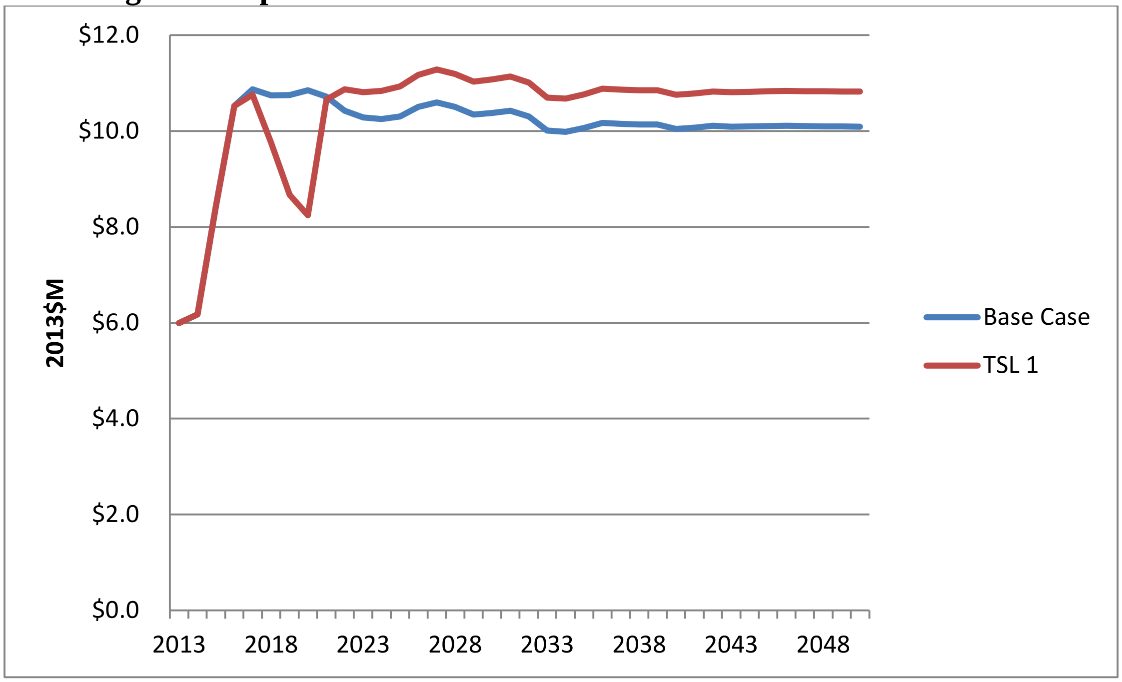
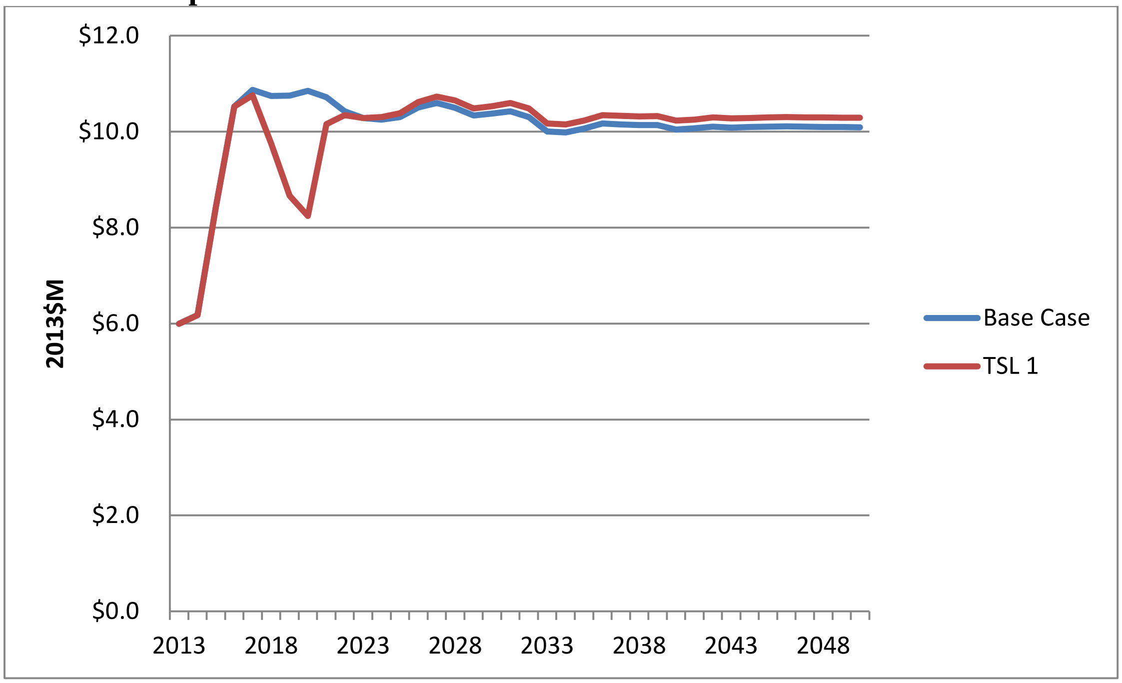


Figure 12.5.2 Annual Industry Net Cash Flows under Preservation of Operating Profit Markup Scenario



12.6 IMPACTS ON SUBGROUPS OF MANUFACTURERS

As discussed above, using average cost assumptions to develop an industry cash flow estimate is not adequate for assessing differential impacts among subgroups of manufacturers. Small manufacturers, niche players, or manufacturers exhibiting a cost structure that differs largely from the industry average could be affected differently. DOE used the results of the industry characterization to group manufacturers exhibiting similar characteristics. Specifically, DOE identified two subgroups of manufacturers for separate impact analyses: (1) manufacturers of gas log sets, and (2) small business manufacturers.

12.6.1 Impacts on Manufacturers of Gas Log Sets

During interviews, multiple manufacturers commented that gas log sets represent a distinct market segment within the gas hearth industry. These manufacturers indicated that gas log sets serve a different market niche and face different space constraints than other gas hearth products. Additionally, gas log sets often sell at lower prices than other gas hearth products. As a result, an increase in manufacturing costs and, by extension, retail price resulting from an energy conservation standard, could have a proportionally greater impact on gas log sets relative to other gas hearth products.

Gas log sets are typically designed for use in existing wood-burning fireplaces. During interviews, manufacturers of gas log sets stated that unlike other gas hearth products, gas log sets compete with wood, coal, and wood/wax logs. These alternatives are typically inexpensive to purchase, such that consumers could feasibly substitute away from gas log sets and toward wood and/or wood/wax logs if an energy conservation standard leads to higher prices. According to these manufacturers, if design constraints specific to gas log sets cause an energy conservation standard to alter product aesthetics, it could further drive consumers to switch products.

Because gas log sets are designed to fit within existing wood-burning fireplaces, manufacturers indicated that design options for gas log sets are constrained by the geometric configurations of pre-existing fireplaces. Manufacturers stated that electronic ignition systems take up more space than standing pilot lights, and that accommodating electronic ignition systems inside existing fireplaces could, in turn, reduce the size of the gas log sets consumers could purchase for their fireplaces. Manufacturers also indicated that electronic ignition system components can be difficult to conceal within a gas log set's design. Unlike other gas hearth products, gas log sets are not sold as part of a packaged unit, leaving manufacturers with limited options for obscuring the gas valve, pilot assembly, control module, wiring, and other components that make up an electronic ignition system. As a result, these components may be more exposed when used with gas log sets compared to other gas hearth products. Manufacturers also stated that electric outlets may not be situated in close enough proximity to wood-burning fireplaces to enable ready installation of units with electronic ignition systems. In such cases, the need for extension cords could impact the aesthetic appeal of products. Alternatively, hiring an electrician could raise installation costs and potentially deter price-sensitive consumers.

Alongside aesthetic impacts, manufacturers expressed concern regarding the cost implications of a potential standard eliminating standing pilot lights. As discussed previously, purchasing components for electronic ignition systems typically costs manufacturers more than purchasing components for standing pilot lights. Higher manufacturing costs, in turn, lead to higher retail prices. To estimate the potential difference in cost resulting from a standard eliminating standing pilot lights, DOE modeled the MPCs for both vented and unvented gas log sets using both standing pilot lights and electronic ignition systems. DOE similarly modeled MPCs for other categories of gas hearth products. Table 12.6.1 presents the relative increase in MPC for products manufactured with electronic ignition systems as opposed to standing pilot lights. See chapter 5 of the TSD for a more detailed discussion of how MPCs were calculated.

Table 12.6.1. Added Cost of Electronic Ignition Systems vs. Standing Pilot Lights

Product Group	**Estimated Increase in MPC of Switching from Standing Pilot to Electronic Ignition*** ***$***	**Increase in Cost of Ignition System** ***%***	**Increase in Overall MPC** ***%***
Vented Fireplace/Insert/Stove	28	56	9
Unvented Fireplace/Insert/Stove	32	47	11

Vented Gas Logs	70	227	37
Unvented Gas Logs	56	194	27
Outdoor	55	65	26

* Standing pilot ignitions largely use two styles of gas valves: manual and millivolt. The incremental costs of switching from standing pilot lights to electronic ignition systems presented here assume gas fireplaces, inserts, and stoves use standing pilot lights with millivolt gas valves while gas log sets and outdoor hearth products use standing pilot lights with manual gas valves. The millivolt gas valve uses a thermopile place in the pilot light to generate a voltage difference, so that a remote control can be used to turn the burner on and off. These valves are larger and more expensive than manual gas valves, which are operated by hand. Based on public comments on previous rulemakings and manufacturer interviews, DOE recognizes the importance of space constraints and cost burden associated with control systems for gas log sets. For the purposes of analysis, DOE chose to represent gas log sets with standing pilots using manual gas valves. Fireplaces, inserts, and stoves provide more opportunity to package and conceal larger, more complex ignition systems. Accordingly, DOE chose to represent the standing pilot variation of this product category with models using millivolt gas valves.

As the results above indicate, DOE estimates that the cost of switching from a standing pilot light to an electronic ignition system could disproportionately affect gas log set manufacturers. These results are driven by two primary factors. First, they are based on the assumption that gas log sets use standing pilot lights with manual gas valves, which are smaller and less expensive than standing pilot lights with millivolt gas valves. Under this assumption, the higher cost of purchasing electronic ignition system components would represent a more significant expenditure both in absolute dollars and in percentage terms for manufacturers of gas log sets using manual standing pilot lights relative to manufacturers of products using more expensive millivolt standing pilot lights. Second, the overall cost of manufacturing gas log sets is often lower than the overall cost of manufacturing other types of gas hearth products. This means the same increase in MPC in absolute dollars would result in a higher proportional increase in MPC for gas log sets. Assuming, as described, that manufacturers of gas log sets are likely to see a greater increase in MPC in absolute dollars compared to manufacturers of other products, this would imply an even greater proportional increase in overall MPC of gas log sets. If retail prices scale with MPCs, manufacturers indicated that demand for gas log sets from price-sensitive consumers could decline and, in turn, negatively affect manufacturer profitability.

12.6.2 Impacts on Small Business Manufacturers

To better assess the potential impacts of this rulemaking on small entities, DOE conducted a more focused inquiry of companies that could be small business manufacturers of products covered by this rulemaking. For hearth products, the Small Business Administration (SBA) has set a size threshold of 500 employees or fewer for an entity to be considered a small business. This 500-employee threshold includes all employees in a business's parent company and any other subsidiaries and applies to both heating and decorative hearth products, categorized respectively under North American Industry Classification System (NAICS) code 333414, "Heating Equipment (Except Warm Air Furnaces) Manufacturing" and NAICS code 335228, "Other Major Household Appliance Manufacturing." Based on this threshold, DOE used publicly available information to identify potential small manufacturers. DOE's research involved industry trade association membership directories (*e.g.*, HPBA), information from previous rulemakings, individual company websites, and market research tools (*e.g.*, Hoover's reports) to create a list of companies that manufacture hearth products covered by this rulemaking. DOE also asked stakeholders and industry representatives if they were aware of any additional small manufacturers during manufacturer interviews. DOE reviewed publicly available data and contacted various companies on its complete list of manufacturers to determine whether they met the SBA's definition of a small business manufacturer. DOE screened out companies that do not manufacture products impacted by this rulemaking, do not meet the definition of a "small business," or are foreign owned and operated.

DOE identified 90 manufacturers of gas hearth products that would be affected by today's proposal. Of these, DOE identified 66 as domestic small business manufacturers. DOE contacted a subset of identified small businesses to invite them to take part in a manufacturer impact analysis interview. Of 25 small businesses contacted, DOE was able to reach and discuss potential standards with five. DOE also obtained information about small businesses and potential impacts on small businesses while interviewing large manufacturers.

In interviews, small manufacturers expressed concern regarding the impact of a standard eliminating standing pilot lights on their ability to compete with larger manufacturers. Manufacturers stated that gas hearth products with electronic ignition systems cost more to produce than gas hearth products with standing pilot lights, as the components purchased for electronic ignition systems tend to be more expensive. Since large manufacturers often produce at higher volumes, they may be able to source components at lower per-unit prices than small manufacturers that produce at lower volumes. Because small manufacturers may not benefit from the same economies of scale as large manufacturers, an energy conservation standard eliminating standing pilot lights could disproportionately affect their production costs and, in turn, the prices at which they sell their products. This anticipated change in MPCs drove small manufacturer concerns surrounding the impact of an energy conservation standard on their ability to remain competitive in the gas hearth market.

To evaluate small manufacturers' concerns regarding the competitive implications of a standard eliminating standing pilot lights, DOE modeled the difference in cost small manufactures might face when sourcing components at lower volumes. Due to limited available information on the relative sales volumes of small and large manufacturers, DOE selected volumes of 1,000 units (used to represent small manufacturers) and 10,000 units (used to represent large manufacturers) for each product group analyzed. DOE developed its analysis based on the engineering teardown analysis and cost model as well as manufacturer feedback on the costs of ignition systems.

Table 12.6.2 presents the estimated added per-unit cost of an electronic ignition system compared to a standing pilot system at the two representative production volumes modeled. As the results indicate, manufacturers likely would pay less per unit when producing 10,000 units versus 1,000 units. Estimated costs would decline further as production volumes climb higher.

Table 12.6.2 Added Cost of Electronic Ignition Systems at Representative Production Volumes

Product Group	Baseline MPC *$*	Added Cost of EIS at 1,000 units *$*	Added Cost of EIS at 10,000 units *$*
Vented Fireplace/Insert/Stove	322	31	26
Unvented Fireplace/Insert/Stove	281	33	24
Vented Log Sets	190	70	58
Unvented Log Sets	208	69	51
Outdoor	210	65	42

DOE's analysis suggests that a standard eliminating standing pilot lights would increase the per-unit MPCs of gas hearth products by a greater amount for small-volume producers than for large-volume producers. Higher MPCs, in turn, typically lead to higher end-user purchase prices. If products manufactured by small businesses cannot compete with products manufactured by large businesses at lower cost, small businesses could potentially experience a decline in profits and/or choose to exit the market.

DOE provides additional analysis in section VI.B of the NOPR, Review Under the Regulatory Flexibility Act.

12.7 OTHER IMPACTS

12.7.1 Direct Employment

12.7.1.1 Methodology

To quantitatively assess the impacts of an energy conservation standard on employment, DOE used the GRIM to estimate the domestic labor expenditures and number of employees in the base case and the standards case from 2014 through 2050. DOE used statistical data from the U.S. Census Bureau's 2011 Annual Survey of Manufacturers (ASM), the results of the engineering analysis, and interviews with manufacturers to determine the inputs necessary to calculate industry-wide labor expenditures and domestic employment levels. Labor expenditures related to manufacturing of the product are a function of the labor intensity of the product, the sales volume, and an assumption that wages remain fixed in real terms over time. The total labor expenditures in each year are calculated by multiplying the MPCs by the labor percentage of MPCs.

The total labor expenditures in the GRIM were then converted to domestic production employment levels by dividing production labor expenditures by the annual payment per production worker (production worker hours times the labor rate found in the ASM). The production worker estimates in this section cover workers up to the line-supervisor level who are directly involved in fabricating and assembling a product within the original equipment manufacturer facility. Workers performing services that are closely associated with production operations, such as materials handling tasks using forklifts, are also included as production labor. DOE's estimates only account for production workers who manufacture the specific products covered by this rulemaking.

To estimate an upper bound to employment change, DOE assumes all domestic manufacturers would choose to continue producing products in the U.S. and would not move production to foreign countries. To estimate a lower bound to employment, DOE estimates the maximum portion of the industry that would choose to leave the industry or relocate production overseas rather than make the necessary conversions at domestic production facilities.

12.7.1.2 Direct Employment Impacts

In the absence of energy conservation standards, DOE estimates that the hearth industry would employ 1,565 domestic production workers in 2021. This estimate assumes U.S. production labor accounts for 86 percent of the industry total, a figure based on the percentage of domestic manufacturers identified as a share of total manufacturers identified for the industry.

Table 12.7.1 shows the range of impacts of potential energy conservation standards on U.S. production workers of gas hearth products. The potential changes to direct employment presented suggest that the industry could experience anything from a slight loss in domestic direct employment to a loss of more than 900 domestic jobs.

Table 12.7.1 Potential Changes in the Total Number of Production Workers in the Gas Hearth Industry in 2021

	Base Case	Standards Case
Domestic Production Workers in 2021	1,565	657 to 1,514
Potential Changes in Domestic Production Workers in 2021*	-	(908) to (51)

*Parentheses indicate negative values

The less severe end of the range of potential employment impacts estimates a loss of 51 domestic production jobs in 2021 in the standards case. This assumes manufacturers would continue to produce the same scope of covered products within the United States. However, because the shipment model predicts a decline in shipment volumes under an energy conservation standard, DOE estimates a related reduction in labor inputs and employment.

The more severe end of the range represents the maximum decrease in total number of U.S. production workers that could be expected to result from an energy conservation standard. For the hearths industry, DOE assumed a worst-case scenario in which all products sold with standing pilot lights in the base case would be eliminated in the standards case and would not be replaced by any additional sales of compliant products. DOE then assumed industry labor requirements would shrink in proportion to lost sales volumes. The NIA shipments analysis forecasts that 58 percent of base-case shipments would consist of units with standing pilot lights in 2021. Based on the worst-case scenario assumptions above, DOE modeled a 58-percent decline in direct production employment. As a result, DOE estimates a loss of up to 908 domestic production jobs in 2021 resulting from a design standard that eliminates standing pilot lights.

The direct employment impacts discussed here do not include indirect employment impacts on the broader U.S. economy, which are documented in the Employment Impact Analysis, chapter 16 of the TSD.

12.7.2 Production Capacity

According to gas hearth manufacturers interviewed, a standard eliminating standing pilot lights would not likely constrain manufacturing production capacity. Converting a gas hearth product's ignition system from a standing pilot light to electronic ignition is primarily a matter of purchasing and assembling different ignition system components. While this may entail higher costs for purchased parts and changes in assembly, it is not likely to impede manufacturers' capacity to continue producing gas hearth products in line with demand. Moreover, several manufacturers stated that the higher costs of producing products with electronic ignition systems could lead to a decline in demand, potentially leaving them with excess production capacity. In that light, the proposed standard is not likely to trigger capacity constraints.

12.7.3 Cumulative Regulatory Burden

While any one regulation may not impose a significant burden on manufacturers, the combined effects of several impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. Multiple regulations affecting the same manufacturer can strain profits and can lead companies to abandon product lines or markets with lower expected future returns than competing products. For these reasons, DOE conducts an analysis of cumulative regulatory burden as part of its rulemakings pertaining to appliance efficiency.

Companies that produce a wide range of regulated products may be faced with more capital and product development expenditures than competitors with a narrower scope of products. Regulatory burdens can prompt companies to exit the market or reduce their product offerings, potentially reducing competition. Smaller companies in particular can be affected by regulatory costs, as these companies have lower sales volumes over which they can amortize the costs of meeting new regulations. A proposed standard is not economically justified if it contributes to an unacceptable level of cumulative regulatory burden.

For the cumulative regulatory burden analysis, DOE looks at other product-specific federal regulations that could affect gas hearth products and that will take effect approximately three years before or after the 2021 compliance date of the proposed energy conservation standard. In interviews, manufacturers cited a Consumer Product Safety Commission regulation requiring barrier screens on gas hearth products. However, this requirement is set to take effect in January 2015 and therefore is not considered in this analysis. DOE did not identify any other federally mandated product-specific regulations that will take effect in the three years before or after the 2021 compliance date for this rulemaking, and therefore has not presented any other regulations in this analysis of cumulative regulatory burden.

12.8 CONCLUSION

The following section summarizes the range of financial impacts gas hearth manufacturers are likely to experience as a result of energy conservation standards. While these scenarios bound the range of most plausible impacts on manufacturers, there potentially could be circumstances that cause manufacturers to experience impacts outside this range.

Table 12.8.1 presents a range of results reflecting both the preservation of gross margin percentage markup scenario and the preservation of operating profit markup scenario. As explained in section 12.4.7, the preservation of operating profit scenario accounts for the more severe impacts presented. Estimated conversion costs and free cash flow in the year prior to the effective date of standards do not vary with the markup scenario.

Table 12.8.1 Manufacturer Impact Analysis Results

	Units	Base Case *$*	Standards Case* *$*
INPV	2013$M	125.3	122.0 to 125.8
Change in INPV	2013$M	-	(3.3) to 0.5
	% Change	-	(2.6) to 0.4
Product Conversion Costs	2013$M	-	7.8
Capital Conversion Costs	2013$M	-	0.9
Total Conversion Costs	2013$M	-	8.7
Free Cash Flow (2020)	2013$M	10.9	8.2
	% Change	-	(24.0)

*Parentheses indicate negative values

Under a standards case that eliminates standing pilot lights, DOE estimates the impacts on INPV to range from -$3.3 million to $0.5 million, or a change of -2.6 percent to 0.4 percent. Industry free cash flow is estimated to decrease by $2.6 million, or a change of 24.0 percent compared to the base-case value of $10.9 million in the year before the compliance date (2020).

DOE estimates that in the year of compliance (2021), 42 percent of all gas hearth shipments will already be sold with electronic ignition systems. Because most manufacturers already offer units with electronic ignition systems, and because the conversion from standing pilot to electronic ignition primarily entails a change in purchased parts, DOE estimates limited capital conversion costs to achieve compliance with a new standard. Product conversion costs in the form of testing and certification costs and potential redesign requirements account for the bulk of estimated conversion costs. DOE estimates total industry conversion costs of $8.7 million under the proposed energy conservation standard.

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CHAPTER 13. EMISSIONS IMPACT ANALYSIS

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CHAPTER 13. EMISSIONS IMPACT ANALYSIS

13.1 INTRODUCTION

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2) and mercury (Hg). The second component estimates the impacts of a potential standard on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the reductions to emissions of all species due to "upstream" activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Together, these emissions account for the full-fuel-cycle (FFC), in accordance with DOE's FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011).

The analysis of power sector emissions uses marginal emissions intensity factors calculated by DOE. As of 2014, DOE is using a new methodology based on results published for the *Annual Energy Outlook 2014 (AEO 2014)* reference case and a set of side cases that implement a variety of efficiency-related policies.[1] The new methodology is described in chapter 15 and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014).[2] Site emissions of CO_2 and NO_X are estimated using emissions intensity factors from a publication of the Environmental Protection Agency (EPA).[3]

Combustion emissions of CH_4 and N_2O are estimated using emissions intensity factors published by the EPA, GHG Emissions Factors Hub.[a] The FFC upstream emissions are estimated based on the methodology developed by Coughlin (2013).[4] The upstream emissions include both emissions from fuel combustion during extraction, processing and transportation of fuel, and "fugitive" emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The emissions intensity factors are expressed in terms of physical units per MWh or MMBtu of site energy savings. Total emissions reductions are estimated using the energy savings calculated in the national impact analysis (chapter 10).

For CH_4 and N_2O, DOE also presents results in terms of units of carbon dioxide equivalent (CO_2e). Gases are converted to CO_2e by multiplying the physical units by the gas global warming potential (GWP) over a 100 year time horizon. Based on the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,[5] DOE used GWP values of 28 for CH_4 and 265 for N_2O.[b]

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[a] www.epa.gov/climateleadership/inventory/ghg-emissions.html

[b] The values are without inclusion of climate-carbon feedbacks in response to emissions of the indicated non-CO_2 gases.

13.2 AIR QUALITY REGULATIONS AND EMISSIONS IMPACTS

Each annual version of the AEO incorporates the projected impacts of existing air quality regulations on emissions. *AEO 2014* generally represents current Federal and State legislation and final implementation regulations in place as of the end of October 2013.

SO_2 emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap and trading programs. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for affected EGUs in the 48 contiguous states and the District of Columbia (D.C.). SO_2 emissions from 28 eastern states and D.C. were also limited under the Clean Air Interstate Rule (CAIR), which created an allowance-based trading program that that operates along with the Title IV program in those States and D.C. 70 FR 25162 (May 12, 2005). CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) but parts of it remained in effect. On July 6, 2011 EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule (CSAPR). 76 FR 48208 (August 8, 2011). On August 21, 2012, the D.C. Circuit issued a decision to vacate CSAPR. See *EME Homer City Generation, LP v. EPA*, 696 F.3d 7, 38 (D.C. Cir. 2012). The court ordered EPA to continue administering CAIR. The *AEO 2014* emissions factors used for the present analysis assume that CAIR remains a binding regulation through 2040. [c]

The attainment of emissions caps is typically flexible among affected Electric Generating Units (EGUs) and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the imposition of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. In past rulemakings, DOE recognized that there was uncertainty about the effects of efficiency standards on SO_2 emissions covered by the existing cap-and-trade system, but it concluded that no reductions in power sector emissions would occur for SO_2 as a result of standards.

Beginning in 2016, however, SO_2 emissions will fall as a result of the Mercury and Air Toxics Standards (MATS) for power plants. 77 FR 9304 (Feb. 16, 2012). In the final MATS rule, EPA established a standard for hydrogen chloride as a surrogate for acid gas hazardous air pollutants (HAP), and also established a standard for SO_2 (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, SO_2 emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO*

[c] On April 29, 2014, the U.S. Supreme Court reversed the judgment of the D.C. Circuit and remanded the case for further proceedings consistent with the Supreme Court's opinion. The Supreme Court held in part that EPA's methodology for quantifying emissions that must be eliminated in certain states due to their impacts in other downwind states was based on a permissible, workable, and equitable interpretation of the Clean Air Act provision that provides statutory authority for CSAPR. See *EPA v. EME Homer City Generation*, No 12-1182, slip op. at 32 (U.S. April 29, 2014).). On October 23, 2014, the D.C. Circuit lifted the stay of CSAPR and CSAPR went into effect (and the CAIR sunset) in January 1, 2015. Because DOE is using emissions factors based on *AEO 2014*, the analysis assumes that CAIR, not CSAPR, is the regulation in force. The difference between CAIR and CSAPR is not relevant for the purpose of DOE's analysis of SO_2 emissions.

2014 assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2016. Both technologies, which are used to reduce acid gas emissions, also reduce SO_2 emissions. Under the MATS, emissions will be far below the cap established by CAIR, so it is unlikely that excess SO_2 emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in SO_2 emissions by any regulated EGU. Therefore, DOE believes that efficiency standards will reduce SO_2 emissions in 2016 and beyond.

CAIR established a cap on NO_x emissions in 28 eastern States and the District of Columbia. Energy conservation standards are expected to have little effect on NO_x emissions in those States covered by CSAPR because excess NO_x emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in NO_x emissions. However, standards would be expected to reduce NO_x emissions in the States not affected by CAIR, so DOE estimated NOx emissions reductions from potential standards for those States.

The MATS limit mercury emissions from power plants, but they do not include emissions caps and, as such, DOE's energy conservation standards would likely reduce Hg emissions. DOE estimated mercury emissions reductions using the NEMS-BT based on *AEO 2014*, which incorporates the MATS.

13.3 POWER SECTOR AND SITE EMISSIONS FACTORS

The analysis of power sector emissions uses marginal emissions intensity factors derived from analysis of the *AEO 2014* reference and a number of side cases incorporating enhanced equipment efficiencies. To model the impact of a standard, DOE calculates factors that relate a unit reduction to annual site electricity demand for a given end use to corresponding reductions to installed capacity by fuel type, fuel use for generation, and power sector emissions. Details on the approach used may be found in Coughlin (2014).

Table 13.3.1 presents the average power plant emissions factors for selected years. These power plant emissions factors are derived from the emissions factors of the plant types used to supply electricity for space heating in homes. The average factors for each year take into account the projected shares of each of the sources in total electricity generation.

Table 13.3.2 presents the natural gas site combustion emissions factors for selected years.

Table 13.3.1 Power Plant Emissions Factors

	Unit*	2021	2025	2030	2035	2040
CO_2	kg/MWh	738	656	592	540	491
SO_2	g/MWh	731	590	496	417	373
NOx	g/MWh	585	497	434	382	345
Hg	g/MWh	0.00225	0.00182	0.00153	0.00129	0.00115
N_2O	g/MWh	7.2	7.1	6.9	6.6	6.4
CH_4	g/MWh	50.1	49.4	47.9	46.4	44.8

* Refers to site electricity savings.

Table 13.3.2 Natural Gas Site Combustion Emissions Factors

	Unit*	2021	2025	2030	2035	2040
CO_2	kg/mcf	54.2	54.2	54.2	54.2	54.2
SO_2	g/ mcf	0.271	0.271	0.271	0.271	0.271
NOx	g/ mcf	69.9	69.9	69.9	69.9	69.9
N_2O	g/ mcf	0.102	0.102	0.102	0.102	0.102
CH_4	g/ mcf	1.022	1.022	1.022	1.022	1.022

* Refers to site gas savings.

13.4 UPSTREAM FACTORS

The upstream emissions accounting uses the same approach as the upstream energy accounting described in appendix 10B. See also Coughlin (2013) and Coughlin (2014). When demand for a particular fuel is reduced, there is a corresponding reduction in the emissions from combustion of that fuel at either the building site or the power plant. The associated reduction in energy use for upstream activities leads to further reductions in emissions. These upstream emissions are defined to include the combustion emissions from the fuel used upstream, the fugitive emissions associated with the fuel used upstream, and the fugitive emissions associated with the fuel used on site.

Fugitive emissions of CO_2 occur during oil and gas production, but are small relative to combustion emissions. They comprise about 2.5 percent of total CO_2 emissions for natural gas and 1.7 percent for petroleum fuels. Fugitive emissions of methane occur during oil, gas and coal production. Combustion emissions of CH_4 are very small, while fugitive emissions (particularly for gas production) may be relatively large. Hence, fugitive emissions make up over 99 percent of total methane emissions for natural gas, about 95 percent for coal, and 93 percent for petroleum fuels.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. Fugitive emissions factors for methane from coal mining and natural gas production were estimated based on a review of recent studies compiled by Burnham (2011).[6] This review includes estimates of the difference between fugitive emissions factors for conventional production of natural vs. unconventional (shale or tight gas). These estimates rely in turn on data gathered by EPA under new GHG reporting requirements for the petroleum and natural gas industries.[7, 8] As more data are made available, DOE will continue to update these estimated emissions factors.

For ease of application in its analysis, DOE developed all of the emissions factors using site (point of use) energy savings in the denominator. Table 13.4.1 presents the electricity upstream emissions factors for selected years. The caps that apply to power sector NO_X emissions do not apply to upstream combustion sources.

Table 13.4.1 Electricity Upstream Emissions Factors

	Unit	2021	2025	2030	2035	2040
CO_2	kg/MWh	29.2	29.4	29.7	29.9	29.8
SO_2	g/MWh	5.0	5.1	4.9	4.7	4.6
NOx	g/MWh	370	375	382	387	387
Hg	g/MWh	0.00001	0.00001	0.00001	0.00001	0.00001
N_2O	g/MWh	0.25	0.25	0.24	0.23	0.23
CH_4	g/MWh	2,157	2,195	2,216	2,248	2,255

Table 13.4.2 illustrates the natural gas upstream emissions factors for selected years. These were used to estimate the emissions associated with the increased gas use at some of the considered efficiency levels.

Table 13.4.2 Natural Gas Upstream Emissions Factors

	Unit	2021	2025	2030	2035	2040
CO_2	kg/ mcf	7.2	7.2	7.3	7.4	7.4
SO_2	g/ mcf	0.031	0.031	0.031	0.032	0.032
NOx	g/ mcf	102	103	105	105	105
N_2O	g/ mcf	0.011	0.011	0.012	0.012	0.012
CH_4	g/ mcf	661	665	666	670	670

13.5 EMISSIONS IMPACT RESULTS

Table 13.5.1 presents the estimated cumulative emissions reductions for the lifetime of products sold in 2021-2050 for each TSL. Negative values indicate that emissions increase.

Table 13.5.1 Cumulative Emissions Reduction for Potential Standard for Hearth Product Ignition Devices

	TSL
	1
Power Sector and Site Emissions	
CO_2 (million metric tons)	32.3
SO_2 (thousand tons)	-4.23
NO_X (thousand tons)	49.2
Hg (tons)	-0.0137
N_2O (thousand tons)	0.279
CH_4 (thousand tons)	0.00634
Upstream Emissions	
CO_2 (million metric tons)	4.78
SO_2 (thousand tons)	-0.0275
NO_X (thousand tons)	75.8
Hg (tons)	-0.00011
N_2O (thousand tons)	485
CH_4 (thousand tons)	0.00629
Total Emissions	
CO_2 (million metric tons)	37.0
SO_2 (thousand tons)	-4.26
NO_X (thousand tons)	125
Hg (tons)	-0.0138
N_2O (thousand tons)	486
CH_4 (thousand tons)	0.0126

Figure 13.5.1 through Figure 13.5.6 show the annual reductions for total emissions for each type of emission from each TSL. The reductions reflect the lifetime impacts of products sold in 2021-2050.

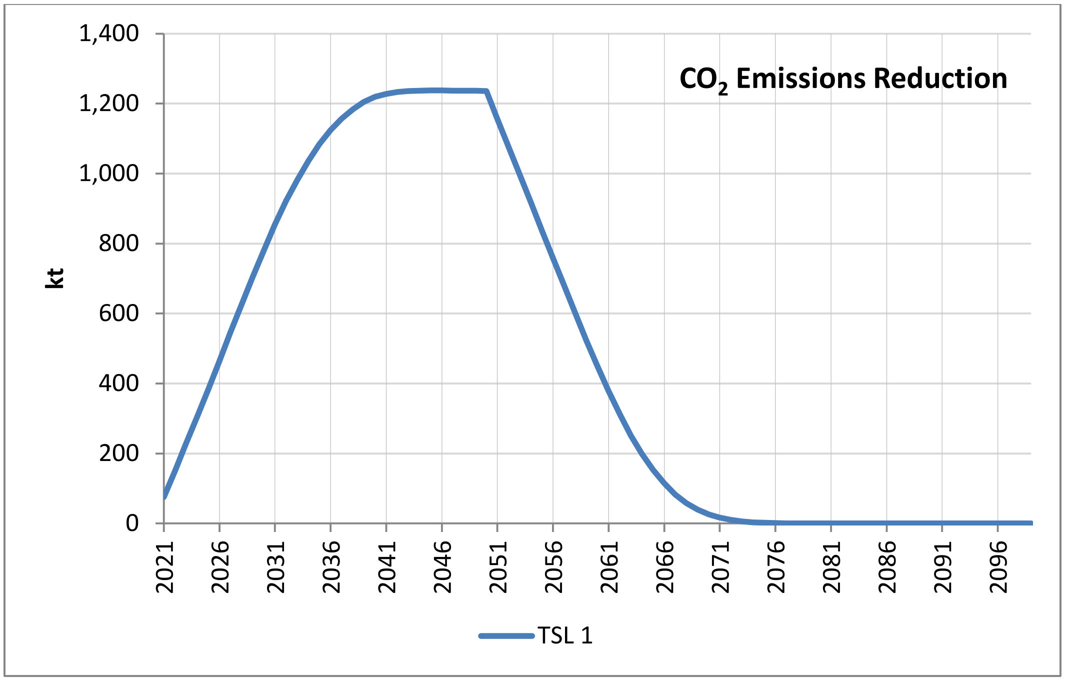

Figure 13.5.1 Hearth Product Ignition Devices: CO_2 Total Emissions Reduction

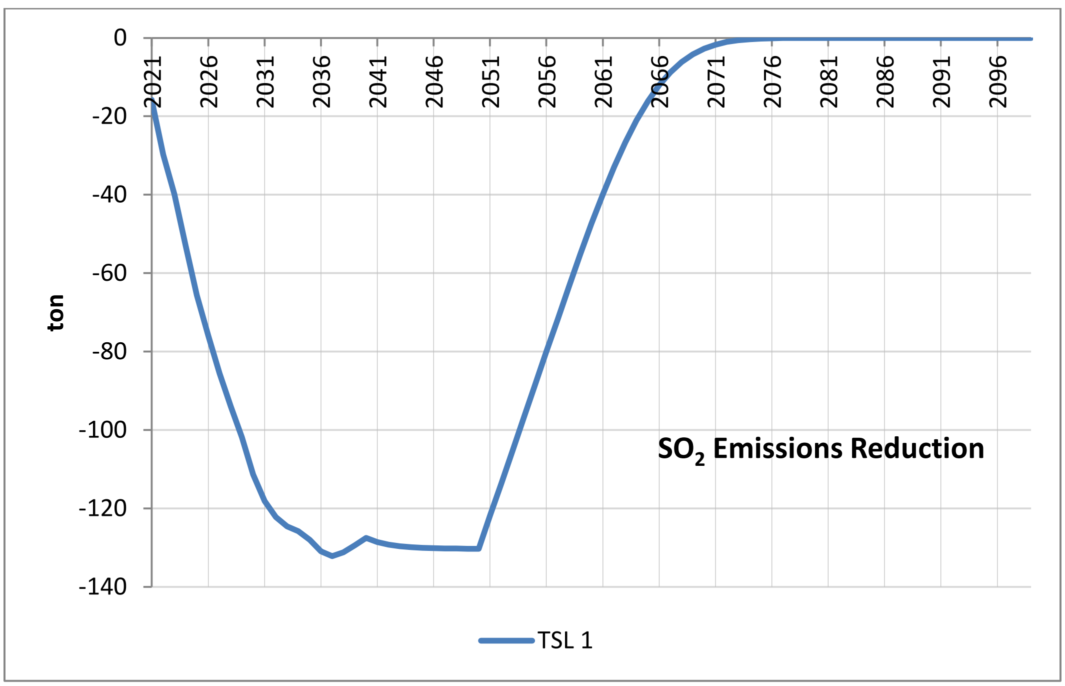

Figure 13.5.2 Hearth Product Ignition Devices: SO_2 Total Emissions Reduction

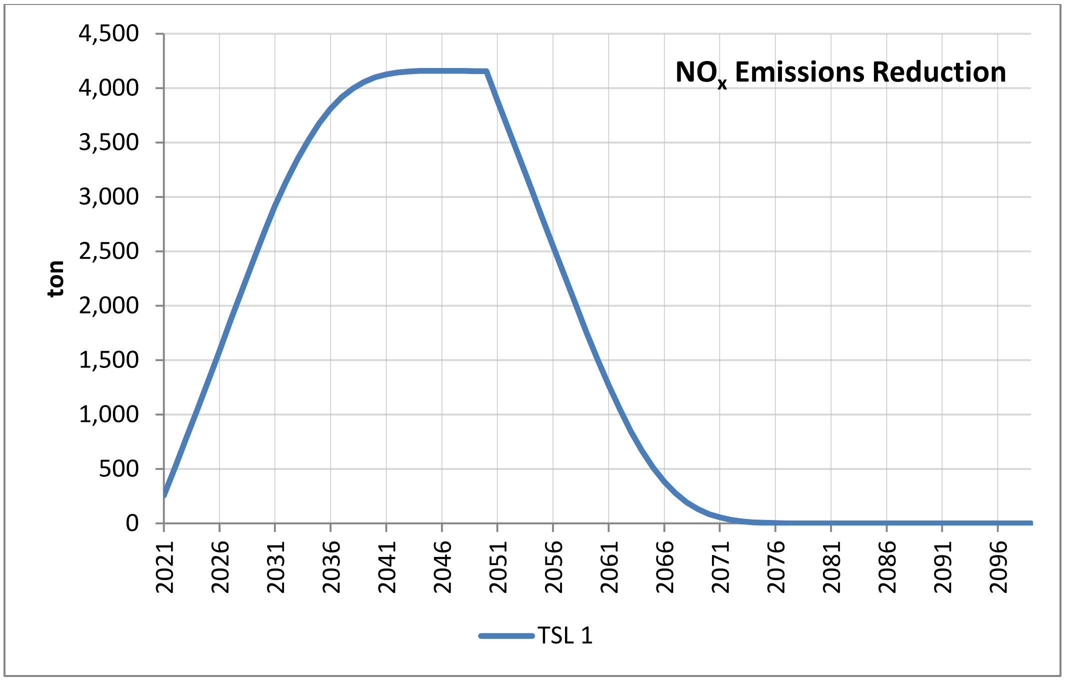

Figure 13.5.3 **Hearth Product Ignition Devices: NO_x Total Emissions Reduction**

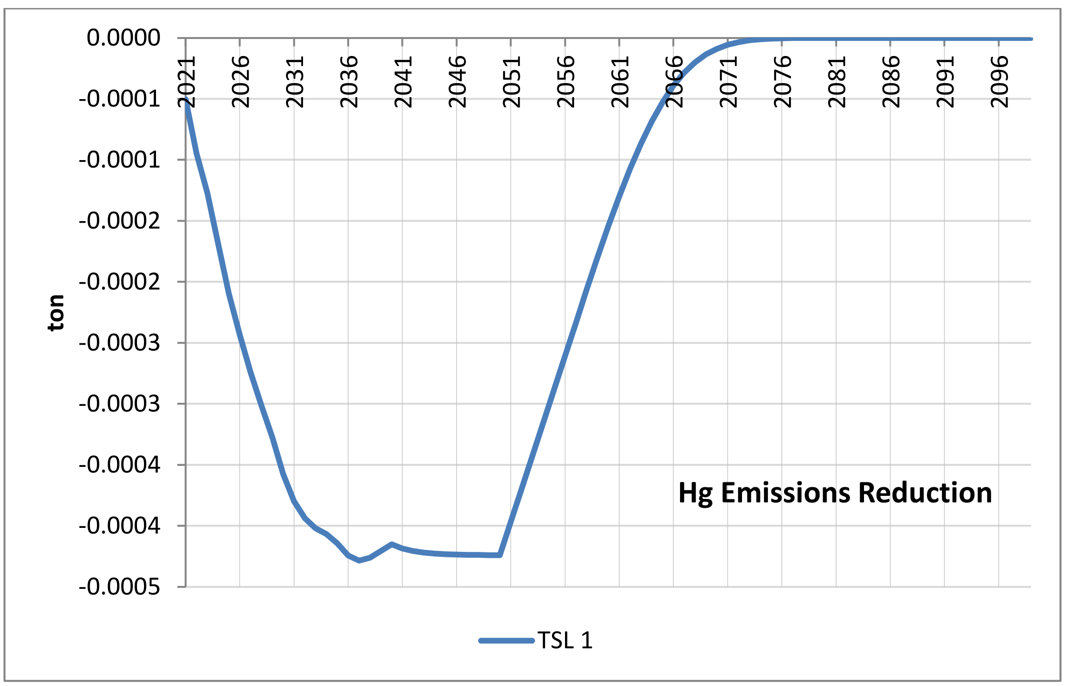

Figure 13.5.4 **Hearth Product Ignition Devices: Hg Total Emissions Reduction**

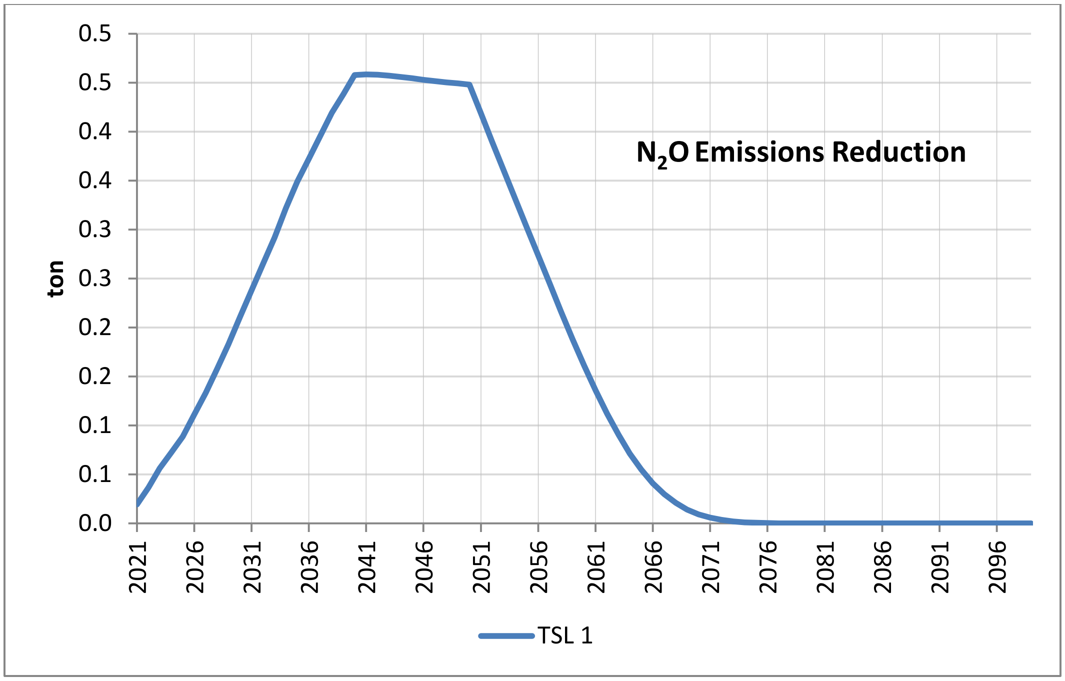

Figure 13.5.5 Hearth Product Ignition Devices: N_2O Total Emissions Reduction

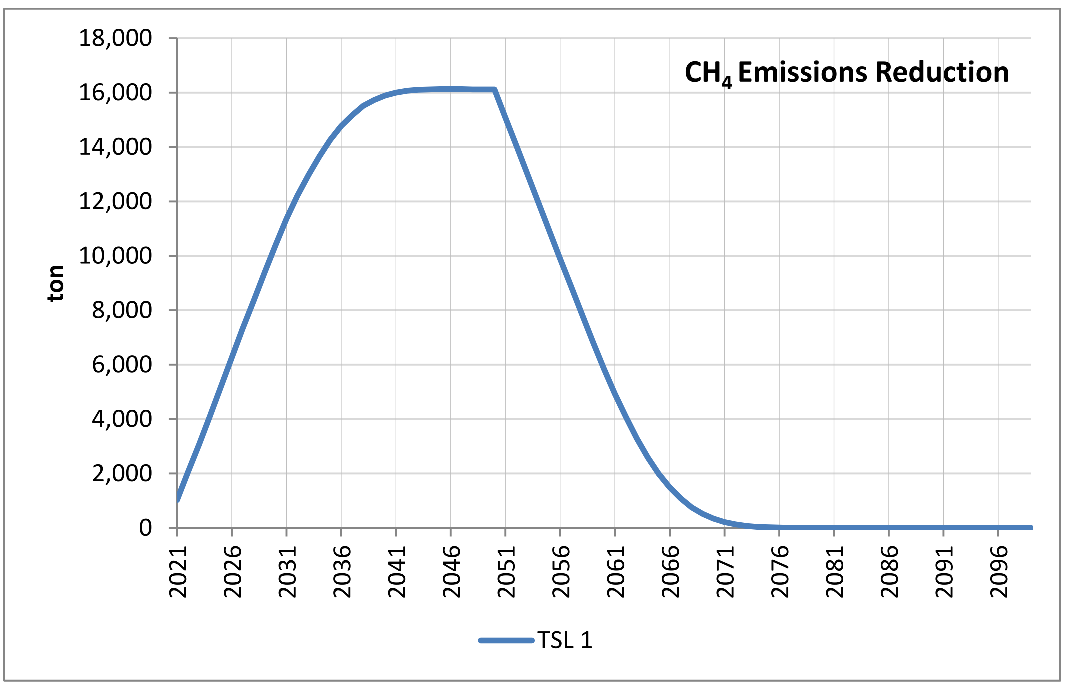

Figure 13.5.6 Hearth Product Ignition Devices: CH_4 Total Emissions Reduction

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14.1 INTRODUCTION

As part of its assessment of the effects of potential energy conservation standards for hearth product ignition devices, the U.S. Department of Energy (DOE) estimated the monetary benefits of the reduced emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_X) that would be expected to result from each trial standard level (TSL) considered for hearth products. This chapter summarizes the basis for the monetary values assigned to emissions and presents the modeled benefits of estimated reductions.

14.2 MONETIZING CARBON DIOXIDE EMISSIONS

One challenge for anyone attempting to calculate the monetary benefits of reduced emissions of CO_2 is what value to assign to each unit eliminated. The value must encompass a broad range of physical, economic, social, and political effects. Analysts developed the concept of the social cost of carbon (SCC) to represent the broad cost or value associated with producing—or reducing—a quantifiable amount of CO_2 emissions.

14.2.1 Social Cost of Carbon

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. The SCC is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. SCC estimates are provided in dollars per metric ton of carbon dioxide. A value for the domestic SCC is meant to represent the damages in the United States resulting from a unit change in carbon dioxide emissions, whereas a global SCC is meant to reflect the value of damages worldwide.

Under section 1(b)(6) of Executive Order 12866,[1] agencies must, to the extent permitted by law, "assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the SCC estimates required by the Executive Order is to enable agencies to incorporate the monetized social benefits of reducing CO_2 emissions into cost-benefit analyses of regulatory actions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they will need updating in response to increasing knowledge of the science and economics of climate impacts.

As part of the interagency process that developed the SCC estimates, technical experts from numerous agencies met regularly to explore the technical literature in relevant fields, discuss key model inputs and assumptions, and consider public comments. The primary objective of the process was to develop a range of SCC values using a defensible set of assumptions regarding model inputs that was grounded in the scientific and economic literature. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates developed for use in the rulemaking process.

14.2.2 Monetizing Carbon Dioxide Emissions

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces several serious challenges. A report from the National Research Council[2] points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the effects of changes in climate on the physical and biological environment, and (4) the translation of those environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change raises serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing CO_2 emissions. An agency can estimate the benefits from reduced (or costs from increased) emissions in any future year by multiplying the change in emissions in that year by the SCC values appropriate for that year. Then the net present value of the benefits can be calculated by multiplying each of the future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions.

14.3 DEVELOPMENT OF SOCIAL COST OF CARBON VALUES

In 2009, an interagency process was initiated to develop a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To provide consistency in how benefits are evaluated across Federal agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the literature to use as interim values until a more comprehensive analysis could be conducted. The outcome of the preliminary assessment was a set of five interim values: global SCC estimates for 2007 (in 2006$) of $55, $33, $19, $10, and $5 per ton of CO_2.[3] Those interim values represented the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of that preliminary effort were presented in several proposed and final rules.

14.3.1 Current Approach and Key Assumptions

After the release of the interim values, the interagency group reconvened regularly to improve the SCC estimates. Specifically, the group considered public comments and further explored the technical literature in relevant fields. The interagency group relied on three integrated assessment models commonly used to estimate the SCC. The models are known by their acronyms of FUND, DICE, and PAGE. Those three models frequently are cited in the peer-reviewed literature and were used in the most recent assessment of the Intergovernmental Panel on Climate Change. Each model was given equal weight in developing SCC values.

Each model takes a slightly different approach to calculating how increases in emissions produce economic damages. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches taken by the key modelers in the field. An extensive review of the literature identified three sets of input parameters for the models: climate sensitivity; socioeconomic and emissions trajectories; and discount rates. A probability distribution for climate sensitivity was specified as an input to all three models. In addition, the interagency group used a range of scenarios for the socioeconomic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from the three integrated assessment models, at discount rates of 2.5 percent, 3 percent, and 5 percent. The fourth value, which represents the 95th percentile of the SCC estimate across all three models at a 3-percent discount rate, is included to represent larger-than-expected effects from temperature changes farther out in the tails of the SCC distribution. The values increase in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although preference is given to consideration of the global benefits of reducing CO_2 emissions. Table 14.3.1 presents the values in the 2010 interagency group report.[4]

Table 14.3.1 Annual SCC Values for 2010-2050 from 2010 Interagency Report (in 2007$ per Metric Ton)

Year	Discount Rate (%)			
	5	3	2.5	3
	Average	Average	Average	95th Percentile
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

The SCC values used for the analysis of the effects of potential standards for hearth products were generated using the most recent versions of the three integrated assessment models that have been published in the peer-reviewed literature, as described in the 2013 update from the interagency working group (revised November 2013). Table 14.3.2 shows the updated sets of SCC estimates in 5-year increments from 2010 to 2050. The full set of annual SCC estimates for 2010–2050 is presented in appendix 14B of this TSD. The central value that emerges is the average SCC across models at a 3-percent discount rate. To capture the uncertainties involved in regulatory impact analysis, however, the interagency group emphasizes the importance of including all four sets of SCC values.

Table 14.3.2 Annual SCC Values for 2010–2050 from 2013 Interagency Update (in 2007$ per Metric Ton of CO_2)

Year	Discount Rate (%)			
	5	3	2.5	3
	Average	Average	Average	95th Percentile
2010	11	32	51	89
2015	11	37	57	109
2020	12	43	64	128
2025	14	47	69	143
2030	16	52	75	159
2035	19	56	80	175
2040	21	61	86	191
2045	24	66	92	206
2050	26	71	97	220

14.3.2 Limitations of Current Estimates

The interagency group recognizes that current models are imperfect and incomplete. Because key uncertainties remain, current SCC estimates should be treated as provisional and revisable. Estimates doubtless will evolve in response to improved scientific and economic understanding. The 2009 National Research Council report points out the tension between producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of current modeling efforts. Several analytic challenges are being addressed by the research community, some by research programs housed in many of the Federal agencies participating in the interagency process. The interagency group intends to review and reconsider SCC estimates periodically to incorporate expanding knowledge of the science and economics of climate impacts, as well as improvements in modeling.

In summary, in considering the potential global benefits resulting from reduced CO_2 emissions, DOE used the values from the 2013 interagency report, applying the GDP price deflator to adjust the values to 2013$. For the four SCC values, the values of emissions in 2015 were $12.0, $40.5, $62.4, and $119 per metric ton avoided (values expressed in 2013$). DOE derived values after 2050 using the relevant growth rates for 2040–2050 in the interagency update.

DOE multiplied the CO_2 emissions reduction estimated for each year by the SCC value for that year under each discount rate. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the same discount rate that had been used to obtain the SCC values in each case.

14.4 VALUATION OF OTHER EMISSIONS REDUCTIONS

DOE considered the potential monetary benefits of reduced NO_X emissions attributable to the TSLs considered for hearth product ignition devices. As noted in chapter 13, new or amended energy conservation standards would reduce NO_X emissions in those States that are not affected by emissions caps. DOE estimated the monetized value of NO_X emissions reductions resulting from each TSL based on estimates of environmental damage found in the scientific literature. Estimates suggest a wide range of monetary values, from $476 to $4,893 per ton (in 2013$).[5] DOE calculated monetary benefits using a median value for NO_X emissions of $2,684 per short ton (in 2013$), at real discount rates of 3 percent and 7 percent.

DOE continues to evaluate appropriate values for monetizing avoided SO_2 and Hg emissions. DOE did not monetize those emissions for this analysis.

14.5 RESULTS

Table 14.5.1 presents the global values of CO_2 emissions reductions for each considered TSL.

Table 14.5.1 Estimates of Global Present Value of CO_2 Emissions Reduction under TSLs for Hearth Product Ignition Devices

TSL	SCC Case*			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
	Million 2013$			
Primary Energy Emissions				
1	196	956	1535	2966
Upstream Emissions				
1	29	142	228	440
Full-Fuel-Cycle Emissions				
1	226	1098	1763	3405

* For each of the four cases, the corresponding global SCC value for emissions in 2015 is $12.0, $40.5, $62.4, and $119 per metric ton (2013$).

After calculating global values of CO_2 emissions reductions for each considered TSL, DOE calculated domestic values as a range of from 7 percent to 23 percent of the global values. Results for domestic values are presented in Table 14.5.2.

Table 14.5.2 Estimates of Domestic Present Value of CO_2 Emissions Reduction under TSLs for Hearth Product Ignition Devices

TSL	SCC Case*			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
	Million 2013$			
Primary Energy Emissions				
1	13.7 to 45.2	66.9 to 220.0	107.5 to 353.1	207.6 to 682.1
Upstream Emissions				
1	2.0 to 6.7	9.9 to 32.6	15.9 to 52.3	30.8 to 101.1
Full-Fuel-Cycle Emissions				
1	15.8 to 51.9	76.9 to 252.6	123.4 to 405.4	238.4 to 783.2

* For each of the four cases, the corresponding SCC value for emissions in 2015 is $12.0, $40.5, $62.4, and $119 per metric ton (2013$).

Table 14.5.3 presents the present value of cumulative NO_X emissions reductions for each TSL. Monetary values are calculated using the average dollar-per-ton values assigned to NO_X emissions at 7-percent and 3-percent discount rates.

Table 14.5.3 Estimates of Present Value of NO_X Emissions Reduction under TSLs for Hearth Product Ignition Devices

TSL	3% discount rate	7% discount rate
	Million 2013$	
Primary Energy Emissions		
1	58	23
Upstream Emissions		
1	90	35
Full-Fuel-Cycle Emissions		
1	148	58

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CHAPTER 15. UTILITY IMPACT ANALYSIS

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CHAPTER 15. UTILITY IMPACT ANALYSIS

15.1 INTRODUCTION

In the utility impact analysis for hearth product ignition devices, the U.S. Department of Energy (DOE) analyzed the changes in electric installed capacity and power generation that result for each trial standard level (TSL).

The utility impact analysis is based on output of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS).[a] NEMS is a public domain, multi-sectored, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce an energy forecast for the United States, the Annual Energy Outlook (AEO). The EIA publishes a reference case, which incorporates all existing energy-related policies at the time of publication, and a variety of side cases which analyze the impact of different policies, energy price and market trends. As of 2014, DOE is using a new methodology based on results published for the *Annual Energy Outlook 2014 (AEO 2014)* Reference case and a set of side cases that implement a variety of efficiency-related policies.[2]

The new approach retains key aspects of DOE's previous methodology, and provides some improvements:

- The assumptions used in the AEO reference case and side cases are fully documented and receive detailed public scrutiny.
- NEMS is updated each year, with each edition of the AEO, to reflect changes in energy prices, supply trends, regulations, *etc.*
- The comprehensiveness of NEMS permits the modeling of interactions among the various energy supply and demand sectors.
- Using EIA published side cases to estimate the utility impacts enhances the transparency of DOE's analysis.
- The variability in impacts estimates from one edition of AEO to the next will be reduced under the new approach.

On average, however, over the full analysis period, the results from the new approach are comparable to results from the old approach.

[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview*.[1]

15.2 METHODOLOGY

DOE estimates the marginal impacts of reduction in energy demand on the energy supply sector. In principle, marginal values should provide a better estimate of the actual impact of energy conservation standards.

NEMS uses predicted growth in demand for each end use to build up a projection of the total electric system load growth. The system load shapes are converted internally to load duration curves, which are then used to estimate the most cost-effective additions to capacity. When electricity demand deviates from the AEO reference case, in general there are three inter-related effects: the annual generation (TWh) from the stock of electric generating capacity changes, the total generation capacity itself (GW) may change, and the mix of capacity by fuel type may change. Each of these effects can vary for different types of end use. The change in total generating capacity is sensitive to the degree to which the end-use is peak coincident, while the capacity mix is sensitive to the hourly load shape associated with the end use. Changes in generation by fuel type lead in turn to changes in total power sector emissions of SO_2, NO_x, Hg and CO_2.

DOE's new approach examines a series of AEO side cases to estimate the relationship between demand reductions and the marginal energy, emissions and capacity changes. The assumptions for each side case are documented in Appendix E of the AEO. The side cases, or scenarios, that incorporate significant changes to equipment efficiencies relative to the Reference case are:

- 2013 Technology (leaves all technologies at 2013 efficiencies);
- Best Available Technology (highest efficiency irrespective of cost);
- High Technology (higher penetration rates for efficiency and demand management);
- Extended Policies (includes efficiency standards that are not in the reference).

Scenarios that incorporate policies that directly affect the power sector without changes in energy demand (for example, subsidies for renewables, or high fuel price assumptions) are not appropriate for this analysis. The methodology proceeds in seven steps:

1. Supply-side data on generation, capacity and emissions, and demand-side data on electricity use by sector and end-use, are extracted from each side case. The data are converted to differences relative to the AEO Reference case.

2. The changes in electricity use on the demand-side data are allocated to one of three categories: on-peak, shoulder, and off-peak. These categories are used in the utility sector to correlate end-use consumption with supply types. For each of the end-uses that are modeled explicitly in NEMS, load shape information is used to identify the fraction of annual electricity use assigned to each category. On-peak hours are defined as noon-5pm, June through September. Off-peak hours are nights and Sundays. All other hours are assigned to the shoulder period.

3. For each year and each side case, the demand-side reductions to on-peak, off-peak and shoulder-period electricity use are matched on the supply-side to reductions in generation by fuel type. The fuel types are petroleum fuels, natural gas, renewables, nuclear and coal. The allocation is based on the following rules:

   3.1. All petroleum-based generation is allocated to peak periods;

   3.2. Natural gas generation is allocated to any remaining peak reduction; this is consistent with the fact that oil and gas steam units are used in NEMS to meet peak demand;

   3.3. Base-load generation (nuclear and coal) is allocated proportionally to all periods;

   3.4. The remaining generation of all types is allocated to the remaining off-peak and shoulder reductions proportionally.

4. The output of step 3 defines fuel-share weights giving the fraction of energy demand in each load category that is met by each fuel type as a function of time. These are combined with the weights that define the load category shares by end-use to produce coefficients that allocate a marginal reduction in end-use electricity demand to each of the five fuel types.

5. A regression model is used to relate reductions in generation by fuel type to reductions in emissions of power sector pollutants. The model produces coefficients that define the change in total annual emissions of a given pollutant resulting from a unit change in total annual generation for each fuel type, as a function of time. These coefficients are combined with the weights calculated in step 4 to produce coefficients that relate emissions changes to changes in end-use demand.

6. A regression model is used to relate reductions in generation by fuel type to reductions in installed capacity. The categories used for installed capacity are the same as for generation except for peak: NEMS uses two peak capacity types (combustion turbine/diesel and oil and gas steam) which are combined here into a single "peak" category. The model produces coefficients that define the change in total installed capacity of a given type resulting from a unit change in total annual generation for the corresponding fuel type. These coefficients are combined with the weights calculated in step 4 to produce coefficients that relate installed capacity changes to changes in end-use demand, as a function of time.

7. The coefficient time-series for fuel share, pollutant emissions and capacity for the appropriate end use are multiplied by the stream of energy savings calculated in the NIA to produce estimates of the utility impacts.

This analysis ignores pumped storage, fuel cells and distributed generation, as these generation types are not affected by the policy changes modeled in the EIA side cases. The methodology is described in more detail in K. Coughlin, "Utility Sector Impacts of Electricity Demand Reductions".[3]

15.3 UTILITY IMPACT RESULTS

This section presents results of the analysis for all of the capacity types.

15.3.1 Installed Capacity

The figures in this section show the changes in U.S. electricity installed capacity that result for each TSL by major plant type for selected years. Note that a negative number means an increase in capacity under a TSL.

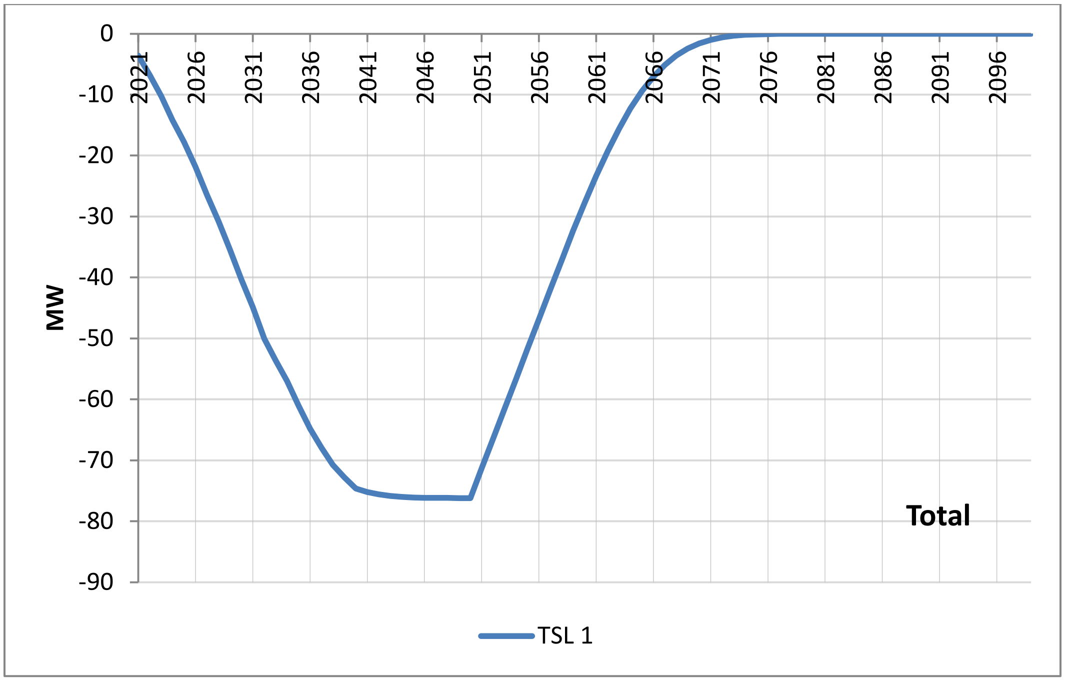

Figure 15.3.1 Hearth Product Ignition Devices: Total Electric Capacity Reduction

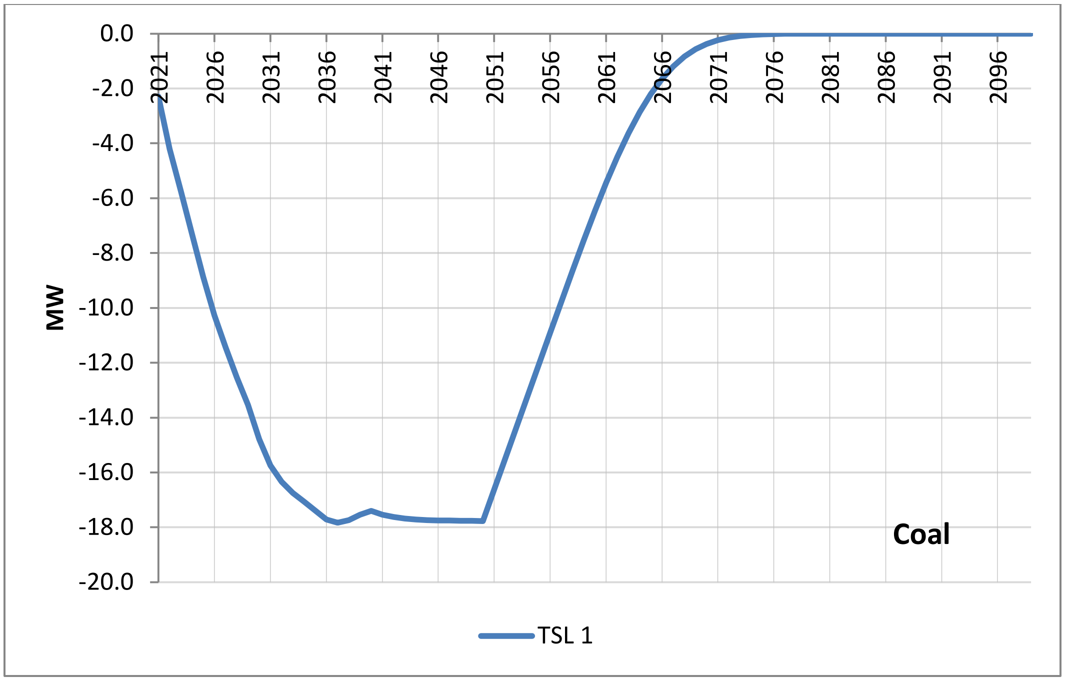

Figure 15.3.2 Hearth Product Ignition Devices: Coal Capacity Reduction

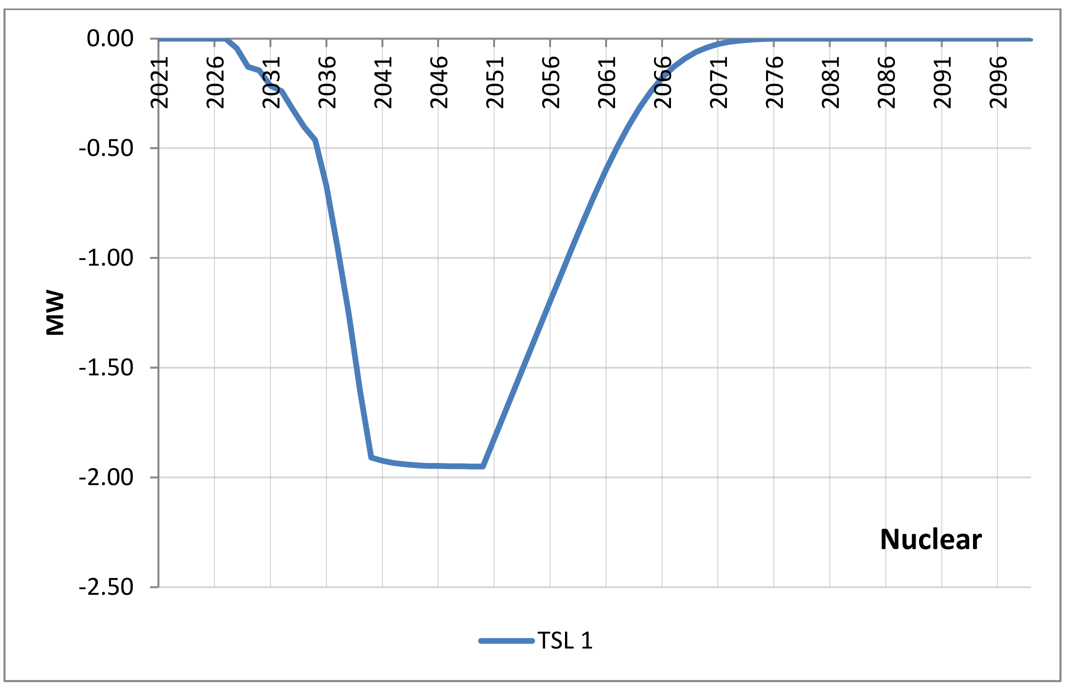

Figure 15.3.3 Hearth Product Ignition Devices: Nuclear Capacity Reduction

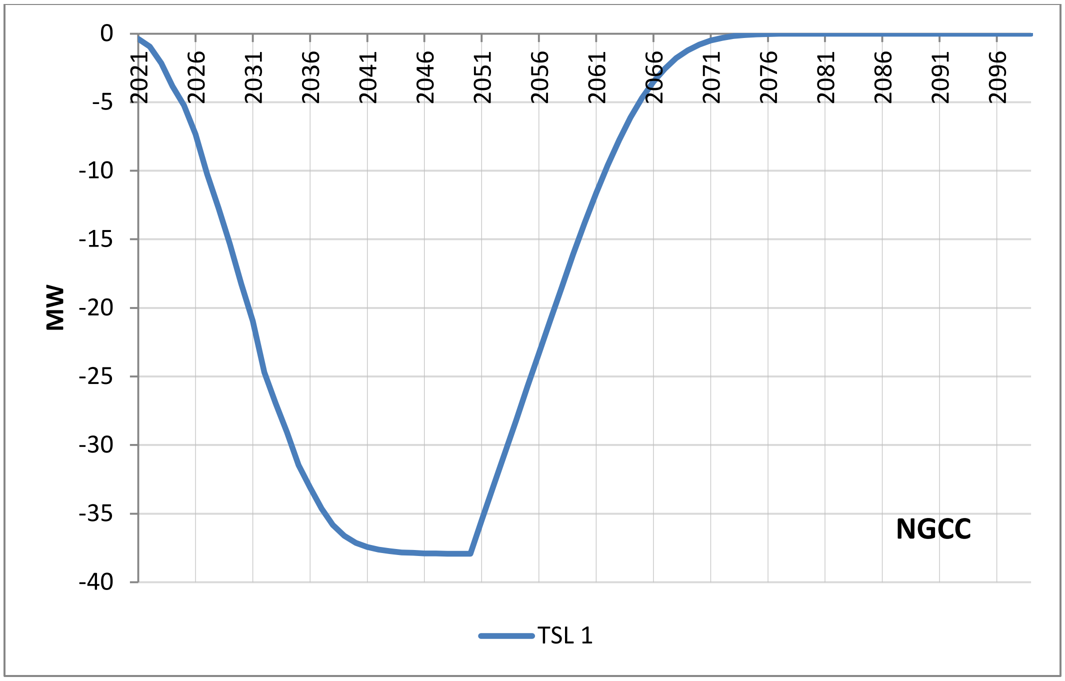

Figure 15.3.4 Hearth Product Ignition Devices: Gas Combined Cycle Capacity Reduction

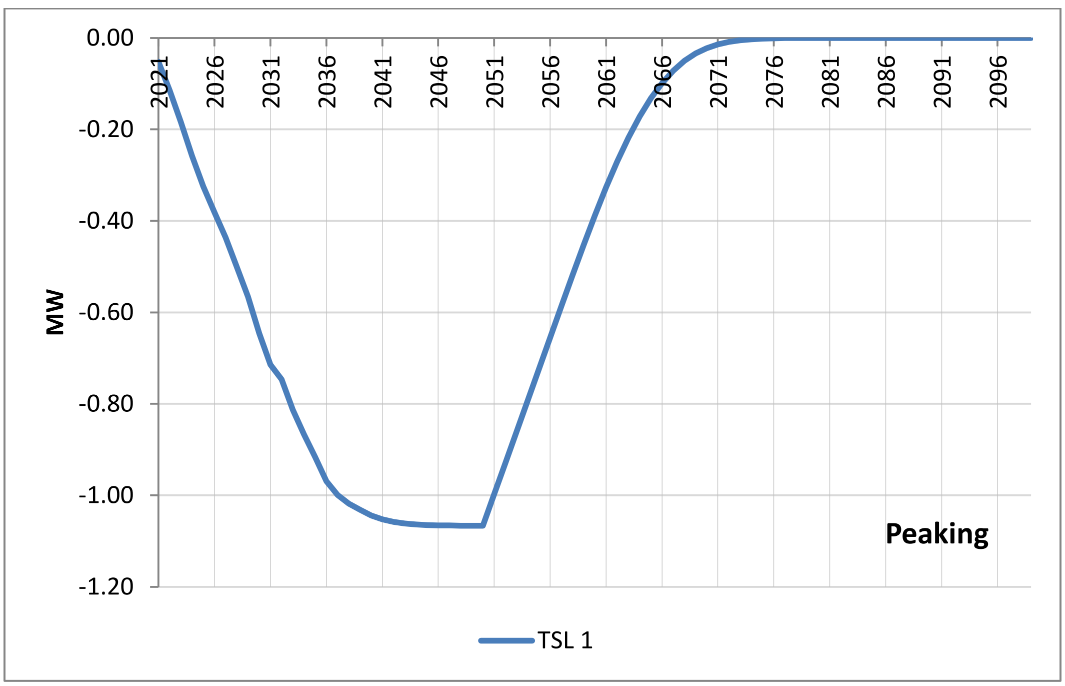

Figure 15.3.5 Hearth Product Ignition Devices: Peaking Capacity Reduction

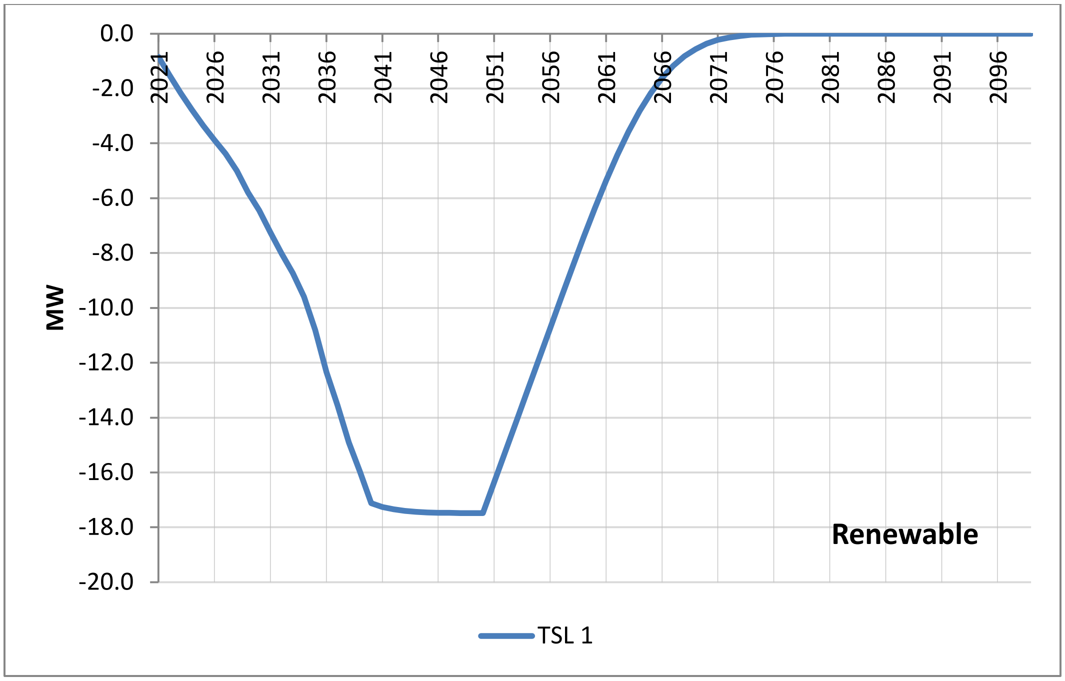

Figure 15.3.6 Hearth Product Ignition Devices: Renewables Capacity Reduction

15.3.2 Electricity Generation

The figures in this section show the annual change in electricity generation that result for each TSL by fuel type. Note that a negative number means an increase in generation under a TSL.

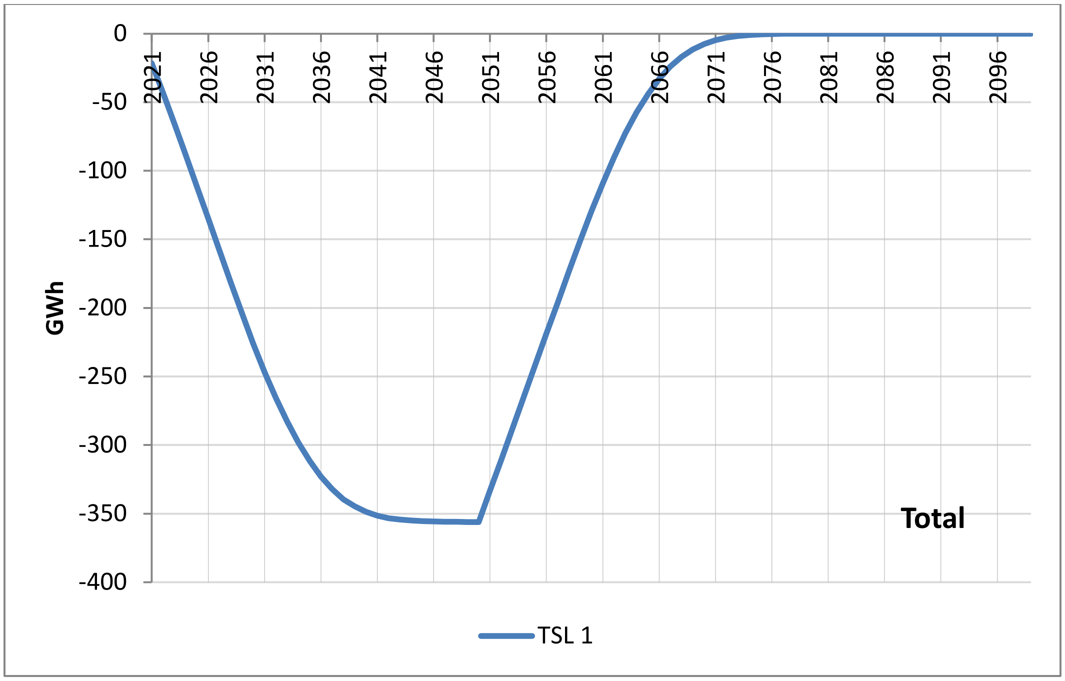

Figure 15.3.7 Hearth Product Ignition Devices: Total Generation Reduction

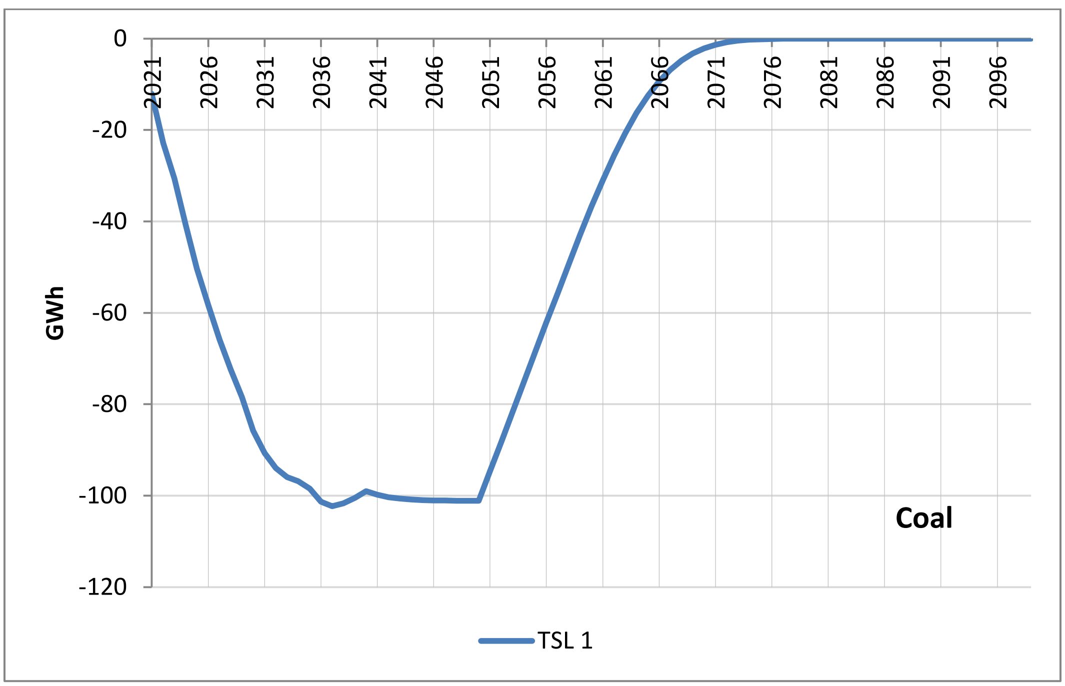

Figure 15.3.8 Hearth Product Ignition Devices: Coal Generation Reduction

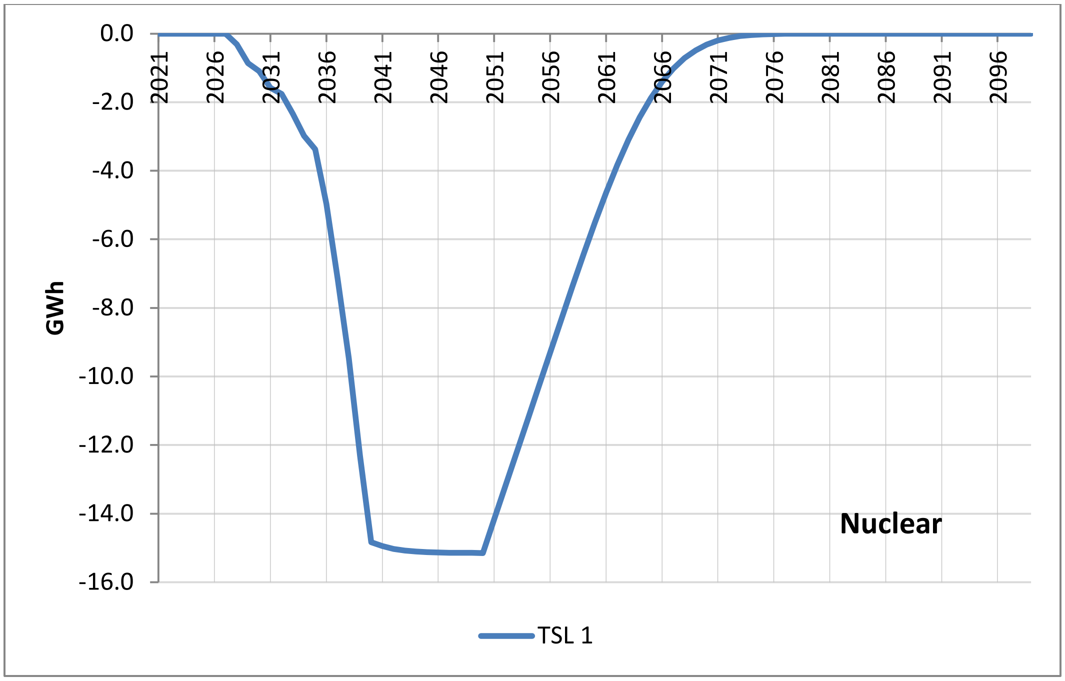

Figure 15.3.9 Hearth Product Ignition Devices: Nuclear Generation Reduction

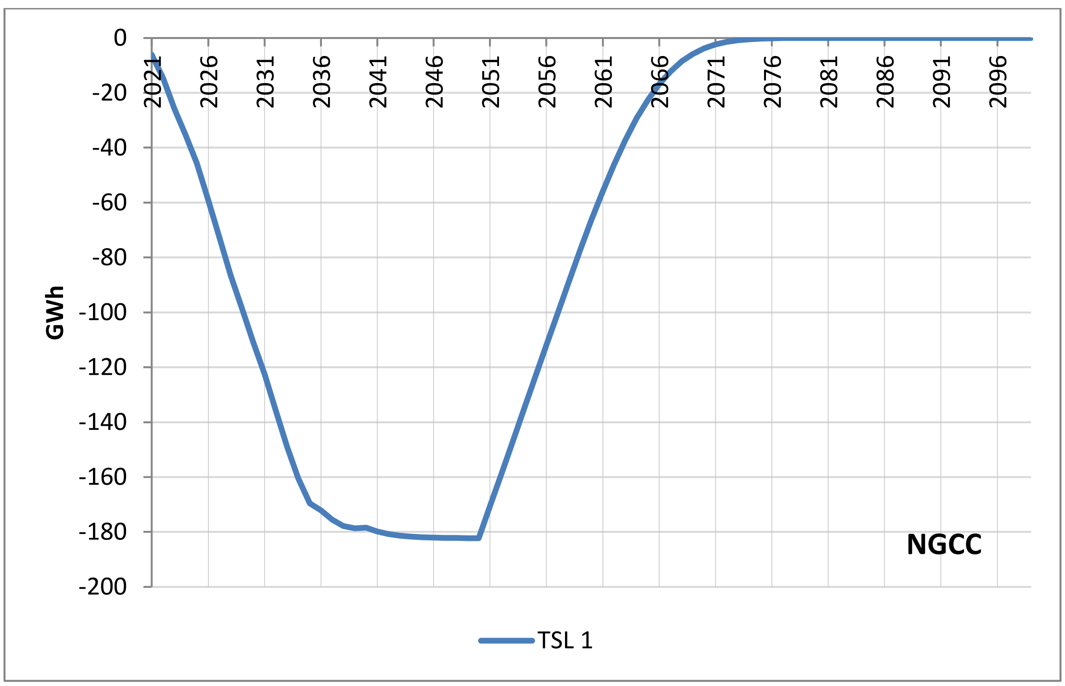

Figure 15.3.10 Hearth Product Ignition Devices: Gas Combined Cycle Generation Reduction

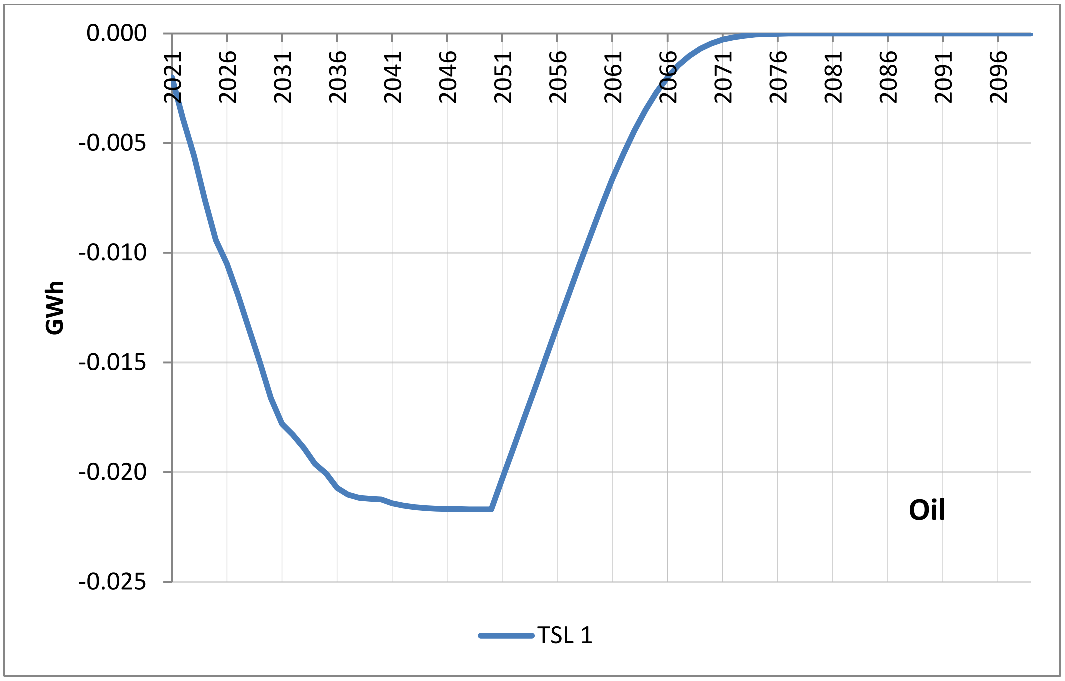

Figure 15.3.11 Hearth Product Ignition Devices: Oil Generation Reduction

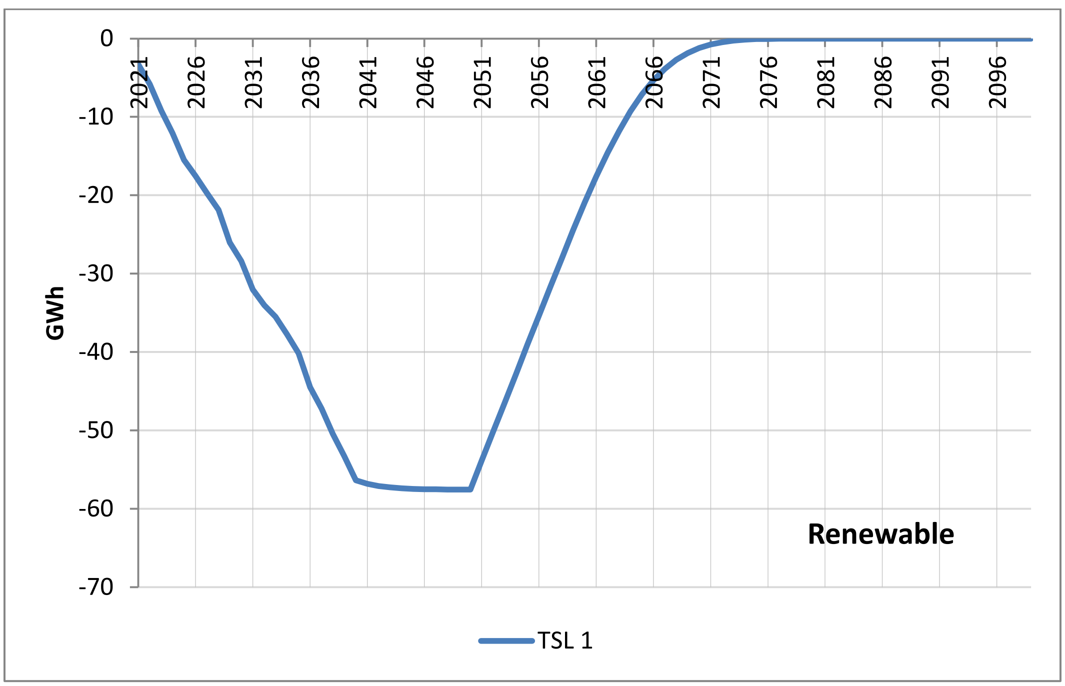

Figure 15.3.12 Hearth Product Ignition Devices: Renewables Generation Reduction

15.3.3 Results Summary

Table 15.3.1 presents a summary of the utility impact results for hearth product ignition devices.

Table 15.3.1 Hearth Product Ignition Devices: Summary of Utility Impact Results

Year	TSL
	1
Installed Capacity Reduction (MW)	
2021	-3.58
2025	-17.8
2030	-40.3
2035	-61.0
2040	-74.6
Electricity Generation Reduction (GWh)	
2021	-21.6
2025	-111
2030	-226
2035	-312
2040	-349

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16.1 INTRODUCTION

DOE's employment impact analysis is designed to estimate indirect national job creation or elimination resulting from possible standards due to reallocation of the associated expenditures for purchasing and operating hearth products. Job increases or decreases reported in this chapter are separate from the direct hearth product production sector employment impacts reported in the manufacturer impact analysis (Chapter 12), and reflect the employment impact of efficiency standards on all other sectors of the economy.

16.2 ASSUMPTIONS

DOE expects energy conservation standards to decrease energy consumption, and therefore to reduce energy expenditures. The savings in energy expenditures may be spent on new investment or not at all (*i.e.*, they may remain "saved"). The standards may increase the purchase price of products, including the retail price plus sales tax, and increase installation costs.

Using an input/output econometric model of the U.S. economy, this analysis estimated the short-term effect of these expenditure impacts on net economic output and employment. DOE intends for this analysis to quantify the indirect employment impacts of these expenditure changes. It evaluated direct employment impacts at manufacturers' facilities in the manufacturer impact analysis (see chapter 12).

DOE notes that ImSET is not a general equilibrium forecasting model, and understands the uncertainties involved in projecting employment impacts, especially changes in the later years of the analysis.[1] Because ImSET does not incorporate price changes, the employment effects predicted by ImSET would over-estimate the magnitude of actual job impacts over the long run for this rule. Because input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. DOE therefore include a qualitative discussion of how labor markets are likely to respond in the longer term. In future rulemakings, DOE may consider the use of other modeling approaches for examining long run employment impacts.

16.3 METHODOLOGY

The Department based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 3.1.1[2] (Impact of Sector Energy Technologies) as a successor to ImBuild,[3] a special-purpose version of the IMPLAN[4] national input/output model. ImSET estimates the employment and income effects of building energy technologies. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy-efficiency investments in buildings.

In an input/output model, the level of employment in an economy is determined by the relationship of different sectors of the economy and the spending flows among them. Different sectors have different levels of labor intensity and so changes in the level of spending (*e.g.*, due to the effects of an efficiency standard) in one sector of the economy will affect flows in other sectors, which affects the overall level of employment.

ImSET uses a 187-sector model of the national economy to predict the economic effects of residential and commercial buildings technologies. ImSET collects estimates of initial investments, energy savings, and economic activity associated with spending the savings resulting from standards (*e.g.*, changes in final demand in personal consumption, business investment and spending, and government spending). It provides overall estimates of the change in national output for each input-output sector. The model applies estimates of employment and wage income per dollar of economic output for each sector and calculates impacts on national employment and wage income.

Energy-efficiency technology primarily affects the U.S. economy along three spending pathways. First, general investment funds are diverted to sectors that manufacture, install, and maintain energy-efficient products. The increased cost of products leads to higher employment in the product manufacturing sectors and lower employment in other economic sectors. Second, commercial firm and residential spending are redirected from utilities toward firms that supply production inputs for energy-efficient products. Third, investment funds are released from the utility and energy production sectors for use in other sectors of the economy. When consumers use less energy, utilities and energy producers experience relative reductions in demand which leads to reductions in employment in those sectors.

DOE also notes that the employment impacts estimated with ImSET for the entire economy differ from the employment impacts in the hearth product manufacturing sector estimated in Chapter 12 using the Government Regulatory Impact Model (GRIM). The methodologies used and the sectors analyzed in the ImSET and GRIM models are different.

16.4 SHORT-TERM RESULTS

The results in this section refer to impacts of a hearth product ignition device standard relative to the base case. DOE disaggregated the impact of standards on employment into three component effects: increased capital investment costs, decreased energy costs, and changes in operations and maintenance costs. This section presents the summary impact.

Conceptually, one can consider the impact of the rule in its first year on three aggregate sectors, the hearth product production sector, the energy generation sector, and the general consumer goods sector (as mentioned above, ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the rule generally increases the purchase price of hearth products; this increase in expenditures causes an increase in employment in this sector. At the same time, the improvements in energy efficiency reduce consumer expenditures on energy, freeing up this money to be spent in other sectors. The reduction in energy demand causes a reduction in employment in that sector. Finally, based on the net impact of increased expenditures on hearth products and reduced expenditures on energy, consumer expenditures on everything else are either positively or negatively affected, increasing or reducing jobs in that sector accordingly. The model also captures any indirect jobs created or lost by changes in consumption due to changes in employment (as more workers are hired they consume more goods, which generates more employment, the converse is true for workers laid off).

Table 16.4.1 present the modeled net employment impact from the rule in 2021, rounded to the nearest ten jobs. The proposed standard is projected to slightly increase employment from 2021 to 2026. Virtually all hearth products are domestically produced, so DOE does not consider imports in this analysis.

Table 16.4.1 Net National Short-term Change in Employment (Number of Jobs)

Trial Standard Level	2021	2026
TSL 1	80	150

For context, the Office of Management of Budget currently assumes that the unemployment rate may decline to 6.0 percent during 2014 and drop further to 5.4 percent by 2017.[5] The unemployment rate in 2021 is projected to be 5.4 percent, which is close to "full employment." When an economy is at full employment any effects on net employment are likely to be transitory as workers change jobs, rather than enter or exit longer-term employment.

16.5 LONG-TERM RESULTS

Over the long term DOE expects the energy savings to consumers to increasingly dominate the increase in product costs, resulting in increased aggregate savings to consumers. As a result, DOE expects demand for energy to decline over time and demand for other goods to increase. Because the utility and energy production sectors are relatively capital intensive compared to the consumer goods sector, the net effect will be an increase in labor demand. In equilibrium, this should lead to upward pressure on wages and a shift in employment away from utilities and energy producers towards consumer goods. Note that in long-run equilibrium there is no net effect on total employment because wages adjust to bring the labor market into equilibrium. Nonetheless, even to the extent that markets are slow to adjust, DOE anticipates that net labor market impacts will in general be negligible over time due to the small magnitude of the short-term effects presented in Table 16.4.1 for most product classes and TSLs. The ImSET model projections, assuming no price or wage effects until 2026, are included in the second column of Table 16.4.1.

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17.1 INTRODUCTION

The U.S. Department of Energy (DOE) has determined that the regulatory action described in the Federal Register notice associated with this TSD constitutes an "economically significant regulatory action" under Executive Order (E.O.) 12866, Regulatory Planning and Review. 58 FR 51735 (October 4, 1993). For such actions, E.O. 12866 requires Federal agencies to provide "an assessment, including the underlying analysis, of costs and benefits of potentially effective and reasonably feasible alternatives to the planned regulation, identified by the agencies or the public (including improving the current regulation and reasonably viable non-regulatory actions), and an explanation why the planned regulatory action is preferable to the identified potential alternatives." 58 FR 51735, 51741.

To conduct this analysis, DOE used an integrated National Impact Analysis (NIA)-RIA model built on the NIA model discussed in Chapter 10. DOE identified five non-regulatory policy alternatives that possibly could provide incentives for the same energy efficiency level as the one in the proposed trial standard level for the hearth product ignition devices that are the subject of this rulemaking. The non-regulatory policy alternatives are listed in Table 17.1.1, which also includes the "no new regulatory action" alternative. DOE evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each to the effectiveness of the proposed standard for each of five types of hearth product ignition devices covered by this rulemaking.

Table 17.1.1 Non-Regulatory Alternatives to National Standards

No New Regulatory Action
Consumer Rebates
Consumer Tax Credits
Manufacturer Tax Credits
Voluntary Energy Efficiency Targets
Bulk Government Purchases

Sections 17.2 and 17.3 discuss the analysis of five selected policies listed above (excluding the alternative of no new regulatory action). Section 17.4 presents the results of the policy alternatives.

17.2 NON-REGULATORY POLICIES

This section describes the method DOE used to analyze the energy savings and cost effectiveness of the non-regulatory policy alternatives for hearth product ignition devices. This section also describes the assumptions underlying the analysis.

17.2.1 Methodology

DOE used its integrated NIA-RIA spreadsheet model to calculate the national energy savings (NES) and net present value (NPV) associated with each non-regulatory policy alternative. Chapter 10 of the technical support document (TSD) describes the NIA spreadsheet model. Appendix 17A discusses the NIA-RIA integrated model approach.

DOE quantified the effect of each alternative on the purchase of equipment that meet the efficiency level corresponding to the proposed TSL. After establishing the quantitative assumptions underlying each alternative, DOE appropriately revised inputs to the NIA-RIA spreadsheet model. The primary model inputs revised were market shares of equipment meeting the target efficiency level set for the proposed TSL. The shipments of equipment for any given year reflect a distribution of efficiency levels. DOE assumed, for the proposed TSL, that new energy efficiency standards would affect 100 percent of the shipments of products that did not meet the TSL target level in the base case,[a] whereas the non-regulatory policies would affect a smaller percentage of those shipments. DOE made certain assumptions about the percentage of shipments affected by each alternative policy. DOE used those percentages to calculate the shipment-weighted average energy consumption and costs of hearth product ignition devices attributable to each policy alternative.

Increasing the efficiency of a product often increases its average installed cost. However, operating costs generally decrease because energy consumption declines. DOE therefore calculated an NPV for each non-regulatory alternative in the same way it did for the proposed standards. In some policy scenarios, increases in total installed cost are mitigated by government rebates or tax credits. Because DOE assumed that consumers would re-pay credits and rebates in some way (such as additional taxes), DOE did not include rebates or tax credits as a consumer benefit when calculating national NPV. DOE's analysis also excluded any administrative costs for the non-regulatory policies; including such costs would decrease the NPVs slightly.

The following are key measures for evaluating the impact of each alternative.

- <u>National Energy Savings</u> (NES), given in quadrillion Btus (quads), describes the cumulative national energy saved over the lifetime of equipment purchased during the 30-year analysis period starting in the effective date of the policy (2021-2050).

- <u>Net Present Value</u> (NPV), represents the value of net monetary savings in 2014, expressed in 2013$, from equipment purchased during the 30-year analysis period starting in the effective date of the policy (2021-2050). DOE calculated the NPV as the difference between the present value of installed equipment cost and operating expenditures in the base case and the present value of those costs in each policy case. DOE calculated operating expenses (including energy costs) for the life of the product.

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[a] The base case for the NIA is a market-weighted average energy efficiency calculated from units at several efficiency levels.

17.2.2 Assumptions Regarding Non-Regulatory Policies

The effects of non-regulatory policies are by nature uncertain because they depend on program implementation, marketing efforts, and on consumers' responses to a program. Because the projected effects depend on assumptions regarding the rate of consumer participation, they are subject to more uncertainty than are the impacts of mandatory standards, which DOE assumes will be met with full compliance. To increase the robustness of the analysis, DOE conducted a literature review regarding each non-regulatory policy and consulted with recognized experts to gather information on similar incentive programs that have been implemented in the United States. By studying experiences with the various types of programs, DOE sought to make credible assumptions regarding potential market impacts. Section 17.3 presents the sources DOE relied on in developing assumptions about each alternative policy and reports DOE's conclusions as they affected the assumptions that underlie the modeling of each alternative policy.

Each non-regulatory policy that DOE considered would improve the average efficiency of new hearth product ignition devices relative to their base case efficiency scenario (which involves no new regulatory action). The analysis considered that each alternative policy would induce consumers to purchase units having the same technology as required by the proposed standards (the target level) set for the proposed TSL. As opposed to the standards case, however, the policy cases may not lead to 100 percent market penetration of units that meet the target level.

Table 17.2.1 shows the relative energy savings from the technology stipulated in the proposed standard for hearth product ignition devices.

Table 17.2.1 Relative Energy Savings for Trial Standard Level 1 for Hearth Product Ignition Devices

Technology	Annual Energy Consumption	
	Natural Gas *mcf*	**Electricity** *kWh*
Fireplace (vented)		
Standing Pilot	3.9	0.0
Intermittent Pilot	0.5	13.6
Relative Energy Savings	87.5%	n/a
Fireplace (ventless)		
Standing Pilot	3.4	0.0
Intermittent Pilot	1.3	99.4
Relative Energy Savings	63.0%	n/a
Logs (vented)		
Standing Pilot	3.1	0.0
Intermittent Pilot	0.3	5.8
Relative Energy Savings	90.8%	n/a
Logs (ventless)		
Standing Pilot	2.2	0.0
Intermittent Pilot	0.9	70.6
Relative Energy Savings	59.6%	n/a
Outdoor		
Standing Pilot	3.8	0.0
Intermittent Pilot	0.0	0.2
Relative Energy Savings	100.0%	n/a

DOE assumed that the effects of non-regulatory policies would last from the effective date of standards—2021—through the end of the analysis period, which is 2050.

17.2.3 Policy Interactions

DOE calculated the effects of each non-regulatory policy separately from those of the other policies. In practice, some policies are most effective when implemented in combination, such as voluntary efficiency targets implemented with consumer rebates or tax credits. However, DOE attempted to make conservative assumptions to avoid double-counting policy impacts. The resulting policy impacts are not additive; the combined effect of several or all policies cannot be inferred from summing their results.

Section 17.4 presents graphs that show the market penetration estimated under each non-regulatory policy for hearth product ignition devices.

17.3 NON-REGULATORY POLICY ASSUMPTIONS

The following subsections describe DOE's analysis of the impacts of the five non-regulatory policy alternatives to proposed standards for hearth product ignition devices. (Because the alternative of No New Regulatory Action has no energy or economic impacts, essentially representing the NIA base case, DOE did not perform any additional analysis for that alternative.) DOE developed estimates of the market penetration of high-efficiency products both with and without each of the non-regulatory policy alternatives.

17.3.1 No New Regulatory Action

The case in which no new regulatory action is taken with regard to the energy efficiency of hearth product ignition devices constitutes the base case, as described in chapter 10, National Impact Analysis. The base case provides the basis of comparison for all other policies. By definition, no new regulatory action yields zero NES and an NPV of zero dollars.

17.3.2 Consumer Rebates

DOE considered the scenario in which the Federal government would provide financial incentives in the form of rebates to consumers for purchasing energy-efficient appliances. This policy provides a consumer rebate for purchasing hearth product ignition devices that operate at the same efficiency as stipulated in the proposed TSL.

17.3.2.1 Methodology

DOE based its evaluation methodology for consumer rebates on a comprehensive study of California's potential for achieving energy efficiency. The study, performed by XENERGY, Inc.,[b] summarized experiences with various utility rebate programs.[1] XENERGY's analytical method utilized graphs, or penetration curves, that estimate the market penetration of a technology based on its benefit/cost (B/C) ratio. DOE consulted with experts and reviewed other methods of estimating the effect of consumer rebate programs on the market penetration of efficient technologies. The other methods, developed after the referenced XENERGY report was published,[2, 3, 4, 5, 6, 7] used different approaches: other economic parameters (*e.g.*, payback period), expert surveys, or model calibration based on specific utility program data rather than multi-utility data. Some models in use by energy efficiency program evaluation experts were so client-specific that generic relationships between economic parameters and consumer response could not be established.[5] DOE decided that the most appropriate available method for this RIA analysis was the XENERGY approach of penetration curves based on B/C ratio, which incorporates lifetime operating cost savings.

XENERGY's model estimates market impacts induced by financial incentives based on the premise that two types of information diffusion drive the adoption of new technologies. *Internal sources* of information encourage consumers to purchase new equipment primarily

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[b] XENERGY is now owned by KEMA, Inc. (www.kema.com)

through word-of-mouth from early adopters. *External sources* affect consumer purchase decisions through marketing efforts and information from outside the consumer group. Appendix 17A contains additional details on internal and external information diffusion.

XENERGY's model equation accounts for the influences of both internal and external sources of information by superimposing the two components. Combining the two mechanisms for information diffusion, XENERGY's model generates a set of penetration (or implementation) curves for a policy measure. XENERGY calibrated the curves based on participation data from utility rebate programs. The curves illustrate the increased penetration (*i.e.*, increased market share) of efficient equipment driven by consumer response to changes in B/C ratio induced by rebate programs. The penetration curves depict various diffusion patterns based on perceived market barriers (from no-barriers to extremely-high-barriers) to consumer purchase of high-efficiency equipment. DOE adjusted the XENERGY former penetration curves based on expert advice founded on more recent utility program experience.[5, 8]

DOE modeled the effects of a consumer rebate policy for hearth product ignition devices by determining, for the proposed TSL, the increase in market penetration of equipment meeting the target level relative to their market penetration in the base case. It used the interpolation method presented in Blum et al (2011)[9] to create customized penetration curves based on relationships between actual base case market penetrations and actual B/C ratios. To inform its estimate of B/C ratios provided by a rebate program DOE performed a thorough nationwide search for existing rebate programs for hearth product ignition devices. It gathered data on utility or agency rebates throughout the nation for this equipment, and used this data to calibrate the customized penetration curve it developed for hearth product ignition devices so they can best reflect the market barrier level faced by hearth product ignition devices. Section 17.3.2.2 shows the interpolated curve used in the analysis.

17.3.2.2 Analysis

DOE estimated the effect of increasing the B/C ratio of hearth product ignition devices via a rebate that would pay part of the increased installed cost of a unit that met the target efficiency level compared to one meeting the baseline efficiency level.[c] To inform its estimate of an appropriate rebate amount, DOE performed a thorough nationwide search for existing rebate programs for hearth product ignition devices. It gathered data from a sample of utility and agency rebate programs that includes 8 rebates for hearth product ignition devices initiated by 6 utilities or agencies in various States. (Appendix 17A identifies the rebate programs.) DOE then estimated a market average rebate value as the simple average calculated over the rebate amounts offered by the existing rebate programs. Since the existing rebate programs target hearth product ignition device units as a whole, DOE further scaled down the market average rebate value it calculated using the ratio of the price of an ignition module and the (full) price of a hearth

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[c] The baseline technology for hearth products is defined in the engineering analysis, Chapter 5, as the technology that represents the basic characteristics of products in that class. A baseline unit typically is one that just meets current Federal energy conservation standards and provides basic consumer utility.

product ignition device. DOE assumed that rebates would remain in effect at the same level throughout the forecast period (2021-2050).

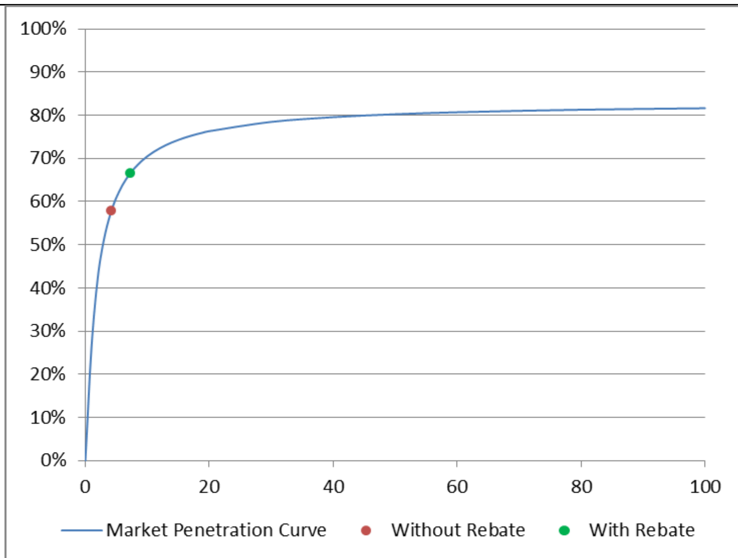
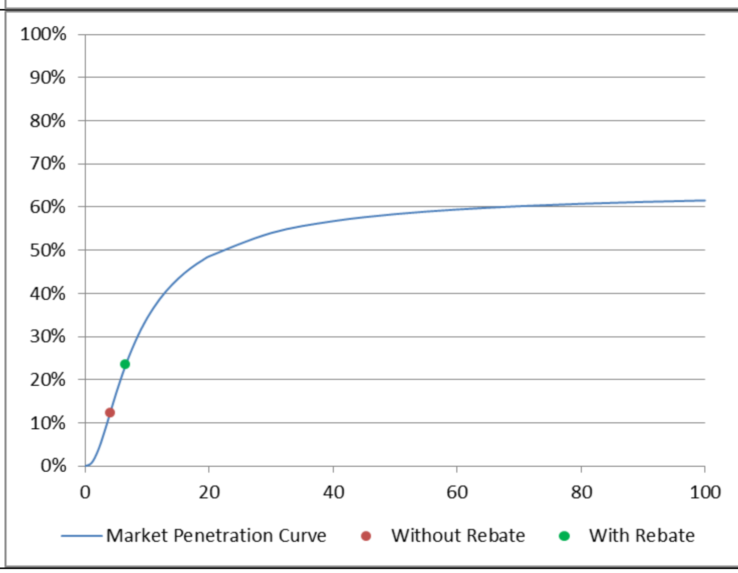
DOE first calculated the B/C ratio of a hearth product ignition device without a rebate using the difference in total installed costs (C) and lifetime operating cost savings[d] (B) between the unit meeting the target level and the baseline unit. It then calculated the B/C ratio given a rebate for the unit meeting the target efficiency level. Because the rebate reduced the incremental cost, the unit receiving the rebate had a larger B/C ratio. Table 17.3.1 shows the effect of consumer rebates for the proposed TSL on the B/C ratio of hearth product ignition devices shipped in the first year of the analysis period. Note that because ventless hearth product ignition devices present negative benefits and benefit-cost ratios, DOE did not assess the impacts from consumer rebates for those types of hearth product ignition devices.

Table 17.3.1 Benefit/Cost Ratios Without and With Rebates for Hearth Product Ignition Devices

	TSL 1
Fireplace (vented)	
B/C Ratio Without Rebate	4.2
Rebate Amount (2013$)	37.03
B/C Ratio With Rebate	7.3
Estimated Market Barriers	No-Low
Fireplace (ventless)	
B/C Ratio Without Rebate	4.0
Rebate Amount (2013$)	37.03
B/C Ratio With Rebate	6.5
Estimated Market Barriers	Mod
Logs (vented)	
B/C Ratio Without Rebate	1.6
Rebate Amount (2013$)	37.03
B/C Ratio With Rebate	2.1
Estimated Market Barriers	Low-Mod
Logs (ventless)	
B/C Ratio Without Rebate	1.6
Rebate Amount (2013$)	37.03
B/C Ratio With Rebate	2.2
Estimated Market Barriers	Low-Mod
Outdoor	
B/C Ratio Without Rebate	3.2
Rebate Amount (2013$)	37.03
B/C Ratio With Rebate	4.2
Estimated Market Barriers	No-Low

[d] The cash flow of the operating cost savings is discounted to the purchase year using a 7 percent discount rate.

DOE used the B/C ratio along with the penetration curves shown in Table 17.3.1 to estimate the percentage of consumers who would purchase hearth product ignition devices that meet the target level both with and without a rebate incentive. The estimated level of market barriers corresponding to the penetration curves DOE calculated to represent the market behavior for hearth product ignition devices at the proposed TSL are indicated in Table 17.3.1. DOE assumed the estimated market barriers would remain the same over the whole analysis period.

<table>
<tr><th colspan="2">TSL 1</th></tr>
<tr><td>Fireplace (vented)</td><td>
</td></tr>
<tr><td>Fireplace (ventless)</td><td>
</td></tr>
</table>

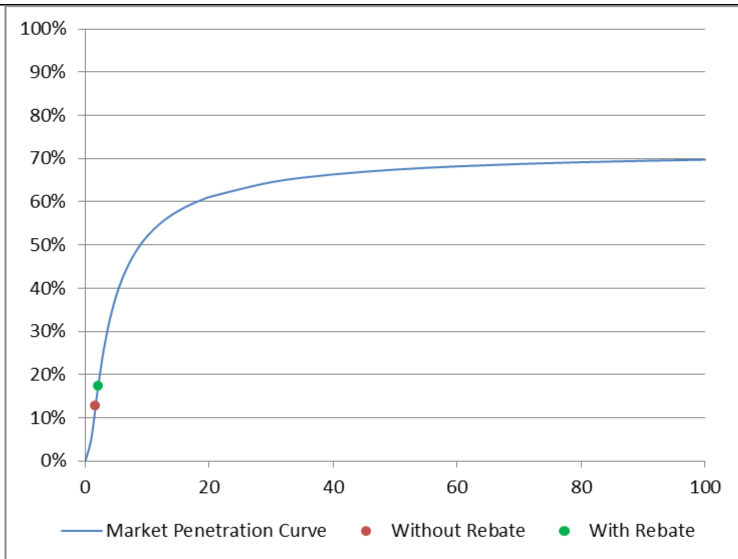
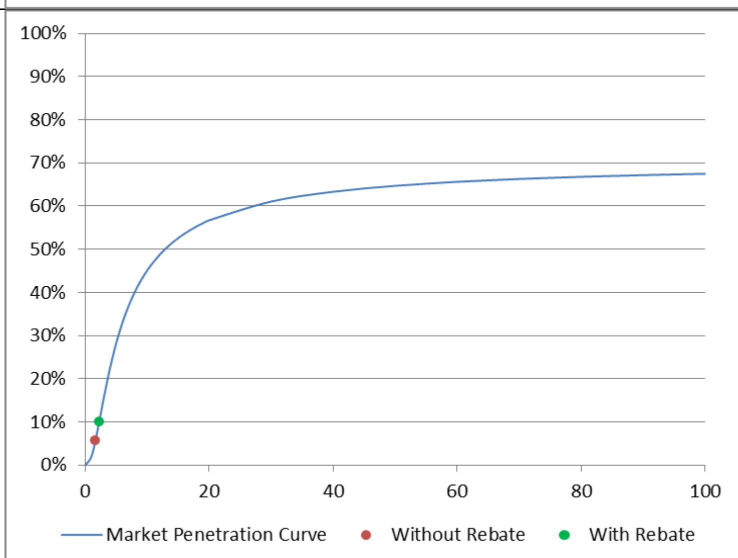
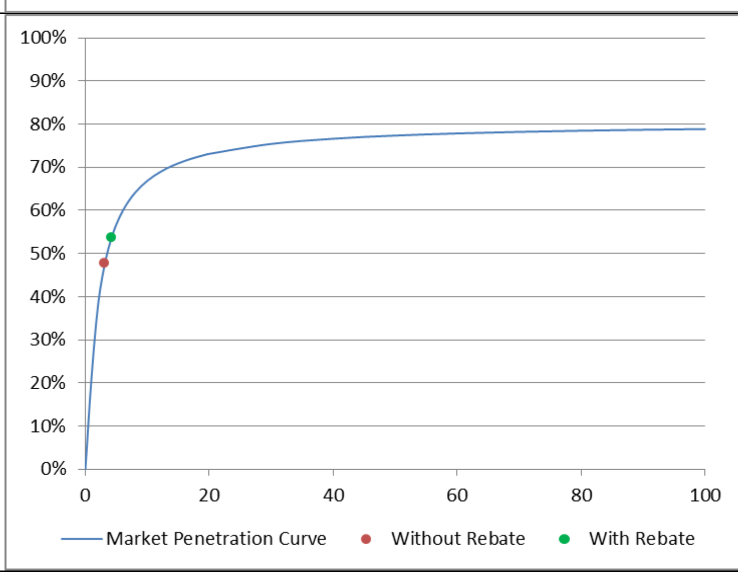
Logs (vented)	
Logs (ventless)	
Outdoor	

Figure 17.3.1 Market Penetration Curves for Hearth Product Ignition Devices (TSL 1)

DOE next estimated the percent increase represented by the change in penetration rate shown on the corresponding penetration curve. It then added this percent increase to the market share of units that meet the target level in the base case to obtain the market share of units that meet the target level in the rebate policy case.

Table 17.3.2 summarizes DOE's assumptions for hearth product ignition devices regarding the market penetration of products in 2021 that meet the target level at the proposed TSL given a consumer rebate.

Table 17.3.2 Market Penetrations in 2021 Attributable to Consumer Rebates for Hearth Product Ignition Devices

	TSL 1
Fireplace (vented)	
Base-Case Market Share	57.8%
Policy Case Market Share	66.6%
Increased Market Share	8.8%
Fireplace (ventless)	
Base-Case Market Share	12.3%
Policy Case Market Share	23.5%
Increased Market Share	11.2%
Logs (vented)	
Base-Case Market Share	12.7%
Policy Case Market Share	17.3%
Increased Market Share	4.6%
Logs (ventless)	
Base-Case Market Share	5.7%
Policy Case Market Share	10.0%
Increased Market Share	4.3%
Outdoor	
Base-Case Market Share	47.8%
Policy Case Market Share	53.6%
Increased Market Share	5.8%

DOE used the resulting annual increases in market shares as inputs to represent the rebate policy case scenario in its NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy. Section 17.4 presents the resulting market penetration trends for the policy case of consumer rebates for hearth product ignition devices. Because energy prices increase over the analysis period and equipment price is assumed constant, the B/C ratio increases over time. With increasing B/C ratio and constant market barriers, the increase in market penetration of a more efficient technology also increases over the analysis period.

17.3.3 Consumer Tax Credits

DOE estimated the effects of tax credits on consumer purchases based on its previous analysis of consumer participation in tax credits. DOE supported its approach using data from Oregon State's tax credit program for energy-efficient appliances. DOE also incorporated previous research that disaggregated the effect of rebates and tax credits into a *direct price effect*, which derives from the savings in purchase price, and an *announcement effect*, which is independent of the amount of the incentive.[10, 11] The announcement effect derives from the credibility that a technology receives from being included in an incentive program, as well as changes in product marketing and modifications in markup and pricing. DOE assumed that the rebate and consumer tax credit policies would encompass both direct price effects and announcement effects, and that half the increase in market penetration associated with either policy would be due to the direct price effect and half to the announcement effect.

In estimating the effects of a tax credit on purchases of consumer products that meet new efficiency standards, DOE assumed the amount of the tax credit would be the same as the corresponding rebate amount discussed above.

DOE estimated that fewer consumers would participate in a tax credit program than would take advantage of a rebate. Research has shown that the delay required for a consumer to receive a tax credit, plus the added time and cost in preparing the tax return, make a tax credit incentive less effective than a rebate received at the time of purchase. Based on previous analyses, DOE assumed that only 60 percent of the consumers who would take advantage of a rebate would take advantage of a tax credit.[12]

In preparing its assumptions to estimate the effects of tax credits on consumer purchases of hearth product ignition devices, DOE also reviewed other tax credit programs that have been offered at both the Federal and State levels for energy-efficient appliances.

The Energy Policy Act of 2005 (EPACT 2005) included Federal tax credits for consumers who purchase energy-efficient products.[13] Those tax credits were in effect in 2006 and 2007, expired in 2008, were reinstated for 2009–2010 by the American Recovery and Reinvestment Act of 2009 (ARRA), extended by Congress for 2011 with some modifications, and expired at the end of 2011.[14, 15] The American Taxpayer Relief Act of 2012 extended, with some modifications, residential tax credits for air conditioners, heat pumps, furnaces, and water heaters placed in service between January 1, 2012 and December 31, 2013.[16] DOE reviewed Internal Revenue Service data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. However, DOE did not find data specific enough to hearth product ignition devices to warrant adjusting its analysis method for the Consumer Tax Credits policy case. Appendix 17A contains more information on Federal consumer tax credits.

DOE also reviewed its previous analysis of Oregon's tax credits for clothes washers to provide support for its assumptions.[17] In that previous analysis, DOE compared the market shares of ultra-high efficiency (UHE) residential clothes washers in Oregon, which offered both

State tax credits and utility rebates, with those in Washington State, which offered only utility rebates during the same period. Based on this analysis, DOE estimated that in Oregon the impact of tax credits was 62 percent of the impact of rebates for UHE clothes washers having equivalent efficiency. This finding supports its original assumption that participation in a tax credit program would be about 60 percent of participation in a rebate program. Additional discussion of State tax credits for Oregon and other states is in Appendix 17A.

DOE applied the assumed 60 percent participation described above to the penetration rates estimated for the rebate policy to estimate penetration rates attributable to consumer tax credits. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the penetration curves selected for hearth product ignition devices.

Table 17.3.3 summarizes DOE's assumptions for hearth product ignition devices regarding the market penetration of units in 2021 that meet the efficiency level at the proposed TSL given a consumer tax credit.

Table 17.3.3 Market Penetrations in 2021 Attributable to Consumer Tax Credits for Hearth Product Ignition Devices

	TSL 1
Fireplace (vented)	
Base-Case Market Share	57.8%
Policy Case Market Share	63.1%
Increased Market Share	5.3%
Fireplace (ventless)	
Base-Case Market Share	12.3%
Policy Case Market Share	19.0%
Increased Market Share	6.7%
Logs (vented)	
Base-Case Market Share	12.7%
Policy Case Market Share	15.5%
Increased Market Share	2.8%
Logs (ventless)	
Base-Case Market Share	5.7%
Policy Case Market Share	8.3%
Increased Market Share	2.6%
Outdoor	
Base-Case Market Share	47.8%
Policy Case Market Share	51.3%
Increased Market Share	3.5%

The increased market shares attributable to consumer tax credits shown in Table 17.3.3 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy. Section 17.4 presents the resulting market penetration trends for the policy case of consumer tax credits for hearth product ignition devices that meet the efficiency level for the proposed TSL. Because the increase in market penetration for consumer tax credits is proportional to the increase in market penetration DOE calculated for consumer rebates, the former follows a similar increasing trend over the analysis period as the latter.

17.3.4 Manufacturer Tax Credits

To analyze the potential effects of a policy that offers tax credits to manufacturers that produce hearth product ignition devices that meet the target efficiency level at the proposed TSL, DOE assumed that a manufacturer tax credit would lower the consumer's purchase cost by an amount equivalent to that provided by the consumer rebates or tax credits described above. DOE further assumed that manufacturers would pass on some of their reduced costs to consumers, causing a direct price effect. DOE assumed that no announcement effect would occur, because the program would not be visible to consumers.[e] Because the direct price effect is approximately equivalent to the announcement effect,[10] DOE estimated that a manufacturer tax credit would induce half the number of consumers assumed to take advantage of a consumer tax credit to purchase more efficient products. Thus the assumed participation rate is equal to 30 percent of the number of consumers who would participate in a rebate program.

DOE attempted to investigate manufacturer response to the Energy Efficient Appliance Credits for manufacturers mandated by EPACT 2005.[18] Those manufacturer tax credits have been in effect for dishwashers, clothes washers and refrigerators produced beginning in 2009. DOE was unable to locate data from the Internal Revenue Service or other sources on manufacturer response to the Federal credits. Appendix 17A presents details on Federal manufacturer tax credits.

DOE applied the assumption of 30 percent participation to the penetration rates predicted for the rebate policy to estimate the effects of a manufacturer tax credit policy. In doing so, the Department incorporated the assumptions for consumer response to financial incentives from the penetration curves calculated for hearth product ignition devices.

Table 17.3.4 summarize DOE's assumptions for hearth product ignition devices regarding the market penetration of units in 2021 meeting the efficiency level the proposed TSL given a manufacturer tax credit.

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[e] Note that this is a conservative assumption, since it is possible that manufacturers or utility/agency efficiency programs might promote the models for which manufacturers increase production due to the tax credits, which in turn might induce some announcement effect. However, DOE found no data on such programs on which to base an estimate of the magnitude of this possible announcement effect on consumer behavior.

Table 17.3.4 Market Penetrations in 2021 Attributable to Manufacturer Tax Credits for Hearth Product Ignition Devices

	TSL 1
Fireplace (vented)	
Base-Case Market Share	57.8%
Policy Case Market Share	60.5%
Increased Market Share	2.6%
Fireplace (ventless)	
Base-Case Market Share	12.3%
Policy Case Market Share	15.7%
Increased Market Share	3.3%
Logs (vented)	
Base-Case Market Share	12.7%
Policy Case Market Share	14.1%
Increased Market Share	1.4%
Logs (ventless)	
Base-Case Market Share	5.7%
Policy Case Market Share	7.0%
Increased Market Share	1.3%
Outdoor	
Base-Case Market Share	47.8%
Policy Case Market Share	49.6%
Increased Market Share	1.7%

The increased market shares attributable to a manufacturer tax credit shown in Table 17.3.4 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy. Section 17.4 presents the resulting market penetration trends for the policy case of manufacturer tax credits for hearth product ignition devices. Because the increase in market penetration for manufacturer tax credits is proportional to the increase in market penetration DOE calculated for consumer rebates, the former follows a similar increasing trend over the analysis period as the latter.

17.3.5 Voluntary Energy Efficiency Targets

DOE assumed that voluntary energy efficiency targets would be achieved as manufacturers of hearth product ignition devices gradually stopped producing units that operated below the efficiency level set for the proposed TSL. DOE assumed that the impetus for phasing out production of low-efficiency units would be a program with impacts similar to those of the ENERGY STAR labeling program conducted by the Environmental Protection Agency (EPA) and DOE in conjunction with industry partners. The ENERGY STAR program specifies the minimum energy efficiencies that various products must have to receive the ENERGY STAR label. ENERGY STAR encourages consumers to purchase efficient products via marketing that promotes consumer label recognition, various incentive programs that adopt the ENERGY STAR specifications, and manufacturers' promotion of their qualifying appliances. ENERGY

STAR projects market penetration of compliant appliances and estimates the percentage of sales of compliant appliances that are attributable to the ENERGY STAR program.

Researchers have analyzed the ENERGY STAR program's effects on sales of several consumer products. Program efforts generally involve a combination of information dissemination and utility or agency rebates. The analyses have been based on State-specific data on percentages of shipments of various appliances that meet ENERGY STAR specifications. The analyses generally have concluded that the market penetration of ENERGY STAR-qualifying appliances is higher in regions or States where ancillary promotional programs have been active.[19, 20, 21]

DOE believes that informational incentive programs – like ENERGY STAR, or any other labeling program sponsored by industry or other organizations – are likely to reduce the market barriers to more efficient products over time. During the rebate analysis, when assessing the B/C ratio and market penetration in the base case for hearth product ignition devices, DOE observed that the level of market barriers for more efficient hearth product ignition devices are in the range of no-to-low barriers to a moderate level of market barriers. DOE estimates that voluntary energy efficiency targets could reduce these barriers to lower levels over 10 years. Table 17.3.5 presents the levels of market barriers DOE estimated for hearth product ignition devices in the base case and in the policy case of voluntary energy efficiency targets. DOE followed the methodology presented by Blum et al (2011)[22] to evaluate the effects that such a reduction in market barriers would have on the market penetration of efficient hearth product ignition devices.[f] The methodology relies on interpolated market penetration curves to calculate – given a B/C ratio – how the market penetration of more efficient units increases as the market barrier level to those units decreases.

Table 17.3.5 Market Barriers Changes Attributable to Voluntary Energy Efficiency Targets for Hearth Product Ignition Devices (TSL1)

	Base Case	Voluntary Energy Efficiency Targets
Fireplace (vented)	No-Low	No
Fireplace (ventless)	Moderate	Moderate
Logs (vented)	Low-Moderate	Low
Logs (ventless)	Low-Moderate	Low
Outdoor	No-Low	No

Table 17.3.6 summarizes DOE's assumptions for hearth product ignition devices regarding the market penetration of units in selected years with the same efficient technology as the one in the proposed TSL given voluntary energy efficiency targets. Because of the decrease in the market barriers level over the first 10 years of the analysis period, the market increase of more efficient hearth product ignition devices significantly increases over that period. For the remaining 20 years of the analysis period, the increase in market penetration keeps growing as a result of increasing energy prices, which – with constant, same market barriers level as in 2030 –

[f] For the calculation of B/C ratios DOE discounted the cash flow of the operating cost savings to the purchase year using a 7 percent discount rate.

eventually lead to increasing B/C ratios and higher market penetration. Notice, however, that since ventless hearth product ignition devices present negative benefits and benefit-cost ratios, DOE did not assess the impacts from voluntary energy efficiency targets for those types of hearth product ignition devices and rather assumed zero increased market share.

Table 17.3.6 Market Penetrations Attributable to Voluntary Energy Efficiency Targets for Hearth Product Ignition Devices (TSL1)

	2021	2030	2050
Fireplace (vented)			
Base-Case Market Share	57.8%	57.8%	57.8%
Policy Case Market Share	60.3%	81.2%	85.0%
Increased Market Share	2.5%	23.4%	27.2%
Fireplace (ventless)			
Base-Case Market Share	12.3%	12.3%	12.3%
Policy Case Market Share	13.2%	20.2%	20.2%
Increased Market Share	0.9%	7.9%	7.9%
Logs (vented)			
Base-Case Market Share	12.7%	12.7%	12.7%
Policy Case Market Share	15.3%	35.2%	41.4%
Increased Market Share	2.6%	22.5%	28.7%
Logs (ventless)			
Base-Case Market Share	5.7%	5.7%	5.7%
Policy Case Market Share	9.4%	31.6%	31.6%
Increased Market Share	3.7%	25.9%	25.9%
Outdoor			
Base-Case Market Share	47.8%	47.8%	47.8%
Policy Case Market Share	51.2%	76.3%	80.8%
Increased Market Share	3.4%	28.5%	33.0%

The increased market shares attributable to voluntary energy efficiency targets shown in Table 17.3.6 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy. Section 17.4 presents the resulting market penetration trends for the policy case of voluntary energy efficiency targets for hearth product ignition devices that meet the efficiency level for the proposed TSL.

17.3.6 Bulk Government Purchases

Bulk government purchases can lead to Federal, State, and local governments purchasing large quantities of products that meet the target efficiency level. Combining the market demands of multiple public sectors also can provide a market signal to manufacturers and vendors that some of their largest customers seek products that meet an efficiency target at favorable prices. Such a program also can induce "market pull," whereby manufacturers and vendors would achieve economies of scale for high efficiency products.

DOE assumed that government agencies would administer bulk purchasing programs for hearth product ignition devices, and that bulk government purchases would affect a subset of housing units for which government agencies purchased or influenced the purchase of hearth product ignition devices. This subset would consist primarily of public housing and housing on military bases. According to the 2009 Residential Energy Consumption Survey (RECS 2009), no housing units in public housing authority use a gas fueled fireplace either as a primary or a secondary source of heating.[23] DOE therefore estimated that there is no market for this alternative policy and, consequently, the increase in market share of more efficient hearth product ignition devices due to this alternative policy is zero.

17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

Figure 17.4.1 through Figure 17.4.5 show the effects of each non-regulatory policy on the market penetration of more efficient hearth product ignition devices. Relative to the base case, the alternative policy cases – excluding bulk government purchases – increase the market shares that meet the target level. Recall the proposed standards (not shown in the figures) would result in a 100-percent market penetration of products that meet the more efficient technology.

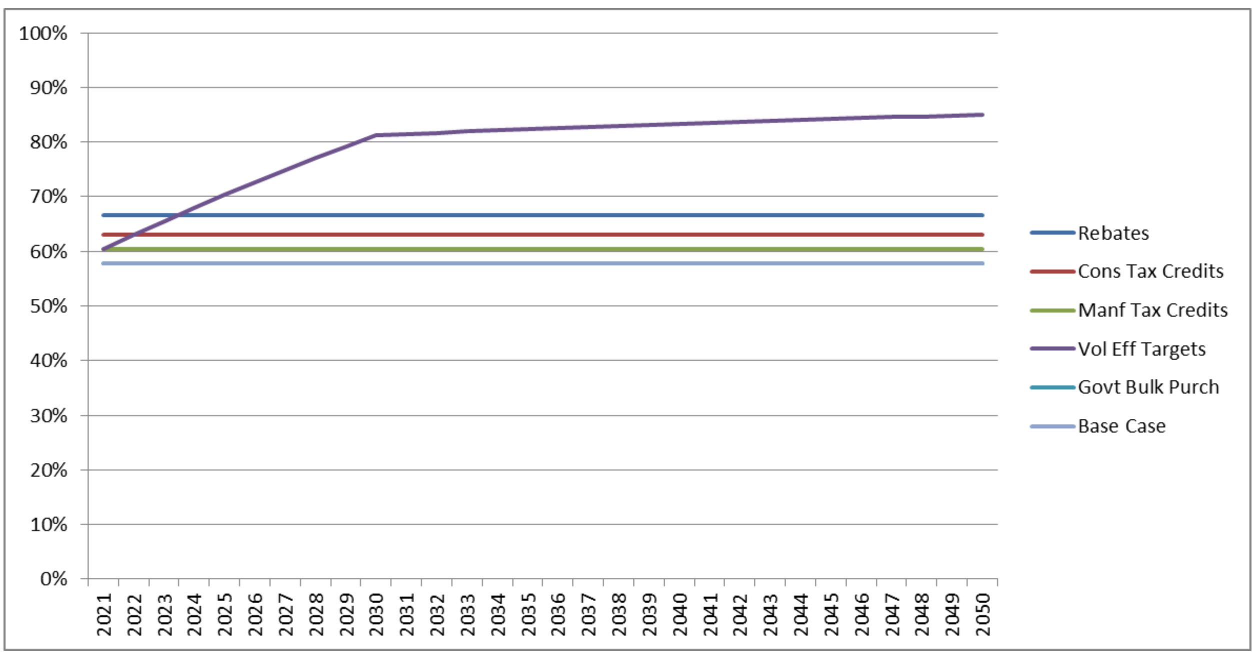

Figure 17.4.1 Market Penetration of Efficient Hearth Product Ignition Devices: Fireplace (vented) (TSL 1)

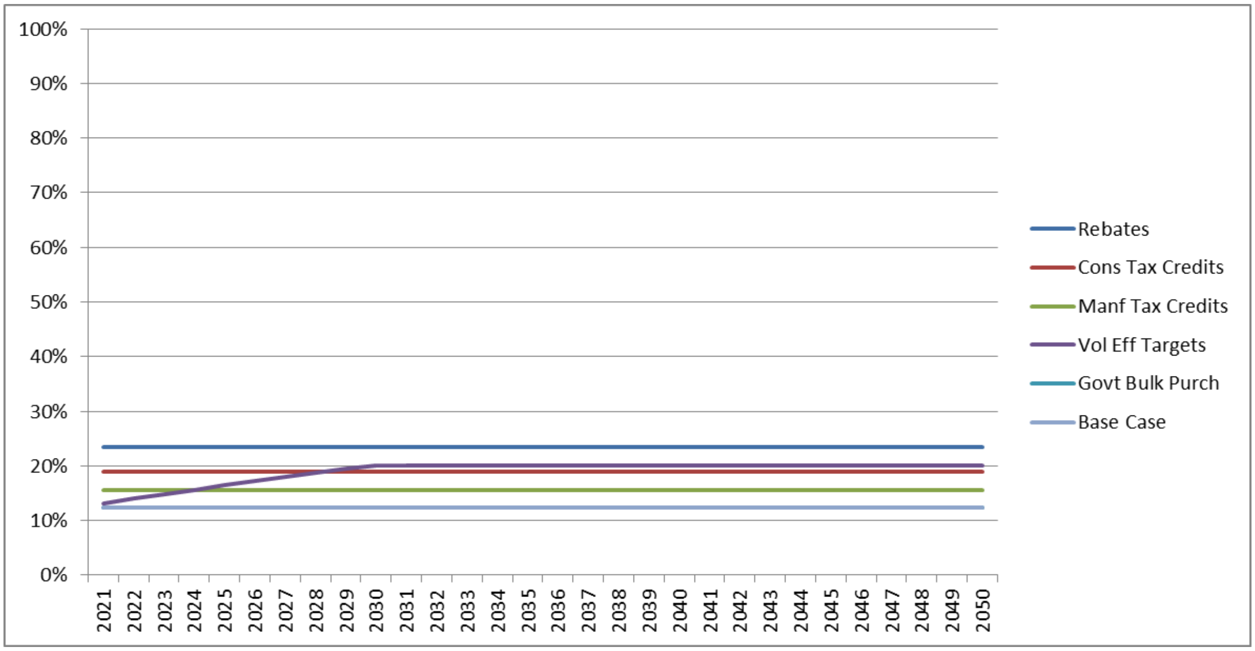

Figure 17.4.2 Market Penetration of Efficient Hearth Product Ignition Devices: Fireplace (ventless) (TSL 1)

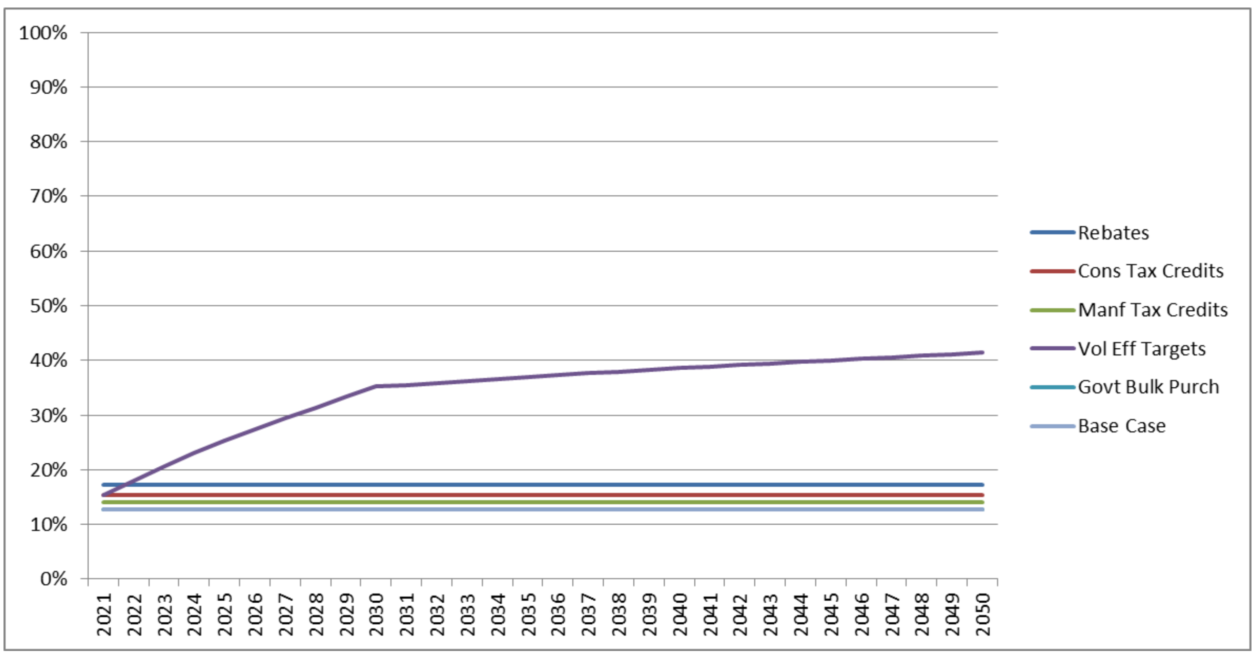

Figure 17.4.3 Market Penetration of Efficient Hearth Product Ignition Devices: Logs (vented) (TSL 1)

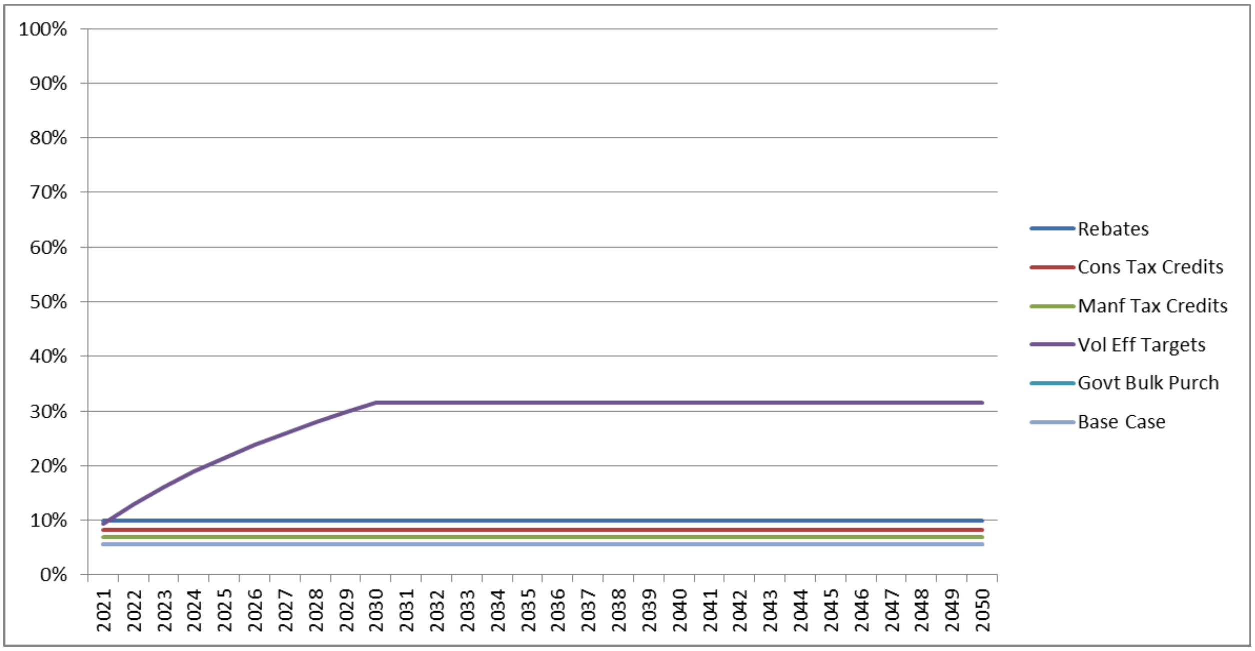

Figure 17.4.4 Market Penetration of Efficient Hearth Product Ignition Devices: Logs (ventless) (TSL 1)

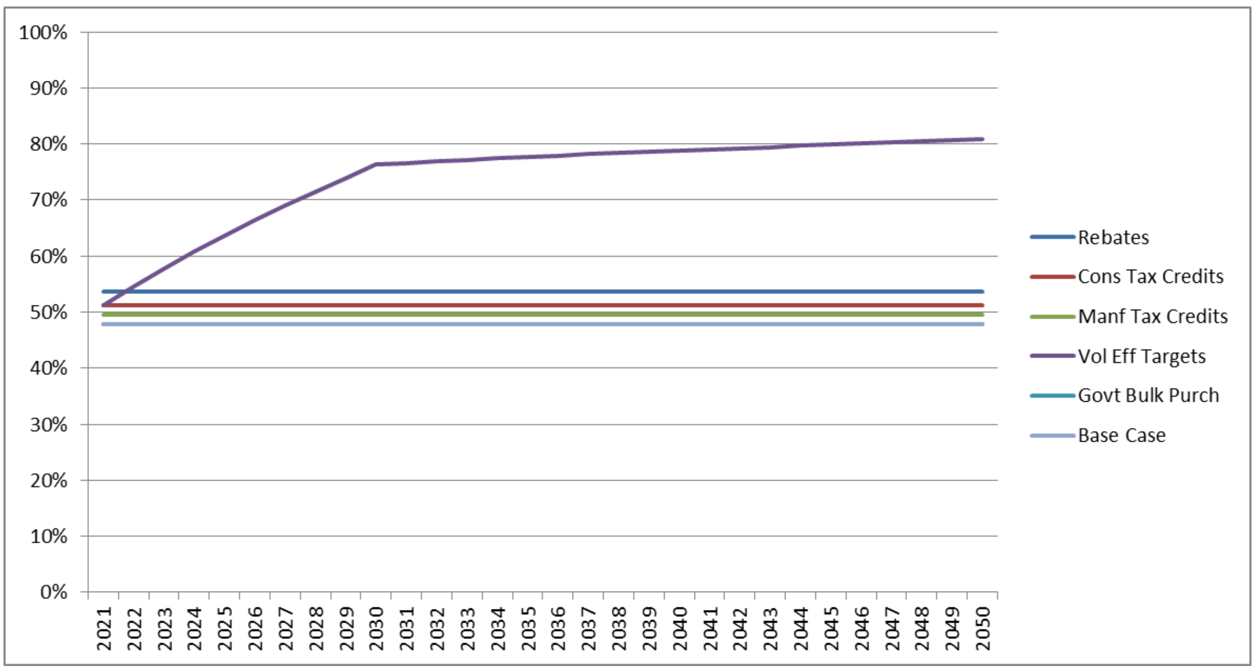

Figure 17.4.5 Market Penetration of Efficient Hearth Product Ignition Devices: Outdoor (TSL 1)

Table 17.4.1 shows the national energy savings and net present value for five non-regulatory policies analyzed in detail for hearth product ignition devices. The target level for each policy corresponds to the same efficient technology proposed for standards in TSL 1. The case in which no regulatory action is taken with regard to hearth product ignition devices constitutes the base case (or "No New Regulatory Action" scenario), in which NES and NPV are zero by definition. For comparison, the tables include the impacts of the proposed standards. Energy savings are given in quadrillion British thermal units (quads).[g] The NPVs shown in Table 17.4.1 are based on two discount rates, 7 percent and 3 percent.

The policy with the highest projected cumulative energy savings is voluntary energy efficiency targets. Savings from rebates and tax credits range from one third to less than on tenth of the savings from voluntary energy efficiency targets. Bulk government purchases, due to the lack of market for gas fueled hearth products in housing units in the public housing authority, lead to zero benefits. Overall, the energy saving benefits from the alternative policies, range from zero percent to 49.2 percent of the benefits from the proposed standards.

Table 17.4.1 Impacts of Non-Regulatory Alternatives for Hearth Product Ignition Devices (TSL 1)

Policy Alternative	**Energy Savings*** *quads*		**Net Present Value*** *million 2013$*	
			7% Discount Rate	3% Discount Rate
Consumer Rebates	0.107	(15.9%)**	182.3	483.0
Consumer Tax Credits	0.059	(8.7%)	109.4	289.8
Manufacturer Tax Credits	0.029	(4.4%)	54.7	144.9
Voluntary Energy Efficiency Targets	0.331	(49.2%)	418.0	1553.1
Bulk Government Purchases	0.000	(0.0%)	0.0	0.0
Proposed Standards***	0.674	(100.0%)	1031.1	3123.8

* For products shipped 2021 – 2050
**The percentages show how the energy savings from each alternative policy compare to the (site) energy savings from the proposed standards (represented in the table as 100%).
*** Refers to site energy savings.

[g] For the alternative policies whose market penetration depends on B/C ratio, the energy savings in Table 17.4.1 correspond to the case where the cash flow of the operating cost savings was discounted to the purchase year using a 7 percent discount rate.

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APPENDIX 6A. DETAILED DATA FOR PRODUCT PRICE MARKUPS

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6A.1 DETAILED WHOLESALER COST DATA

Based on data provided by the Heating Air-conditioning & Refrigeration Distributors International (HARDI), Table 6.5.1 of chapter 6 shows wholesaler revenues and costs in aggregated form. Table 6A.1.1 in this appendix provides the complete breakdown of costs and expenses. The column labeled “Scaling” in Table 6A.1.1 indicates which expenses the U.S. Department of Energy (DOE) assumed to scale with only the baseline markup and which with both the baseline and incremental markups. As described in chapter 6, section 6.4.1, only those expenses that scale with both baseline and incremental costs are marked up when there is an incremental change in equipment costs.

Table 6A.1.1 Disaggregated Costs and Expenses for Wholesalers

Item	Percent of Revenue %	Scaling
Cost of Goods Sold	**73.9**	
Gross Margin	**26.1**	
Payroll Expenses	**15.1**	Baseline
Executive Salaries & Bonuses	1.6	
Branch Manager Salaries and Commissions	1.3	
Sales Executive Salaries & Commissions	0.5	
Outside Sales Salaries & Commissions	2.3	
Inside/Counter Sales/Wages	2.6	
Purchasing Salaries/Wages	0.5	
Credit Salaries/Wages	0.2	
IT Salaries/Wages	0.2	
Warehouse Salaries/Wages	1.4	
Accounting	0.5	
Delivery Salaries/Wages	0.8	
All Other Salaries/Wages & Bonuses	0.8	
Payroll Taxes	1.0	
Group Insurance	1.0	
Benefit Plans	0.4	
Occupancy Expenses	**3.5**	Baseline
Utilities: Heat, Light, Power, Water	0.4	
Telephone	0.3	
Building Repairs & Maintenance	0.3	
Rent or Ownership in Real Estate	2.5	
Other Operating Expenses	**5.2**	Baseline & Incremental
Sales Expenses (incl. advertising & promotion)	0.9	
Insurance (business liability & casualty)	0.2	
Depreciation	0.4	
Vehicle Expenses	1.2	
Personal Property Taxes/Licenses	0.1	
Collection Expenses	0.3	
Bad Debt Losses	0.2	
Data Processing	0.3	
All Other Operating Expenses	1.6	
Total Operating Expenses	**23.8**	
Operating Profit	**2.3**	Baseline & Incremental
Other Income	0.4	
Interest Expense	0.4	
Other Non-operating Expenses	0.0	

Item	Percent of Revenue %	Scaling
Profit Before Taxes	**2.3**	

Source: Heating, Air-conditioning & Refrigeration Distributors International. 2013. 2013 Profit Report (2012 Data).

6A.2 DETAILED MECHANICAL CONTRACTOR DATA

Table 6.5.3 and Table 6.5.4 of chapter 6 provide mechanical contractor revenues and costs in aggregated form by 'Cost of Goods Sold' and 'Gross Margin.' The tables are based on data in the 2005 edition of *Financial Analysis for the HVACR Contracting Industry,* published by the Air Conditioning Contractors of America (ACCA). The ACCA report did not provide a more disaggregated tabulation of these costs and expenses. As in section 6A.1, the gross margin category was assumed to scale only with the baseline markup.

A further disaggregated breakdown of costs used to scale the incremental markup as presented in Table 6.5.2 of chapter 6 are shown in Table 6A.2.1 by both dollar value and percentage terms from the 2007 Census of Business. As the ACCA data were used to calculate the baseline markup, in Table 6A.2.1 only the categories in the 'Scaling' column that are scaled with both the baseline and incremental markups are marked when there is an incremental change in equipment costs.

Table 6A.2.1 Mechanical Contractor Expenses and Markups Used To Scale the Incremental Markups

Item	Dollar Value $1,000	Percentage %	Scaling
Total Cost of Equipment Sales	**107,144,428**	**67.80**	
Total payroll, construction workers wages	31,373,558	19.85	
Cost of materials, components, and supplies	59,023,964	37.35	
Cost of construction work subcontracted out to others	13,646,192	8.63	
Total cost of selected power, fuels, and lubricants	3,100,714	1.96	
Gross Margin	**50,895,129**	**32.20**	
Payroll Expenses	**28,065,632**	**17.76**	Baseline
Total payroll, other employee wages	14,041,336	8.88	
Total fringe benefits	13,585,040	8.60	
Temporary staff and leased employee expenses	439,256	0.28	
Occupancy Expenses	**3,436,208**	**2.17**	Baseline
Rental costs of machinery and equipment	1,047,026	0.66	
Rental costs of buildings	1,231,263	0.78	
Communication services	640,851	0.41	
Cost of repair to machinery and equipment	517,068	0.33	
Other Operating Expenses	**12,671,194**	**8.02**	Baseline & Incremental
Purchased professional and technical services	843,641	0.53	
Data processing and other purchased computer services	98,016	0.06	
Expensed computer hardware and other equipment	255,474	0.16	
Expensed purchases of software	64,195	0.04	
Advertising and promotion services	1,018,265	0.64	
All other expenses	6,944,674	4.39	
Refuse removal (including hazardous waste) services	153,241	0.10	
Taxes and license fees	996,138	0.63	
Total depreciation ($1,000)	2,297,550	1.45	
Net Profit Before Income Taxes	**6,722,095**	**4.25**	Baseline & Incremental

Source: U.S. Census Bureau. 2007. Plumbing, Heating, and Air-Conditioning Contractors: 2007. Sector 23: 238220. Construction: Geographic Area Series. Detailed Statistics for Establishments: 2007.
Note: Mechanical contractor costs and expenses are first presented as *total dollar* values and then converted to *percentage* values. This is in contrast to the *cost per dollar of sales revenue* values shown in Table 6.5.2.

6A.3 DETAILED GENERAL CONTRACTOR COST DATA

Based on U.S. Department of Census data, Table 6.5.6 of chapter 6 show residential building general contractor revenues and costs in aggregated form. Table 6A.3.1 shows the complete breakdown of costs and expenses of residential building contractor provided by the U.S. Department of Census. The column labeled “Scaling” indicates which expenses DOE assumed to scale with only the baseline markup and which are scaled with both the baseline and incremental markups. Only those expenses that scale with baseline and incremental costs are marked up when there is an incremental change in equipment costs.

Table 6A.3.1 Residential General Contractor Expenses and Markups

Item	Dollar Value *$1,000*	Percentage *%*	Scaling
Total Cost of Equipment Sales	**238,431,389**	**67.55**	
Total payroll, construction workers wages	16,629,321	4.71	
Cost of materials, components, and supplies	126,764,975	35.91	
Cost of construction work subcontracted out to others	90,956,668	25.77	
Total cost of selected power, fuels, and lubricants	4,080,425	1.16	
Gross Margin	**114,558,247**	**32.45**	
Payroll Expenses	**28,806,792**	**8.16**	Baseline
Total payroll, other employee wages	20,843,029	5.90	
Total fringe benefits	7,464,670	2.11	
Temporary staff and leased employee expenses	499,093	0.14	
Occupancy Expenses	**3,558,796**	1.01	Baseline
Rental costs of machinery and equipment	572,783	0.16	
Rental costs of buildings	1,532,841	0.43	
Communication services	810,436	0.23	
Cost of repair to machinery and equipment	642,736	0.18	
Other Operating Expenses	**21,341,175**	**6.05**	Baseline & Incremental
Purchased professional and technical services	1,834,816	0.52	
Data processing and other purchased computer services	141,344	0.04	
Expensed computer hardware and other equipment	261,701	0.07	
Expensed purchases of software	105,338	0.03	
Advertising and promotion services	2,544,687	0.72	
All other expenses	10,840,757	3.07	
Refuse removal (including hazardous waste) services	520,907	0.15	
Taxes and license fees	1,791,539	0.51	
Total depreciation ($1,000)	3,300,086	0.93	
Net Profit Before Income Taxes	**60,851,484**	**17.24**	Baseline & Incremental

Source: U.S. Census Bureau. 2007. Residential Building Construction. Sector 23, EC0723I1: 236115 through 236118. Construction, Industry Series, Preliminary Detailed Statistics for Establishments: 2007.
Note: General contractor costs and expenses are first presented as *total dollar* values and then converted to *percentage* values. This is in contrast to the *cost per dollar of sales revenue* values shown in Table 6.5.6.

6A.4 ESTIMATION OF CONTRACTOR MARK-UP BY STATE

Table 6A.4.1 Mechanical Contractor Markup Estimation by State, 2007

State	Value of Const. *$1,000*	Cost of Goods Sold *$1,000*	Baseline MU	Incremental MU	Replacement Baseline MU	Replacement Incremental MU	New Const. Baseline MU	New Const. Incremental MU
Alabama	2,010,305	1,401,223	1.435	1.148	1.498	1.198	1.393	1.114

State	Value of Const. *$1,000*	Cost of Goods Sold *$1,000*	Baseline MU	Incremental MU	Replacement Baseline MU	Replacement Incremental MU	New Const. Baseline MU	New Const. Incremental MU
Alaska	583,171	344,729	1.692	1.353	1.766	1.413	1.642	1.314
Arizona	3,522,116	2,326,475	1.514	1.211	1.580	1.264	1.470	1.176
Arkansas	1,065,754	743,395	1.434	1.147	1.496	1.197	1.392	1.113
California	16,726,969	10,865,201	1.539	1.232	1.607	1.286	1.495	1.196
Colorado	3,056,988	2,084,454	1.467	1.173	1.531	1.225	1.424	1.139
Connecticut	1,704,668	1,135,871	1.501	1.201	1.566	1.253	1.457	1.166
Delaware	481,900	D	1.421	1.137	1.483	1.186	1.379	1.104
District of Columbia	34,600	D	1.458	1.167	1.522	1.218	1.416	1.133
Florida	9,061,426	6,254,391	1.449	1.159	1.512	1.210	1.407	1.125
Georgia	4,700,799	3,329,842	1.412	1.129	1.474	1.179	1.371	1.096
Hawaii	800,221	455,122	1.758	1.407	1.835	1.468	1.707	1.366
Idaho	900,698	617,165	1.459	1.168	1.523	1.219	1.417	1.133
Illinois	7,641,642	5,058,047	1.511	1.209	1.577	1.262	1.467	1.173
Indiana	4,002,323	2,605,238	1.536	1.229	1.604	1.283	1.491	1.193
Iowa	1,868,483	1,305,883	1.431	1.145	1.493	1.195	1.389	1.111
Kansas	1,395,359	966,707	1.443	1.155	1.507	1.205	1.401	1.121
Kentucky	1,747,925	1,157,360	1.510	1.208	1.576	1.261	1.466	1.173
Louisiana	1,997,044	1,317,429	1.516	1.213	1.582	1.266	1.472	1.177
Maine	580,816	394,847	1.471	1.177	1.535	1.228	1.428	1.142
Maryland	5,329,135	3,739,560	1.425	1.140	1.487	1.190	1.383	1.107
Massachusetts	4,099,301	2,781,377	1.474	1.179	1.538	1.231	1.431	1.145
Michigan	4,420,638	3,015,948	1.466	1.173	1.530	1.224	1.423	1.138
Minnesota	3,402,921	2,315,330	1.470	1.176	1.534	1.227	1.427	1.141
Mississippi	1,025,452	715,571	1.433	1.146	1.496	1.197	1.391	1.113
Missouri	3,335,124	2,353,598	1.417	1.134	1.479	1.183	1.376	1.101
Montana	483,578	345,458	1.400	1.120	1.461	1.169	1.359	1.087
Nebraska	1,004,296	755,338	1.330	1.064	1.388	1.110	1.291	1.033
Nevada	2,327,842	1,600,555	1.454	1.164	1.518	1.214	1.412	1.130
New Hampshire	620,761	D	1.472	1.178	1.537	1.230	1.429	1.144
New Jersey	5,062,336	3,337,013	1.517	1.214	1.583	1.267	1.473	1.178
New Mexico	891,914	595,659	1.497	1.198	1.563	1.250	1.454	1.163
New York	10,364,779	6,760,337	1.533	1.227	1.600	1.280	1.488	1.191
North Carolina	5,111,396	3,631,802	1.407	1.126	1.469	1.175	1.366	1.093

State	Value of Const. *$1,000*	Cost of Goods Sold *$1,000*	Baseline MU	Incremental MU	Replacement Baseline MU	Replacement Incremental MU	New Const. Baseline MU	New Const. Incremental MU
North Dakota	360,683	255,057	1.414	1.131	1.476	1.181	1.373	1.098
Ohio	5,618,591	3,809,806	1.475	1.180	1.539	1.231	1.432	1.145
Oklahoma	1,352,943	924,264	1.464	1.171	1.528	1.222	1.421	1.137
Oregon	1,893,678	1,237,956	1.530	1.224	1.597	1.277	1.485	1.188
Pennsylvania	6,487,476	4,579,367	1.417	1.133	1.479	1.183	1.375	1.100
Rhode Island	631,202	410,653	1.537	1.230	1.604	1.284	1.492	1.194
South Carolina	1,991,303	1,326,690	1.501	1.201	1.567	1.253	1.457	1.166
South Dakota	386,186	239,017	1.616	1.293	1.686	1.349	1.569	1.255
Tennessee	2,595,613	1,834,242	1.415	1.132	1.477	1.182	1.374	1.099
Texas	10,810,308	7,532,064	1.435	1.148	1.498	1.198	1.393	1.115
Utah	1,746,398	1,235,004	1.414	1.131	1.476	1.181	1.373	1.098
Vermont	294,806	D	1.472	1.178	1.537	1.230	1.429	1.144
Virginia	4,623,151	3,099,329	1.492	1.193	1.557	1.246	1.448	1.158
Washington	4,111,543	2,734,093	1.504	1.203	1.570	1.256	1.460	1.168
West Virginia	655,100	D	1.464	1.171	1.528	1.222	1.421	1.137
Wisconsin	2,926,545	2,023,634	1.446	1.157	1.510	1.208	1.404	1.123
Wyoming	289,391	198,105	1.461	1.169	1.525	1.220	1.418	1.135

Sources: U.S. Bureau of the Census. American Factfinder: 2007. Sector 23: Plumbing, Heating, and Air-Conditioning Contractors (NAICS 238220), Detailed Statistics for Establishments: 2007
http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ECN_2007_US_23I1&prodType=table and
Geographic Area Series: Detailed Statistics for Establishments: 2007.
Notes: The Census Bureau withheld data for some states.
Markups may vary across states for several reasons, including differences in firm size.
Due to sample size and/or magnitude of reporting error relative to the mean, disaggregated information not provided for all of the Subcontract, Materials, and Fuels fields. In these cases, the state markup ratio is calculated as an average of neighboring states (ex. Delaware, District of Columbia, New Hampshire, Vermont, and West Virginia)

Table 6A.4.2 Residential Building General Contractor Baseline Markups by State

State	Value of Residential Construction *$1,000*	Cost of Goods Sold *$1,000*	Baseline Markup	Incremental Markup
Alabama	4,232,349	3,106,308	1.363	1.234
Alaska	598,572	322,897	1.854	1.678
Arizona	14,743,264	8,636,727	1.707	1.546
Arkansas	821,493	638,546	1.287	1.165
California	49,325,592	28,727,843	1.717	1.555
Colorado	9,711,667	6,478,218	1.499	1.357
Connecticut	2,835,015	1,914,706	1.481	1.341
Delaware	912,121	714,609	1.276	1.156
District of Columbia	177,004	115,545	1.532	1.387
Florida	33,290,091	21,780,175	1.528	1.384
Georgia	12,492,752	8,745,668	1.428	1.293
Hawaii	2,739,122	1,933,143	1.417	1.283
Idaho	2,565,176	2,014,522	1.273	1.153
Illinois	13,035,923	8,206,105	1.589	1.438
Indiana	4,637,976	3,418,576	1.357	1.228
Iowa	1,846,602	1,449,114	1.274	1.154
Kansas	1,940,745	1,443,265	1.345	1.217
Kentucky	3,074,656	2,244,283	1.370	1.240
Louisiana	2,429,529	1,650,884	1.472	1.332
Maine	821,980	630,393	1.304	1.181
Maryland	6,616,960	4,635,717	1.427	1.292
Massachusetts	7,693,991	5,728,767	1.343	1.216
Michigan	5,383,752	3,501,797	1.537	1.392
Minnesota	5,558,816	3,847,679	1.445	1.308
Mississippi	1,241,083	939,692	1.321	1.196
Missouri	4,754,552	3,588,694	1.325	1.200
Montana	1,148,453	919,206	1.249	1.131
Nebraska	577,746	424,822	1.360	1.231
Nevada	6,697,489	4,026,111	1.664	1.506
New Hampshire	292,227	228,854	1.277	1.156
New Jersey	8,492,015	5,649,618	1.503	1.361
New Mexico	2,236,262	1,395,073	1.603	1.451
New York	16,958,113	12,176,837	1.393	1.261
North Carolina	16,254,736	11,579,895	1.404	1.271

State	Value of Residential Construction *$1,000*	Cost of Goods Sold *$1,000*	Baseline Markup	Incremental Markup
North Dakota	D	D	1.331	1.205
Ohio	6,788,825	4,883,462	1.390	1.259
Oklahoma	1,419,859	1,075,586	1.320	1.195
Oregon	5,519,819	4,019,693	1.373	1.243
Pennsylvania	9,971,624	7,323,399	1.362	1.233
Rhode Island	309,403	205,383	1.506	1.364
South Carolina	5,921,453	4,350,205	1.361	1.232
South Dakota	297,424	228,839	1.300	1.177
Tennessee	5,243,037	3,874,974	1.353	1.225
Texas	32,123,700	21,429,103	1.499	1.357
Utah	4,201,276	3,095,214	1.357	1.229
Vermont	527,837	387,905	1.361	1.232
Virginia	12,761,751	8,799,880	1.450	1.313
Washington	11,158,559	7,361,497	1.516	1.372
West Virginia	348,291	225,500	1.545	1.398
Wisconsin	3,820,533	2,850,921	1.340	1.213
Wyoming	524,809	418,215	1.255	1.136

Sources: U.S. Bureau of the Census, American Factfinder. 2007 Economic Census. Sector 23: Subsectors 236115 (residential single-family), 236116 (residential multifamily), 236117 (operative builders), and 236118 (residential remodelers). Sector 23: EC0723A1: Construction: Geographic Area Series: Detailed Statistics for Establishments: 2007.
Notes: The Census Bureau withheld data for some states.
Markups may vary across states for several reasons, including differences in firm size.
Due to sample size and/or magnitude of reporting error relative to the mean, disaggregated information not provided for all of the Subcontract, Materials, and Fuels fields. In these cases, the state markup ratio is calculated as an average of neighboring states (ex. North Dakota).

6A.5 STATE SALES TAX RATES

Table 6A.5.1 State Sales Tax Rates

State	Combined State and Local Tax Rate %	State	Combined State and Local Tax Rate %	State	Combined State and Local Tax Rate %
Alabama	8.55	Kentucky	6.00	North Dakota	5.90
Alaska	1.30	Louisiana	8.75	Ohio	7.10
Arizona	7.15	Maine	5.50	Oklahoma	8.35
Arkansas	8.90	Maryland	6.00	Oregon	--
California	8.45	Massachusetts	6.25	Pennsylvania	6.40
Colorado	6.05	Michigan	6.00	Rhode Island	7.00
Connecticut	6.35	Minnesota	7.20	South Carolina	7.20
Delaware	--	Mississippi	7.00	South Dakota	5.40
Dist. of Columbia	5.75	Missouri	7.45	Tennessee	9.45
Florida	6.65	Montana	--	Texas	7.90
Georgia	7.05	Nebraska	6.00	Utah	6.70
Hawaii	4.40	Nevada	7.85	Vermont	6.05
Idaho	6.05	New Hampshire	--	Virginia	5.60
Illinois	8.05	New Jersey	6.95	Washington	8.90
Indiana	7.00	New Mexico	6.60	West Virginia	6.10
Iowa	6.85	New York	8.40	Wisconsin	5.45
Kansas	7.85	North Carolina	6.90	Wyoming	5.50

Source: The Sales Tax Clearinghouse at https://thestc.com/STRates.stm (Accessed on January 22, 2014).

APPENDIX 7A. BUILDING VARIABLES

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APPENDIX 7A. BUILDING VARIABLES

7A.1 INTRODUCTION

DOE created a database containing a subset of the records and variables from DOE's Energy Information Administration (EIA)'s 2009 Residential Energy Consumption Survey (RECS 2009) using Microsoft ACCESS.[1] DOE used this RECS 2009 subset in the life-cycle cost (LCC) analysis of the Hearth Products Rulemaking. This appendix explains the variable name abbreviations and provides definitions of the variable values.

For the entire RECS 2009 dataset, refer to www.eia.gov/consumption/residential/data/2009/index.cfm?view=microdata.

7A.2 RECS SAMPLE DETERMINATION

The RECS consists of three parts:

- Personal interviews with households for information about energy used, how it is used, energy-using appliances, structural features, energy efficiency measures, and demographic characteristics of the household.
- Telephone interviews with rental agents for households that have any of their energy use included in their rent. This information augments information collected from those households that may not be knowledgeable about the fuels used for space heating or water heating.
- Mail questionnaires sent to energy suppliers (after obtaining permission from households) to collect the actual billing data on energy consumption and expenditures.

For vented hearth heaters, the subset of RECS 2009 records used in the analysis met all of the following criteria:

- used a fireplace for secondary or primary space heating,
- used a heating fuel that is natural gas or liquefied petroleum gas (LPG), and
- had a flue on the gas fireplace to the outside.

For ventless hearth heaters, the subset of RECS 2009 records used in the analysis met all of the following criteria:

- used a fireplace for secondary space heating,
- used a fuel for a fireplace that is used for secondary space heating that is natural gas or LPG, and
- did not have a flue on the gas fireplace to the outside.

The RECS 2009 weighting indicates how commonly each household configuration occurs in the general population.

Table 7A.2.1 lists the variables use in the analysis.

Table 7A.2.1 List of RECS 2009 Variables Used for Hearth Products

Variable	**Description**
Location Variables	
REGIONC	Census Region
DIVISION	Census Division
REPORTABLE_DOMAIN	Reportable states and groups of states
HDD65	Heating degree days in 2009, base temperature 65F
CDD65	Heating degree days in 2009, base temperature 65F
Household Characteristics Variables	
NWEIGHT	Final sample weight
DOEID	Unique identifier for each respondent
TYPEHUQ	Type of housing unit
YEARMADE	Year housing unit was built
BTUNGSPH	Natural Gas usage for space heating, in thousand BTU, 2009
BTULPSPH	LPG/Propane usage for space heating, in thousand BTU, 2009
CHIMNEY	Fireplace used for secondary space heating
NGFPFLUE	Flue on gas fireplace
USENGFP	Frequency gas fireplace used
ROOMHEAT	Built-in room heaters used for secondary space heating
EQUIPM	Type of main space heating equipment used
FUELHEAT	Main space heating fuel
HEATOTH	Main space heating equipment heats other homes, business, or farm
MAINTHT	Routine service or maintenance performed on main space heating equipment
EQUIPAGE	Age of main space heating equipment
MONEYPY	2009 gross household income
RMHTFUEL	Fuel used by built-in electric units for secondary space heating
FPFUEL	Fuel used by fireplace for secondary space heating
EQMAMT	Portion of space heating provided by main space heating equipment (for homes with main and secondary heating only)
NHSLDMEM	Number of household members
Seniors*	Number of household members age 65 or older
POVERTY100	Household income at or below 100% of poverty line
StationID*	ID number of weather station identified with household (See Appendix 7B)
TOTSQFT	Total square footage (includes all attached garages, all basements, and finished/heated/cooled attics)
TOTSQFT_EN	Total square footage (includes heated/cooled garages, all basements, and finished/heated/cooled attics). Used for EIA data tables.
TOTHSQFT	Total heated square footage
CENACHP	Central air conditioner is a heat pump
COOLTYPE	Type of air conditioning equipment used

* Not part of RECS 2009 variables.

7A.3 RECS 2009 DATABASE VARIABLE RESPONSE CODES

Table 7A.3.1 provides the response codes for all RECS 2009 variables used in the hearth products samples.

Table 7A.3.1 Definitions of RECS 2009 Variables Used in Life-Cycle Cost Analysis

Variable	Response Codes	
BTULPSPH	Thousand BTU	
BTUNGSPH	Thousand BTU	
CDD65	Cooling degree days in 2009, base temperature 65F	
CENACHP	0 1 -2	No Yes Not Applicable
CHIMNEY	0 1 -2	No Yes Not Applicable
COOLTYPE	1 2 3 -2	Central system Window/wall units Both a central system and window/wall units Not Applicable
ROOMHEAT	0 1 -2	No Yes Not Applicable
DIVISION	1 2 3 4 5 6 7 8 9 10	New England Census Division (CT, MA, ME, NH, RI, VT) Middle Atlantic Census Division (NJ, NY, PA) East North Central Census Division (IL, IN, MI, OH, WI) West North Central Census Division (IA, KS, MN, MO, ND, NE, SD) South Atlantic Census Division (DC, DE, FL, GA, MD, NC, SC, VA, WV) East South Central Census Division (AL, KY, MS, TN) West South Central Census Division (AR, LA, OK, TX) Mountain North Sub-Division (CO, ID, MT, UT, WY) Mountain South Sub-Division (AZ, NM, NV) Pacific Census Division (AK, CA, HI, OR, WA)
DOEID	00001 - 12083	Unique identifier for each respondent
EQMAMT	1 2 3 -2	Almost all About three-fourths Closer to half Not Applicable
EQUIPAGE	1 2 3 41 42	Less than 2 years old 2 to 4 years old 5 to 9 years old 10 to 14 years old 15 to 19 years old

	5	20 years or older
	-2	Not Applicable
	2	Steam or Hot Water System
	3	Central Warm-Air Furnace
	4	Heat Pump
	5	Built-In Electric Units
	6	Floor or Wall Pipeless Furnace
	7	Built-In Room Heater
	8	Heating Stove
	9	Fireplace
	10	Portable Electric Heaters
	11	Portable Kerosene Heaters
	12	Cooking Stove
	21	Other Equipment
EQUIPM	-2	Not Applicable
	1	Natural Gas
	2	Propane/LPG
	7	Wood
	21	Other Fuel
FPFUEL	-2	Not Applicable
	1	Natural Gas
	2	Propane/LPG
	3	Fuel Oil
	4	Kerosene
	5	Electricity
	7	Wood
	8	Solar
	9	District Steam
	21	Other Fuel
FUELHEAT	-2	Not Applicable
HDD65	Heating degree days in 2009, base temperature 65F	
	0	No
	1	Yes
HEATOTH	-2	Not Applicable
	0	No
	1	Yes
MAINTHT	-2	Not Applicable
	1	Less than $2,500
	2	$2,500 to $4,999
	3	$5,000 to $7,499
	4	$7,500 to $9,999
	5	$10,000 to $14,999
	6	$15,000 to $19,999
	7	$20,000 to $24,999
	8	$25,000 to $29,999
	9	$30,000 to $34,999
	10	$35,000 to $39,999
	11	$40,000 to $44,999
MONEYPY	12	$45,000 to $49,999

	13 $50,000 to $54,999 14 $55,000 to $59,999 15 $60,000 to $64,999 16 $65,000 to $69,999 17 $70,000 to $74,999 18 $75,000 to $79,999 19 $80,000 to $84,999 20 $85,000 to $89,999 21 $90,000 to $94,999 22 $95,000 to $99,999 23 $100,000 to $119,999 24 $120,000 or More
NGFPFLUE	1 Flue to the outside 2 Flueless -2 Not Applicable
NHSLDMEM	0 - 15 Number of household members
NWEIGHT	Final sample weight
POVERTY100	0 No 1 Yes
REGIONC	1 Northeast Census Region 2 Midwest Census Region 3 South Census Region 4 West Census Region
REPORTABLE_DOMAIN	1 Connecticut, Maine, New Hampshire, Rhode Island, Vermont 2 Massachusetts 3 New York 4 New Jersey 5 Pennsylvania 6 Illinois 7 Indiana, Ohio 8 Michigan 9 Wisconsin 10 Iowa, Minnesota, North Dakota, South Dakota 11 Kansas, Nebraska 12 Missouri 13 Virginia 14 Delaware, District of Columbia, Maryland, West Virginia 15 Georgia 16 North Carolina, South Carolina 17 Florida 18 Alabama, Kentucky, Mississippi 19 Tennessee 20 Arkansas, Louisiana, Oklahoma 21 Texas 22 Colorado 23 Idaho, Montana, Utah, Wyoming 24 Arizona 25 Nevada, New Mexico 26 California

	27	Alaska, Hawaii, Oregon, Washington
	1	Natural Gas
	2	Propane/LPG
	3	Fuel Oil
	4	Kerosene
RMHTFUEL	-2	Not Applicable
	0	No
Seniors	1	Yes
StationID	Three character identifier for weather station	
TOTHSQFT	Square Feet	
TOTSQFT	Square Feet	
TOTSQFT_EN	Square Feet	
	1	Mobile Home
	2	Single-Family Detached
	3	Single-Family Attached
	4	Apartment in Building with 2 - 4 Units
TYPEHUQ	5	Apartment in Building with 5+ Units
	1	Most days
	2	About once a week
	3	Fewer than 4 times each month
USENGFP	-2	Not Applicable
YEARMADE	1600 - 2009	Year housing unit was built

* Not part of RECS 2009 variables.

REFERENCES

1. U.S. Department of Energy: Energy Information Administration, *Residential Energy Consumption Survey (RECS): 2009 RECS Survey Data,* 2009. (Last accessed January 7, 2015.) <www.eia.gov/consumption/residential/data/2009/>

APPENDIX 7B. MAPPING OF WEATHER STATION DATA TO RECS HOUSEHOLDS

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APPENDIX 7B. MAPPING OF WEATHER STATION DATA TO RECS HOUSEHOLDS

7B.1 INTRODUCTION

Energy Information Administration's (EIA) 2009 Residential Energy Consumption Survey (RECS 2009)[1] provides annual data on heating and cooling degree-days but not on other weather parameters needed for the analysis such as length of the heating and cooling season, monthly heating degree days (HDD) and monthly cooling degree days (CDD). Energy price data used in this analysis are available on a monthly basis. Monthly HDD are used to disaggregate the annual energy use provided by RECS by month. Monthly energy use is combined with monthly energy prices to find the monthly operating cost.

7B.2 MAPPING METHODOLOGY

To derive the additional weather data that is needed for the analysis (*e.g.*, HDD, CDD), for each building in the sample, DOE developed an approach to assign a physical location to each RECS household. [a] The methodology consists of the following steps:

1. DOE assembled monthly weather data from 360 weather stations from the National Oceanic and Atmospheric Administration (NOAA) that provide the heating and cooling degree-days at base temperature 65°F for year 2009 for these weather stations.[2] The 2009 heating and cooling degree days match the period used to determine the degree-days in RECS 2009.
2. RECS reports both HDD and CDD to base temperature 65°F for each household record. DOE assigned each household to one of the 339 weather stations by calculating which weather station (within the appropriate region) was the closest using the best linear least squares fit of the RECS data to the weather data. The following equation calculates the U.S. weather station closest (or with minimum "distance") to the RECS household:

$$"Distance" = \sqrt{(HDD_2 - HDD_1)^2 + (CDD_2 - CDD_1)^2}$$

Eq. 7B.2.1

Where:

HDD_1 = heating degree days from U.S. weather data,
HDD_2 = heating degree days from RECS data,
CDD_1 = cooling degree days from U.S. weather data, and
CDD_2 = cooling degree days from RECS data.

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[a] For confidentiality, heating and cooling degree day values were altered slightly by EIA to mask the exact geographic location of the housing unit.

7B.3 MAPPING RESULTS

Table 7B.3.1 shows the imputation results for all RECS 2009 locations. Note that some U.S. weather station data match with several of the RECS weather data. The number of RECS households that were matched to the specified weather station is indicated in the column "Count". Table 7B.3.1 shows the data matches (321 weather stations) including the heating and cooling ODT as well as annual average outdoor temperature for the weather stations..

Table 7B.3.1 Weather Station Mapping Statistics, Heating and Cooling ODT, and Average Outdoor Temperature

Station Location		Code	RECS 2009			Heating ODT	Cooling ODT	Average Outdoor Temp
State	City		HDD	CDD	Count			
AK	Anchorage	ANC	10335	2	8	-18	68	36
AK	Bethel	BET	12530	0	1	-24	68	30
AK	Cold Bay	CDB	9668	0	2	10	57	38
AK	Cordova	CDV	9511	0	2	1	67	38
AK	Homer	HOM	9817	0	10	4	62	38
AK	Juneau	JNU	8536	6	2	1	70	42
AK	Kenai	ENA	10423	0	1	-14	65	36
AK	Ketchikan	KTN	7359	68	2	20	68	38
AK	King Salmon	AKN	11088	0	1	-19	67	35
AK	Kodiak	ADQ	8903	0	1	13	65	41
AK	Sitka	SIT	-	-	-	21	64	42
AK	St Paul Island	SNP	11420	0	4	3	52	35
AK	Talkeetna	TKA	-	-	-	-21	73	34
AK	Valdez	VWS	7074	23	2	7	66	38
AK	Yakutat	YAK	9295	1	1	2	63	40
AL	Birmingham	BHM	2605	1958	25	21	93	62
AL	Huntsville	HSV	2982	1863	26	16	92	61
AL	Mobile	MOB	1594	2681	59	29	92	67
AL	Montgomery	MGM	2137	2367	3	25	94	65
AL	Muscle Shoals	MSL	2948	1773	12	21	93	61
AL	Tuscaloosa	TCL	2349	2136	10	23	93	64
AR	Fayetteville	FYV	3957	1185	48	12	93	58
AR	Fort Smith	FSM	3174	1906	3	17	96	61
AR	Little Rock	LIT	2946	1943	27	20	95	62
AR	Texarkana	TXK	2573	2006	10	23	96	61
AZ	Douglas	DUG	2160	2204	27	31	98	61
AZ	Flagstaff	FLG	6741	176	2	4	83	46
AZ	Phoenix	PHX	807	4942	26	34	108	74
AZ	Tucson	TUS	1268	3626	85	32	104	69
AZ	Winslow	INW	4233	1395	4	10	93	55
AZ	Yuma	NYL	671	4757	82	39	109	75
CA	Bakersfield	BFL	1873	2644	177	32	101	65
CA	Blythe	BLH	968	4580	8	33	112	71
CA	Eureka	EKA	5137	2	2	33	65	53
CA	Fresno	FAT	2239	2390	50	30	101	63
CA	Los Angeles	LAX	1294	569	117	43	80	63

Station Location		Code	RECS 2009			Heating ODT	Cooling ODT	Average Outdoor Temp
State	**City**		**HDD**	**CDD**	**Count**			
CA	Mt Shasta	MHS	5474	433	5	21	88	49
CA	Paso Robles	PRB	2676	1095	144	29	98	58
CA	Red Bluff	RBL	2452	2122	70	32	102	62
CA	Redding	RDD	2750	2086	63	31	102	62
CA	Sacramento	SAC	2531	1357	30	32	98	61
CA	San Diego	SAN	1050	813	540	44	81	64
CA	San Francisco	SFO	2614	220	278	38	78	57
CA	Stockton	SCK	2451	1468	122	30	98	62
CO	Alamosa	ALS	8229	49	27	-16	82	41
CO	Colorado Spring	COS	6301	356	90	2	88	48
CO	Denver	DEN	5988	541	69	1	92	50
CO	Eagle	EGE	7593	124	15	-7	86	41
CO	Pueblo	PUB	5427	818	77	0	96	52
CO	Trinidad	TAD	5323	719	17	3	90	51
CT	Bridgeport	BDR	5484	669	57	9	85	52
CT	Hartford	BDL	6072	610	94	7	88	50
DC	Washington	DCA	4124	1427	39	17	93	58
DE	Wilmington	ILG	4789	1031	14	14	89	54
FL	Daytona Beach	DAB	753	3321	99	35	91	71
FL	Fort Myers	FMY	294	4151	63	44	93	75
FL	Ft Lauderdale	FLL	118	4839	30	46	91	75
FL	Gainesville	GNV	1181	2789	118	31	92	69
FL	Jacksonville	JAX	1339	2772	60	32	93	68
FL	Key West	EYW	108	5017	11	57	89	78
FL	Melbourne	MLB	526	3718	80	43	91	73
FL	Miami	MIA	109	4914	2	47	91	77
FL	Orlando	MCO	588	3620	103	38	93	73
FL	Pensacola	PNS	1443	2729	44	29	92	68
FL	Tallahassee	TLH	1574	2802	31	30	94	68
FL	Tampa	TPA	496	3876	112	40	91	73
FL	Vero Beach	VRB	477	3604	26	43	91	73
FL	West Palm Beach	PBI	239	4314	169	45	90	75
GA	Albany	ABY	1767	2686	5	29	95	66
GA	Athens	AHN	2882	1903	253	22	93	62
GA	Atlanta	ATL	2813	1838	87	22	92	62
GA	Augusta	AGS	2475	2068	55	23	95	63
GA	Brunswick	SSI	-	-	-	32	91	69
GA	Columbus	CSG	2183	2194	2	24	94	65
GA	Macon	MCN	2288	2133	17	25	94	64
GA	Savannah	SAV	1739	2497	21	27	93	66
GA	Waycross	AYS				29	94	67
HI	Hilo-Hawaii	ITO	0	3050	14	62	85	74
HI	Honolulu-Oahu	HNL	0	4816	14	63	89	78
HI	Kahului-Maui	OGG	1	3746	21	61	88	76
HI	Lihue-Kauai	LIH	2	3611	5	62	85	76
IA	Burlington	BRL	5687	810	24	-3	91	50
IA	Cedar Rapids	CID	6977	419	15	-5	89	47

Station Location		Code	RECS 2009			Heating ODT	Cooling ODT	Average Outdoor Temp
State	City		HDD	CDD	Count			
IA	Des Moines	DSM	6124	898	33	-5	90	50
IA	Dubuque	DBQ	7204	345	1	-7	86	47
IA	Mason City	MCW	7856	338	15	-11	88	47
IA	Ottumwa	OTM	6317	588	43	-4	92	50
IA	Sioux City	SUX	6913	678	75	-7	90	48
IA	Waterloo	ALO	7253	448	58	-10	89	47
ID	Boise	BOI	5592	1199	9	10	95	52
ID	Burley	BYI	6697	397	1	2	90	47
ID	Idaho Falls	IDA	-	-	-	-6	89	47
ID	Lewiston	LWS	5386	1008	3	6	94	52
ID	Pocatello	PIH	7463	321	17	-1	91	47
IL	Chicago	ORD	6417	585	40	0	90	49
IL	Moline	MLI	6250	636	35	-4	91	50
IL	Peoria	PIA	5841	752	62	-4	90	51
IL	Quincy	UIN	5460	849	12	3	90	51
IL	Rockford	RFD	6738	433	58	-4	89	48
IL	Springfield	SPI	5234	933	41	2	91	53
IN	Evansville	EVV	4397	1283	13	9	92	56
IN	Fort Wayne	FWA	6077	601	41	1	88	50
IN	Indianapolis	IND	5203	953	22	2	89	53
IN	South Bend	SBN	6426	545	54	1	88	50
IN	West Lafayette	LAF	5436	826	32	3	90	50
KS	Concordia	CNK	5558	1094	18	3	96	54
KS	Dodge City	DDC	4975	1257	27	5	97	55
KS	Garden City	GCK	5014	1154	31	4	97	55
KS	Goodland	GLD	6016	722	11	0	94	51
KS	Russell	RSL	5298	1194	46	4	96	54
KS	Salina	SLN	-	-	-	5	98	56
KS	Topeka	TOP	4968	1195	9	4	94	54
KS	Wichita	ICT	4552	1506	68	7	97	56
KY	Bowling Green	BWG	3808	1407	52	10	91	57
KY	Jackson	JKL	4237	984	15	14	87	56
KY	Lexington	LEX	4670	1020	40	8	89	55
KY	Louisville	SDF	4155	1316	29	10	91	57
KY	Paducah	PAH	4198	1239	39	12	93	57
LA	Baton Rouge	BTR	1404	2985	24	29	93	67
LA	Lafayette	LFT	1296	3086	3	30	93	68
LA	Lake Charles	LCH	1380	2980	10	31	93	68
LA	Monroe	MLU	2118	2547	11	25	95	66
LA	New Orleans	MSY	1156	3221	35	33	92	69
LA	Shreveport	SHV	-	-	-	25	95	66
MA	Boston	BOS	5694	581	243	9	87	52
MA	Worcester	ORH	6699	370	258	4	83	47
MD	Baltimore	BWI	4745	1088	34	13	91	55
MD	Salisbury	SBY	4345	1149	19	16	90	57
ME	Augusta	AUG	7487	276	18	23	95	63
ME	Bangor	BGR	8098	246	19	-6	84	46

Station Location		Code	RECS 2009			Heating ODT	Cooling ODT	Average Outdoor Temp
State	City		HDD	CDD	Count			
ME	Caribou	CAR	9415	149	13	-13	82	39
ME	Houlton	HUL	9316	178	24	-13	85	40
ME	Portland	PWM	7107	294	108	-1	83	46
MI	Alpena	APN	-	-	-	-6	84	43
MI	Detroit	DTW	6224	588	81	6	87	50
MI	Flint	FNT	7068	328	40	1	86	47
MI	Grand Rapids	GRR	6580	444	35	5	86	48
MI	Houghton Lake	HTL	-	-	-	1	85	43
MI	Jackson	JXN	6585	420	11	14	87	56
MI	Lansing	LAN	6830	372	36	1	86	47
MI	Marquette	MQT	-	-	-	-8	83	39
MI	Muskegon	MKG	6719	371	38	6	83	47
MI	Saginaw	MBS	6960	350	19	4	87	47
MI	Sault St Marie	SSM	-	-	-	-8	80	40
MI	Traverse City	TVC	7695	253	14	1	86	47
MN	Alexandria	AXN	8922	340	8	-16	86	42
MN	Duluth	DLH	9517	118	10	-16	81	39
MN	Hibbing	HIB	10159	64	4	-20	81	37
MN	Int'l Falls	INL	10648	72	8	-25	83	37
MN	Minneapolis	MSP	7613	646	48	-12	88	45
MN	Rochester	RST	7884	321	9	-12	85	43
MN	Saint Cloud	STC	8704	301	74	-11	88	42
MO	Columbia	COU	4999	958	125	4	92	54
MO	Joplin	JLN	4216	1382	98	10	94	56
MO	Kansas City	MCI	5084	1093	213	6	93	54
MO	Saint Louis	STL	4438	1457	70	6	93	56
MO	Springfield	SGF	4596	1114	180	2	91	53
MS	Greenwood	GWO	2376	2250	1	20	94	61
MS	McComb	MCB	1833	2472	34	26	92	64
MS	Tupelo	TUP	2842	1947	20	19	94	61
MT	Billings	BIL	6948	627	9	-10	90	47
MT	Butte	BTM	-	-	-	-17	84	40
MT	Cut Bank	CTB	-	-	-	-20	84	40
MT	Great Falls	GTF	7941	300	1	-15	89	44
MT	Havre	HVR	-	-	-	-11	90	44
MT	Helena	HLN	7704	444	1	-16	87	44
MT	Kalispell	FCA	-	-	-	-7	86	43
MT	Lewistown	LWT	-	-	-	-16	86	44
MT	Miles City	MLS	7700	716	1	-15	93	46
MT	Missoula	MSO	7588	355	2	-6	88	45
NC	Asheville	AVL	4194	768	23	14	86	55
NC	Cape Hatteras	HAT	-	-	-	29	86	63
NC	Charlotte	CLT	3346	1611	71	22	91	61
NC	Greensboro	GSO	3605	1510	41	18	90	58
NC	Hickory	HKY	3593	1353	42	18	90	58
NC	New Bern	EWN	2769	1788	16	24	92	64
NC	Raleigh Durham	RDU	3164	1865	55	20	92	60

Station Location		Code	RECS 2009			Heating ODT	Cooling ODT	Average Outdoor Temp
State	City		HDD	CDD	Count			
NC	Wilmington	ILM	2521	1937	14	14	89	54
ND	Bismarck	BIS	9130	332	16	-19	90	42
ND	Devil's Lake	P11	10245	236	8	-21	87	40
ND	Fargo	FAR	9304	362	17	-18	88	42
ND	Grand Forks	GFK	9928	269	8	-22	89	40
ND	Minot	MOT	9559	314	9	-20	89	41
ND	Williston	ISN	9721	297	8	-21	92	41
NE	Grand Island	GRI	6431	788	26	-3	93	50
NE	Lincoln	LNK	6159	912	14	-2	94	51
NE	Norfolk	OFK	6789	643	4	-4	92	49
NE	North Platte	LBF	6946	534	14	-4	92	49
NE	Omaha	OMA	6288	851	32	-3	90	51
NE	Scottsbluff	BFF	6689	579	6	-3	92	48
NE	Valentine	VTN	7279	527	2	-8	94	47
NH	Concord	CON	7462	325	5	-3	87	46
NH	Lebanon	LEB	7312	371	18	-3	86	46
NJ	Atlantic City	ACY	4693	994	57	13	89	54
NJ	Newark	EWR	4790	1021	147	14	91	55
NM	Albuquerque	ABQ	3823	1435	17	16	93	57
NM	Carlsbad	CNM	2398	2376	2	19	98	63
NM	Clayton	CAO	4517	1143	31	9	91	53
NM	Gallup	GUP	6134	442	6	5	87	53
NM	Roswell	ROW	3098	1961	7	18	96	61
NV	Elko	EKO	6948	450	1	-2	92	46
NV	Ely	ELY	7925	125	4	-4	87	45
NV	Las Vegas	LAS	1882	3818	66	28	106	68
NV	Lovelock	LOL	-	-	-	12	97	50
NV	Reno	RNO	-	-	-	10	92	51
NV	Tonopah	TPH	5298	874	5	10	92	51
NV	Winnemucca	WMC	6236	611	2	3	94	49
NY	Albany	ALB	6644	433	149	29	95	66
NY	Binghamton	BGM	7067	261	59	1	82	46
NY	Buffalo	BUF	6651	361	54	6	84	48
NY	Glens Falls	GFL	7612	285	26	-5	85	46
NY	Massena	MSS	7980	298	2	-8	84	46
NY	New York	LGA	4647	1041	469	15	89	55
NY	Rochester	ROC	6765	315	46	-12	85	43
NY	Syracuse	SYR	6687	439	23	2	86	47
NY	Utica	UCA	-	-	-	-6	85	47
NY	Watertown	ART	7707	298	11	-6	83	46
OH	Akron Canton	CAK	6131	497	6	6	86	50
OH	Cincinnati	CVG	4950	874	13	6	90	54
OH	Cleveland	CLE	5833	664	44	5	87	50
OH	Columbus	CMH	5243	874	32	24	94	65
OH	Dayton	DAY	5602	732	45	4	88	52
OH	Findlay	FDY	5901	698	34	3	87	50
OH	Mansfield	MFD	6214	468	10	5	85	49

Station Location		Code	RECS 2009			Heating ODT	Cooling ODT	Average Outdoor Temp
State	City		HDD	CDD	Count			
OH	Toledo	TOL	6283	592	32	1	88	50
OH	Youngstown	YNG	6239	443	8	4	86	49
OK	Hobart	HBR	3392	2034	1	16	101	60
OK	McAlester	MLC	3136	1845	6	19	96	60
OK	Oklahoma City	OKC	3519	1849	37	13	96	60
OK	Tulsa	TUL	3608	1885	24	13	97	61
OR	Astoria	AST	4871	39	4	29	72	51
OR	Baker	BKE	7529	220	2	6	91	45
OR	Eugene	EUG	4999	331	89	22	88	52
OR	Medford	MFR	-	-	-	23	95	54
OR	Pendleton	PDT	5713	720	6	5	93	52
OR	Portland	PDX	4357	635	32	-1	83	46
OR	Redmond	RDM	6737	313	17	9	90	44
OR	Salem	SLE	4660	457	50	23	88	53
PA	Allentown	ABE	5725	622	22	9	88	51
PA	Altoona	AOO	6109	433	17	5	86	50
PA	Bradford	BFD	-	-	-	-1	80	50
PA	Du Bois	DUJ	6753	254	5	5	84	50
PA	Erie	ERI	6183	423	9	9	84	50
PA	Harrisburg	CXY	5097	866	111	11	90	53
PA	Philadelphia	PHL	4557	1219	46	14	90	55
PA	Pittsburgh	PIT	5661	617	6	5	87	51
PA	Williamsport	IPT	5636	644	69	7	87	50
RI	Providence	PVD	5717	579	69	9	86	51
SC	Charleston	CHS	1941	2390	13	27	93	65
SC	Columbia	CAE	2561	2220	19	4	92	54
SC	Florence	FLO	2541	2061	13	25	94	64
SC	Greenville	GSP	3116	1735	42	22	91	60
SD	Aberdeen	ABR	8872	329	13	-15	91	44
SD	Huron	HON	8070	469	105	-14	91	45
SD	Pierre	PIR	7738	577	36	-10	95	48
SD	Rapid City	RAP	7738	362	12	-7	91	47
SD	Sioux Falls	FSD	7670	481	42	-11	90	45
TN	Bristol	TRI	4267	930	28	14	87	55
TN	Chattanooga	CHA	3168	1808	35	18	92	60
TN	Crossville	CSV	4100	940	33	15	87	54
TN	Jackson	MKL	3379	1597	22	14	87	56
TN	Knoxville	TYS	3643	1392	91	19	90	58
TN	Memphis	MEM	2906	2091	3	18	94	62
TN	Nashville	BNA	3615	1558	37	14	92	59
TX	Abilene	ABI	2359	2494	217	20	97	64
TX	Alice	ALI	738	4832	23	34	99	72
TX	Amarillo	AMA	4034	1340	33	11	95	57
TX	Austin	AUS	1722	3214	45	28	96	69
TX	Brownsville	BRO	525	4300	20	39	94	73
TX	College Station	CLL	1404	3476	29	29	96	69
TX	Corpus Christi	CRP	811	4058	8	35	94	72

Station Location		Code	RECS 2009			Heating ODT	Cooling ODT	Average Outdoor Temp
State	City		HDD	CDD	Count			
TX	Dallas-Ft. Worth	DFW	2097	2745	61	22	98	66
TX	Del Rio	DRT	1252	3807	29	31	98	70
TX	El Paso	ELP	2106	2783	43	24	98	65
TX	Galveston	GLS	907	3640	3	36	91	71
TX	Houston	IAH	1267	3410	170	32	96	69
TX	Laredo	LRD	602	5330	1	36	101	73
TX	Lubbock	LBB	3178	1965	10	15	96	60
TX	Lufkin	LFK	1803	2839	64	29	95	69
TX	McAllen	MFE	393	5387	3	39	99	73
TX	Midland Odessa	MAF	2495	2445	81	21	98	63
TX	San Angelo	SJT	2020	2814	56	22	97	65
TX	San Antonio	SAT	1270	3598	28	30	97	69
TX	Victoria	VCT	1123	3608	35	32	95	70
TX	Waco	ACT	1927	3086	18	26	99	67
TX	Wichita Falls	SPS	2838	2394	14	18	100	63
UT	Cedar City	CDC	6058	645	56	5	91	52
UT	Salt Lake City	SLC	5716	1147	29	8	95	52
VA	Lynchburg	LYH	4433	1003	159	16	90	55
VA	Norfolk	ORF	3330	1659	41	-4	92	49
VA	Richmond	RIC	3781	1564	47	17	92	58
VA	Roanoke	ROA	3931	1173	34	16	90	56
VT	Burlington	BTV	-	-	-	-3	91	50
VT	Montpelier	MPV	7998	237	12	-6	83	45
WA	Bellingham	BLI	5568	115	8	15	76	51
WA	Olympia	OLM	5614	178	24	22	83	50
WA	Quillayute	UIL	5869	44	7	27	74	49
WA	Seattle Tacoma	SEA	4879	319	94	26	81	52
WA	Spokane	GEG	6942	599	5	2	89	47
WA	Walla Walla	ALW	5062	1144	12	7	95	54
WA	Yakima	YKM	6204	699	25	5	92	49
WI	Eau Claire	EAU	8208	333	23	-11	87	44
WI	Green Bay	GRB	8005	275	55	-9	85	44
WI	Lacrosse	LSE	7334	536	16	-9	89	47
WI	Madison	MSN	7343	368	66	-7	87	46
WI	Milwaukee	MKE	6816	474	28	-4	87	48
WI	Wausau	AUW	8337	277	54	-12	85	44
WV	Beckley	BKW	5325	404	16	4	84	52
WV	Charleston	CRW	4443	960	3	27	93	65
WV	Elkins	EKN	5993	284	3	6	83	50
WV	Huntington	HTS	4557	922	3	10	89	55
WV	Martinsburg	MRB	5046	854	63	10	91	54
WV	Morgantown	MGW	4957	836	15	8	87	54
WV	Parkersburg	PKB	4910	850	19	11	88	54
WY	Casper	CPR	-	-	-	-5	91	45
WY	Cheyenne	CYS	7390	203	11	-1	86	45
WY	Cody	COD	7551	410	2	-13	87	45
WY	Lander	LND	7743	351	1	-11	87	45

Station Location		Code	RECS 2009			Heating ODT	Cooling ODT	Average Outdoor Temp
State	City		HDD	CDD	Count			
WY	Rock Springs	RKS	8204	230	3	-3	84	43
WY	Sheridan	SHR	7844	287	2	-8	90	45
WY	Worland	WRL	7757	467	2	-13	93	45

7B.3.2 Developing Monthly Heating Degree Day Fractions

Table 7B.3.2 shows the 10-year average monthly HDD data based on NOAA data for each weather station.[2] This data was then used to determine the monthly fractions of HDD as shown in Table 7B.3.3. Monthly HDD are used to disaggregate the annual energy use provided by RECS 2009 by month. The monthly energy use is then combined with monthly energy prices to find the monthly operating cost (see appendix 8C for more details).

Table 7B.3.2 Weather Station Monthly Heating Degree Day Data (10-Year Average)

Station Location		Code	Monthly Heating Degree Days											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AK	Anchorage	ANC	1558	1202	1238	824	510	292	184	234	464	855	1316	1421
AK	Bethel	BET	1914	1447	1684	1155	661	355	273	318	547	1004	1477	1690
AK	Cold Bay	CDB	1167	971	1177	939	755	559	440	388	497	744	944	1068
AK	Cordova	CDV	1225	1001	1074	797	594	413	321	330	490	762	1064	1127
AK	Homer	HOM	1314	1052	1163	829	622	436	320	337	487	786	1127	1201
AK	Juneau	JNU	1138	971	1006	720	492	310	248	280	444	707	980	1110
AK	Kenai	ENA	1608	1223	1285	838	560	362	248	292	478	828	1303	1439
AK	Ketchikan	KTN	930	823	861	666	479	298	212	203	349	600	805	924
AK	King Salmon	AKN	1632	1199	1427	932	620	406	299	307	505	886	1342	1474
AK	Kodiak	ADQ	1090	928	1063	806	621	442	313	294	454	724	969	1059
AK	Sitka	SIT	895	787	868	670	513	354	258	233	345	577	779	876
AK	St Paul Island	SNP	1277	1131	1314	1086	910	671	552	489	572	802	965	1127
AK	Talkeetna	TKA	1636	1267	1281	836	494	234	155	239	504	909	1394	1529
AK	Valdez	VWS	1212	912	952	622	371	194	136	154	319	594	996	1036
AK	Yakutat	YAK	1144	966	1045	796	602	404	297	316	462	719	987	1086
AL	Birmingham	BHM	635	502	261	105	21	0	0	0	4	114	312	563
AL	Huntsville	HSV	722	578	324	135	25	0	0	0	9	145	371	641
AL	Mobile	MOB	427	331	143	45	4	0	0	0	0	55	201	385
AL	Montgomery	MGM	543	417	198	70	9	0	0	0	2	80	265	481
AL	Muscle Shoals	MSL	716	576	317	135	25	0	0	0	7	149	366	640
AL	Tuscaloosa	TCL	606	477	234	95	16	0	0	0	2	110	299	539
AR	Fayetteville	FYV	859	724	446	230	76	2	0	1	32	233	458	803
AR	Fort Smith	FSM	745	599	313	120	26	0	0	0	4	122	343	685
AR	Little Rock	LIT	708	579	310	114	22	0	0	0	3	122	341	654
AR	Texarkana	TXK	606	488	240	84	15	0	0	0	1	96	274	559
AZ	Douglas	DUG	555	426	298	118	14	0	0	0	0	70	307	571
AZ	Flagstaff	FLG	1066	946	828	640	389	136	13	36	202	533	797	1085
AZ	Phoenix	PHX	234	172	63	11	0	0	0	0	0	4	68	283
AZ	Tucson	TUS	342	280	143	44	2	0	0	0	0	15	140	381

Station Location		Code	Monthly Heating Degree Days											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AZ	Winslow	INW	918	716	526	311	97	4	0	0	20	256	586	913
AZ	Yuma	NYL	148	128	46	13	0	0	0	0	0	2	54	227
CA	Bakersfield	BFL	484	327	217	133	21	2	0	0	1	51	274	491
CA	Blythe	BLH	271	191	73	13	0	0	0	0	0	5	105	337
CA	Eureka	EKA	557	513	527	496	414	314	276	258	308	365	467	579
CA	Fresno	FAT	527	367	250	146	25	1	0	0	2	52	289	518
CA	Los Angeles	LAX	215	220	200	152	68	13	2	2	4	33	124	251
CA	Mt Shasta	MHS	876	754	707	568	322	126	11	20	114	414	704	908
CA	Paso Robles	PRB	507	418	341	257	89	22	2	2	17	123	344	535
CA	Red Bluff	RBL	530	408	325	218	54	7	0	0	4	86	343	558
CA	Redding	RDD	551	423	351	241	61	9	0	0	5	100	374	583
CA	Sacramento	SAC	544	397	307	211	56	8	0	0	6	84	340	549
CA	San Diego	SAN	214	196	157	107	47	14	2	0	0	15	105	243
CA	San Francisco	SFO	438	344	308	262	187	105	61	52	53	104	266	427
CA	Stockton	SCK	549	393	299	190	45	5	0	0	3	72	327	541
CO	Alamosa	ALS	1432	1202	914	655	390	139	25	63	283	642	1012	1438
CO	Colorado Spring	COS	1025	942	712	503	259	57	7	19	133	443	736	1074
CO	Denver	DEN	1016	946	687	487	252	54	4	10	107	422	727	1075
CO	Eagle	EGE	1322	1086	854	621	367	112	8	26	223	567	918	1305
CO	Pueblo	PUB	1020	895	623	393	151	17	1	4	71	377	698	1062
CO	Trinidad	TAD	960	861	626	412	176	26	2	6	79	357	665	1005
CT	Bridgeport	BDR	1076	920	758	432	190	27	0	1	35	283	544	886
CT	Hartford	BDL	1204	1013	811	441	195	32	1	5	74	376	649	1007
DC	Washington	DCA	885	753	520	245	68	3	0	0	9	191	438	755
DE	Wilmington	ILG	1000	867	639	341	124	13	0	1	26	274	529	849
FL	Daytona Beach	DAB	240	173	75	21	1	0	0	0	0	11	60	172
FL	Fort Myers	FMY	119	65	24	3	0	0	0	0	0	3	15	75
FL	Ft Lauderdale	FLL	61	34	11	1	0	0	0	0	0	0	4	37
FL	Gainesville	GNV	345	249	116	37	1	0	0	0	0	28	120	279
FL	Jacksonville	JAX	385	287	140	51	3	0	0	0	0	32	148	313
FL	Key West	EYW	42	19	5	0	0	0	3	0	0	0	1	16
FL	Melbourne	MLB	181	117	49	15	0	0	0	0	0	9	35	116
FL	Miami	MIA	54	29	8	1	0	0	0	0	0	0	3	31
FL	Orlando	MCO	196	124	48	11	0	0	0	0	0	9	40	134
FL	Pensacola	PNS	394	306	128	36	1	0	0	0	0	36	159	344
FL	Tallahassee	TLH	424	328	149	53	2	0	0	0	0	42	189	368
FL	Tampa	TPA	183	117	46	10	0	0	0	0	0	6	32	129
FL	Vero Beach	VRB	165	107	47	13	0	0	0	0	0	6	26	102
FL	West Palm Beach	PBI	92	53	20	4	0	0	0	0	0	3	11	55
GA	Albany	ABY	469	370	173	56	2	0	0	0	0	51	217	418
GA	Athens	AHN	662	522	304	131	23	0	0	0	4	126	352	602
GA	Atlanta	ATL	650	519	292	118	21	0	0	0	3	110	325	581
GA	Augusta	AGS	598	475	265	106	11	0	0	0	2	100	314	532
GA	Brunswick	SSI	411	328	151	58	3	0	0	0	0	36	154	333
GA	Columbus	CSG	543	421	204	67	5	0	0	0	1	68	240	472
GA	Macon	MCN	563	445	239	91	10	0	0	0	2	89	295	510
GA	Savannah	SAV	478	373	191	69	6	0	0	0	0	50	215	399
GA	Waycross	AYS	412	317	143	50	2	12	0	0	0	40	180	369

Station Location		Code	Monthly Heating Degree Days											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HI	Hilo-Hawaii	ITO	0	0	0	0	0	0	0	0	0	0	0	0
HI	Honolulu-Oahu	HNL	0	0	0	0	0	0	0	0	0	0	0	0
HI	Kahului-Maui	OGG	0	0	0	0	0	0	0	0	0	0	0	0
HI	Lihue-Kauai	LIH	0	0	0	0	0	0	0	0	0	0	0	0
IA	Burlington	BRL	1233	1043	667	337	125	8	1	5	71	339	617	1078
IA	Cedar Rapids	CID	1404	1197	807	441	187	21	5	14	128	450	763	1259
IA	Des Moines	DSM	1310	1109	716	360	128	6	0	4	72	359	697	1159
IA	Dubuque	DBQ	1421	1215	846	475	219	31	6	16	141	466	774	1275
IA	Mason City	MCW	1514	1288	924	514	230	33	6	23	153	505	865	1370
IA	Ottumwa	OTM	1310	1110	724	395	159	15	2	9	103	396	699	1152
IA	Sioux City	SUX	1393	1177	792	424	166	17	2	8	112	435	807	1282
IA	Waterloo	ALO	1449	1225	841	468	192	19	3	14	128	458	802	1304
ID	Boise	BOI	985	785	611	430	220	54	0	6	62	356	722	993
ID	Burley	BYI	1119	945	747	559	339	124	5	24	170	496	817	1106
ID	Idaho Falls	IDA	1379	1179	885	610	385	159	11	36	220	585	934	1270
ID	Lewiston	LWS	867	718	593	416	211	57	1	4	58	376	699	937
ID	Pocatello	PIH	1229	1046	806	589	366	128	5	22	182	535	887	1196
IL	Chicago	ORD	1256	1078	773	451	208	30	2	6	79	371	678	1109
IL	Moline	MLI	1280	1095	716	375	147	13	1	5	82	369	675	1145
IL	Peoria	PIA	1221	1034	666	346	134	10	0	5	64	348	646	1086
IL	Quincy	UIN	1178	996	628	328	120	8	0	5	66	332	611	1041
IL	Rockford	RFD	1330	1137	794	437	192	22	4	9	96	403	724	1193
IL	Springfield	SPI	1155	972	606	308	111	9	0	5	61	323	586	1006
IN	Evansville	EVV	981	828	505	242	73	4	0	1	27	247	516	863
IN	Fort Wayne	FWA	1247	1086	751	414	174	18	1	7	86	388	669	1074
IN	Indianapolis	IND	1131	968	620	316	120	10	1	3	46	314	592	987
IN	South Bend	SBN	1253	1090	783	442	210	29	2	11	96	404	685	1079
IN	West Lafayette	LAF	1178	1006	653	350	145	14	0	5	63	345	612	1022
KS	Concordia	CNK	1117	938	595	329	121	7	0	2	57	306	641	1067
KS	Dodge City	DDC	979	847	555	317	110	5	0	2	45	276	609	978
KS	Garden City	GCK	1010	868	572	336	112	6	1	2	43	294	624	1007
KS	Goodland	GLD	1059	946	668	436	196	24	3	5	89	394	720	1078
KS	Russell	RSL	1074	911	582	328	116	7	0	2	50	297	638	1050
KS	Salina	SLN	1043	872	532	279	87	3	0	1	36	256	570	997
KS	Topeka	TOP	1079	892	545	271	86	3	0	2	46	274	574	972
KS	Wichita	ICT	985	810	487	240	69	2	0	0	24	227	528	924
KY	Bowling Green	BWG	877	727	438	220	59	3	0	1	21	215	467	779
KY	Jackson	JKL	924	774	479	230	88	7	1	2	37	242	464	802
KY	Lexington	LEX	993	842	547	278	99	6	0	2	42	278	540	874
KY	Louisville	SDF	932	780	473	210	58	3	0	0	19	213	462	809
KY	Paducah	PAH	933	779	484	240	71	5	0	2	35	253	515	842
LA	Baton Rouge	BTR	398	310	128	40	3	0	0	0	0	48	182	376
LA	Lafayette	LFT	380	289	116	29	1	0	0	0	0	40	149	349
LA	Lake Charles	LCH	383	299	121	32	1	0	0	0	0	33	153	348
LA	Monroe	MLU	548	439	208	63	7	0	0	0	1	80	257	501
LA	New Orleans	MSY	347	263	99	23	0	0	0	0	0	24	124	309
LA	Shreveport	SHV	521	418	193	58	7	0	0	0	0	69	236	490
MA	Boston	BOS	1111	947	792	467	230	56	3	5	55	315	574	905

Station Location		Code	Monthly Heating Degree Days											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MA	Worcester	ORH	1273	1083	892	514	268	79	9	16	107	435	682	1057
MD	Baltimore	BWI	969	837	602	309	109	8	0	0	26	265	511	836
MD	Salisbury	SBY	929	806	599	328	141	14	1	1	29	254	481	775
ME	Augusta	AUG	1410	1181	992	594	317	101	12	23	148	484	769	1168
ME	Bangor	BGR	1475	1245	1039	633	333	106	14	30	177	510	808	1212
ME	Caribou	CAR	1680	1420	1228	766	423	153	36	79	268	628	944	1401
ME	Houlton	HUL	1630	1393	1184	756	438	172	48	84	272	620	907	1359
ME	Portland	PWM	1318	1116	950	598	332	103	11	19	138	463	727	1089
MI	Alpena	APN	1419	1264	1076	685	387	118	31	54	209	545	826	1219
MI	Detroit	DTW	1226	1077	812	445	192	22	2	5	77	378	665	1049
MI	Flint	FNT	1306	1148	884	513	252	47	11	19	130	452	733	1116
MI	Grand Rapids	GRR	1264	1118	853	488	229	34	5	11	108	434	713	1077
MI	Houghton Lake	HTL	1433	1280	1044	629	335	103	37	65	223	562	836	1225
MI	Jackson	JXN	1286	1126	842	483	238	45	9	17	131	451	713	1100
MI	Lansing	LAN	1303	1148	873	510	250	46	10	19	130	455	729	1110
MI	Marquette	MQT	1515	1339	1152	765	441	162	64	82	264	616	945	1356
MI	Muskegon	MKG	1215	1097	875	528	268	54	8	17	119	432	701	1043
MI	Saginaw	MBS	1323	1172	917	540	261	48	10	20	129	450	738	1129
MI	Sault St Marie	SSM	1526	1324	1144	715	404	152	51	61	217	571	869	1299
MI	Traverse City	TVC	1312	1186	980	630	342	90	21	26	155	486	763	1132
MN	Alexandria	AXN	1675	1443	1085	589	298	66	10	29	183	561	967	1497
MN	Duluth	DLH	1676	1419	1140	713	430	156	45	69	256	630	1004	1506
MN	Hibbing	HIB	1780	1506	1170	737	454	181	75	126	334	695	1073	1599
MN	Int'l Falls	INL	1853	1586	1229	734	443	167	69	125	328	695	1099	1660
MN	Minneapolis	MSP	1512	1267	921	466	203	25	2	8	116	460	842	1353
MN	Rochester	RST	1531	1308	944	512	236	38	8	25	147	489	851	1377
MN	Saint Cloud	STC	1625	1385	1036	565	288	56	10	29	184	553	949	1463
MO	Columbia	COU	1077	896	547	274	96	5	0	3	48	287	557	955
MO	Joplin	JLN	914	751	439	218	70	3	0	1	28	217	445	821
MO	Kansas City	MCI	1104	918	564	280	92	5	0	1	46	281	575	993
MO	Saint Louis	STL	1002	835	498	230	67	3	0	1	26	227	498	883
MO	Springfield	SGF	970	800	498	258	89	4	0	2	39	261	511	881
MS	Greenwood	GWO	628	506	255	98	17	0	0	0	5	123	282	565
MS	McComb	MCB	490	384	174	61	9	0	0	0	1	71	230	446
MS	Tupelo	TUP	692	555	294	124	23	0	0	0	6	134	343	621
MT	Billings	BIL	1148	1004	776	536	332	93	3	13	146	499	829	1170
MT	Butte	BTM	1349	1201	996	783	564	301	67	117	366	724	1096	1424
MT	Cut Bank	CTB	1288	1157	981	709	487	238	50	88	300	671	984	1319
MT	Great Falls	GTF	1189	1070	889	641	431	188	22	50	231	575	900	1211
MT	Havre	HVR	1435	1273	990	608	380	142	13	42	234	612	1003	1418
MT	Helena	HLN	1252	1035	837	594	370	140	7	30	188	566	935	1285
MT	Kalispell	FCA	1145	946	764	513	281	132	20	45	216	517	882	1158
MT	Lewistown	LWT	1254	1139	939	702	490	235	41	72	275	631	956	1279
MT	Miles City	MLS	1368	1191	866	519	312	82	2	12	155	535	918	1331
MT	Missoula	MSO	1201	979	807	598	384	168	15	33	205	600	960	1246
NC	Asheville	AVL	857	712	500	267	89	6	0	0	33	272	521	786
NC	Cape Hatteras	HAT	440	383	263	90	21	0	0	0	1	24	102	292
NC	Charlotte	CLT	734	598	373	172	40	0	0	0	9	169	412	658

Station Location		Code	Monthly Heating Degree Days											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NC	Greensboro	GSO	780	648	415	192	55	2	0	0	14	187	429	700
NC	Hickory	HKY	780	647	412	190	53	3	0	0	15	189	427	706
NC	New Bern	EWN	659	548	352	148	29	0	0	0	2	117	315	552
NC	Raleigh Durham	RDU	729	599	384	170	43	1	0	0	9	163	385	642
NC	Wilmington	ILM	617	510	324	128	24	0	0	0	1	103	297	517
ND	Bismarck	BIS	1595	1394	1044	589	328	80	8	28	198	594	1015	1472
ND	Devil's Lake	P11	1771	1580	1237	670	373	117	21	45	227	630	1091	1612
ND	Fargo	FAR	1718	1498	1119	575	288	56	12	31	185	557	992	1522
ND	Grand Forks	GFK	1803	1593	1226	639	355	83	22	46	223	618	1078	1609
ND	Minot	MOT	1606	1438	1119	609	360	101	17	37	204	624	1051	1512
ND	Williston	ISN	1635	1447	1089	620	381	119	13	36	226	654	1090	1553
NE	Grand Island	GRI	1231	1042	698	398	160	17	2	5	86	389	739	1172
NE	Lincoln	LNK	1261	1055	680	377	137	10	1	5	83	371	717	1169
NE	Norfolk	OFK	1313	1106	752	426	176	22	3	8	109	417	777	1223
NE	North Platte	LBF	1210	1048	752	487	234	37	3	10	135	477	821	1219
NE	Omaha	OMA	1292	1088	705	363	133	10	1	5	75	360	714	1179
NE	Scottsbluff	BFF	1138	1000	742	510	263	53	5	12	133	482	811	1190
NE	Valentine	VTN	1262	1117	816	510	260	51	4	12	143	496	848	1247
NH	Concord	CON	1380	1159	965	571	282	81	9	26	151	487	770	1150
NH	Lebanon	LEB	1439	1217	1000	598	285	81	9	28	152	511	794	1199
NJ	Atlantic City	ACY	975	847	663	366	151	20	0	1	31	263	512	817
NJ	Newark	EWR	1016	856	651	338	113	11	0	1	20	253	510	844
NM	Albuquerque	ABQ	821	668	469	236	58	1	0	0	15	199	536	859
NM	Carlsbad	CNM	617	470	255	86	21	0	0	0	4	94	349	638
NM	Clayton	CAO	853	788	564	343	126	11	2	5	52	278	558	888
NM	Gallup	GUP	1078	901	765	535	279	52	1	4	124	464	801	1090
NM	Roswell	ROW	701	545	314	123	27	0	0	0	7	127	418	740
NV	Elko	EKO	1221	990	795	593	349	109	2	16	156	516	863	1180
NV	Ely	ELY	1215	1032	864	663	434	151	6	33	218	569	884	1214
NV	Las Vegas	LAS	470	350	165	58	6	0	0	0	0	28	228	522
NV	Lovelock	LOL	987	771	617	431	183	35	0	4	71	373	741	1039
NV	Reno	RNO	886	727	585	431	190	43	0	3	47	303	637	912
NV	Tonopah	TPH	955	807	675	482	211	42	0	3	62	347	697	1011
NV	Winnemucca	WMC	1053	859	727	564	317	96	2	15	151	498	826	1097
NY	Albany	ALB	1303	1106	885	489	215	37	2	11	99	438	713	1092
NY	Binghamton	BGM	1328	1145	942	561	274	77	12	26	150	487	743	1133
NY	Buffalo	BUF	1242	1122	911	551	247	49	4	10	94	424	674	1041
NY	Glens Falls	GFL	1437	1236	996	581	282	74	12	34	177	518	789	1193
NY	Massena	MSS	1531	1318	1083	622	302	81	10	36	169	537	835	1287
NY	New York	LGA	976	834	657	338	118	12	0	1	11	206	456	786
NY	Rochester	ROC	1241	1106	888	537	254	54	6	15	107	427	692	1038
NY	Syracuse	SYR	1271	1125	908	523	232	46	3	12	99	417	690	1069
NY	Utica	UCA	1198	1011	784	386	142	32	2	11	57	307	599	991
NY	Watertown	ART	1434	1269	1007	607	308	89	14	35	157	486	757	1159
OH	Akron Canton	CAK	1208	1066	800	439	192	39	3	8	91	406	664	1036
OH	Cincinnati	CVG	1063	908	603	304	110	9	1	2	44	309	577	930
OH	Cleveland	CLE	1166	1030	795	451	197	32	2	5	71	365	619	994
OH	Columbus	CMH	1109	963	665	326	124	11	0	2	47	329	586	950

Station Location		Code	Monthly Heating Degree Days											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
OH	Dayton	DAY	1171	1010	697	368	151	15	1	4	67	358	628	1013
OH	Findlay	FDY	1212	1055	755	412	166	19	1	5	81	371	639	1041
OH	Mansfield	MFD	1229	1079	799	447	203	42	6	11	100	415	664	1053
OH	Toledo	TOL	1231	1079	797	446	189	22	1	6	86	389	678	1067
OH	Youngstown	YNG	1215	1068	820	464	219	55	7	16	108	425	666	1037
OK	Hobart	HBR	769	642	367	174	41	0	0	0	6	149	401	753
OK	McAlester	MLC	731	588	308	140	33	0	0	0	9	135	335	673
OK	Oklahoma City	OKC	785	640	347	148	35	1	0	0	9	144	390	744
OK	Tulsa	TUL	809	663	363	155	37	1	0	0	11	151	388	751
OR	Astoria	AST	646	584	578	493	365	222	127	112	184	362	547	682
OR	Baker	BKE	1176	964	817	649	426	214	38	62	256	611	923	1191
OR	Eugene	EUG	723	629	558	455	305	147	22	23	100	358	595	763
OR	Medford	MFR	760	595	527	391	188	52	1	3	39	276	606	790
OR	Pendleton	PDT	910	745	606	454	248	85	5	8	88	399	715	972
OR	Portland	PDX	718	594	523	388	217	89	8	8	59	290	554	755
OR	Redmond	RDM	946	835	760	640	414	214	42	60	214	540	801	1029
OR	Salem	SLE	712	616	554	443	269	121	14	14	86	336	583	755
PA	Allentown	ABE	1134	974	739	413	168	23	1	4	61	362	623	966
PA	Altoona	AOO	1176	1037	788	440	203	42	5	12	108	413	659	1028
PA	Bradford	BFD	1367	1213	991	621	350	138	58	75	229	574	797	1176
PA	Du Bois	DUJ	1276	1125	867	509	255	78	16	27	141	473	714	1103
PA	Erie	ERI	1167	1068	869	529	252	47	5	8	78	372	619	976
PA	Harrisburg	CXY	1049	918	670	355	133	15	0	2	44	318	573	908
PA	Philadelphia	PHL	986	848	613	308	94	7	0	1	15	238	490	822
PA	Pittsburgh	PIT	1141	997	731	386	165	27	2	5	76	381	631	981
PA	Williamsport	IPT	1165	1011	766	414	175	26	1	6	71	380	649	1001
RI	Providence	PVD	1104	946	781	453	218	44	2	3	57	331	585	916
SC	Charleston	CHS	504	393	205	72	7	0	0	0	1	62	226	412
SC	Columbia	CAE	606	478	269	103	12	0	0	0	3	101	321	543
SC	Florence	FLO	624	498	285	113	18	0	0	0	3	106	301	524
SC	Greenville	GSP	688	567	344	145	32	1	0	0	6	147	375	632
SD	Aberdeen	ABR	1624	1399	1024	572	285	57	7	28	192	573	993	1471
SD	Huron	HON	1494	1288	919	516	245	45	5	15	147	505	909	1378
SD	Pierre	PIR	1384	1215	887	513	267	51	3	9	129	495	893	1316
SD	Rapid City	RAP	1228	1116	840	559	332	88	6	16	154	509	863	1228
SD	Sioux Falls	FSD	1479	1265	900	502	239	35	4	15	141	488	872	1356
TN	Bristol	TRI	903	748	497	258	82	4	0	1	28	266	531	820
TN	Chattanooga	CHA	737	589	338	141	30	0	0	0	6	144	393	668
TN	Crossville	CSV	898	742	482	252	89	6	1	2	37	256	489	793
TN	Jackson	MKL	797	660	373	173	41	1	0	1	17	186	418	712
TN	Knoxville	TYS	808	654	397	182	46	1	0	0	11	191	444	738
TN	Memphis	MEM	700	566	296	111	18	0	0	0	3	115	329	623
TN	Nashville	BNA	813	665	392	175	45	2	0	0	12	175	422	718
TX	Abilene	ABI	584	469	230	79	20	0	0	0	3	87	279	570
TX	Alice	ALI	242	176	58	9	0	0	0	0	0	9	64	224
TX	Amarillo	AMA	820	717	457	242	81	2	0	1	25	218	501	821
TX	Austin	AUS	470	356	165	46	3	0	0	0	0	44	192	436
TX	Brownsville	BRO	144	109	28	7	0	0	0	0	0	1	28	145

Station Location		Code	Monthly Heating Degree Days											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TX	College Station	CLL	417	316	127	33	2	0	0	0	0	32	145	375
TX	Corpus Christi	CRP	252	177	58	11	0	0	0	0	0	9	66	226
TX	Dallas-Ft. Worth	DFW	550	438	195	53	9	0	0	0	0	53	213	506
TX	Del Rio	DRT	384	253	80	16	1	0	0	0	0	18	135	380
TX	El Paso	ELP	560	416	216	62	7	0	0	0	1	52	303	584
TX	Galveston	GLS	291	224	73	12	0	0	0	0	0	7	62	233
TX	Houston	IAH	362	271	106	23	0	0	0	0	0	23	129	332
TX	Laredo	LRD	216	146	31	6	0	0	0	0	0	5	47	199
TX	Lubbock	LBB	710	584	337	150	45	0	0	0	10	143	405	718
TX	Lufkin	LFK	474	368	165	49	4	0	0	0	0	53	202	433
TX	McAllen	MFE	160	117	22	10	0	0	0	0	0	3	31	149
TX	Midland Odessa	MAF	622	480	254	83	19	0	0	0	4	87	329	614
TX	San Angelo	SJT	548	422	196	67	10	0	0	0	1	72	259	524
TX	San Antonio	SAT	374	275	105	24	2	0	0	0	1	28	135	354
TX	Victoria	VCT	337	243	90	21	1	0	0	0	0	22	116	306
TX	Waco	ACT	521	404	184	55	6	0	0	0	0	54	211	485
TX	Wichita Falls	SPS	665	540	267	95	23	0	0	0	2	94	306	641
UT	Cedar City	CDC	1100	910	731	535	268	58	0	3	103	436	771	1110
UT	Salt Lake City	SLC	1092	857	641	432	218	45	0	3	58	350	718	1055
VA	Lynchburg	LYH	904	773	526	269	101	7	0	2	34	271	523	822
VA	Norfolk	ORF	737	632	440	201	55	1	0	0	3	129	349	605
VA	Richmond	RIC	821	694	463	213	60	2	0	0	10	181	409	704
VA	Roanoke	ROA	846	719	478	229	78	4	0	0	27	224	474	765
VT	Burlington	BTV	1427	1226	1002	581	263	61	5	23	133	495	768	1188
VT	Montpelier	MPV	1501	1280	1065	652	335	114	24	52	200	568	842	1269
WA	Bellingham	BLI	767	672	628	492	341	187	78	78	209	442	647	792
WA	Olympia	OLM	772	686	636	510	342	186	67	68	180	433	658	817
WA	Quillayute	UIL	702	639	651	549	430	282	179	160	237	441	619	742
WA	Seattle Tacoma	SEA	706	611	586	451	285	142	34	29	122	368	597	745
WA	Spokane	GEG	1094	904	769	556	320	141	17	23	147	511	879	1144
WA	Walla Walla	ALW	869	701	532	383	195	51	1	3	51	335	662	930
WA	Yakima	YKM	1029	785	662	476	242	84	8	15	124	456	817	1102
WI	Eau Claire	EAU	1546	1309	977	533	258	49	7	26	169	524	878	1386
WI	Green Bay	GRB	1452	1253	979	576	289	60	12	23	165	494	813	1274
WI	Lacrosse	LSE	1452	1226	870	457	197	27	2	11	117	442	790	1303
WI	Madison	MSN	1404	1202	887	510	240	36	6	17	140	462	784	1247
WI	Milwaukee	MKE	1288	1111	858	550	289	64	7	9	100	397	713	1135
WI	Wausau	AUW	1547	1312	1019	585	294	67	13	31	192	549	892	1369
WV	Beckley	BKW	1050	897	647	355	171	36	9	9	87	368	607	938
WV	Charleston	CRW	942	810	537	257	100	7	0	1	36	273	519	838
WV	Elkins	EKN	1130	996	750	455	225	62	17	11	122	436	693	1005
WV	Huntington	HTS	956	811	533	253	95	6	0	1	39	280	528	846
WV	Martinsburg	MRB	1020	884	642	341	138	15	0	1	48	323	569	906
WV	Morgantown	MGW	1040	904	633	337	138	19	3	2	52	333	558	890
WV	Parkersburg	PKB	1040	891	605	302	124	14	0	2	50	329	567	904
WY	Casper	CPR	1191	1088	864	644	408	129	12	28	208	574	880	1244
WY	Cheyenne	CYS	1084	1037	826	630	390	120	14	30	201	556	837	1163
WY	Cody	COD	1171	1048	793	600	382	139	14	36	196	551	869	1209

Station Location		Code	Monthly Heating Degree Days											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WY	Lander	LND	1301	1128	842	605	380	121	7	22	171	563	923	1328
WY	Rock Springs	RKS	1320	1173	941	691	444	159	8	35	219	598	980	1336
WY	Sheridan	SHR	1220	1081	843	612	404	138	11	30	197	555	908	1272
WY	Worland	WRL	1416	1161	795	529	321	85	5	16	167	553	934	1415

Table 7B.3.3 Weather Station Monthly Heating Degree Day Data Fractions (10-Year Average)

Station Location		Code	Monthly Heating Degree Day Fractions											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AK	Anchorage	ANC	15%	12%	12%	8%	5%	3%	2%	2%	5%	8%	13%	14%
AK	Bethel	BET	15%	12%	13%	9%	5%	3%	2%	3%	4%	8%	12%	13%
AK	Cold Bay	CDB	12%	10%	12%	10%	8%	6%	5%	4%	5%	8%	10%	11%
AK	Cordova	CDV	13%	11%	12%	9%	6%	4%	3%	4%	5%	8%	12%	12%
AK	Homer	HOM	14%	11%	12%	9%	6%	5%	3%	3%	5%	8%	12%	12%
AK	Juneau	JNU	14%	12%	12%	9%	6%	4%	3%	3%	5%	8%	12%	13%
AK	Kenai	ENA	15%	12%	12%	8%	5%	3%	2%	3%	5%	8%	12%	14%
AK	Ketchikan	KTN	13%	12%	12%	9%	7%	4%	3%	3%	5%	8%	11%	13%
AK	King Salmon	AKN	15%	11%	13%	8%	6%	4%	3%	3%	5%	8%	12%	13%
AK	Kodiak	ADQ	12%	11%	12%	9%	7%	5%	4%	3%	5%	8%	11%	12%
AK	Sitka	SIT	13%	11%	12%	9%	7%	5%	4%	3%	5%	8%	11%	12%
AK	St Paul Island	SNP	12%	10%	12%	10%	8%	6%	5%	4%	5%	7%	9%	10%
AK	Talkeetna	TKA	16%	12%	12%	8%	5%	2%	1%	2%	5%	9%	13%	15%
AK	Valdez	VWS	16%	12%	13%	8%	5%	3%	2%	2%	4%	8%	13%	14%
AK	Yakutat	YAK	13%	11%	12%	9%	7%	5%	3%	4%	5%	8%	11%	12%
AL	Birmingham	BHM	25%	20%	10%	4%	1%	0%	0%	0%	0%	5%	12%	22%
AL	Huntsville	HSV	24%	20%	11%	5%	1%	0%	0%	0%	0%	5%	13%	22%
AL	Mobile	MOB	27%	21%	9%	3%	0%	0%	0%	0%	0%	3%	13%	24%
AL	Montgomery	MGM	26%	20%	10%	3%	0%	0%	0%	0%	0%	4%	13%	23%
AL	Muscle Shoals	MSL	24%	20%	11%	5%	1%	0%	0%	0%	0%	5%	12%	22%
AL	Tuscaloosa	TCL	25%	20%	10%	4%	1%	0%	0%	0%	0%	5%	13%	23%
AR	Fayetteville	FYV	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	21%
AR	Fort Smith	FSM	25%	20%	11%	4%	1%	0%	0%	0%	0%	4%	12%	23%
AR	Little Rock	LIT	25%	20%	11%	4%	1%	0%	0%	0%	0%	4%	12%	23%
AR	Texarkana	TXK	26%	21%	10%	4%	1%	0%	0%	0%	0%	4%	12%	24%
AZ	Douglas	DUG	24%	18%	13%	5%	1%	0%	0%	0%	0%	3%	13%	24%
AZ	Flagstaff	FLG	16%	14%	12%	10%	6%	2%	0%	1%	3%	8%	12%	16%
AZ	Phoenix	PHX	28%	21%	8%	1%	0%	0%	0%	0%	0%	1%	8%	34%
AZ	Tucson	TUS	25%	21%	11%	3%	0%	0%	0%	0%	0%	1%	10%	28%
AZ	Winslow	INW	21%	16%	12%	7%	2%	0%	0%	0%	0%	6%	13%	21%
AZ	Yuma	NYL	24%	21%	7%	2%	0%	0%	0%	0%	0%	0%	9%	37%
CA	Bakersfield	BFL	24%	16%	11%	7%	1%	0%	0%	0%	0%	3%	14%	25%
CA	Blythe	BLH	27%	19%	7%	1%	0%	0%	0%	0%	0%	1%	11%	34%
CA	Eureka	EKA	11%	10%	10%	10%	8%	6%	5%	5%	6%	7%	9%	11%
CA	Fresno	FAT	24%	17%	11%	7%	1%	0%	0%	0%	0%	2%	13%	24%
CA	Los Angeles	LAX	17%	17%	16%	12%	5%	1%	0%	0%	0%	3%	10%	20%
CA	Mt Shasta	MHS	16%	14%	13%	10%	6%	2%	0%	0%	2%	7%	13%	16%
CA	Paso Robles	PRB	19%	16%	13%	10%	3%	1%	0%	0%	1%	5%	13%	20%

Station Location		Code	Monthly Heating Degree Day Fractions											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CA	Red Bluff	RBL	21%	16%	13%	9%	2%	0%	0%	0%	0%	3%	14%	22%
CA	Redding	RDD	20%	16%	13%	9%	2%	0%	0%	0%	0%	4%	14%	22%
CA	Sacramento	SAC	22%	16%	12%	8%	2%	0%	0%	0%	0%	3%	14%	22%
CA	San Diego	SAN	19%	18%	14%	10%	4%	1%	0%	0%	0%	1%	10%	22%
CA	San Francisco	SFO	17%	13%	12%	10%	7%	4%	2%	2%	2%	4%	10%	16%
CA	Stockton	SCK	23%	16%	12%	8%	2%	0%	0%	0%	0%	3%	13%	22%
CO	Alamosa	ALS	17%	15%	11%	8%	5%	2%	0%	1%	3%	8%	12%	18%
CO	Colorado Spring	COS	17%	16%	12%	9%	4%	1%	0%	0%	2%	7%	12%	18%
CO	Denver	DEN	18%	16%	12%	8%	4%	1%	0%	0%	2%	7%	13%	19%
CO	Eagle	EGE	18%	15%	12%	8%	5%	2%	0%	0%	3%	8%	12%	18%
CO	Pueblo	PUB	19%	17%	12%	7%	3%	0%	0%	0%	1%	7%	13%	20%
CO	Trinidad	TAD	19%	17%	12%	8%	3%	1%	0%	0%	2%	7%	13%	19%
CT	Bridgeport	BDR	21%	18%	15%	8%	4%	1%	0%	0%	1%	5%	11%	17%
CT	Hartford	BDL	21%	17%	14%	8%	3%	1%	0%	0%	1%	6%	11%	17%
DC	Washington	DCA	23%	19%	13%	6%	2%	0%	0%	0%	0%	5%	11%	20%
DE	Wilmington	ILG	21%	19%	14%	7%	3%	0%	0%	0%	1%	6%	11%	18%
FL	Daytona Beach	DAB	32%	23%	10%	3%	0%	0%	0%	0%	0%	2%	8%	23%
FL	Fort Myers	FMY	39%	21%	8%	1%	0%	0%	0%	0%	0%	1%	5%	25%
FL	Ft Lauderdale	FLL	41%	23%	7%	1%	0%	0%	0%	0%	0%	0%	3%	25%
FL	Gainesville	GNV	29%	21%	10%	3%	0%	0%	0%	0%	0%	2%	10%	24%
FL	Jacksonville	JAX	28%	21%	10%	4%	0%	0%	0%	0%	0%	2%	11%	23%
FL	Key West	EYW	49%	22%	6%	0%	0%	0%	4%	0%	0%	0%	1%	18%
FL	Melbourne	MLB	35%	22%	9%	3%	0%	0%	0%	0%	0%	2%	7%	22%
FL	Miami	MIA	43%	23%	7%	0%	0%	0%	0%	0%	0%	0%	3%	25%
FL	Orlando	MCO	35%	22%	9%	2%	0%	0%	0%	0%	0%	2%	7%	24%
FL	Pensacola	PNS	28%	22%	9%	3%	0%	0%	0%	0%	0%	3%	11%	24%
FL	Tallahassee	TLH	27%	21%	10%	3%	0%	0%	0%	0%	0%	3%	12%	24%
FL	Tampa	TPA	35%	22%	9%	2%	0%	0%	0%	0%	0%	1%	6%	25%
FL	Vero Beach	VRB	35%	23%	10%	3%	0%	0%	0%	0%	0%	1%	6%	22%
FL	West Palm Beach	PBI	39%	22%	8%	2%	0%	0%	0%	0%	0%	1%	5%	23%
GA	Albany	ABY	27%	21%	10%	3%	0%	0%	0%	0%	0%	3%	12%	24%
GA	Athens	AHN	24%	19%	11%	5%	1%	0%	0%	0%	0%	5%	13%	22%
GA	Atlanta	ATL	25%	20%	11%	5%	1%	0%	0%	0%	0%	4%	12%	22%
GA	Augusta	AGS	25%	20%	11%	4%	0%	0%	0%	0%	0%	4%	13%	22%
GA	Brunswick	SSI	28%	22%	10%	4%	0%	0%	0%	0%	0%	2%	10%	23%
GA	Columbus	CSG	27%	21%	10%	3%	0%	0%	0%	0%	0%	3%	12%	23%
GA	Macon	MCN	25%	20%	11%	4%	0%	0%	0%	0%	0%	4%	13%	23%
GA	Savannah	SAV	27%	21%	11%	4%	0%	0%	0%	0%	0%	3%	12%	22%
GA	Waycross	AYS	27%	21%	9%	3%	0%	1%	0%	0%	0%	3%	12%	24%
HI	Hilo-Hawaii	ITO	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
HI	Honolulu-Oahu	HNL	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
HI	Kahului-Maui	OGG	0%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%
HI	Lihue-Kauai	LIH	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
IA	Burlington	BRL	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	11%	20%
IA	Cedar Rapids	CID	21%	18%	12%	7%	3%	0%	0%	0%	2%	7%	11%	19%
IA	Des Moines	DSM	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
IA	Dubuque	DBQ	21%	18%	12%	7%	3%	0%	0%	0%	2%	7%	11%	19%
IA	Mason City	MCW	20%	17%	12%	7%	3%	0%	0%	0%	2%	7%	12%	18%

Station Location		Code	Monthly Heating Degree Day Fractions											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IA	Ottumwa	OTM	22%	18%	12%	6%	3%	0%	0%	0%	2%	7%	12%	19%
IA	Sioux City	SUX	21%	18%	12%	6%	3%	0%	0%	0%	2%	7%	12%	19%
IA	Waterloo	ALO	21%	18%	12%	7%	3%	0%	0%	0%	2%	7%	12%	19%
ID	Boise	BOI	19%	15%	12%	8%	4%	1%	0%	0%	1%	7%	14%	19%
ID	Burley	BYI	17%	15%	12%	9%	5%	2%	0%	0%	3%	8%	13%	17%
ID	Idaho Falls	IDA	18%	15%	12%	8%	5%	2%	0%	0%	3%	8%	12%	17%
ID	Lewiston	LWS	18%	15%	12%	8%	4%	1%	0%	0%	1%	8%	14%	19%
ID	Pocatello	PIH	18%	15%	12%	8%	5%	2%	0%	0%	3%	8%	13%	17%
IL	Chicago	ORD	21%	18%	13%	7%	3%	0%	0%	0%	1%	6%	11%	18%
IL	Moline	MLI	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	11%	19%
IL	Peoria	PIA	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
IL	Quincy	UIN	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
IL	Rockford	RFD	21%	18%	13%	7%	3%	0%	0%	0%	2%	6%	11%	19%
IL	Springfield	SPI	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	11%	20%
IN	Evansville	EVV	23%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
IN	Fort Wayne	FWA	21%	18%	13%	7%	3%	0%	0%	0%	1%	7%	11%	18%
IN	Indianapolis	IND	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	19%
IN	South Bend	SBN	21%	18%	13%	7%	3%	0%	0%	0%	2%	7%	11%	18%
IN	West Lafayette	LAF	22%	19%	12%	6%	3%	0%	0%	0%	1%	6%	11%	19%
KS	Concordia	CNK	22%	18%	11%	6%	2%	0%	0%	0%	1%	6%	12%	21%
KS	Dodge City	DDC	21%	18%	12%	7%	2%	0%	0%	0%	1%	6%	13%	21%
KS	Garden City	GCK	21%	18%	12%	7%	2%	0%	0%	0%	1%	6%	13%	21%
KS	Goodland	GLD	19%	17%	12%	8%	3%	0%	0%	0%	2%	7%	13%	19%
KS	Russell	RSL	21%	18%	12%	6%	2%	0%	0%	0%	1%	6%	13%	21%
KS	Salina	SLN	22%	19%	11%	6%	2%	0%	0%	0%	1%	5%	12%	21%
KS	Topeka	TOP	23%	19%	11%	6%	2%	0%	0%	0%	1%	6%	12%	20%
KS	Wichita	ICT	23%	19%	11%	6%	2%	0%	0%	0%	1%	5%	12%	22%
KY	Bowling Green	BWG	23%	19%	11%	6%	2%	0%	0%	0%	1%	6%	12%	20%
KY	Jackson	JKL	23%	19%	12%	6%	2%	0%	0%	0%	1%	6%	11%	20%
KY	Lexington	LEX	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	19%
KY	Louisville	SDF	24%	20%	12%	5%	1%	0%	0%	0%	0%	5%	12%	20%
KY	Paducah	PAH	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
LA	Baton Rouge	BTR	27%	21%	9%	3%	0%	0%	0%	0%	0%	3%	12%	25%
LA	Lafayette	LFT	28%	21%	9%	2%	0%	0%	0%	0%	0%	3%	11%	26%
LA	Lake Charles	LCH	28%	22%	9%	2%	0%	0%	0%	0%	0%	2%	11%	25%
LA	Monroe	MLU	26%	21%	10%	3%	0%	0%	0%	0%	0%	4%	12%	24%
LA	New Orleans	MSY	29%	22%	8%	2%	0%	0%	0%	0%	0%	2%	10%	26%
LA	Shreveport	SHV	26%	21%	10%	3%	0%	0%	0%	0%	0%	3%	12%	25%
MA	Boston	BOS	20%	17%	15%	9%	4%	1%	0%	0%	1%	6%	11%	17%
MA	Worcester	ORH	20%	17%	14%	8%	4%	1%	0%	0%	2%	7%	11%	16%
MD	Baltimore	BWI	22%	19%	13%	7%	2%	0%	0%	0%	1%	6%	11%	19%
MD	Salisbury	SBY	21%	19%	14%	8%	3%	0%	0%	0%	1%	6%	11%	18%
ME	Augusta	AUG	20%	16%	14%	8%	4%	1%	0%	0%	2%	7%	11%	16%
ME	Bangor	BGR	19%	16%	14%	8%	4%	1%	0%	0%	2%	7%	11%	16%
ME	Caribou	CAR	19%	16%	14%	8%	5%	2%	0%	1%	3%	7%	10%	16%
ME	Houlton	HUL	18%	16%	13%	9%	5%	2%	1%	1%	3%	7%	10%	15%
ME	Portland	PWM	19%	16%	14%	9%	5%	1%	0%	0%	2%	7%	11%	16%
MI	Alpena	APN	18%	16%	14%	9%	5%	2%	0%	1%	3%	7%	11%	16%

Station Location		Code	Monthly Heating Degree Day Fractions											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MI	Detroit	DTW	21%	18%	14%	7%	3%	0%	0%	0%	1%	6%	11%	18%
MI	Flint	FNT	20%	17%	13%	8%	4%	1%	0%	0%	2%	7%	11%	17%
MI	Grand Rapids	GRR	20%	18%	13%	8%	4%	1%	0%	0%	2%	7%	11%	17%
MI	Houghton Lake	HTL	18%	16%	13%	8%	4%	1%	0%	1%	3%	7%	11%	16%
MI	Jackson	JXN	20%	17%	13%	7%	4%	1%	0%	0%	2%	7%	11%	17%
MI	Lansing	LAN	20%	17%	13%	8%	4%	1%	0%	0%	2%	7%	11%	17%
MI	Marquette	MQT	17%	15%	13%	9%	5%	2%	1%	1%	3%	7%	11%	16%
MI	Muskegon	MKG	19%	17%	14%	8%	4%	1%	0%	0%	2%	7%	11%	16%
MI	Saginaw	MBS	20%	17%	14%	8%	4%	1%	0%	0%	2%	7%	11%	17%
MI	Sault St Marie	SSM	18%	16%	14%	9%	5%	2%	1%	1%	3%	7%	10%	16%
MI	Traverse City	TVC	18%	17%	14%	9%	5%	1%	0%	0%	2%	7%	11%	16%
MN	Alexandria	AXN	20%	17%	13%	7%	4%	1%	0%	0%	2%	7%	12%	18%
MN	Duluth	DLH	19%	16%	13%	8%	5%	2%	0%	1%	3%	7%	11%	17%
MN	Hibbing	HIB	18%	15%	12%	8%	5%	2%	1%	1%	3%	7%	11%	16%
MN	Int'l Falls	INL	19%	16%	12%	7%	4%	2%	1%	1%	3%	7%	11%	17%
MN	Minneapolis	MSP	21%	18%	13%	6%	3%	0%	0%	0%	2%	6%	12%	19%
MN	Rochester	RST	21%	18%	13%	7%	3%	1%	0%	0%	2%	7%	11%	18%
MN	Saint Cloud	STC	20%	17%	13%	7%	4%	1%	0%	0%	2%	7%	12%	18%
MO	Columbia	COU	23%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
MO	Joplin	JLN	23%	19%	11%	6%	2%	0%	0%	0%	1%	6%	11%	21%
MO	Kansas City	MCI	23%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
MO	Saint Louis	STL	23%	20%	12%	5%	2%	0%	0%	0%	1%	5%	12%	21%
MO	Springfield	SGF	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
MS	Greenwood	GWO	25%	20%	10%	4%	1%	0%	0%	0%	0%	5%	11%	23%
MS	McComb	MCB	26%	21%	9%	3%	0%	0%	0%	0%	0%	4%	12%	24%
MS	Tupelo	TUP	25%	20%	11%	4%	1%	0%	0%	0%	0%	5%	12%	22%
MT	Billings	BIL	18%	15%	12%	8%	5%	1%	0%	0%	2%	8%	13%	18%
MT	Butte	BTM	15%	13%	11%	9%	6%	3%	1%	1%	4%	8%	12%	16%
MT	Cut Bank	CTB	16%	14%	12%	9%	6%	3%	1%	1%	4%	8%	12%	16%
MT	Great Falls	GTF	16%	14%	12%	9%	6%	3%	0%	1%	3%	8%	12%	16%
MT	Havre	HVR	18%	16%	12%	7%	5%	2%	0%	1%	3%	8%	12%	17%
MT	Helena	HLN	17%	14%	12%	8%	5%	2%	0%	0%	3%	8%	13%	18%
MT	Kalispell	FCA	17%	14%	12%	8%	4%	2%	0%	1%	3%	8%	13%	17%
MT	Lewistown	LWT	16%	14%	12%	9%	6%	3%	1%	1%	3%	8%	12%	16%
MT	Miles City	MLS	19%	16%	12%	7%	4%	1%	0%	0%	2%	7%	13%	18%
MT	Missoula	MSO	17%	14%	11%	8%	5%	2%	0%	0%	3%	8%	13%	17%
NC	Asheville	AVL	21%	18%	12%	7%	2%	0%	0%	0%	1%	7%	13%	19%
NC	Cape Hatteras	HAT	27%	24%	16%	6%	1%	0%	0%	0%	0%	1%	6%	18%
NC	Charlotte	CLT	23%	19%	12%	5%	1%	0%	0%	0%	0%	5%	13%	21%
NC	Greensboro	GSO	23%	19%	12%	6%	2%	0%	0%	0%	0%	5%	13%	20%
NC	Hickory	HKY	23%	19%	12%	6%	2%	0%	0%	0%	0%	6%	12%	21%
NC	New Bern	EWN	24%	20%	13%	5%	1%	0%	0%	0%	0%	4%	12%	20%
NC	Raleigh Durham	RDU	23%	19%	12%	5%	1%	0%	0%	0%	0%	5%	12%	21%
NC	Wilmington	ILM	24%	20%	13%	5%	1%	0%	0%	0%	0%	4%	12%	21%
ND	Bismarck	BIS	19%	17%	13%	7%	4%	1%	0%	0%	2%	7%	12%	18%
ND	Devil's Lake	P11	19%	17%	13%	7%	4%	1%	0%	0%	2%	7%	12%	17%
ND	Fargo	FAR	20%	18%	13%	7%	3%	1%	0%	0%	2%	7%	12%	18%
ND	Grand Forks	GFK	19%	17%	13%	7%	4%	1%	0%	0%	2%	7%	12%	17%

Station Location		Code	Monthly Heating Degree Day Fractions											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ND	Minot	MOT	19%	17%	13%	7%	4%	1%	0%	0%	2%	7%	12%	17%
ND	Williston	ISN	18%	16%	12%	7%	4%	1%	0%	0%	3%	7%	12%	18%
NE	Grand Island	GRI	21%	18%	12%	7%	3%	0%	0%	0%	1%	7%	12%	20%
NE	Lincoln	LNK	21%	18%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
NE	Norfolk	OFK	21%	17%	12%	7%	3%	0%	0%	0%	2%	7%	12%	19%
NE	North Platte	LBF	19%	16%	12%	8%	4%	1%	0%	0%	2%	7%	13%	19%
NE	Omaha	OMA	22%	18%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
NE	Scottsbluff	BFF	18%	16%	12%	8%	4%	1%	0%	0%	2%	8%	13%	19%
NE	Valentine	VTN	19%	17%	12%	8%	4%	1%	0%	0%	2%	7%	13%	18%
NH	Concord	CON	20%	16%	14%	8%	4%	1%	0%	0%	2%	7%	11%	16%
NH	Lebanon	LEB	20%	17%	14%	8%	4%	1%	0%	0%	2%	7%	11%	16%
NJ	Atlantic City	ACY	21%	18%	14%	8%	3%	0%	0%	0%	1%	6%	11%	18%
NJ	Newark	EWR	22%	19%	14%	7%	2%	0%	0%	0%	0%	5%	11%	18%
NM	Albuquerque	ABQ	21%	17%	12%	6%	2%	0%	0%	0%	0%	5%	14%	22%
NM	Carlsbad	CNM	24%	19%	10%	3%	1%	0%	0%	0%	0%	4%	14%	25%
NM	Clayton	CAO	19%	18%	13%	8%	3%	0%	0%	0%	1%	6%	13%	20%
NM	Gallup	GUP	18%	15%	13%	9%	5%	1%	0%	0%	2%	8%	13%	18%
NM	Roswell	ROW	23%	18%	10%	4%	1%	0%	0%	0%	0%	4%	14%	25%
NV	Elko	EKO	18%	15%	12%	9%	5%	2%	0%	0%	2%	8%	13%	17%
NV	Ely	ELY	17%	14%	12%	9%	6%	2%	0%	0%	3%	8%	12%	17%
NV	Las Vegas	LAS	26%	19%	9%	3%	0%	0%	0%	0%	0%	2%	12%	29%
NV	Lovelock	LOL	19%	15%	12%	8%	3%	1%	0%	0%	1%	7%	14%	20%
NV	Reno	RNO	19%	15%	12%	9%	4%	1%	0%	0%	1%	6%	13%	19%
NV	Tonopah	TPH	18%	15%	13%	9%	4%	1%	0%	0%	1%	7%	13%	19%
NV	Winnemucca	WMC	17%	14%	12%	9%	5%	2%	0%	0%	2%	8%	13%	18%
NY	Albany	ALB	20%	17%	14%	8%	3%	1%	0%	0%	2%	7%	11%	17%
NY	Binghamton	BGM	19%	17%	14%	8%	4%	1%	0%	0%	2%	7%	11%	16%
NY	Buffalo	BUF	19%	18%	14%	9%	4%	1%	0%	0%	1%	7%	11%	16%
NY	Glens Falls	GFL	20%	17%	14%	8%	4%	1%	0%	0%	2%	7%	11%	16%
NY	Massena	MSS	20%	17%	14%	8%	4%	1%	0%	0%	2%	7%	11%	16%
NY	New York	LGA	22%	19%	15%	8%	3%	0%	0%	0%	0%	5%	10%	18%
NY	Rochester	ROC	19%	17%	14%	8%	4%	1%	0%	0%	2%	7%	11%	16%
NY	Syracuse	SYR	20%	18%	14%	8%	4%	1%	0%	0%	2%	7%	11%	17%
NY	Utica	UCA	22%	18%	14%	7%	3%	1%	0%	0%	1%	6%	11%	18%
NY	Watertown	ART	20%	17%	14%	8%	4%	1%	0%	0%	2%	7%	10%	16%
OH	Akron Canton	CAK	20%	18%	13%	7%	3%	1%	0%	0%	2%	7%	11%	17%
OH	Cincinnati	CVG	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	19%
OH	Cleveland	CLE	20%	18%	14%	8%	3%	1%	0%	0%	1%	6%	11%	17%
OH	Columbus	CMH	22%	19%	13%	6%	2%	0%	0%	0%	1%	6%	11%	19%
OH	Dayton	DAY	21%	18%	13%	7%	3%	0%	0%	0%	1%	7%	11%	18%
OH	Findlay	FDY	21%	18%	13%	7%	3%	0%	0%	0%	1%	6%	11%	18%
OH	Mansfield	MFD	20%	18%	13%	7%	3%	1%	0%	0%	2%	7%	11%	17%
OH	Toledo	TOL	21%	18%	13%	7%	3%	0%	0%	0%	1%	6%	11%	18%
OH	Youngstown	YNG	20%	18%	13%	8%	4%	1%	0%	0%	2%	7%	11%	17%
OK	Hobart	HBR	23%	19%	11%	5%	1%	0%	0%	0%	0%	5%	12%	23%
OK	McAlester	MLC	25%	20%	10%	5%	1%	0%	0%	0%	0%	5%	11%	23%
OK	Oklahoma City	OKC	24%	20%	11%	5%	1%	0%	0%	0%	0%	4%	12%	23%
OK	Tulsa	TUL	24%	20%	11%	5%	1%	0%	0%	0%	0%	5%	12%	23%

Station Location		Code	Monthly Heating Degree Day Fractions											
State	**City**		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
OR	Astoria	AST	13%	12%	12%	10%	7%	5%	3%	2%	4%	7%	11%	14%
OR	Baker	BKE	16%	13%	11%	9%	6%	3%	1%	1%	3%	8%	13%	16%
OR	Eugene	EUG	15%	13%	12%	10%	7%	3%	0%	0%	2%	8%	13%	16%
OR	Medford	MFR	18%	14%	12%	9%	4%	1%	0%	0%	1%	7%	14%	19%
OR	Pendleton	PDT	17%	14%	12%	9%	5%	2%	0%	0%	2%	8%	14%	19%
OR	Portland	PDX	17%	14%	12%	9%	5%	2%	0%	0%	1%	7%	13%	18%
OR	Redmond	RDM	15%	13%	12%	10%	6%	3%	1%	1%	3%	8%	12%	16%
OR	Salem	SLE	16%	14%	12%	10%	6%	3%	0%	0%	2%	7%	13%	17%
PA	Allentown	ABE	21%	18%	14%	8%	3%	0%	0%	0%	1%	7%	11%	18%
PA	Altoona	AOO	20%	18%	13%	7%	3%	1%	0%	0%	2%	7%	11%	17%
PA	Bradford	BFD	18%	16%	13%	8%	5%	2%	1%	1%	3%	8%	11%	15%
PA	Du Bois	DUJ	19%	17%	13%	8%	4%	1%	0%	0%	2%	7%	11%	17%
PA	Erie	ERI	19%	18%	15%	9%	4%	1%	0%	0%	1%	6%	10%	16%
PA	Harrisburg	CXY	21%	18%	13%	7%	3%	0%	0%	0%	1%	6%	11%	18%
PA	Philadelphia	PHL	22%	19%	14%	7%	2%	0%	0%	0%	0%	5%	11%	19%
PA	Pittsburgh	PIT	21%	18%	13%	7%	3%	0%	0%	0%	1%	7%	11%	18%
PA	Williamsport	IPT	21%	18%	14%	7%	3%	0%	0%	0%	1%	7%	11%	18%
RI	Providence	PVD	20%	17%	14%	8%	4%	1%	0%	0%	1%	6%	11%	17%
SC	Charleston	CHS	27%	21%	11%	4%	0%	0%	0%	0%	0%	3%	12%	22%
SC	Columbia	CAE	25%	20%	11%	4%	1%	0%	0%	0%	0%	4%	13%	22%
SC	Florence	FLO	25%	20%	12%	5%	1%	0%	0%	0%	0%	4%	12%	21%
SC	Greenville	GSP	23%	19%	12%	5%	1%	0%	0%	0%	0%	5%	13%	22%
SD	Aberdeen	ABR	20%	17%	12%	7%	3%	1%	0%	0%	2%	7%	12%	18%
SD	Huron	HON	20%	17%	12%	7%	3%	1%	0%	0%	2%	7%	12%	18%
SD	Pierre	PIR	19%	17%	12%	7%	4%	1%	0%	0%	2%	7%	12%	18%
SD	Rapid City	RAP	18%	16%	12%	8%	5%	1%	0%	0%	2%	7%	12%	18%
SD	Sioux Falls	FSD	20%	17%	12%	7%	3%	0%	0%	0%	2%	7%	12%	19%
TN	Bristol	TRI	22%	18%	12%	6%	2%	0%	0%	0%	1%	6%	13%	20%
TN	Chattanooga	CHA	24%	19%	11%	5%	1%	0%	0%	0%	0%	5%	13%	22%
TN	Crossville	CSV	22%	18%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
TN	Jackson	MKL	24%	20%	11%	5%	1%	0%	0%	0%	0%	6%	12%	21%
TN	Knoxville	TYS	23%	19%	11%	5%	1%	0%	0%	0%	0%	6%	13%	21%
TN	Memphis	MEM	25%	21%	11%	4%	1%	0%	0%	0%	0%	4%	12%	23%
TN	Nashville	BNA	24%	19%	11%	5%	1%	0%	0%	0%	0%	5%	12%	21%
TX	Abilene	ABI	25%	20%	10%	3%	1%	0%	0%	0%	0%	4%	12%	25%
TX	Alice	ALI	31%	23%	7%	1%	0%	0%	0%	0%	0%	1%	8%	29%
TX	Amarillo	AMA	21%	18%	12%	6%	2%	0%	0%	0%	1%	6%	13%	21%
TX	Austin	AUS	27%	21%	10%	3%	0%	0%	0%	0%	0%	3%	11%	25%
TX	Brownsville	BRO	31%	24%	6%	2%	0%	0%	0%	0%	0%	0%	6%	31%
TX	College Station	CLL	29%	22%	9%	2%	0%	0%	0%	0%	0%	2%	10%	26%
TX	Corpus Christi	CRP	32%	22%	7%	1%	0%	0%	0%	0%	0%	1%	8%	28%
TX	Dallas-Ft. Worth	DFW	27%	22%	10%	3%	0%	0%	0%	0%	0%	3%	11%	25%
TX	Del Rio	DRT	30%	20%	6%	1%	0%	0%	0%	0%	0%	1%	11%	30%
TX	El Paso	ELP	25%	19%	10%	3%	0%	0%	0%	0%	0%	2%	14%	27%
TX	Galveston	GLS	32%	25%	8%	1%	0%	0%	0%	0%	0%	1%	7%	26%
TX	Houston	IAH	29%	22%	8%	2%	0%	0%	0%	0%	0%	2%	10%	27%
TX	Laredo	LRD	33%	22%	5%	1%	0%	0%	0%	0%	0%	1%	7%	31%
TX	Lubbock	LBB	23%	19%	11%	5%	1%	0%	0%	0%	0%	5%	13%	23%

Station Location		Code	Monthly Heating Degree Day Fractions											
State	City		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TX	Lufkin	LFK	27%	21%	9%	3%	0%	0%	0%	0%	0%	3%	12%	25%
TX	McAllen	MFE	33%	24%	5%	2%	0%	0%	0%	0%	0%	1%	6%	30%
TX	Midland Odessa	MAF	25%	19%	10%	3%	1%	0%	0%	0%	0%	3%	13%	25%
TX	San Angelo	SJT	26%	20%	9%	3%	0%	0%	0%	0%	0%	3%	12%	25%
TX	San Antonio	SAT	29%	21%	8%	2%	0%	0%	0%	0%	0%	2%	10%	27%
TX	Victoria	VCT	30%	21%	8%	2%	0%	0%	0%	0%	0%	2%	10%	27%
TX	Waco	ACT	27%	21%	10%	3%	0%	0%	0%	0%	0%	3%	11%	25%
TX	Wichita Falls	SPS	25%	21%	10%	4%	1%	0%	0%	0%	0%	4%	12%	24%
UT	Cedar City	CDC	18%	15%	12%	9%	4%	1%	0%	0%	2%	7%	13%	18%
UT	Salt Lake City	SLC	20%	16%	12%	8%	4%	1%	0%	0%	1%	6%	13%	19%
VA	Lynchburg	LYH	21%	18%	12%	6%	2%	0%	0%	0%	1%	6%	12%	19%
VA	Norfolk	ORF	23%	20%	14%	6%	2%	0%	0%	0%	0%	4%	11%	19%
VA	Richmond	RIC	23%	20%	13%	6%	2%	0%	0%	0%	0%	5%	11%	20%
VA	Roanoke	ROA	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	20%
VT	Burlington	BTV	20%	17%	14%	8%	4%	1%	0%	0%	2%	7%	11%	17%
VT	Montpelier	MPV	19%	16%	13%	8%	4%	1%	0%	1%	3%	7%	11%	16%
WA	Bellingham	BLI	14%	13%	12%	9%	6%	4%	1%	1%	4%	8%	12%	15%
WA	Olympia	OLM	14%	13%	12%	10%	6%	3%	1%	1%	3%	8%	12%	15%
WA	Quillayute	UIL	12%	11%	12%	10%	8%	5%	3%	3%	4%	8%	11%	13%
WA	Seattle Tacoma	SEA	15%	13%	13%	10%	6%	3%	1%	1%	3%	8%	13%	16%
WA	Spokane	GEG	17%	14%	12%	9%	5%	2%	0%	0%	2%	8%	14%	18%
WA	Walla Walla	ALW	18%	15%	11%	8%	4%	1%	0%	0%	1%	7%	14%	20%
WA	Yakima	YKM	18%	14%	11%	8%	4%	1%	0%	0%	2%	8%	14%	19%
WI	Eau Claire	EAU	20%	17%	13%	7%	3%	1%	0%	0%	2%	7%	11%	18%
WI	Green Bay	GRB	20%	17%	13%	8%	4%	1%	0%	0%	2%	7%	11%	17%
WI	Lacrosse	LSE	21%	18%	13%	7%	3%	0%	0%	0%	2%	6%	11%	19%
WI	Madison	MSN	20%	17%	13%	7%	3%	1%	0%	0%	2%	7%	11%	18%
WI	Milwaukee	MKE	20%	17%	13%	8%	4%	1%	0%	0%	2%	6%	11%	17%
WI	Wausau	AUW	20%	17%	13%	7%	4%	1%	0%	0%	2%	7%	11%	17%
WV	Beckley	BKW	20%	17%	12%	7%	3%	1%	0%	0%	2%	7%	12%	18%
WV	Charleston	CRW	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	19%
WV	Elkins	EKN	19%	17%	13%	8%	4%	1%	0%	0%	2%	7%	12%	17%
WV	Huntington	HTS	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	12%	19%
WV	Martinsburg	MRB	21%	18%	13%	7%	3%	0%	0%	0%	1%	7%	12%	19%
WV	Morgantown	MGW	21%	18%	13%	7%	3%	0%	0%	0%	1%	7%	11%	18%
WV	Parkersburg	PKB	22%	18%	13%	6%	3%	0%	0%	0%	1%	7%	12%	19%
WY	Casper	CPR	16%	15%	12%	9%	6%	2%	0%	0%	3%	8%	12%	17%
WY	Cheyenne	CYS	16%	15%	12%	9%	6%	2%	0%	0%	3%	8%	12%	17%
WY	Cody	COD	17%	15%	11%	9%	5%	2%	0%	1%	3%	8%	12%	17%
WY	Lander	LND	18%	15%	11%	8%	5%	2%	0%	0%	2%	8%	12%	18%
WY	Rock Springs	RKS	17%	15%	12%	9%	6%	2%	0%	0%	3%	8%	12%	17%
WY	Sheridan	SHR	17%	15%	12%	8%	6%	2%	0%	0%	3%	8%	12%	17%
WY	Worland	WRL	19%	16%	11%	7%	4%	1%	0%	0%	2%	7%	13%	19%

REFERENCES

1. U.S. Department of Energy: Energy Information Administration, *Residential Energy Consumption Survey (RECS): 2009 RECS Survey Data,* 2009. (Last accessed January 7, 2015.) <www.eia.gov/consumption/residential/data/2009/>

2. National Oceanic And Atmospheric Administration, *Degree Days Archives,* 1997-Present. <ftp://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/>

APPENDIX 8A. USER INSTRUCTIONS FOR THE LIFE-CYCLE COST ANALYSIS SPREADSHEET FOR HEARTH PRODUCTS

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APPENDIX 8A. USER INSTRUCTIONS FOR THE LIFE-CYCLE COST ANALYSIS SPREADSHEET FOR HEARTH PRODUCTS

8A.1 USER INSTRUCTIONS

The results obtained in this analysis can be examined and reproduced using the Microsoft Excel spreadsheets available on the Department of Energy's (DOE's) hearth product rulemaking website: www1.eere.energy.gov/buildings/appliance_standards/product.aspx?productid=83. From that page, follow the links to the notice of data availability rulemaking phase and then to Analytical Tools.

8A.2 STARTUP

DOE's spreadsheets enables users to perform life-cycle cost (LCC) and payback period (PBP) analyses for each product class. A spreadsheet labeled LCC exists for the hearth which contains the data inputs and calculations for the LCC analysis.

To examine the spreadsheet, DOE assumes that the user has access to a personal computer with a hardware configuration capable of running Windows XP or later. The LCC spreadsheet requires Microsoft Excel 2003 or later installed under the Windows operating system. Because certain variables inside the spreadsheets are defined as distributions, a copy of Crystal Ball[a] (a commercially available add-on program) is required to view them.

8A.3 DESCRIPTION OF THE LIFE-CYCLE COST WORKSHEET

For the hearth products analysis, DOE created a single LCC spreadsheet containing a collection of worksheets. Each worksheet represents a conceptual component within the LCC calculation. To facilitate navigability and identify how worksheets are related, each worksheet contains an area on the extreme left showing variables imported to and exported from the current worksheet. The LCC spreadsheet contains the following worksheets:

Introduction The *Introduction* worksheet contains an overview of each worksheet and a flow chart of the inputs and outputs of the spreadsheet,

Statistics The *Statistics* worksheet contains the statistics of key parameters from the outcome of the Monte Carlo simulations for the sample of households

Summary The *Summary* worksheet contains a user interface to manipulate energy price trends and start year inputs, and to run the Crystal Ball simulation. LCC and PBP simulation results for each efficiency level are also displayed here.

[a] See www.oracle.com/us/products/applications/crystalball/overview/index.html

LCC&PB Calcs*	The *LCC&PB Calcs* worksheet shows LCC calculation results for different efficiency levels for a single Residential Energy Consumption Survey (RECS) 2009 household.[1] During a Crystal Ball simulation, the spreadsheet records the LCC and PBP values for every sampled household.
Rebuttable Payback	The manufacturer costs, retail prices, installation costs, repair and maintenance costs, energy use calculations, and the simple PBP calculations for each efficiency level. DOE's direct heating equipment test procedure is used to calculate parameters *Rebuttable Payback* worksheet contains the total and incremental used in energy use calculations.
Equip Price*	The *Equip Price* worksheet calculates retail price values used as inputs in the LCC calculations in the *Summary* worksheet.
Markups*	The *Markups* worksheet calculates markup values used as inputs in the *Equip Price* worksheet. DOE applied baseline and incremental markups to calculate final retail prices. DOE calculated the markups differently for replacement units and new units.
Installation Cost*	The *Installation Cost* worksheet provides the weighted average installation cost for each design option. These results are used to calculate the total installed prices of the design options.
Maintenance and Repair Cost*	The *Maintenance and Repair Cost* worksheet provides the maintenance and repair costs for each design option. These results are used to determine operating costs for the design options.
Labor Costs*	The *Labor Cost* worksheet provides the labor cost by region as used to determine the installation and repair/maintenance costs.
Base Case EL	The *Base Case Efficiency Level* worksheet provides the fraction of hearth product types that have an intermittent pilot ignition under the base case.
Building Sample*	The *Building Sample* worksheet contains the RECS 2009 household data for each product class. During a Crystal Ball simulation, DOE uses these household characteristics to determine the analysis parameters.
Energy Use*	The *Energy Use* worksheet calculates annual energy use by fuel type. The annual energy use calculations for each design option are inputs to the *LCC&PB Calcs* worksheet to calculate the annual operating cost of the LCC.
Energy Use (Calcs)*	The *Energy Use (Calcs)* worksheet displays intermediate energy use calculations. The intermediate energy use calculations for each design option are inputs to the *Energy Use* worksheet to calculate the annual energy use by fuel type, depending on product class.
Energy Price*	The *Energy Price* worksheet shows the estimated monthly natural gas, liquid petroleum gas (LPG), electricity, and oil prices.

Energy Price Trends* The *Energy Price Trends* worksheet shows the future price trends of the different fuels. DOE used energy price data and forecasts from the Energy Information Administration's (EIA's) Annual Energy Outlook 2014 for the period until 2040 and extrapolated beyond 2040.[2]

Discount Rate* The *Discount Rate* worksheet contains the distributions of discount rates for replacement and new units.

Lifetime* The *Lifetime* worksheet contains the distribution of lifetimes for equipment of that product class.

Energy Use Adjustment Factors* The *Energy Use Adjustment Factors* worksheet contains adjustment factors for normal heating degree days and cooling degree days, as well as building shell efficiency index.

Weather Data* The *Weather Data* worksheet contains heating degree days, cooling degree days, heating and cooling outdoor design temperature, and annual mean temperature by weather station.

* Results displayed in these worksheets are for only one household, not the entire population.

Figure 8A.3.1 depicts how these various inputs are used in order to generate the LCC and PBP outputs.

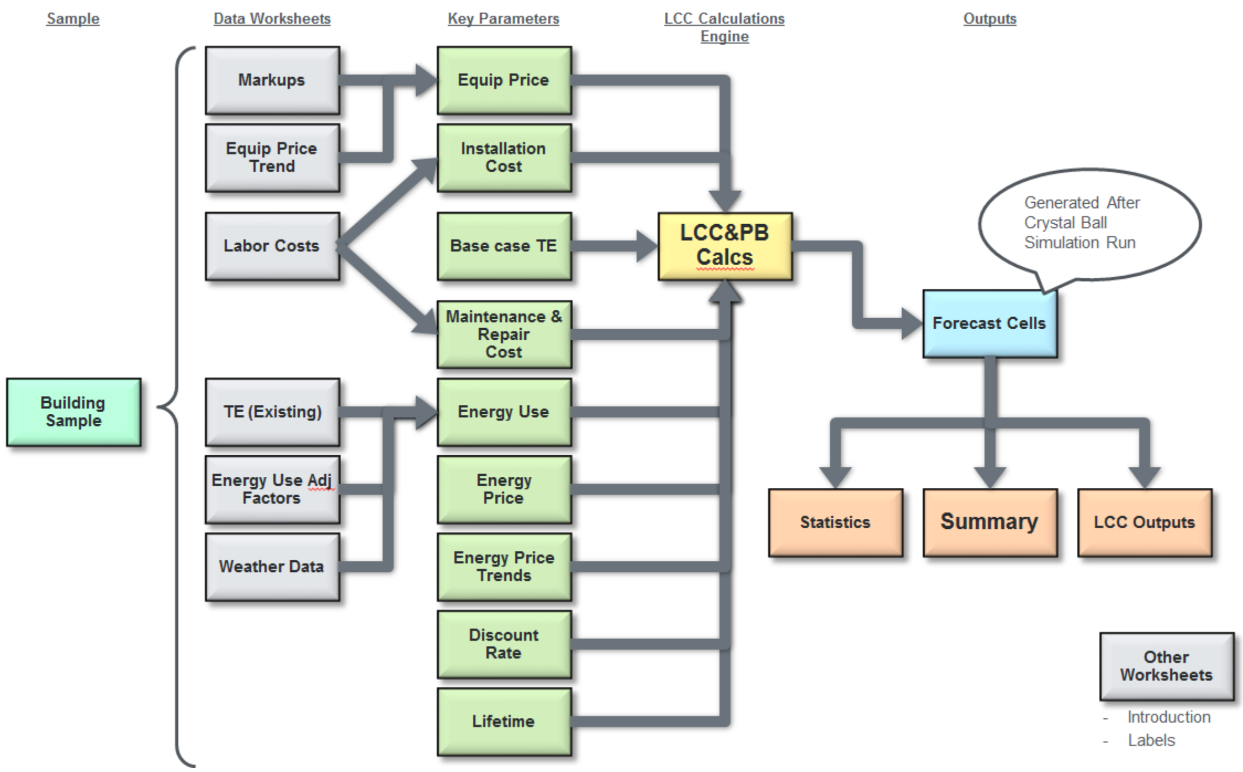

Figure 8A.3.1 LCC and Payback Calculation Process

8A.4 BASIC INSTRUCTIONS FOR OPERATING THE LIFE-CYCLE COST SPREADSHEET

Basic instructions for operating the LCC spreadsheet are as follows:

1. Once the LCC spreadsheet has been downloaded, open the file using Excel. Click “Enable Macro” when prompted and then click on the tab for the *Summary* worksheet.

2. Use Excel's View/Zoom commands at the top menu bar to change the size of the display to fit your monitor.

3. The user can change the parameters listed under USER OPTIONS on the *Summary* worksheet. There are three drop-down boxes and one command button. The default parameters are:

    a. Energy Price Trend: Defaults to “AEO 2014 - Reference Case.” To change the input, use the drop-down menu and select the desired trend (Reference, Low, or High).

    b. Start Year: Defaults to “2021.” To change the value, use the drop-down menu and select the desired year (2018, 2019, 2020, 2021, or 2022).

    c. # of Trials: Defaults to “10,000.” To change the value, use the drop-down menu and select the desired number of trials (1,000, 2,000, 3,000, 5,000, 10,000, or 20,000).

    d. Equipment Price Trend: Defaults to “Constant”, which is the only option in this analysis.

4. To run the Crystal Ball simulation, click the “run” button (you must re-run after changing any parameters). The spreadsheet will then be minimized. You can monitor the progress of the simulation by watching the count of iterations at the left bottom corner. When the simulation is finished, the worksheet named *Summary* will reappear with the results.

REFERENCES

1. U.S. Department of Energy: Energy Information Administration, *Residential Energy Consumption Survey (RECS): 2009 RECS Survey Data,* 2009. (Last accessed January 7, 2015.) <www.eia.gov/consumption/residential/data/2009/>

2. U.S. Department of Energy: Energy Information Administration, *Annual Energy Outlook 2014 with Projections to 2040*, 2014. Washington, DC. <http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf>

APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN THE LCC ANALYSIS

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APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN THE LCC ANALYSIS

8B.1 INTRODUCTION

Analysis of energy conservation standards involves calculations of impacts, for example, the impact of a standard on consumer life-cycle cost (LCC). In order to perform the calculation, the analyst must: 1) specify the equation or model that will be used; 2) define the quantities in the equation; and 3) provide numerical values for each quantity. In the simplest case, the equation is unambiguous (contains all relevant quantities and no others), each quantity has a single numerical value, and the calculation results in a single value. However, unambiguity and precision are rarely the case. In almost all cases, the model and/or the numerical values for each quantity in the model are not completely known (*i.e.*, there is uncertainty) or the model and/or the numerical values for each quantity in the model depend upon other conditions (*i.e.*, there is variability).

Thorough analysis involves accounting for uncertainty and variability. While the simplest analysis involves a single numerical value for each quantity in a calculation, arguments can arise about what the appropriate value is for each quantity. Explicit analysis of uncertainty and variability is intended to provide more complete information to the decision-making process.

8B.2 UNCERTAINTY

When making observations of past events or speculating about the future, imperfect knowledge is the rule rather than the exception. For example, the energy actually consumed by a particular appliance type (such as the average U.S. water heater, direct heating equipment, or pool heater) is not directly recorded, but rather estimated based upon available information. Even direct laboratory measurements have some margin of error. When estimating numerical values expected for quantities at some future date, the exact outcome is rarely known in advance.

8B.3 VARIABILITY

Variability results when different applications or situations produce different numerical values when calculating a quantity. Specifying an exact value for a quantity may be difficult because the value depends on something else. For example, water heater energy consumption depends upon the specific circumstances and behaviors of the occupants (*e.g.*, number of persons, length and temperature of showers, *etc.*). Variability makes specifying an appropriate population value more difficult inasmuch as any one value may not be representative of the entire population. Surveys can be helpful here, and analysis of surveys can relate the variable of interest (*e.g.*, hours of use) to other variables that are better known or easier to forecast (*e.g.*, persons per household).

8B.4 APPROACHES TO UNCERTAINTY AND VARIABILITY

This section describes two approaches to uncertainty and variability:

- scenario analysis, and
- probability analysis.

Scenario analysis uses a single numerical value for each quantity in a calculation, then changes one (or more) of the numerical values and repeats the calculation. A number of calculations are done, which provide some indication of the extent to which the result depends upon the assumptions. For example, the life-cycle cost of an appliance could be calculated for energy rates of 2, 8, and 14¢ per kWh.

The advantages of scenario analysis are that each calculation is simple; a range of estimates is used and crossover points can be identified. (An example of a crossover point is the energy rate above which the life-cycle cost is reduced, holding all other inputs constant. That is, the crossover point is the energy rate at which the consumer achieves savings in operating expense that more than compensate for the increased purchase expense.) The disadvantage of scenario analysis is that there is no information about the likelihood of each scenario.

Probability analysis considers the probabilities within a range of values. For quantities with variability (*e.g.*, electricity rates in different households), surveys can be used to generate a frequency distribution of numerical values (*e.g.*, the number of households with electricity rates at particular levels) to estimate the probability of each value. For quantities with uncertainty, statistical or subjective measures can be used to provide probabilities (*e.g.*, manufacturing cost to improve energy efficiency to some level may be estimated to be $10 ± $3).

The major disadvantage of the probability approach is that it requires more information, namely information about the shapes and magnitudes of the variability and uncertainty of each quantity. The advantage of the probability approach is that it provides greater information about the outcome of the calculations; that is, it provides the probability that the outcome will be in a particular range.

Scenario and probability analysis provide some indication of the robustness of the policy given the uncertainties and variability. A policy is robust when the impacts are acceptable over a wide range of possible conditions.

8B.5 PROBABILITY ANALYSIS AND THE USE OF CRYSTAL BALL

To quantify the uncertainty and variability that exist in inputs to the engineering, LCC, and payback period (PBP) analyses, DOE used Microsoft Excel spreadsheets combined with Crystal Ball, a commercially available add-in, to conduct probability analyses. The probability analyses used Monte Carlo simulation and probability distributions.

Simulation refers to any analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce. Without the aid of simulation, a spreadsheet model will only reveal a single outcome, generally the most likely or average scenario. Spreadsheet risk analysis uses both a spreadsheet model and simulation to automatically analyze the effect of varying inputs on outputs of the modeled system. One type of spreadsheet simulation is Monte Carlo simulation, which randomly generates values for uncertain variables again and again to simulate a model. Monte Carlo simulation was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance. Games of chance, such as roulette wheels, dice, and slot machines, exhibit random behavior. The random behavior in games of chance is similar to how Monte Carlo simulation selects variable values at random to simulate a model. When you roll a die, you know that a 1, 2, 3, 4, 5, or 6 will come up, but you do not know which for any particular roll. The same applies to the variables that have a known range of values but an uncertain value for any particular time or event (*e.g.*, equipment lifetime, discount rate, and installation cost).

For each uncertain variable (one that has a range of possible values), possible values are defined with a probability distribution. The type of distribution selected is based on the conditions surrounding that variable. Probability distribution types include:

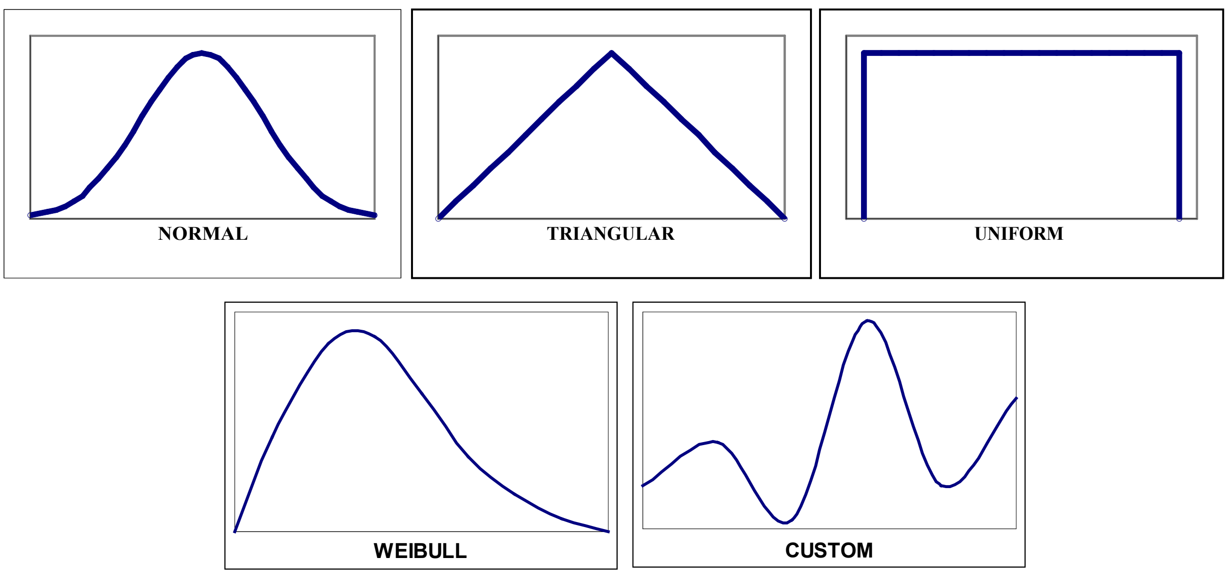

Figure 8B.5.1 Normal, Triangular, Uniform, Weibull, and Custom Probability Distributions

During a simulation, multiple scenarios of a model are calculated by repeatedly sampling values from the probability distributions for the uncertain variables and using those values for the cell. Crystal Ball simulations can consist of as many trials (or scenarios) as desired—hundreds or even thousands. During a single trial, Crystal Ball randomly selects a value from the defined possibilities (the range and shape of the probability distribution) for each uncertain variable and then recalculates the spreadsheet.

APPENDIX 8C. ENERGY PRICE CALCULATIONS FOR HEARTH PRODUCTS

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APPENDIX 8C. ENERGY PRICE CALCULATIONS FOR HEARTH PRODUCTS

8C.1 INTRODUCTION

Figure 8C.1.1 depicts the energy price calculation process, which also encompasses average energy price, seasonal marginal price factor, and monthly price factor calculations.

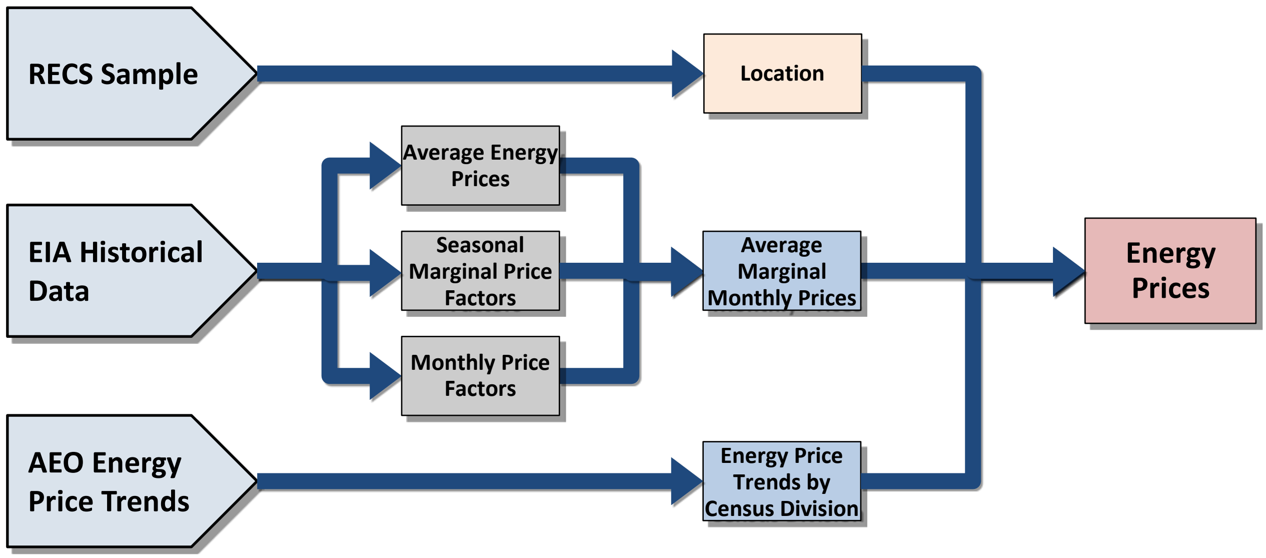

Figure 8C.1.1 Energy Price Calculation Process

8C.2 RECS SAMPLE MAPPING PROCESS

To match the state data from EIA to the RECS 2009 household samples, DOE used the housing projections in 2021 for each geographic area. See appendix 7A for more details. RECS 2009 utilizes 27 regions (also called reportable domains). DOE further subdivided the RECS 2009 regions into 30 regions based on climate data to disaggregate northern and rest of country states. The 27th RECS region includes Oregon, Washington, Alaska, and Hawaii. DOE subdivided Alaska and Hawaii into separate regions (28 and 29, respectively), based on cooling and heating degree days. In addition, West Virginia, which is in RECS region 14, was disaggregated into region 30 based on cooling and heating degree days.

8C.3 AVERAGE MARGINAL MONTHLY PRICES

8C.3.1 Average Annual Prices Determination

8C.3.1.1 Annual Electrical Prices

DOE derived 2012 annual electricity prices from EIA Form 826 data.[1] The EIA Form

826 data include energy prices by state. DOE calculated residential annual electricity prices for each geographical area by averaging monthly energy prices by state to get state electricity prices. For areas with more than one state, DOE weighted each state's average price by its 2021 housing projection. Table 8C.3.1 shows the monthly residential electricity prices for each state. Note that all energy prices were converted from 2012$ to 2013$ in the LCC spreadsheet using the consumer price index (CPI).[a]

Table 8C.3.1 2012 Monthly Residential Electricity Prices by State (2012¢/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg. 2012
United States	11.41	11.51	11.70	11.92	11.90	12.09	12.00	12.17	12.30	12.03	11.75	11.62	11.87
Alabama	10.91	11.21	11.48	11.56	11.14	11.56	11.58	11.71	11.76	11.71	11.04	10.96	11.39
Alaska	18.04	17.44	17.97	17.64	18.43	18.10	19.44	19.07	17.34	17.82	17.10	17.06	17.95
Arizona	10.01	10.26	10.44	11.17	11.88	11.90	11.86	11.83	11.66	11.36	10.73	10.41	11.13
Arkansas	8.41	8.68	8.99	9.35	9.14	9.58	9.62	9.69	9.80	9.39	9.46	9.07	9.27
California	15.29	14.56	14.70	14.66	15.02	15.92	15.22	16.46	16.82	14.22	14.88	15.49	15.27
Colorado	10.61	10.76	10.84	11.04	11.27	12.01	12.32	12.15	12.11	11.33	11.38	11.07	11.41
Connecticut	17.32	17.09	17.16	17.64	17.71	17.30	17.08	17.12	17.24	18.08	17.82	17.06	17.39
Delaware	13.03	13.17	13.52	13.93	14.37	13.98	13.32	13.57	13.74	14.53	13.63	13.03	13.65
District of Columbia	11.78	12.21	12.20	12.49	12.39	13.18	12.26	12.23	12.22	12.35	12.21	11.98	12.29
Florida	11.55	11.33	11.09	11.42	11.00	11.49	11.31	11.49	11.60	11.53	11.82	11.38	11.42
Georgia	10.23	10.61	10.58	10.77	11.08	11.88	12.13	12.18	11.87	10.89	10.28	10.29	11.07
Hawaii	36.25	36.80	37.05	37.51	38.21	40.16	37.84	37.18	37.21	36.96	36.81	36.33	37.36
Idaho	8.15	8.09	8.18	8.16	8.39	9.04	9.75	9.77	8.31	9.11	8.67	8.54	8.68
Illinois	11.21	11.45	11.97	12.45	12.73	11.24	10.81	10.78	11.36	11.91	11.35	10.62	11.49
Indiana	10.00	10.18	10.85	11.56	10.85	10.54	9.94	10.44	10.92	11.09	10.45	10.49	10.61
Iowa	9.74	9.77	10.26	11.23	10.98	11.32	11.54	12.03	11.38	10.99	10.34	10.16	10.81
Kansas	10.23	10.71	10.81	11.15	11.28	11.69	11.74	11.72	11.52	11.29	10.96	10.90	11.17
Kentucky	8.98	9.07	9.47	9.63	9.72	9.48	9.27	9.45	9.83	9.72	9.41	9.46	9.46
Louisiana	8.15	8.40	8.40	8.38	8.48	8.01	8.38	8.29	8.56	8.68	8.39	8.47	8.38
Maine	15.02	15.07	14.28	14.46	14.41	14.21	14.63	14.66	14.81	14.76	14.83	14.70	14.65
Maryland	12.48	12.55	12.86	12.90	12.95	13.14	12.88	13.09	13.17	13.03	12.40	12.67	12.84
Massachusetts	15.10	15.41	15.72	14.80	15.39	15.48	14.58	14.16	15.20	14.38	13.77	15.19	14.93
Michigan	13.48	13.48	13.63	13.69	14.39	14.13	15.06	14.53	14.37	14.22	13.98	14.08	14.09
Minnesota	10.76	10.71	10.94	11.14	11.30	11.79	11.84	12.18	12.09	11.54	11.03	10.95	11.36
Mississippi	10.03	10.43	10.62	10.66	10.37	10.26	10.14	9.95	9.98	10.31	10.65	10.29	10.31
Missouri	8.66	8.90	9.33	10.06	10.90	11.53	11.31	11.49	10.46	9.89	9.20	9.03	10.06
Montana	9.57	9.59	9.70	9.86	10.13	10.43	10.60	10.52	10.74	10.54	10.04	9.89	10.13
Nebraska	8.61	8.86	9.16	9.95	9.68	10.71	11.38	11.24	11.50	10.43	9.43	9.13	10.01
Nevada	11.38	12.55	12.16	12.40	12.10	11.80	11.52	11.46	11.58	12.04	12.45	11.82	11.94
New Hampshire	16.17	16.12	16.33	16.45	16.53	16.51	15.81	15.59	15.88	16.03	15.90	15.83	16.10
New Jersey	16.07	16.22	15.86	15.91	15.93	15.67	16.12	15.81	15.57	15.17	15.24	15.49	15.76
New Mexico	10.79	10.62	10.71	10.77	11.04	12.08	12.19	12.49	11.98	11.51	10.69	10.71	11.30
New York	16.79	16.51	16.64	16.70	17.33	18.31	18.38	18.12	18.52	18.44	17.44	17.47	17.55
North Carolina	10.09	10.76	11.00	11.42	10.80	11.00	11.03	11.23	11.52	11.41	10.53	10.41	10.93

[a] http://www.bls.gov/cpi/

North Dakota	7.65	8.12	8.43	9.22	9.60	10.57	10.00	10.27	10.47	9.42	8.61	8.61	9.25
Ohio	11.08	11.04	11.35	11.93	11.85	12.24	12.16	12.14	12.27	12.06	11.67	11.39	11.77
Oklahoma	8.70	9.48	9.87	10.31	9.53	9.50	9.12	9.70	10.13	10.09	9.57	8.71	9.56
Oregon	9.58	9.63	9.66	9.73	9.86	9.92	10.01	10.01	10.00	10.00	9.82	9.74	9.83
Pennsylvania	12.82	12.79	12.77	12.97	12.99	12.89	12.62	12.68	12.57	12.80	12.60	12.62	12.76
Rhode Island	14.75	14.94	14.82	13.15	14.41	15.32	13.90	14.00	15.09	13.66	13.06	15.70	14.40
South Carolina	11.15	11.64	12.04	11.94	11.40	12.32	11.48	12.14	11.85	11.80	11.67	11.87	11.78
South Dakota	9.22	9.26	9.49	10.22	10.61	10.47	10.59	10.60	10.85	10.66	10.01	9.59	10.13
Tennessee	9.80	9.64	9.83	10.11	10.24	10.24	10.14	10.00	10.18	10.41	10.33	10.48	10.12
Texas	10.77	11.05	11.01	11.02	10.84	10.97	10.87	10.96	11.11	11.16	11.11	10.99	10.99
Utah	9.23	9.33	9.36	9.47	9.87	10.35	10.68	10.66	10.23	9.59	9.70	9.73	9.85
Vermont	16.52	17.07	16.76	16.87	16.41	16.93	16.77	16.38	16.38	17.51	19.26	17.20	17.01
Virginia	10.45	10.89	11.09	11.38	11.50	11.84	11.42	11.25	11.10	11.03	10.71	10.51	11.10
Washington	8.37	8.28	8.35	8.46	8.52	8.70	8.70	8.72	8.79	8.68	8.61	8.53	8.56
West Virginia	9.49	9.68	9.85	9.84	10.48	9.92	9.88	9.85	10.04	10.18	9.85	9.63	9.89
Wisconsin	12.66	12.88	13.10	13.36	13.35	13.36	13.28	13.50	13.83	13.43	13.16	12.61	13.21
Wyoming	9.12	9.16	9.40	9.74	10.08	10.22	10.38	10.27	10.38	10.36	10.01	9.89	9.92

All prices in 2012$ were converted to 2013$ to be consistent with the rest of the prices used in the analysis. This conversion was performed using the Consumer Price Index. Table 8C.3.2 shows the average residential electricity prices weighted by housing projections in 2021 for each geographic area.

Table 8C.3.2 Average Residential Electricity Prices by Region in 2012

	Geographic Area	2013$/MMBtu
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$0.16
2	Massachusetts	$0.15
3	New York	$0.18
4	New Jersey	$0.16
5	Pennsylvania	$0.13
6	Illinois	$0.12
7	Indiana, Ohio	$0.12
8	Michigan	$0.14
9	Wisconsin	$0.13
10	Iowa, Minnesota, North Dakota, South Dakota	$0.11
11	Kansas, Nebraska	$0.11
12	Missouri	$0.10
13	Virginia	$0.11
14	Delaware, District of Columbia, Maryland	$0.13
15	Georgia	$0.11
16	North Carolina, South Carolina	$0.11
17	Florida	$0.12
18	Alabama, Kentucky, Mississippi	$0.11
19	Tennessee	$0.10
20	Arkansas, Louisiana, Oklahoma	$0.09
21	Texas	$0.11
22	Colorado	$0.12
23	Idaho, Montana, Utah, Wyoming	$0.10
24	Arizona	$0.11
25	Nevada, New Mexico	$0.12
26	California	$0.15
27	Oregon, Washington	$0.09
28	Alaska	$0.18
29	Hawaii	$0.38
30	West Virginia	$0.10
31	U.S. Average	$0.12

8C.3.1.2 Annual Natural Gas Prices

DOE obtained the data for natural gas prices from EIA's Natural Gas Navigator,[2] which includes monthly natural gas prices by state for residential, commercial, and industrial customers. For areas with more than one state, DOE weighted each state's average price by its

2021 housing projection. Table 8C.3.3 shows the monthly residential natural gas prices for each state.

Table 8C.3.3 2012 Monthly Residential Natural Gas Prices by State (2012$/tcf)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg. 2012
United States	9.67	9.52	10.45	11.01	12.66	14.25	15.2	15.89	14.81	11.78	10.06	9.75	12.09
Alabama	14.27	14.41	15.25	18.67	19.77	21.34	21.77	21.96	21.04	20.05	15.9	15.25	18.31
Alaska	8.26	8.48	8.17	8.47	8.93	9.57	9.7	10.07	8.74	8.21	7.86	8.57	8.75
Arizona	13.3	14.09	14.68	15.94	18.55	20.39	21.99	22.43	21.8	19.34	15.74	14.94	17.77
Arkansas	10.57	10.78	11.84	15.02	13.59	15.26	16.64	17.47	16.27	13.67	10.96	10.71	13.57
California	9.27	8.36	8.69	8.48	9.04	9.7	9.97	10.12	10.07	9.79	9.09	9.33	9.33
Colorado	7.68	7.79	8.65	8.23	10.36	12.9	12.92	12.93	11.44	8.62	7.64	7.06	9.69
Connecticut	12.11	12.16	12.54	14.53	16.24	20.41	20.85	21.47	20.45	17.85	14.74	13.08	16.37
Delaware	13.87	14.03	14.52	16.12	17.76	22.2	23.55	24.59	24.14	20.49	14.52	12.8	18.22
District of Columbia	11.92	11.11	12.64	11.93	17.28	17.62	17.96	14.31	13.35	12.38	11	11.58	13.59
Florida	16.19	15.93	16.65	18.02	19.39	21.14	21.43	22.42	21.81	21.43	17.98	16.29	19.06
Georgia	14	14.66	14.86	16.65	20.53	21.52	22.29	23.82	23.03	21.8	16.39	15.09	18.72
Hawaii	49.97	54.89	57.26	54.93	50.72	51.23	51.92	54.81	56.21	52.76	49.59	49.76	52.84
Idaho	8.43	8.27	8.45	8.37	8.6	9.07	8.8	9.28	9.15	8.01	7.71	7.81	8.50
Illinois	7.09	6.66	8.25	7.62	11.49	12.67	15.31	15.68	13.14	9.12	7.83	7.56	10.20
Indiana	8.06	8.31	11.24	11.18	12.18	12.89	14.84	14.7	12.23	8.04	7.04	7.63	10.70
Iowa	8.26	7.97	10.34	9.04	10.86	13.41	17.34	17.16	14.6	11.78	8.84	8.23	11.49
Kansas	8.16	8.66	8.92	12.31	14.22	16.09	17.69	19.11	18.15	13.67	9.87	9.07	12.99
Kentucky	8.62	9.2	11.41	11.97	15.02	16.95	19.34	18.81	17.68	11.16	8.36	8.44	13.08
Louisiana	10.24	10.91	11.63	12.3	12.24	13.48	14.12	14.92	13.86	13.51	10.84	10.06	12.34
Maine	15.87	16.65	16.44	17.12	16.33	16.62	16.47	17.93	16.55	13.28	13.41	15.81	16.04
Maryland	11.33	11.06	13.63	13.91	16.1	17.83	18.44	18.5	15.81	12.91	10.01	10.74	14.19
Massachusetts	13.69	12.59	12.83	12.75	12.54	12.18	14.1	14.84	14.9	12.74	13.77	13.28	13.35
Michigan	10.32	10.35	11.12	10.64	13.95	14.34	15.99	16.16	13.66	10.79	9.99	9.67	12.25
Minnesota	7.53	7.42	8.2	7.41	9.34	10.56	11.47	11.86	9.95	7.85	7.81	7.55	8.91
Mississippi	7.55	9.41	10.28	12.28	12.26	12.21	12.59	13.05	12	11.6	8.52	8.39	10.85
Missouri	9.41	9.6	11.07	17.24	18.56	22.53	24.82	26.15	23.73	16.25	11.86	9.9	16.76
Montana	8.05	7.78	7.82	7.99	8.03	8.48	10.61	10.81	11.02	8.06	7.61	7.56	8.65
Nebraska	7.57	7.37	7.47	10.34	10.64	12.06	12.4	15.01	14.43	11.49	8.61	8.08	10.46
Nevada	9.07	9.43	9.77	10.62	12.08	12.75	13.36	13.8	13.37	12.43	9.44	8.46	11.22
New Hampshire	13.02	13.25	13.56	15.41	13.94	16.03	18.18	19.98	18.85	14.63	12.74	12.19	15.15
New Jersey	10.29	9.82	10.46	11.11	12.01	13.21	13.77	14.34	13.83	12.51	11.61	11.27	12.02
New Mexico	7.41	7.41	7.48	8.65	10.23	11.82	13.71	14.31	14.3	12.59	9.32	8.17	10.45
New York	11.67	11.69	12.99	13.06	15.13	18	17.4	18.78	18.16	15.26	11.35	11.97	14.62
North Carolina	10.95	10.44	13.92	15.21	16.87	18.85	21.56	21.41	20.48	14.26	10.32	10.84	15.43
North Dakota	7.18	6.53	7.28	7.2	8.78	12.45	13.95	14.17	11.99	7.1	6.55	6.69	9.16
Ohio	8.56	8.05	8.53	10.74	13.9	22.17	28.1	29.98	25.43	14.67	9.93	9.27	15.78
Oklahoma	8.33	8.07	9.03	14.4	17.92	19.96	22.84	24.51	23.52	17.7	11.78	9.16	15.60
Oregon	11.47	11.53	10.7	10.56	12.33	12.25	12.53	13.18	14.12	11.79	10.49	10.27	11.77
Pennsylvania	11	11.12	11.34	12.04	13.42	18.09	18.65	19.7	18.56	13.9	11	10.68	14.13
Rhode Island	13.1	13.96	14.16	16.06	18.05	17.88	18.91	19.36	19.58	14.84	12.33	12.01	15.85

South Carolina	11.28	11.18	13.94	17.96	19.81	23.52	25.17	22.38	24.25	15.79	10.63	11.78	17.31
South Dakota	7.84	7.64	9.14	7.78	8.55	10.89	13.37	13.71	12.44	8.82	7.81	7.66	9.64
Tennessee	8.97	8.73	9.48	12.53	13.79	14.54	15.55	17.35	15.22	12.3	9.13	8.87	12.21
Texas	8.56	8.2	9.7	12.05	13.18	14.18	14.51	16.21	15.67	14.54	11.35	10.11	12.36
Utah	7.97	8.5	8.66	9.13	8.87	9.09	9.92	10.24	10.13	9.88	8.76	8.47	9.14
Vermont	15.64	15.45	15.79	16.53	17.4	21.35	23.4	24.02	23.23	19.28	16.62	15.21	18.66
Virginia	11.86	11.14	13.19	13.43	15.77	19.29	19.93	20.13	19.31	12.97	9.94	11.04	14.83
Washington	11.25	11.38	11.45	11.9	12.7	13.53	14.85	15.59	15.63	13.1	11.41	10.56	12.78
West Virginia	10.32	10.29	10.81	11.1	14.33	18	18.38	17.85	14.51	12.02	9.65	9.35	13.05
Wisconsin	8.63	8.73	10.05	9.73	9.58	11.44	13.35	13.6	10.83	8.25	9.03	8.93	10.18
Wyoming	7.87	7.7	7.59	8.06	8.74	10.58	14.37	14.9	14.23	9.7	7.87	7.51	9.93

All prices in 2012$ were converted to 2013$ to be consistent with the rest of the prices used in the analysis. This conversion was performed using the Consumer Price Index. DOE also used a conversion factor (1.025) to convert from cubic feet of natural gas to MMBtu.[b] Table 8C.3.4 displays the annual average residential natural gas prices weighted by housing projections in 2021 by geographic region.

[b] www.eia.gov/tools/faqs/faq.cfm?id=45&t=7

Table 8C.3.4 Average Residential Natural Gas Prices by Region in 2012

	Geographic Area	2013$/MMBtu
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$16.10
2	Massachusetts	$13.21
3	New York	$14.47
4	New Jersey	$11.89
5	Pennsylvania	$13.99
6	Illinois	$10.09
7	Indiana, Ohio	$13.85
8	Michigan	$12.16
9	Wisconsin	$10.07
10	Iowa, Minnesota, North Dakota, South Dakota	$9.67
11	Kansas, Nebraska	$11.88
12	Missouri	$16.64
13	Virginia	$14.69
14	Delaware, District of Columbia, Maryland	$14.51
15	Georgia	$18.56
16	North Carolina, South Carolina	$15.88
17	Florida	$18.88
18	Alabama, Kentucky, Mississippi	$14.57
19	Tennessee	$12.08
20	Arkansas, Louisiana, Oklahoma	$13.63
21	Texas	$12.24
22	Colorado	$9.62
23	Idaho, Montana, Utah, Wyoming	$8.88
24	Arizona	$17.63
25	Nevada, New Mexico	$10.77
26	California	$9.23
27	Oregon, Washington	$12.30
28	Alaska	$8.67
29	Hawaii	$52.52
30	West Virginia	$12.94
31	U.S. Average	$16.10

8C.3.1.3 Annual LPG Prices

DOE collected 2012 average LPG prices from EIA's 2012 State Energy Consumption, Price, and Expenditures Estimates (SEDS).[3] SEDS includes annual LPG prices for residential, commercial, industrial, and transportation consumers by state. For areas with more than one state, DOE weighted each state's average price by its 2021 housing projection. Table 8C.3.5 shows the annual residential LPG prices for each state.

Table 8C.3.5 2012 Residential Average LPG Prices by State (2012$/MMBtu)

Geographical Area	Avg. 2012
United States	28.18
Alabama	29.73

Alaska	38.46
Arizona	35.22
Arkansas	30.25
California	33.84
Colorado	21.93
Connecticut	34.13
Delaware	33.37
District of Columbia	35.37
Florida	42.42
Georgia	28.42
Hawaii	64.01
Idaho	22.59
Illinois	23.02
Indiana	24.78
Iowa	22.97
Kansas	23.03
Kentucky	28.49
Louisiana	29.68
Maine	36
Maryland	38.13
Massachusetts	38.04
Michigan	22.97
Minnesota	23.16
Mississippi	30.74
Missouri	22.58
Montana	21.31
Nebraska	22.86
Nevada	35.45
New Hampshire	34.83
New Jersey	37.58
New Mexico	28.8
New York	35.44
North Carolina	30.28
North Dakota	22.75
Ohio	28.19
Oklahoma	22.64
Oregon	28.85
Pennsylvania	31.96
Rhode Island	43.86
South Carolina	31.84
South Dakota	22.53
Tennessee	29.9
Texas	30.76
Utah	22.58
Vermont	34.44
Virginia	26.67
Washington	29.24
West Virginia	35.78

Wisconsin	20.8
Wyoming	22.16

All prices in 2012$ were converted to 2013$ to be consistent with the rest of the prices used in the analysis. This conversion was performed using the Consumer Price Index. Table 8C.3.6 shows the housing-projection-weighted average residential LPG prices for each geographic area.

Table 8C.3.6 Average Residential LPG Prices by Region in 2012

	Geographic Area	2013$/MMBtu
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$32.55
2	Massachusetts	$34.94
3	New York	$33.08
4	New Jersey	$34.31
5	Pennsylvania	$31.19
6	Illinois	$21.69
7	Indiana, Ohio	$25.35
8	Michigan	$23.30
9	Wisconsin	$21.51
10	Iowa, Minnesota, North Dakota, South Dakota	$22.34
11	Kansas, Nebraska	$21.47
12	Missouri	$22.09
13	Virginia	$24.48
14	Delaware, District of Columbia, Maryland	$33.32
15	Georgia	$26.61
16	North Carolina, South Carolina	$26.64
17	Florida	$27.55
18	Alabama, Kentucky, Mississippi	$23.62
19	Tennessee	$26.99
20	Arkansas, Louisiana, Oklahoma	$20.33
21	Texas	$15.30
22	Colorado	$24.35
23	Idaho, Montana, Utah, Wyoming	$23.36
24	Arizona	$29.91
25	Nevada, New Mexico	$24.77
26	California	$28.49
27	Oregon, Washington	$26.18
28	Alaska	$28.45
29	Hawaii	$38.22
30	West Virginia	$31.69
31	U.S. Average	$18.28

8C.3.2 Monthly Energy Price Factors Determination

For hearth products, the Department of Energy (DOE) developed monthly energy price factors and used monthly energy consumption data for the life-cycle cost and payback period calculation. DOE developed monthly energy price factors to capture robust seasonal trends in monthly energy prices. To convert annual energy prices into monthly energy prices, DOE determined monthly energy price factors.

8C.3.2.1 Monthly Residential Electricity Price Factor Calculations

DOE collected historical electricity prices from 1993 to 2012 from EIA's Form 826.[1] These data are published annually and include annual electricity sales, revenues from electricity sales, and average price for the residential, commercial, industrial, and transportation sectors by state. DOE aggregated the data into 30 geographical areas described in Chapter 8 (section 8.2.3.2 Energy Prices).

For each geographic region, DOE determined average electricity prices from 1993 to 2012 by weighting the average residential electricity prices for each state by the housing projections in 2021 in each state.

As an example, to illustrate the methodology for producing monthly price factors, the following tables and charts show the calculation of monthly average electricity price factors, based on New York historic electricity price data. Table 8C.3.7 shows the average residential electricity prices for New York.

Table 8C.3.7 1990-2011 Average Residential Electricity Prices for New York (nominal cents/kWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1990	10.71	11.12	11.19	11.02	11.31	11.64	11.80	11.89	11.98	11.71	11.62	11.48	11.46
1991	11.48	11.44	11.63	11.58	11.82	12.41	12.38	12.63	12.57	12.02	11.84	11.77	11.96
1992	11.43	11.42	11.49	11.60	12.21	13.09	13.31	13.46	13.46	12.95	12.71	12.55	12.47
1993	12.17	12.14	12.35	12.71	13.35	13.93	13.94	13.92	13.90	13.28	13.35	13.10	13.18
1994	12.92	12.74	13.01	13.19	13.61	14.11	14.19	14.30	14.37	13.43	13.50	13.15	13.54
1995	13.16	13.11	13.34	13.54	14.06	14.63	14.69	14.58	14.51	13.76	13.81	13.50	13.89
1996	13.39	13.46	13.71	13.80	14.00	14.54	14.67	14.78	14.59	13.97	13.83	13.75	14.04
1997	13.75	13.67	13.83	13.69	13.84	14.70	14.80	14.68	14.56	14.01	13.93	13.84	14.11
1998	13.87	13.73	13.77	13.84	14.05	13.78	13.78	13.65	13.66	13.29	13.04	12.92	13.62
1999	12.85	12.75	12.95	13.34	12.85	13.44	13.44	13.54	13.74	13.64	13.44	13.24	13.27
2000	12.90	13.18	13.33	13.52	13.54	14.22	15.40	14.77	14.52	14.12	13.94	13.98	13.95
2001	13.89	13.93	13.58	13.44	14.01	14.41	14.99	14.61	14.23	14.22	13.53	13.25	14.01
2002	12.95	13.00	12.81	12.69	13.30	14.01	14.19	14.16	14.42	13.87	13.37	13.19	13.50
2003	12.77	13.30	13.91	14.55	14.77	14.98	15.14	14.94	14.92	14.75	14.23	13.63	14.32
2004	13.32	14.02	13.98	14.03	14.20	14.99	15.36	15.32	15.10	14.93	14.88	14.29	14.53
2005	14.05	14.53	14.40	14.64	15.36	15.58	15.63	16.16	16.69	17.36	17.57	16.53	15.71
2006	16.61	16.66	15.89	16.36	16.56	17.33	17.56	17.74	17.92	17.22	16.33	15.88	16.84
2007	16.09	15.89	16.83	17.14	17.50	18.17	17.27	17.96	17.15	17.48	16.94	16.66	17.09
2008	16.86	17.31	16.92	18.08	18.79	19.42	19.66	20.93	19.49	17.57	16.95	16.61	18.22
2009	16.83	16.72	16.40	16.57	16.86	18.22	18.79	18.21	18.75	18.12	16.72	17.47	17.47
2010	17.29	18.04	17.55	18.92	19.21	19.41	20.11	19.35	20.09	18.36	18.25	17.72	18.69
2011	17.25	17.45	17.58	17.63	18.30	19.07	19.22	19.25	18.84	18.78	17.93	17.26	18.21

DOE then calculated monthly energy price factors by dividing the monthly prices by the annual average for each year. Table 8C.3.8 and Figure 8C.3.1 show the calculated results for New York.

Table 8C.3.8 Monthly Electricity Price Factors for 1990-2011 for New York

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	0.94	0.97	0.98	0.96	0.99	1.02	1.03	1.04	1.05	1.02	1.01	1.00
1991	0.96	0.96	0.97	0.97	0.99	1.04	1.03	1.06	1.05	1.00	0.99	0.98
1992	0.92	0.92	0.92	0.93	0.98	1.05	1.07	1.08	1.08	1.04	1.02	1.01
1993	0.92	0.92	0.94	0.96	1.01	1.06	1.06	1.06	1.05	1.01	1.01	0.99
1994	0.95	0.94	0.96	0.97	1.00	1.04	1.05	1.06	1.06	0.99	1.00	0.97
1995	0.95	0.94	0.96	0.97	1.01	1.05	1.06	1.05	1.04	0.99	0.99	0.97
1996	0.95	0.96	0.98	0.98	1.00	1.04	1.04	1.05	1.04	0.99	0.98	0.98
1997	0.97	0.97	0.98	0.97	0.98	1.04	1.05	1.04	1.03	0.99	0.99	0.98
1998	1.02	1.01	1.01	1.02	1.03	1.01	1.01	1.00	1.00	0.98	0.96	0.95
1999	0.97	0.96	0.98	1.01	0.97	1.01	1.01	1.02	1.04	1.03	1.01	1.00
2000	0.92	0.94	0.96	0.97	0.97	1.02	1.10	1.06	1.04	1.01	1.00	1.00
2001	0.99	0.99	0.97	0.96	1.00	1.03	1.07	1.04	1.02	1.02	0.97	0.95
2002	0.96	0.96	0.95	0.94	0.99	1.04	1.05	1.05	1.07	1.03	0.99	0.98
2003	0.89	0.93	0.97	1.02	1.03	1.05	1.06	1.04	1.04	1.03	0.99	0.95
2004	0.92	0.96	0.96	0.97	0.98	1.03	1.06	1.05	1.04	1.03	1.02	0.98
2005	0.89	0.93	0.92	0.93	0.98	0.99	0.99	1.03	1.06	1.11	1.12	1.05
2006	0.99	0.99	0.94	0.97	0.98	1.03	1.04	1.05	1.06	1.02	0.97	0.94
2007	0.94	0.93	0.98	1.00	1.02	1.06	1.01	1.05	1.00	1.02	0.99	0.97
2008	0.93	0.95	0.93	0.99	1.03	1.07	1.08	1.15	1.07	0.96	0.93	0.91
2009	0.96	0.96	0.94	0.95	0.97	1.04	1.08	1.04	1.07	1.04	0.96	1.00
2010	0.93	0.97	0.94	1.01	1.03	1.04	1.08	1.04	1.07	0.98	0.98	0.95
2011	0.95	0.96	0.97	0.97	1.00	1.05	1.06	1.06	1.03	1.03	0.98	0.95

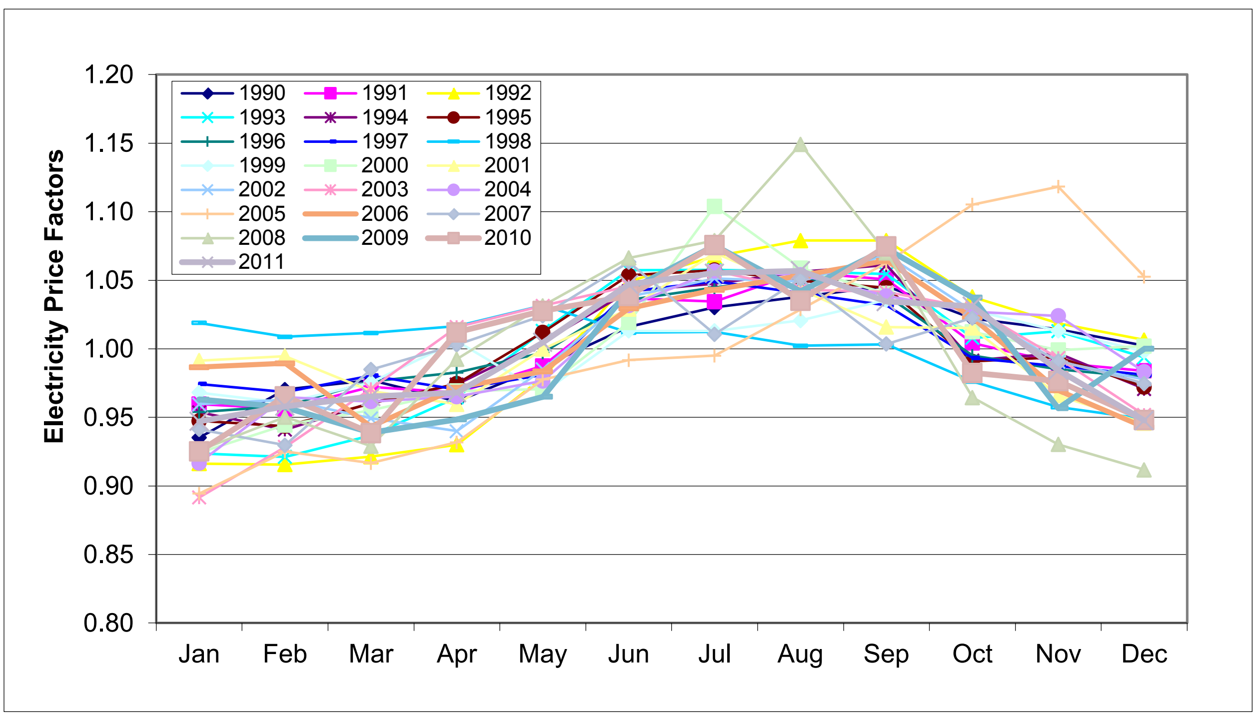

Figure 8C.3.1 Monthly Electricity Price Factors for 1990-2011 for New York

DOE then averaged the monthly energy price factors for 1993 to 2012 to develop an average energy price factor for each month. DOE performed the same calculations for each geographic region to develop the average monthly energy price factors weighted by 2021 housing projections shown in Table 8C.3.9, which includes the results for New York.

Table 8C.3.9 Monthly Residential Electricity Price Factors

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.98	0.98	0.99	1.00	1.01	1.01	1.00	1.01	1.01	1.01	1.00	1.00
Massachusetts	0.98	0.99	0.99	0.99	1.00	1.03	1.00	1.00	1.02	1.01	0.99	1.01
New York	0.95	0.96	0.96	0.98	1.00	1.04	1.05	1.05	1.05	1.02	0.99	0.97
New Jersey	0.95	0.95	0.96	0.96	0.98	1.06	1.08	1.08	1.06	0.97	0.97	0.97
Pennsylvania	0.93	0.94	0.95	0.98	1.02	1.06	1.07	1.06	1.04	1.02	0.98	0.95
Illinois	0.89	0.93	0.96	1.01	1.05	1.07	1.06	1.04	1.05	1.06	0.97	0.91
Indiana, Ohio	0.90	0.92	0.95	1.01	1.05	1.06	1.03	1.04	1.05	1.05	1.01	0.94
Michigan	0.97	0.97	0.97	0.98	0.99	1.03	1.05	1.05	1.02	0.99	0.98	0.99
Wisconsin	0.96	0.99	0.98	1.00	1.02	1.03	1.00	1.01	1.01	1.02	1.00	0.98
Iowa, Minnesota, North Dakota, South Dakota	0.91	0.93	0.95	0.98	1.03	1.07	1.08	1.07	1.05	1.02	0.97	0.94
Kansas, Nebraska	0.87	0.91	0.94	0.98	1.02	1.09	1.10	1.11	1.10	1.00	0.96	0.91
Missouri	0.84	0.86	0.90	0.96	1.08	1.18	1.17	1.16	1.06	0.98	0.94	0.87
Virginia	0.91	0.93	0.95	0.99	1.04	1.06	1.07	1.07	1.04	1.02	0.98	0.93
Delaware, District of Columbia, Maryland	0.90	0.90	0.92	0.94	1.03	1.12	1.11	1.11	1.08	1.00	0.95	0.93
Georgia	0.90	0.93	0.96	0.97	1.01	1.09	1.10	1.11	1.06	1.00	0.95	0.91
North Carolina, South Carolina	0.94	0.96	0.98	1.01	1.01	1.00	1.02	1.02	1.03	1.05	1.01	0.97
Florida	0.98	0.99	1.00	1.01	1.00	0.99	1.00	1.00	1.00	1.01	1.02	1.00
Alabama, Kentucky, Mississippi	0.92	0.94	0.97	1.02	1.03	1.03	1.02	1.03	1.02	1.03	1.01	0.96
Tennessee	0.96	0.96	0.98	1.01	1.02	1.01	0.99	0.99	1.00	1.04	1.03	1.01
Arkansas, Louisiana, Oklahoma	0.90	0.93	0.97	1.00	1.02	1.05	1.05	1.05	1.07	1.04	0.99	0.93
Texas	0.92	0.93	0.97	0.99	1.02	1.05	1.05	1.05	1.04	1.04	0.98	0.96
Colorado	0.95	0.96	0.97	0.99	1.02	1.03	1.02	1.02	1.03	1.02	1.00	0.97
Idaho, Montana, Utah, Wyoming	0.95	0.96	0.96	0.97	1.01	1.04	1.04	1.04	1.03	1.03	0.99	0.98
Arizona	0.88	0.91	0.93	0.98	1.09	1.08	1.07	1.06	1.06	1.06	0.94	0.95
Nevada, New Mexico	0.96	0.98	1.00	1.01	1.01	1.00	0.99	1.00	1.00	1.03	1.02	0.99
California	1.00	0.97	0.97	0.97	1.00	1.02	1.05	1.05	1.01	0.96	1.00	1.01
Oregon, Washington	0.98	0.99	0.99	0.98	0.98	1.00	1.00	1.01	1.01	1.02	1.02	1.02
Alaska	0.95	0.96	0.98	0.99	1.02	1.02	1.04	1.03	1.01	1.01	1.00	0.99
Hawaii	0.96	0.97	0.96	0.97	0.99	1.00	1.01	1.02	1.02	1.03	1.03	1.02
West Virginia	0.94	0.95	0.98	1.01	1.04	1.02	1.00	1.00	1.02	1.05	1.02	0.97
United States	0.93	0.94	0.96	0.99	1.02	1.04	1.04	1.05	1.04	1.02	0.99	0.96

8C.3.2.2 Monthly Residential Natural Gas Price Factor Calculations

DOE collected historical natural gas prices from 1993 to 2012 from the Energy Information Administration's (EIA's) Natural Gas Navigator.[2] The Natural Gas Navigator includes annual and monthly natural gas prices for residential, commercial, and industrial consumers by state. DOE aggregated the data into 30 geographical areas for residential buildings and 9 census division for commercial buildings as described in Chapter 8.

For each geographic area, DOE determined average natural gas prices from 1993 to 2012 by weighting the average residential natural gas prices for each state by the housing projections in 2021 in each state.

Again, as an example for how DOE determined monthly natural gas price factors, the methodology used to determine monthly average price factors can be seen below. Table 8C.3.10 shows the historic average residential gas prices for New York.

Table 8C.3.10 1989-2010 Average Residential Natural Gas Prices for New York ($/tcf)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1990	6.60	6.66	7.46	6.87	7.11	8.31	9.01	9.36	9.18	7.98	7.58	6.77	7.74
1991	6.77	7.18	6.91	7.08	7.64	8.13	9.02	9.61	9.01	8.38	7.41	7.35	7.87
1992	6.96	6.97	6.82	6.91	7.53	8.91	9.53	9.79	8.90	8.03	7.44	7.14	7.91
1993	7.10	6.83	6.89	6.79	7.40	8.70	9.70	10.28	9.92	8.62	8.68	7.74	8.22
1994	7.57	7.20	7.14	7.71	9.17	9.83	10.95	11.43	10.88	9.33	8.38	8.43	9.00
1995	7.69	7.99	8.33	8.87	9.20	10.64	11.64	12.00	11.42	9.70	9.36	8.64	9.62
1996	8.10	7.66	7.66	7.88	8.70	10.20	11.64	12.00	11.81	11.09	8.70	7.77	9.43
1997	8.01	8.22	8.12	8.39	8.80	10.03	11.08	0.00	0.00	0.00	0.00	0.00	5.22
1998	9.88	9.55	8.86	8.51	9.01	10.83	12.70	11.62	12.59	11.38	9.93	9.34	10.35
1999	9.17	9.09	8.90	9.56	10.73	11.99	7.08	13.24	12.66	11.62	9.50	9.30	10.24
2000	8.21	8.49	8.05	8.74	10.10	11.79	12.65	12.01	11.93	10.29	9.66	9.01	10.08
2001	7.97	8.49	9.55	9.82	11.66	13.30	14.81	14.68	15.05	12.15	10.16	9.02	11.39
2002	12.47	11.24	10.53	11.43	13.50	13.84	14.25	14.41	13.14	11.57	11.16	10.89	12.37
2003	9.35	8.65	9.17	9.34	9.96	11.66	13.04	13.18	13.21	11.84	10.08	9.48	10.75
2004	9.63	9.88	11.69	12.22	12.93	14.71	16.01	16.17	15.58	13.01	12.02	11.36	12.93
2005	11.41	11.33	11.48	11.51	13.07	15.34	16.29	16.89	16.22	14.41	13.44	13.19	13.72
2006	12.80	12.65	12.42	13.45	14.49	16.16	17.62	18.48	20.78	22.24	20.21	17.44	16.56
2007	16.61	15.11	13.99	14.58	16.09	16.69	18.04	18.91	18.43	13.37	14.75	14.97	15.96
2008	15.24	14.43	15.08	15.47	17.33	19.59	19.95	18.94	18.53	18.64	16.04	14.83	17.01
2009	14.99	14.91	15.21	16.76	19.95	22.88	24.96	24.20	21.66	18.42	16.48	16.26	18.89
2010	15.46	14.84	14.63	14.19	15.13	16.82	18.24	17.81	17.74	14.71	14.97	14.02	15.71
2011	12.97	13.01	13.60	15.08	15.82	18.42	20.00	20.17	18.54	16.47	13.88	12.09	15.84

DOE then calculated monthly energy price factors for each year by dividing the residential natural gas prices for each month by the natural gas annual average price for each year. Table 8C.3.11 and Figure 8C.3.2 show the calculated results for New York.

Table 8C.3.11 1989-2011 Monthly Natural Gas Price Factors for New York

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	0.85	0.86	0.96	0.89	0.92	1.07	1.16	1.21	1.19	1.03	0.98	0.87
1991	0.86	0.91	0.88	0.90	0.97	1.03	1.15	1.22	1.14	1.06	0.94	0.93
1992	0.88	0.88	0.86	0.87	0.95	1.13	1.20	1.24	1.13	1.02	0.94	0.90
1993	0.86	0.83	0.84	0.83	0.90	1.06	1.18	1.25	1.21	1.05	1.06	0.94
1994	0.84	0.80	0.79	0.86	1.02	1.09	1.22	1.27	1.21	1.04	0.93	0.94
1995	0.80	0.83	0.87	0.92	0.96	1.11	1.21	1.25	1.19	1.01	0.97	0.90
1996	0.86	0.81	0.81	0.84	0.92	1.08	1.23	1.27	1.25	1.18	0.92	0.82
1997	0.95	0.92	0.86	0.82	0.87	1.05	1.23	1.12	1.22	1.10	0.96	0.90
1998	0.90	0.89	0.87	0.93	1.05	1.17	0.69	1.29	1.24	1.14	0.93	0.91
1999	0.81	0.84	0.80	0.87	1.00	1.17	1.26	1.19	1.18	1.02	0.96	0.89
2000	0.70	0.75	0.84	0.86	1.02	1.17	1.30	1.29	1.32	1.07	0.89	0.79
2001	1.01	0.91	0.85	0.92	1.09	1.12	1.15	1.16	1.06	0.94	0.90	0.88
2002	0.87	0.80	0.85	0.87	0.93	1.08	1.21	1.23	1.23	1.10	0.94	0.88
2003	0.74	0.76	0.90	0.94	1.00	1.14	1.24	1.25	1.20	1.01	0.93	0.88
2004	0.83	0.83	0.84	0.84	0.95	1.12	1.19	1.23	1.18	1.05	0.98	0.96
2005	0.77	0.76	0.75	0.81	0.87	0.98	1.06	1.12	1.25	1.34	1.22	1.05
2006	1.04	0.95	0.88	0.91	1.01	1.05	1.13	1.18	1.15	0.84	0.92	0.94
2007	0.90	0.85	0.89	0.91	1.02	1.15	1.17	1.11	1.09	1.10	0.94	0.87
2008	0.79	0.79	0.81	0.89	1.06	1.21	1.32	1.28	1.15	0.98	0.87	0.86
2009	0.98	0.94	0.93	0.90	0.96	1.07	1.16	1.13	1.13	0.94	0.95	0.89
2010	0.82	0.82	0.86	0.95	1.00	1.16	1.26	1.27	1.17	1.04	0.88	0.76
2011	0.77	0.78	0.81	0.86	1.01	1.26	1.26	1.26	1.26	1.05	0.89	0.80

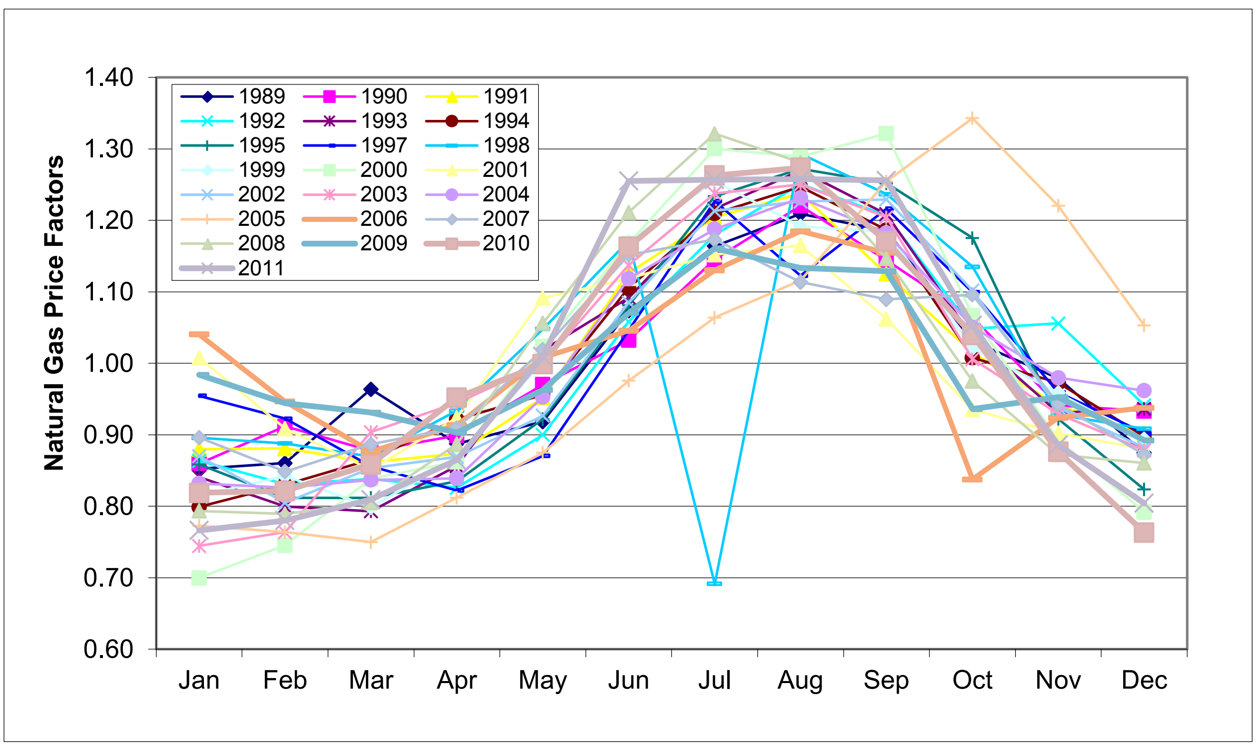

Figure 8C.3.2 1989-2011 Monthly Natural Gas Price Factors for New York

DOE then averaged the monthly energy price factors for 1993 to 2012 to develop an average energy price factor for each month. DOE performed the same calculations for each geographic area to develop the average monthly energy price factors weighted by housing projections in 2021 shown in Table 8C.3.12, which also includes the monthly energy price factor results calculated for New York.

Table 8C.3.12 Monthly Residential Natural Gas Energy Price Factors

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.89	0.90	0.91	0.93	0.97	1.05	1.14	1.16	1.13	1.01	0.97	0.94
Massachusetts	0.98	0.98	0.97	0.99	0.93	0.96	1.05	1.11	1.07	0.93	1.00	1.00
New York	0.88	0.87	0.88	0.92	1.02	1.16	1.23	1.16	1.13	1.00	0.89	0.84
New Jersey	0.91	0.90	0.90	0.93	0.98	1.08	1.12	1.12	1.10	1.01	0.96	0.94
Pennsylvania	0.82	0.82	0.84	0.88	0.99	1.14	1.26	1.29	1.23	1.00	0.89	0.84
Illinois	0.80	0.81	0.81	0.86	1.04	1.20	1.29	1.31	1.21	0.96	0.85	0.80
Indiana, Ohio	0.82	0.82	0.85	0.91	1.02	1.17	1.28	1.29	1.20	0.96	0.85	0.83
Michigan	0.83	0.83	0.84	0.89	0.99	1.13	1.25	1.29	1.19	0.99	0.90	0.87
Wisconsin	0.95	0.93	0.94	0.96	0.96	1.10	1.14	1.15	1.06	0.88	0.97	0.95
Iowa, Minnesota, North Dakota, South Dakota	0.85	0.84	0.85	0.87	0.99	1.16	1.25	1.29	1.20	0.95	0.89	0.85
Kansas, Nebraska	0.80	0.80	0.80	0.88	0.99	1.15	1.24	1.30	1.26	1.08	0.88	0.82
Missouri	0.73	0.73	0.74	0.83	0.96	1.17	1.34	1.42	1.32	1.12	0.88	0.78
Virginia	0.82	0.79	0.78	0.87	1.03	1.20	1.29	1.27	1.26	1.02	0.84	0.82
Delaware, District of Columbia, Maryland	0.82	0.81	0.83	0.91	1.04	1.16	1.24	1.24	1.21	1.01	0.88	0.84
Georgia	0.72	0.77	0.80	0.89	1.10	1.23	1.29	1.28	1.24	1.07	0.82	0.77
North Carolina, South Carolina	0.79	0.79	0.81	0.87	1.00	1.18	1.25	1.30	1.25	1.04	0.87	0.84
Florida	0.81	0.83	0.88	0.94	1.02	1.09	1.12	1.14	1.13	1.11	1.02	0.90
Alabama, Kentucky, Mississippi	0.80	0.80	0.83	0.92	1.04	1.16	1.19	1.22	1.19	1.08	0.92	0.85
Tennessee	0.82	0.83	0.83	0.90	0.99	1.13	1.20	1.24	1.19	1.08	0.91	0.86
Arkansas, Louisiana, Oklahoma	0.77	0.77	0.79	0.87	1.04	1.14	1.21	1.25	1.22	1.13	0.96	0.82
Texas	0.77	0.78	0.80	0.92	1.05	1.17	1.21	1.24	1.23	1.11	0.91	0.80
Colorado	0.81	0.82	0.85	0.88	0.97	1.23	1.24	1.31	1.22	0.97	0.88	0.83
Idaho, Montana, Utah, Wyoming	0.92	0.93	0.94	0.92	0.96	1.04	1.13	1.18	1.10	0.97	0.96	0.94
Arizona	0.77	0.79	0.82	0.90	1.01	1.11	1.21	1.26	1.22	1.14	0.96	0.83
Nevada, New Mexico	0.80	0.82	0.84	0.91	1.04	1.21	1.18	1.23	1.19	1.05	0.89	0.81
California	1.00	0.99	0.95	0.95	0.99	1.04	1.05	1.03	1.01	1.01	0.98	0.98
Oregon, Washington	0.90	0.91	0.91	0.93	0.97	1.02	1.12	1.17	1.14	1.03	0.95	0.93
Alaska	0.94	0.94	0.95	0.96	1.01	1.05	1.13	1.10	1.02	0.97	0.94	0.97
Hawaii	0.95	0.97	0.97	0.97	0.99	1.00	1.02	1.05	1.05	1.04	1.02	1.00
West Virginia	0.83	0.84	0.84	0.87	0.97	1.17	1.30	1.29	1.18	0.96	0.88	0.86
United States	0.85	0.86	0.87	0.91	1.00	1.12	1.19	1.22	1.16	1.00	0.91	0.87

8C.3.2.3 Monthly Residential Liquid Petroleum Gas Price Factor Calculations

DOE collected historical liquid petroleum gas (LPG) prices from 1995 to 2009 from EIA's Short-Term Energy Outlook.[4] The Short-Term Energy Outlook includes monthly LPG prices by Census Region (Northeast, South, Midwest, and West).[c]

The same process as used for electricity and natural gas price factors was used for calculating the monthly LPG price factors. These monthly price factors were calculated below, using data from the Northeast region. Table 8C.3.13 shows the Northeast residential LPG prices from 1995 to 2009.

Table 8C.3.13 Average LPG Prices for the Northeast (nominal cents/gallon)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	119	118	120	121	124	126	126	125	122	121	118	117
1996	123	125	128	125	130	131	129	127	127	133	135	145
1997	143	137	131	131	130	130	130	127	126	127	123	122
1998	121	120	120	123	124	124	122	121	119	118	115	114
1999	112	113	114	118	122	124	126	129	127	129	128	128
2000	132	148	148	145	148	151	155	154	157	159	156	160
2001	176	170	162	160	162	160	156	152	150	150	144	139
2002	139	138	139	143	142	144	143	141	141	142	142	142
2003	150	166	182	164	161	161	159	156	155	155	155	158
2004	169	173	171	168	170	173	173	176	181	187	193	187
2005	186	186	190	197	199	200	202	205	217	224	220	217
2006	221	220	220	225	231	237	242	244	240	232	229	228
2007	227	229	235	239	247	252	253	252	254	260	274	275
2008	282	280	284	292	306	320	333	329	324	305	280	267
2009	268	267	267	263	258	255	255	251	249	250	252	255

DOE then calculated monthly energy price factors for each year by dividing the prices for each month by the average price for each year. Table 8C.3.14 and Figure 8C.3.3 show the calculated results for the Northeast.

[c] Refer to www.census.gov/geo/www/us_regdiv.pdf.

Table 8C.3.14 Monthly LPG Price Factors for 1995-2009 for the Northeast

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	0.98	0.97	0.99	1.00	1.02	1.03	1.04	1.03	1.00	1.00	0.97	0.96
1996	0.94	0.97	0.99	0.96	1.00	1.01	0.99	0.98	0.98	1.02	1.04	1.12
1997	1.10	1.06	1.01	1.01	1.01	1.00	1.00	0.98	0.97	0.98	0.95	0.94
1998	1.01	1.00	1.00	1.02	1.03	1.03	1.02	1.01	0.99	0.98	0.96	0.95
1999	0.92	0.92	0.93	0.96	1.00	1.02	1.03	1.05	1.04	1.06	1.05	1.04
2000	0.87	0.98	0.98	0.96	0.98	1.00	1.03	1.02	1.04	1.05	1.03	1.06
2001	1.12	1.08	1.03	1.02	1.04	1.02	0.99	0.97	0.96	0.96	0.92	0.89
2002	0.98	0.97	0.98	1.01	1.01	1.02	1.01	1.00	1.00	1.01	1.00	1.00
2003	0.94	1.04	1.13	1.03	1.01	1.00	1.00	0.97	0.97	0.97	0.97	0.99
2004	0.95	0.98	0.96	0.95	0.96	0.98	0.98	1.00	1.02	1.06	1.09	1.06
2005	0.91	0.91	0.93	0.97	0.98	0.98	0.99	1.01	1.07	1.10	1.08	1.07
2006	0.96	0.95	0.95	0.98	1.00	1.03	1.05	1.06	1.04	1.01	0.99	0.99
2007	0.91	0.92	0.94	0.96	0.99	1.01	1.01	1.01	1.02	1.04	1.10	1.10
2008	0.94	0.93	0.95	0.97	1.02	1.06	1.11	1.10	1.08	1.02	0.93	0.89
2009	1.04	1.04	1.04	1.02	1.00	0.99	0.99	0.97	0.97	0.97	0.98	0.99
Avg	0.97	0.98	0.99	0.99	1.00	1.01	1.02	1.01	1.01	1.01	1.00	1.00

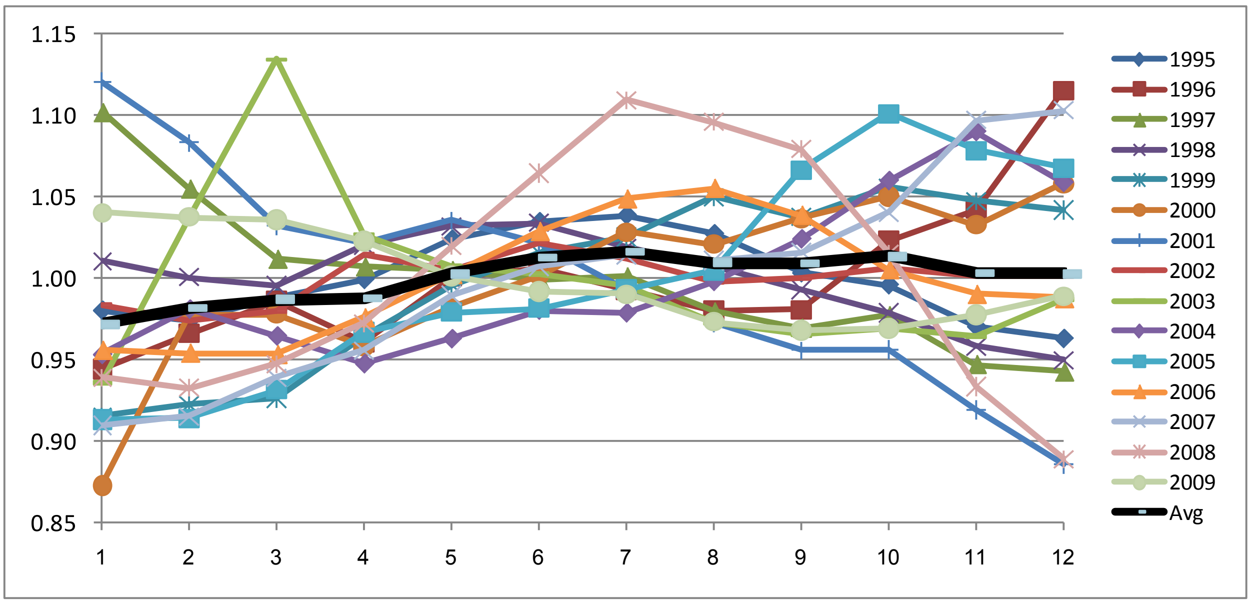

Figure 8C.3.3 Monthly LPG Factors for 1995-2009 for the Northeast

DOE then averaged the monthly energy price factors for 1995 to 2009 to develop an average energy price factor for each month. DOE performed the same calculations for each Census Region to develop the average monthly energy price factors weighted by housing projections in 2021 shown in Table 8C.3.15, which includes the calculated Northeast region monthly LPG energy price factors from 1995 to 2009.

Table 8C.3.15 Monthly Residential LPG Energy Price Factors

Census Regions	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northeast	0.97	0.98	0.99	0.99	1.00	1.01	1.02	1.01	1.01	1.01	1.00	1.00
South	1.04	1.04	1.03	1.01	1.00	0.97	0.94	0.93	0.96	0.98	1.03	1.07
Midwest	1.04	1.04	1.03	1.01	0.99	0.97	0.95	0.93	0.96	1.00	1.03	1.06
West	1.05	1.05	1.03	1.01	0.99	0.96	0.92	0.91	0.95	1.01	1.04	1.08
U.S.	1.02	1.03	1.02	1.02	1.02	1.00	0.95	0.93	0.96	0.99	1.02	1.05

8C.3.3 Seasonal Marginal Price Factors Determination

Marginal energy prices are the prices consumers pay for the last unit of energy used. DOE used the marginal energy prices for each building for the cost of saved energy associated with the use of higher-efficiency equipment. Because marginal prices reflect a change in a consumer's bill associated with a change in energy consumed, such prices are appropriate for determining energy cost savings associated with possible changes to efficiency standards.

EIA provides historical monthly consumption and expenditures by state. This data were used to determine 10 year average marginal prices for the RECS 2009 geographical areas, which are then used to convert average monthly energy prices into marginal monthly energy prices. Because a hearth product operates during both the heating and cooling seasons, DOE determined summer and winter marginal price factors. EIA provided RECS 2009 billing data that had been gathered from a subset of RECS housing records. For each household with billing data, the following are provided for each billing cycle: the start and end date, the electricity consumption in kWh, the electricity cost in dollars, the natural gas bill in dollars, and the gas consumption in hundreds of cubic feet. This data was used to validate marginal energy price factors by RECS 2009 geographical area.

For LPG-fired hearth products, DOE used the average LPG prices for each house for both base case products and higher-efficiency products, as the data necessary for estimating marginal prices were not available.

8C.3.3.1 Marginal Price Factor Calculation for Electricity and Natural Gas

EIA provides historical monthly consumption and expenditures by state. This data was used to determine 10 year average marginal prices for the RECS 2009 geographical areas DOE interpreted the slope of the regression line (consumption vs. expenditures) for each state as the marginal energy price for that state.

Table 8C.3.16 and Table 8C.3.17 show the resulting marginal electricity and natural gas marginal price factors.

Table 8C.3.16 Residential Marginal Electricity Price Factors using EIA 2003-2012 Data

Geographical Area	Summer	Winter
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.95	0.99
Massachusetts	0.96	1.04
New York	1.13	0.87
New Jersey	1.21	0.98
Pennsylvania	1.08	0.83
Illinois	0.98	0.72
Indiana, Ohio	1.00	0.75
Michigan	1.14	0.97
Wisconsin	1.01	0.89
Iowa, Minnesota, North Dakota, South Dakota	1.06	0.84
Kansas, Nebraska	1.16	0.74
Missouri	1.21	0.76
Virginia	1.08	0.85
Delaware, District of Columbia, Maryland	1.16	0.91
Georgia	1.16	0.84
North Carolina, South Carolina	0.97	0.83
Florida	1.01	0.93
Alabama, Kentucky, Mississippi	1.00	0.82
Tennessee	0.93	0.84
Arkansas, Louisiana, Oklahoma	1.04	0.74
Texas	1.05	0.90
Colorado	1.08	0.79
Idaho, Montana, Utah, Wyoming	1.10	0.93
Arizona	1.05	0.84
Nevada, New Mexico	1.04	0.88
California	1.21	1.13
Oregon, Washington	0.89	0.95
Alaska	0.85	0.91
Hawaii	1.46	0.89
West Virginia	0.92	0.84
United States	1.07	0.81

Table 8C.3.17 Residential Marginal Natural Gas Price Factors using EIA 2003-2012 Data

Geographical Area	Summer	Winter
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.83	0.92
Massachusetts	0.89	1.03
New York	0.75	0.89
New Jersey	0.84	0.95
Pennsylvania	0.73	0.93
Illinois	0.68	0.97
Indiana, Ohio	0.73	0.92
Michigan	0.78	0.93
Wisconsin	0.79	0.98
Iowa, Minnesota, North Dakota, South Dakota	0.72	0.97
Kansas, Nebraska	0.69	0.93
Missouri	0.60	0.82
Virginia	0.68	0.93
Delaware, District of Columbia, Maryland	0.70	0.92
Georgia	0.56	0.87
North Carolina, South Carolina	0.66	0.89
Florida	0.64	0.82
Alabama, Kentucky, Mississippi	0.75	0.87
Tennessee	0.74	0.94
Arkansas, Louisiana, Oklahoma	0.65	0.84
Texas	0.59	0.85
Colorado	0.69	0.91
Idaho, Montana, Utah, Wyoming	0.84	0.96
Arizona	0.64	0.85
Nevada, New Mexico	0.72	0.89
California	0.85	1.08
Oregon, Washington	0.84	0.94
Alaska	0.86	0.96
Hawaii	0.77	0.91
West Virginia	0.80	0.95
United States	0.74	0.94

8C.3.4 Results

DOE applied the regional monthly energy price factors to develop residential and commercial monthly energy prices for 2012 for electricity and natural gas (Table 8C.3.18 and Table 8C.3.19). Each geographical area was matched with the appropriate Census Region.

Table 8C.3.18 Residential Average Monthly Electricity Prices for 2012 Using Monthly Price Factors (2013$/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16
Massachusetts	0.15	0.15	0.15	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.15	0.15
New York	0.17	0.17	0.17	0.17	0.18	0.18	0.19	0.19	0.19	0.18	0.18	0.17
New Jersey	0.15	0.15	0.15	0.15	0.16	0.17	0.17	0.17	0.17	0.16	0.16	0.16
Pennsylvania	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.14	0.13	0.13	0.13	0.12
Illinois	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11
Indiana, Ohio	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11
Michigan	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.14	0.14	0.14
Wisconsin	0.13	0.13	0.13	0.13	0.14	0.14	0.13	0.13	0.14	0.14	0.13	0.13
Iowa, Minnesota, North Dakota, South Dakota	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.11	0.11	0.10
Kansas, Nebraska	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.11	0.10	0.10
Missouri	0.09	0.09	0.09	0.10	0.11	0.12	0.12	0.12	0.11	0.10	0.10	0.09
Virginia	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.10
Delaware, District of Columbia, Maryland	0.12	0.12	0.12	0.12	0.14	0.15	0.15	0.15	0.14	0.13	0.12	0.12
Georgia	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.13	0.12	0.11	0.11	0.10
North Carolina, South Carolina	0.11	0.11	0.11	0.11	0.12	0.11	0.12	0.12	0.12	0.12	0.11	0.11
Florida	0.11	0.11	0.12	0.12	0.12	0.11	0.12	0.12	0.12	0.12	0.12	0.12
Alabama, Kentucky, Mississippi	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10
Tennessee	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.10
Arkansas, Louisiana, Oklahoma	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.09	0.09
Texas	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.11	0.11
Colorado	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11
Idaho, Montana, Utah, Wyoming	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Arizona	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11
Nevada, New Mexico	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
California	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.16
Oregon, Washington	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Alaska	0.17	0.17	0.18	0.18	0.19	0.19	0.19	0.19	0.18	0.18	0.18	0.18
Hawaii	0.36	0.37	0.37	0.37	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.39
West Virginia	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.10
United States	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11

Table 8C.3.19 Residential Average Monthly Natural Gas Prices for 2012 Using Monthly Price Factors (2013$/MMBtu)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	14.4	14.5	14.6	14.9	15.6	16.9	18.4	18.7	18.2	16.3	15.5	15.1
Massachusetts	12.9	12.9	12.8	13.1	12.3	12.6	13.9	14.7	14.2	12.3	13.3	13.2
New York	12.8	12.6	12.8	13.3	14.8	16.9	17.8	16.8	16.4	14.4	12.9	12.1
New Jersey	10.9	10.7	10.7	11.0	11.7	12.9	13.4	13.4	13.2	12.1	11.5	11.2
Pennsylvania	11.4	11.6	11.8	12.3	13.8	15.9	17.6	18.1	17.2	14.0	12.4	11.8
Illinois	8.1	8.2	8.2	8.7	10.6	12.2	13.1	13.3	12.3	9.7	8.6	8.1
Indiana, Ohio	11.3	11.4	11.8	12.6	14.1	16.2	17.7	17.9	16.6	13.3	11.8	11.5
Michigan	10.1	10.1	10.3	10.8	12.0	13.7	15.2	15.7	14.5	12.1	10.9	10.5
Wisconsin	9.6	9.3	9.5	9.6	9.7	11.1	11.5	11.7	10.7	8.8	9.8	9.6
Iowa, Minnesota, North Dakota, South Dakota	8.3	8.1	8.2	8.4	9.6	11.2	12.1	12.5	11.6	9.2	8.6	8.2
Kansas, Nebraska	9.5	9.5	9.5	10.4	11.7	13.7	14.7	15.4	15.0	12.9	10.4	9.8
Missouri	12.2	12.2	12.3	13.8	15.9	19.4	22.2	23.5	21.9	18.6	14.6	13.0
Virginia	12.1	11.6	11.5	12.8	15.1	17.6	18.9	18.6	18.6	15.1	12.4	12.0
Delaware, District of Columbia, Maryland	11.9	11.8	12.1	13.2	15.0	16.9	18.0	17.9	17.6	14.6	12.8	12.2
Georgia	13.4	14.2	14.9	16.5	20.5	22.8	24.0	23.8	23.1	19.9	15.3	14.3
North Carolina, South Carolina	12.6	12.5	12.9	13.9	15.9	18.8	19.9	20.7	19.8	16.5	13.8	13.3
Florida	15.4	15.7	16.7	17.7	19.3	20.5	21.2	21.6	21.3	20.9	19.2	17.0
Alabama, Kentucky, Mississippi	11.7	11.7	12.1	13.3	15.2	16.9	17.3	17.7	17.3	15.7	13.4	12.4
Tennessee	9.9	10.0	10.0	10.9	12.0	13.7	14.6	15.0	14.3	13.0	11.0	10.4
Arkansas, Louisiana, Oklahoma	10.6	10.5	10.8	11.9	14.1	15.6	16.6	17.1	16.6	15.5	13.1	11.2
Texas	9.5	9.5	9.8	11.2	12.9	14.4	14.8	15.2	15.1	13.6	11.2	9.9
Colorado	7.8	7.9	8.2	8.4	9.3	11.8	11.9	12.6	11.7	9.3	8.4	8.0
Idaho, Montana, Utah, Wyoming	8.2	8.2	8.4	8.2	8.5	9.2	10.0	10.5	9.8	8.6	8.5	8.3
Arizona	13.5	14.0	14.5	15.8	17.7	19.6	21.4	22.1	21.4	20.0	16.9	14.6
Nevada, New Mexico	8.7	8.9	9.1	9.8	11.3	13.1	12.8	13.3	12.8	11.3	9.6	8.7
California	9.2	9.1	8.8	8.8	9.2	9.6	9.7	9.6	9.3	9.4	9.0	9.0
Oregon, Washington	11.0	11.2	11.2	11.5	12.0	12.6	13.9	14.4	14.0	12.7	11.7	11.4
Alaska	8.1	8.2	8.3	8.4	8.8	9.1	9.8	9.6	8.9	8.4	8.2	8.4
Hawaii	49.6	50.7	50.8	51.0	51.8	52.3	53.6	54.9	54.8	54.5	53.7	52.6
West Virginia	10.8	10.8	10.9	11.3	12.5	15.1	16.9	16.6	15.3	12.5	11.5	11.1
United States	10.5	10.5	10.6	11.2	12.3	13.8	14.6	14.9	14.3	12.3	11.2	10.7

DOE then applied the marginal price factors to the monthly energy prices to develop marginal residential monthly energy prices for 2012 for electricity and natural gas (Table 8C.3.20 and Table 8C.3.21).

Table 8C.3.20 Residential Marginal Monthly Electricity Prices for 2012 Using Marginal Price Factors (2013$/MMBtu)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Massachusetts	0.15	0.16	0.16	0.14	0.15	0.15	0.14	0.15	0.15	0.15	0.16	0.16
New York	0.15	0.15	0.15	0.20	0.20	0.21	0.21	0.21	0.21	0.20	0.15	0.15
New Jersey	0.15	0.15	0.15	0.19	0.19	0.20	0.21	0.21	0.21	0.19	0.15	0.15
Pennsylvania	0.10	0.10	0.10	0.14	0.14	0.15	0.15	0.15	0.15	0.14	0.11	0.10
Illinois	0.07	0.08	0.08	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.08	0.08
Indiana, Ohio	0.08	0.08	0.08	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.09	0.08
Michigan	0.13	0.14	0.13	0.16	0.16	0.17	0.17	0.17	0.17	0.16	0.14	0.14
Wisconsin	0.11	0.12	0.12	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.12	0.12
Iowa, Minnesota, North Dakota, South Dakota	0.09	0.09	0.09	0.12	0.12	0.13	0.13	0.13	0.12	0.12	0.09	0.09
Kansas, Nebraska	0.07	0.07	0.07	0.12	0.13	0.14	0.14	0.14	0.14	0.13	0.08	0.07
Missouri	0.07	0.07	0.07	0.12	0.13	0.15	0.14	0.14	0.13	0.12	0.07	0.07
Virginia	0.09	0.09	0.09	0.12	0.13	0.13	0.13	0.13	0.13	0.12	0.09	0.09
Delaware, District of Columbia, Maryland	0.11	0.11	0.11	0.14	0.16	0.17	0.17	0.17	0.16	0.15	0.11	0.11
Georgia	0.09	0.09	0.09	0.13	0.13	0.14	0.14	0.15	0.14	0.13	0.09	0.09
North Carolina, South Carolina	0.09	0.09	0.09	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.09	0.09
Florida	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11
Alabama, Kentucky, Mississippi	0.08	0.08	0.08	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.09	0.08
Tennessee	0.08	0.08	0.08	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.09	0.09
Arkansas, Louisiana, Oklahoma	0.06	0.06	0.06	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.07	0.06
Texas	0.09	0.09	0.10	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.10	0.10
Colorado	0.09	0.09	0.09	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.09	0.09
Idaho, Montana, Utah, Wyoming	0.09	0.09	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.09	0.09
Arizona	0.08	0.09	0.09	0.12	0.13	0.13	0.13	0.13	0.13	0.12	0.09	0.09
Nevada, New Mexico	0.10	0.10	0.10	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.11	0.10
California	0.17	0.17	0.17	0.18	0.19	0.19	0.20	0.20	0.19	0.18	0.18	0.18
Oregon, Washington	0.08	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09
Alaska	0.16	0.16	0.16	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.16
Hawaii	0.33	0.33	0.33	0.54	0.55	0.55	0.56	0.56	0.56	0.57	0.35	0.35
West Virginia	0.08	0.08	0.08	0.09	0.10	0.09	0.09	0.09	0.09	0.10	0.09	0.08
United States	0.09	0.09	0.09	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.10	0.09

Table 8C.3.21 Residential Marginal Monthly Natural Gas Prices for 2012 Using Marginal Price Factors (2012$/MMBtu)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	13.21	13.32	13.42	12.40	12.97	14.03	15.26	15.52	15.11	13.52	14.27	13.84
Massachusetts	13.30	13.29	13.19	11.75	10.98	11.30	12.45	13.13	12.71	11.00	13.66	13.60
New York	11.44	11.24	11.38	10.01	11.12	12.67	13.38	12.61	12.35	10.85	11.47	10.81
New Jersey	10.33	10.20	10.22	9.23	9.82	10.78	11.23	11.18	11.03	10.13	10.89	10.64
Pennsylvania	10.58	10.70	10.90	8.93	10.02	11.55	12.78	13.11	12.45	10.16	11.50	10.91
Illinois	7.93	7.96	8.01	5.91	7.17	8.26	8.88	8.99	8.33	6.58	8.40	7.91
Indiana, Ohio	10.43	10.53	10.88	9.17	10.20	11.78	12.82	12.99	12.08	9.65	10.91	10.65
Michigan	9.40	9.41	9.55	8.38	9.33	10.68	11.82	12.25	11.30	9.41	10.19	9.81
Wisconsin	9.37	9.16	9.33	7.66	7.67	8.78	9.11	9.26	8.48	7.02	9.64	9.39
Iowa, Minnesota, North Dakota, South Dakota	8.04	7.89	8.03	6.03	6.83	8.01	8.65	8.92	8.30	6.59	8.39	8.02
Kansas, Nebraska	8.81	8.86	8.87	7.21	8.12	9.51	10.18	10.69	10.39	8.92	9.70	9.08
Missouri	9.98	9.98	10.11	8.20	9.50	11.59	13.25	14.03	13.07	11.08	12.00	10.67
Virginia	11.23	10.82	10.69	8.65	10.23	11.95	12.83	12.63	12.59	10.21	11.53	11.20
Delaware, District of Columbia, Maryland	11.03	10.94	11.20	9.32	10.59	11.89	12.65	12.64	12.38	10.28	11.83	11.25
Georgia	11.58	12.31	12.86	9.19	11.42	12.74	13.40	13.30	12.88	11.08	13.22	12.39
North Carolina, South Carolina	11.26	11.22	11.53	9.20	10.56	12.46	13.22	13.70	13.15	10.93	12.31	11.94
Florida	12.65	12.90	13.78	11.41	12.42	13.21	13.62	13.91	13.71	13.48	15.83	14.05
Alabama, Kentucky, Mississippi	10.15	10.13	10.46	9.95	11.33	12.59	12.92	13.19	12.89	11.69	11.61	10.76
Tennessee	9.31	9.44	9.44	8.04	8.84	10.11	10.78	11.12	10.61	9.63	10.39	9.80
Arkansas, Louisiana, Oklahoma	8.88	8.84	9.07	7.70	9.16	10.09	10.74	11.08	10.78	10.05	10.96	9.43
Texas	8.01	8.06	8.28	6.68	7.66	8.54	8.80	9.02	8.97	8.10	9.45	8.35
Colorado	7.09	7.18	7.43	5.78	6.41	8.12	8.17	8.67	8.02	6.42	7.66	7.28
Idaho, Montana, Utah, Wyoming	7.84	7.87	8.01	6.82	7.13	7.71	8.38	8.76	8.18	7.22	8.13	7.97
Arizona	11.51	11.87	12.29	10.04	11.27	12.47	13.57	14.08	13.62	12.72	14.33	12.39
Nevada, New Mexico	7.69	7.88	8.08	7.10	8.13	9.46	9.20	9.56	9.24	8.15	8.50	7.77
California	9.94	9.84	9.48	7.45	7.77	8.17	8.22	8.10	7.89	7.95	9.75	9.77
Oregon, Washington	10.35	10.47	10.52	9.67	10.05	10.56	11.64	12.11	11.77	10.65	11.01	10.72
Alaska	7.82	7.89	7.95	7.20	7.55	7.81	8.41	8.25	7.63	7.25	7.87	8.12
Hawaii	45.38	46.34	46.42	39.47	40.05	40.49	41.44	42.49	42.37	42.15	49.08	48.09
West Virginia	10.26	10.30	10.42	9.02	9.99	12.08	13.44	13.28	12.20	9.95	10.91	10.59
United States	9.80	9.85	9.97	8.31	9.14	10.24	10.86	11.09	10.61	9.14	10.47	10.03

DOE applied the regional monthly energy price factors to the annual LPG data presented in chapter 8 to develop residential energy prices for 2012 (Table 8C.3.22). Each geographical area was matched with the appropriate Census Region.

Table 8C.3.22 Residential Monthly LPG Prices for 2012 Using Average Price Factors (2013$/MMBtu)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	31.63	31.96	32.13	32.15	32.64	32.97	33.07	32.87	32.84	32.99	32.66	32.64
Massachusetts	33.96	34.31	34.49	34.51	35.04	35.39	35.51	35.29	35.26	35.42	35.06	35.04
New York	32.15	32.48	32.65	32.67	33.17	33.50	33.61	33.40	33.38	33.53	33.19	33.17
New Jersey	33.35	33.69	33.87	33.89	34.41	34.75	34.86	34.65	34.62	34.78	34.43	34.40
Pennsylvania	30.32	30.63	30.79	30.81	31.28	31.59	31.70	31.50	31.48	31.62	31.30	31.28
Illinois	22.60	22.59	22.32	21.97	21.70	20.94	20.31	20.25	20.72	21.34	22.31	23.29
Indiana, Ohio	26.41	26.40	26.08	25.67	25.36	24.47	23.74	23.67	24.22	24.93	26.07	27.22
Michigan	24.27	24.26	23.97	23.60	23.30	22.49	21.82	21.75	22.26	22.91	23.96	25.02
Wisconsin	22.40	22.40	22.13	21.78	21.51	20.76	20.14	20.08	20.54	21.15	22.12	23.09
Iowa, Minnesota, North Dakota, South Dakota	23.27	23.26	22.98	22.62	22.34	21.56	20.92	20.85	21.34	21.97	22.97	23.99
Kansas, Nebraska	22.37	22.36	22.09	21.75	21.48	20.72	20.10	20.05	20.51	21.12	22.08	23.06
Missouri	23.01	23.00	22.72	22.37	22.09	21.32	20.68	20.62	21.10	21.72	22.71	23.72
Virginia	25.45	25.53	25.14	24.66	24.27	23.81	23.27	22.83	23.40	24.37	25.12	25.94
Delaware, District of Columbia, Maryland	34.64	34.75	34.23	33.56	33.03	32.41	31.67	31.07	31.85	33.17	34.20	35.31
Georgia	27.67	27.75	27.33	26.80	26.38	25.89	25.29	24.82	25.43	26.49	27.31	28.20
North Carolina, South Carolina	27.70	27.78	27.36	26.83	26.41	25.91	25.32	24.84	25.46	26.52	27.34	28.23
Florida	28.63	28.72	28.29	27.74	27.31	26.79	26.18	25.68	26.33	27.42	28.27	29.19
Alabama, Kentucky, Mississippi	24.55	24.63	24.26	23.79	23.41	22.97	22.44	22.02	22.57	23.51	24.24	25.02
Tennessee	28.05	28.14	27.72	27.18	26.75	26.25	25.65	25.16	25.79	26.86	27.70	28.59
Arkansas, Louisiana, Oklahoma	21.13	21.20	20.88	20.48	20.15	19.77	19.32	18.96	19.43	20.24	20.86	21.54
Texas	15.90	15.95	15.71	15.40	15.16	14.88	14.54	14.26	14.62	15.22	15.70	16.21
Colorado	25.58	25.63	25.19	24.62	24.02	23.34	22.50	22.21	23.09	24.47	25.26	26.24
Idaho, Montana, Utah, Wyoming	24.54	24.59	24.17	23.62	23.05	22.39	21.58	21.31	22.15	23.48	24.23	25.18
Arizona	31.43	31.48	30.94	30.24	29.51	28.67	27.63	27.29	28.36	30.06	31.03	32.24
Nevada, New Mexico	26.03	26.07	25.63	25.04	24.44	23.74	22.89	22.60	23.49	24.90	25.70	26.70
California	29.93	29.99	29.48	28.81	28.11	27.31	26.32	25.99	27.02	28.63	29.56	30.71
Oregon, Washington	27.50	27.56	27.08	26.47	25.83	25.09	24.19	23.88	24.83	26.31	27.16	28.21
Alaska	29.89	29.95	29.43	28.76	28.07	27.27	26.28	25.95	26.98	28.59	29.51	30.66
Hawaii	40.16	40.24	39.55	38.65	37.72	36.64	35.32	34.87	36.25	38.42	39.65	41.20
West Virginia	32.94	33.04	32.55	31.92	31.41	30.82	30.11	29.55	30.28	31.54	32.52	33.57
United States	18.70	18.81	18.69	18.56	18.58	18.20	17.38	16.98	17.50	18.07	18.65	19.21

8C.4 HOUSEHOLD ENERGY PRICE ADJUSTMENT FACTOR

RECS 2009 reports the total annual consumption and expenditure of each energy use type. From this data DOE determined average energy prices per geographical area. To take into account that household energy prices vary inside a geographical area, DOE developed an adjustment factor based on the reported average energy price in RECS 2009 divided by the average energy price of the geographical region. This factor was then multiplied times the monthly marginal energy prices (for natural gas and electricity) or the monthly price developed above to come up with the household energy price.

8C.5 ENERGY PRICE TRENDS

8C.5.1 Residential Energy Price Trends

DOE used *AEO 2014* Reference Case scenarios for the nine census divisions. DOE applied the projected energy price for each of the nine census divisions to each household in the sample based on the household's location.

To arrive at prices in future years, DOE multiplied the prices described in the preceding section by the forecast of annual average price changes in EIA's *AEO 2014*.[5] Figure 8C.5.1 shows the national residential electricity price trend. To estimate the trend after 2040, DOE followed past guidelines provided to the Federal Energy Management Program (FEMP) by EIA and used the average rate of change during 2025–2040 for electricity, natural gas, and LPG.

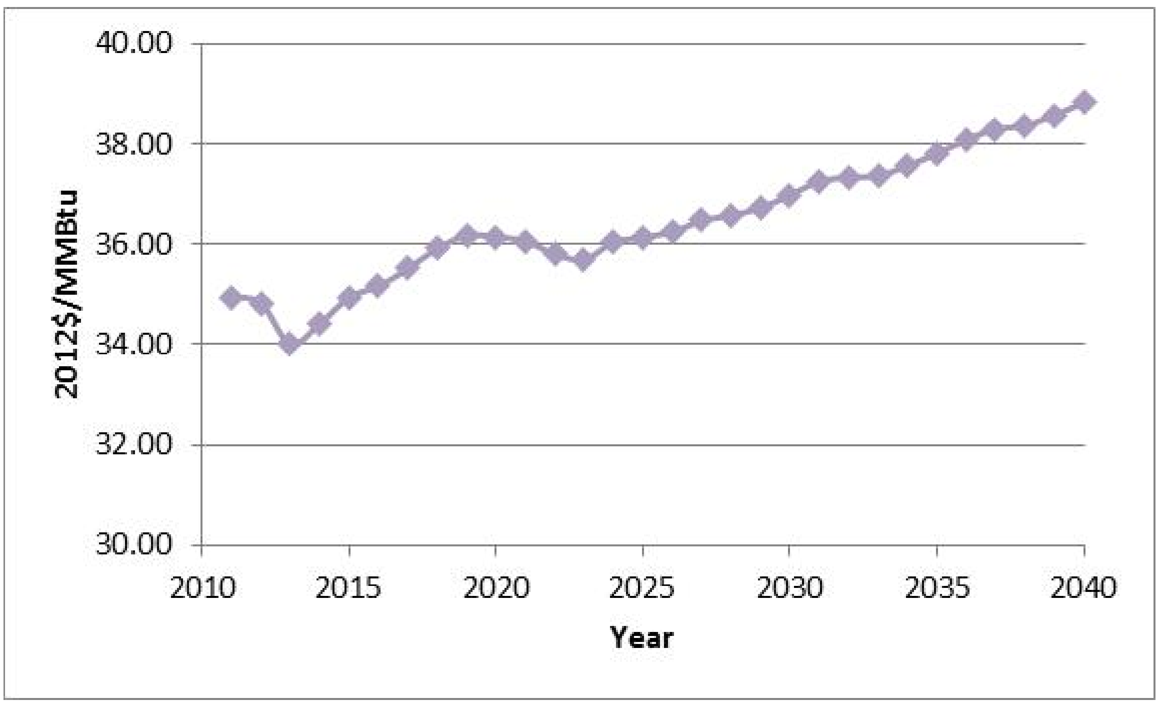

Figure 8C.5.1 Projected Residential National Electricity Price

Figure 8C.5.2 shows the residential national electricity price trends, disaggregated by the nine census divisions.

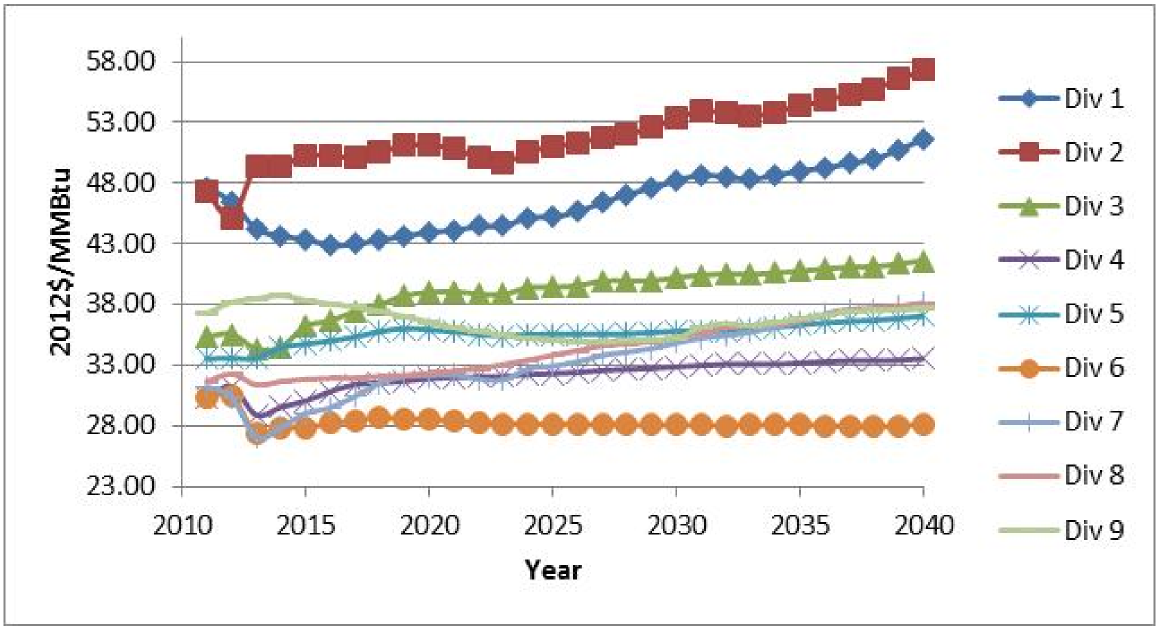

Figure 8C.5.2 Projected Residential Division Electricity Prices

Figure 8C.5.3 shows the residential national natural gas price trends.

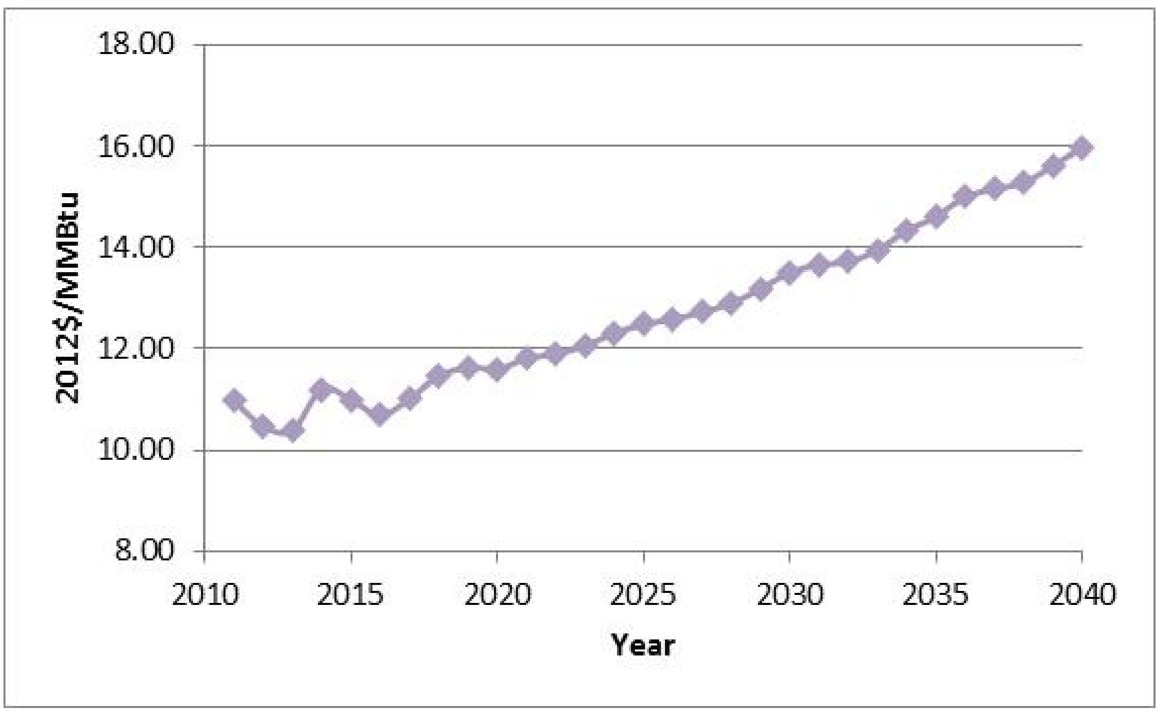

Figure 8C.5.3 Projected Residential National Natural Gas Price

Figure 8C.5.4 shows the residential national natural gas price trends, disaggregated by the nine census divisions.

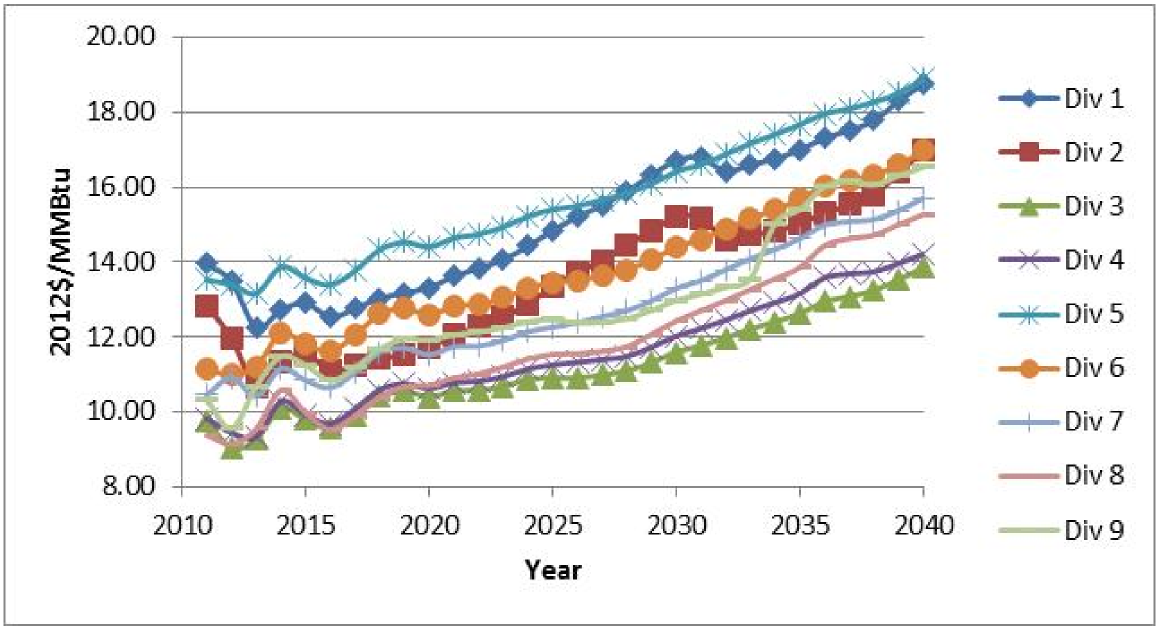

Figure 8C.5.4 Projected Residential Division Natural Gas Prices

Figure 8C.5.5 shows the residential national LPG price trends.

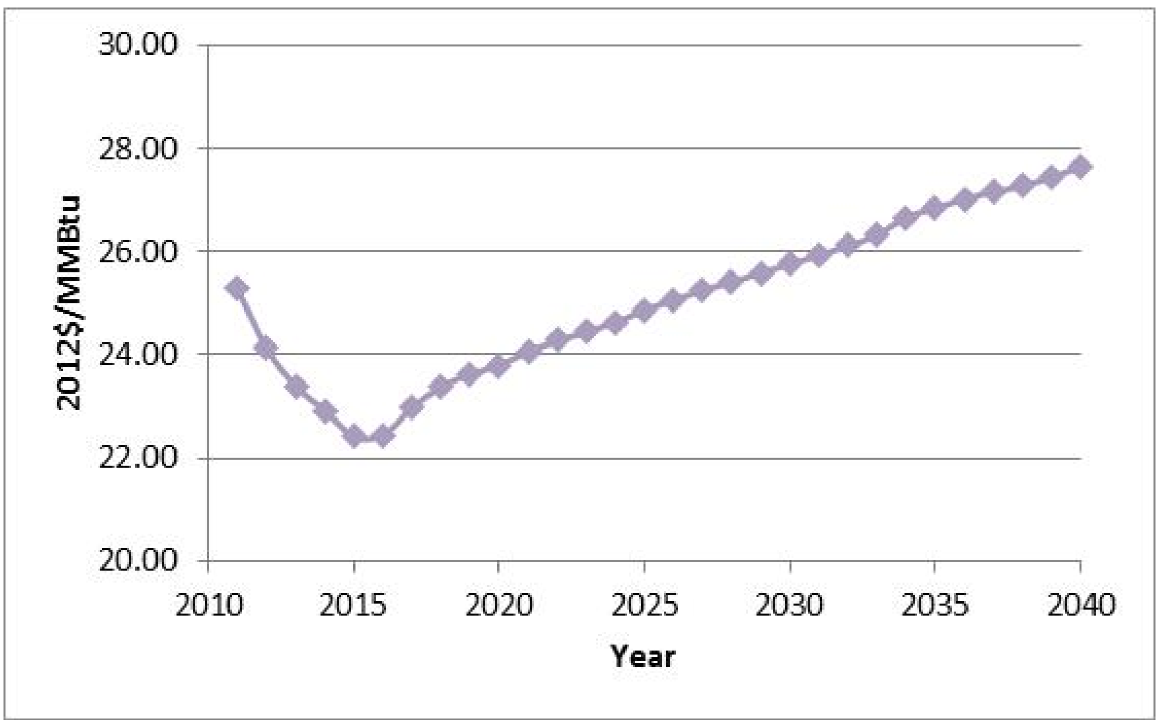

Figure 8C.5.5 Projected Residential National LPG Prices

Figure 8C.5.6 shows the residential national LPG price trends, disaggregated by the nine census divisions.

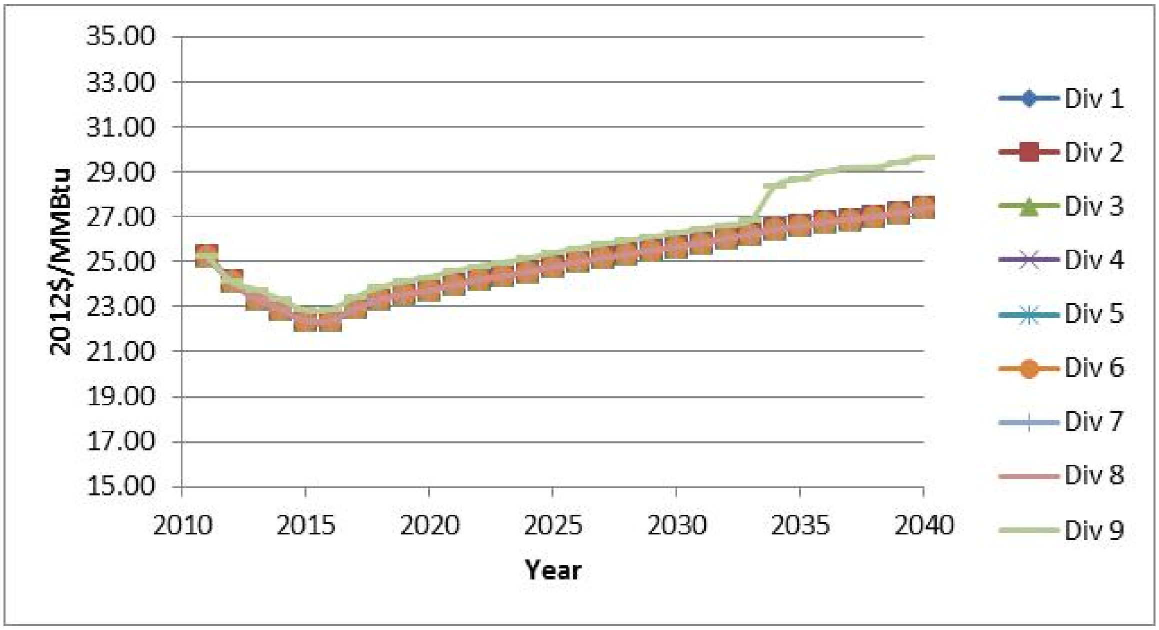

Figure 8C.5.6 Projected Residential Division LPG Prices

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APPENDIX 8D. DISTRIBUTIONS USED FOR DISCOUNT RATES

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APPENDIX 8D. DISTRIBUTIONS USED FOR DISCOUNT RATES

8D.1 INTRODUCTION

The Department of Energy (DOE) estimated discount rate distributions by consumer type: residential and commercial consumers. This appendix describes the distributions used.

8D.2 DISTRIBUTIONS USED FOR RESIDENTIAL CONSUMER DISCOUNT RATES

The Department of Energy (DOE) derived consumer discount rates for the life-cycle cost (LCC) analysis using data on interest or return rates for various types of debt and equity to calculate a real effective discount rate for each household in the Federal Reserve Board's *Survey of Consumer Finances (SCF)* in 1995, 1998, 2001, 2004, 2007, and 2010.[1] To account for variation among households in rates for each of the types, DOE sampled a rate for each household in its building sample from a distribution of discount rates for each of six income groups. This appendix describes the distributions used.

8D.2.1 Distribution of Rates for Debt Classes

Figure 8D.2.1 through Figure 8D.2.6 show the distribution of real interest rates for different types of household debt. The data source for the interest rates for mortgages, home equity loans, credit cards, installment loans, other residence loans, and other lines of credit is the Federal Reserve Board's *SCF* in 1995, 1998, 2001, 2004, 2007, and 2010.[1] DOE adjusted the nominal rates to real rates using the annual inflation rate in each year.

Using the appropriate *SCF* data for each year, DOE adjusted the nominal mortgage interest rate and the nominal home equity loan interest rate for each relevant household in the *SCF* for mortgage tax deduction and inflation. In cases where the effective interest rate is equal to or below the inflation rate (resulting in a negative real interest rate), DOE set the real effective interest rate to zero.

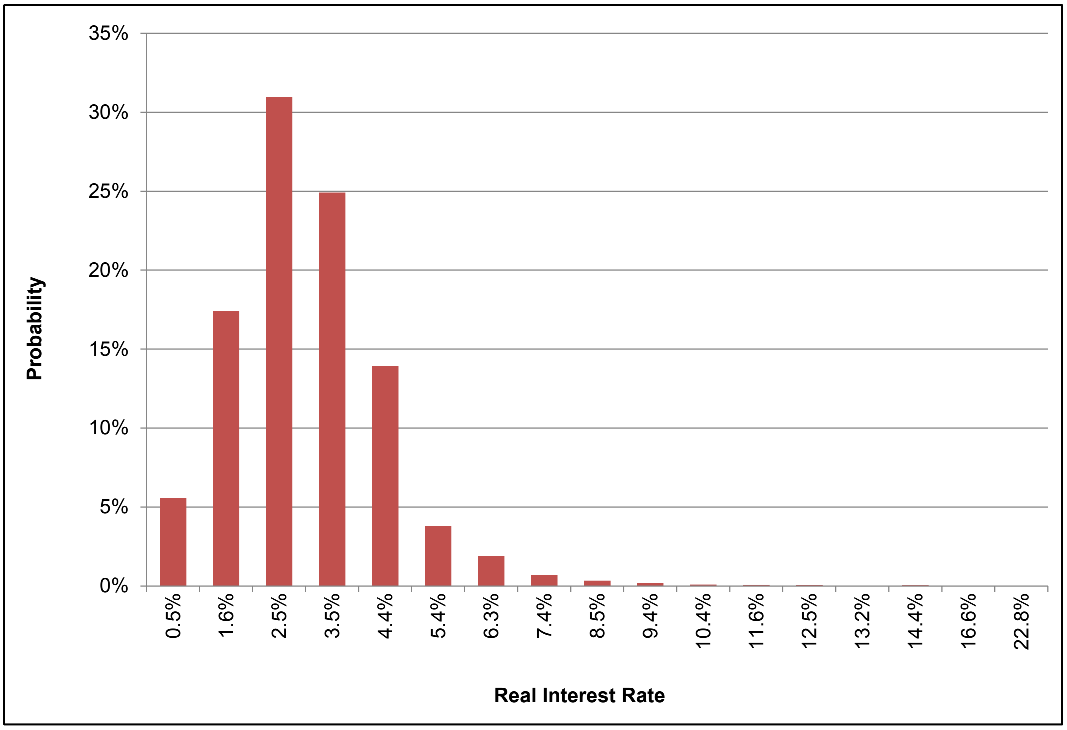

Figure 8D.2.1 Distribution of Mortgage Interest Rates

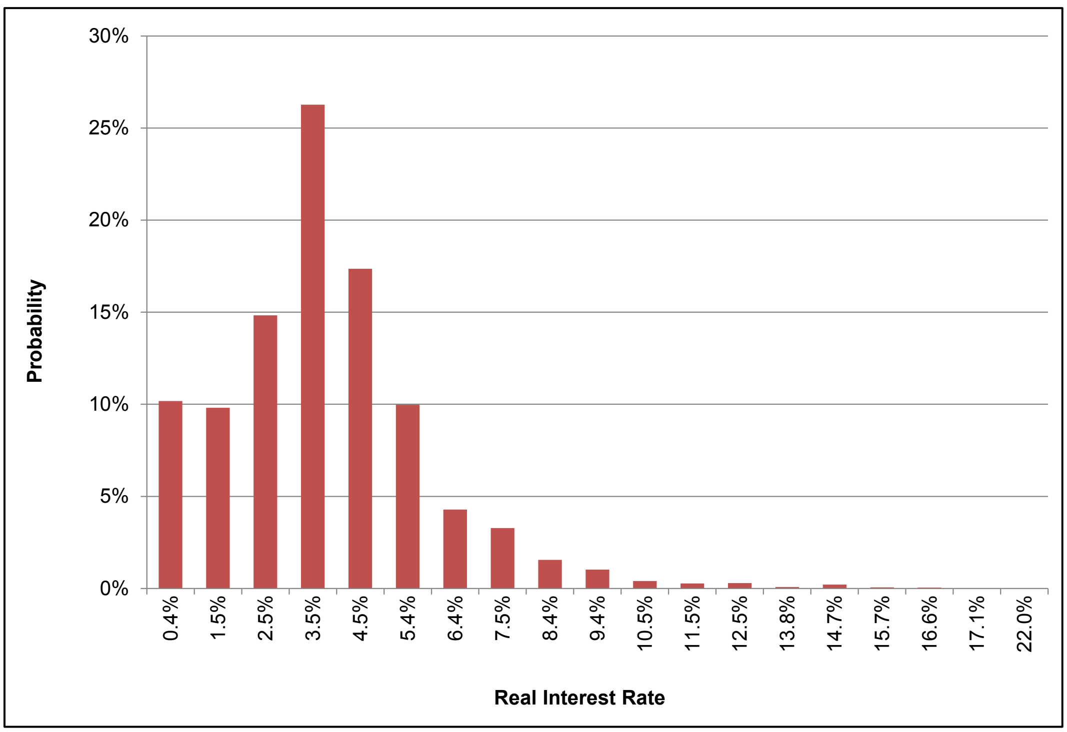

Figure 8D.2.2 Distribution of Home Equity Loan Interest Rates

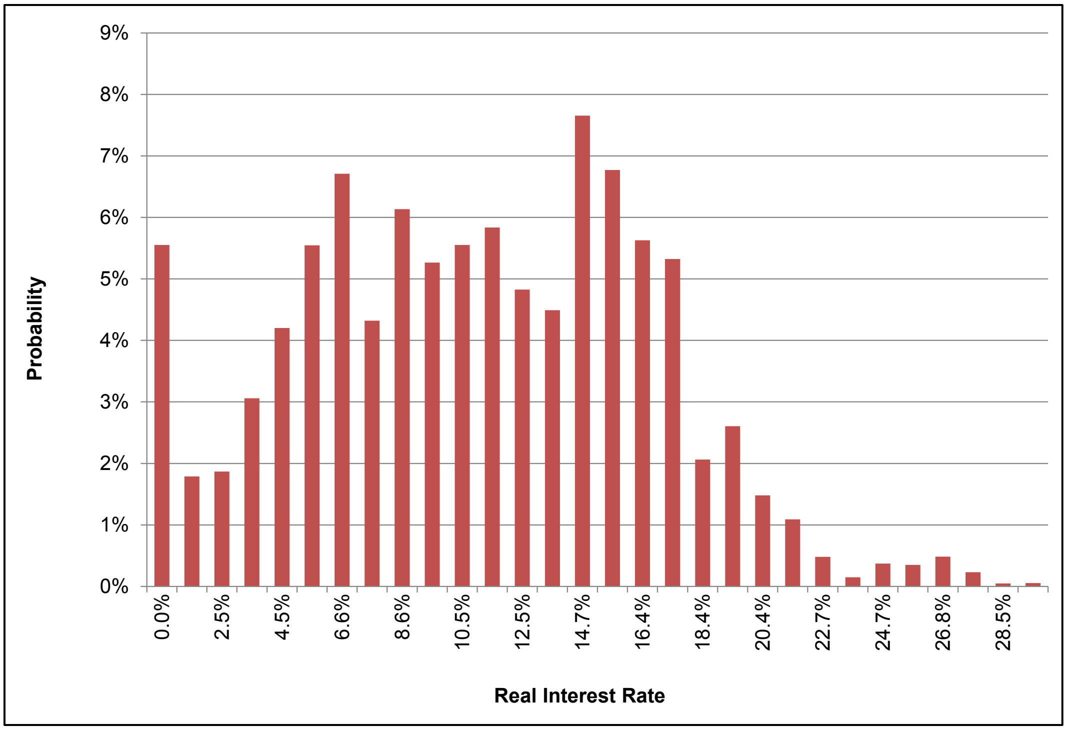

Figure 8D.2.3 Distribution of Credit Card Interest Rates

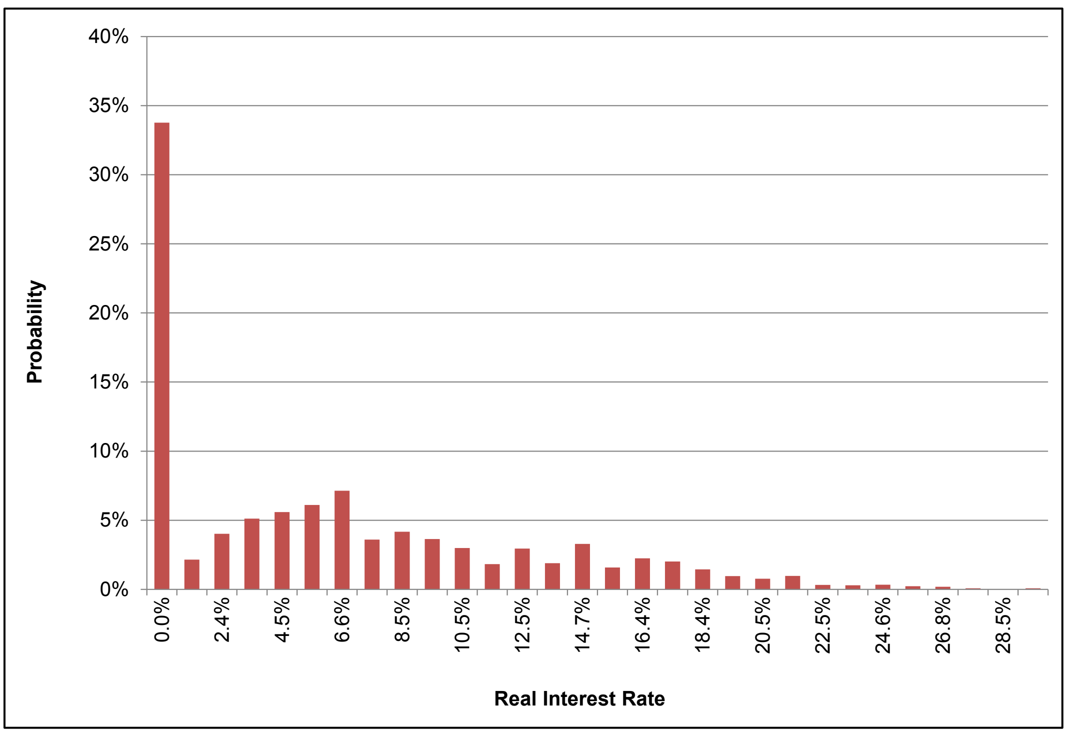

Figure 8D.2.4 Distribution of Installment Loan Interest Rates

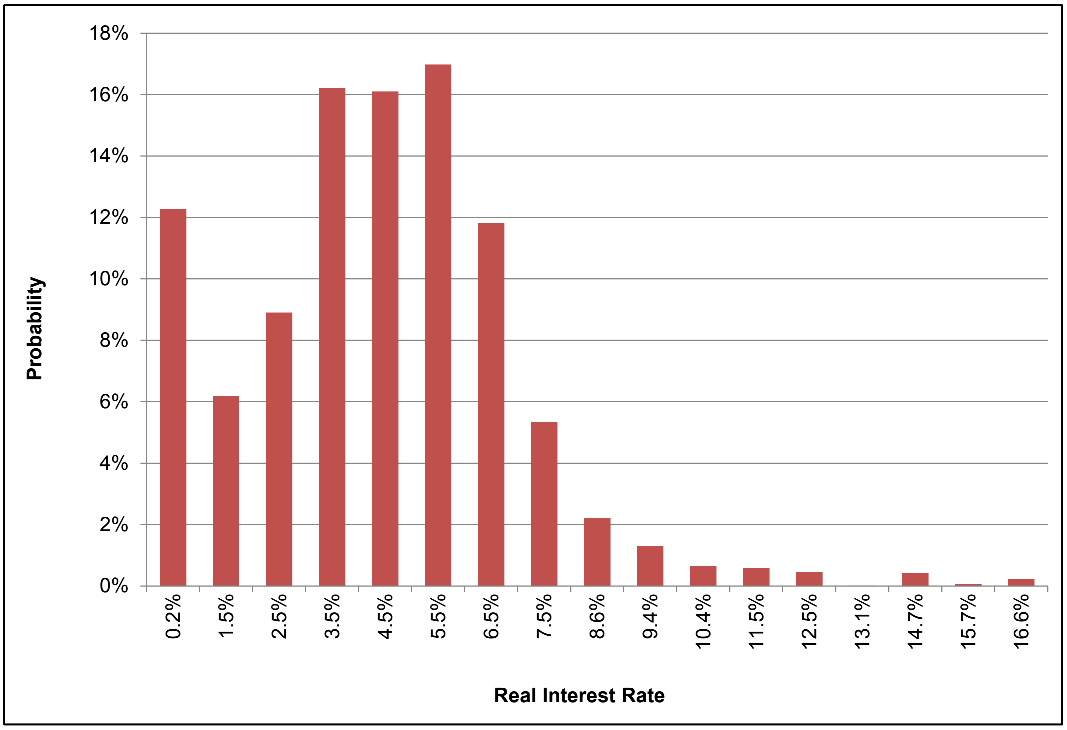

Figure 8D.2.5 Distribution of Other Residence Loan Interest Rates

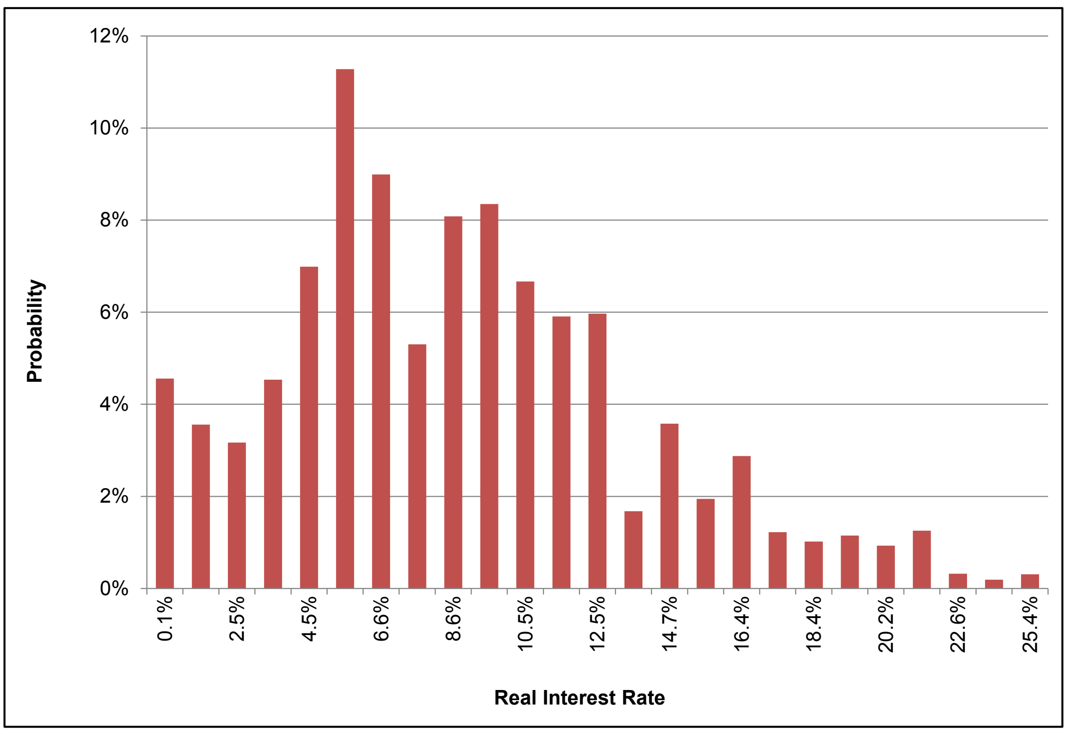

Figure 8D.2.6 Distribution of Other Lines of Credit Loan Interest Rates

8D.2.2 Distribution of Rates for Equity Classes

Figure 8D.2.7 through Figure 8D.2.13 show the distribution of real interest rates for different types of equity. Data for equity classes are not available from the Federal Reserve Board's *SCF*, so DOE derived data for these classes from national-level historical data (1984-2013). The interest rates associated with certificates of deposit (CDs),[2] savings bonds,[3] and AAA corporate bonds[4] are from Federal Reserve Board time-series data. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts are from Cost of Savings Index data.[5] The rates for stocks are the annual returns on the Standard and Poor's (S&P) 500.[6] The mutual fund rates are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year.

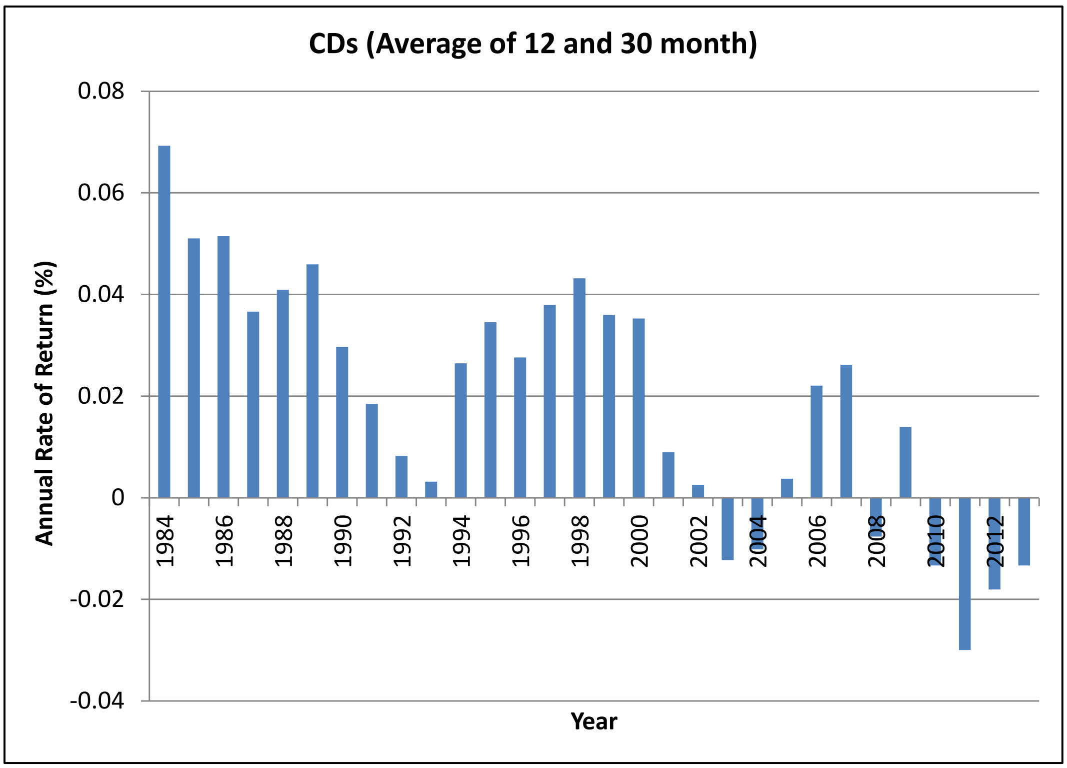

Figure 8D.2.7 Distribution of Annual Rate of Return on CDs

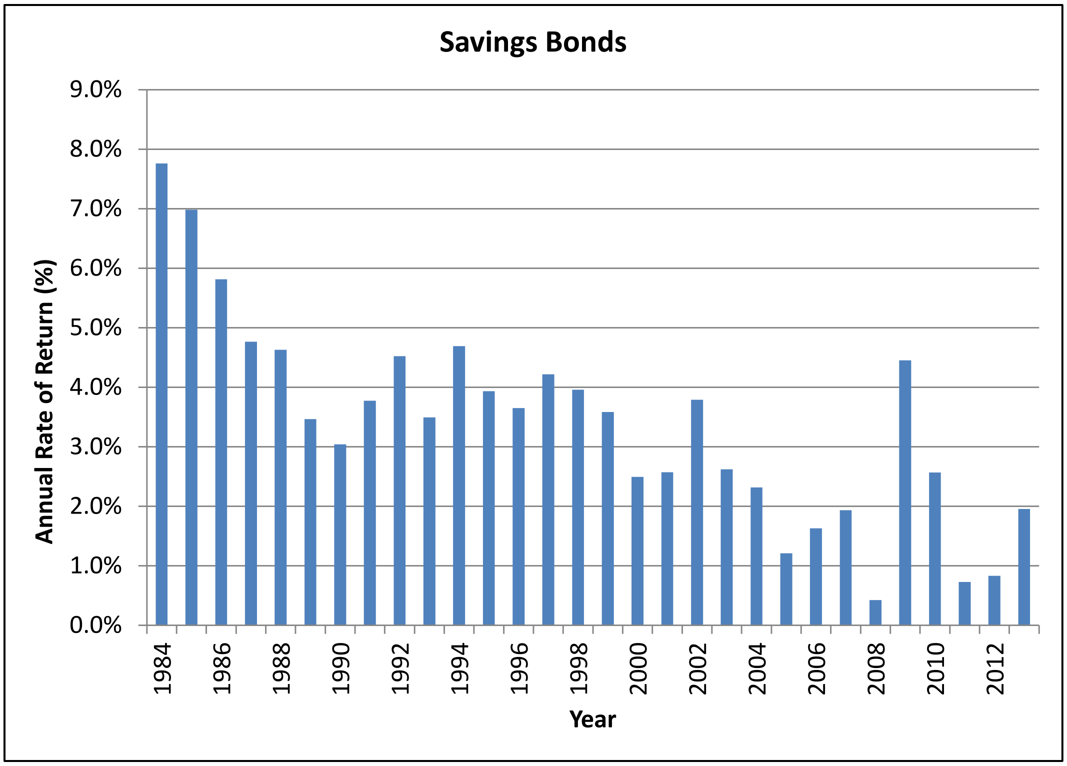

Figure 8D.2.8 Distribution of Annual Rate of Return on Savings Bonds

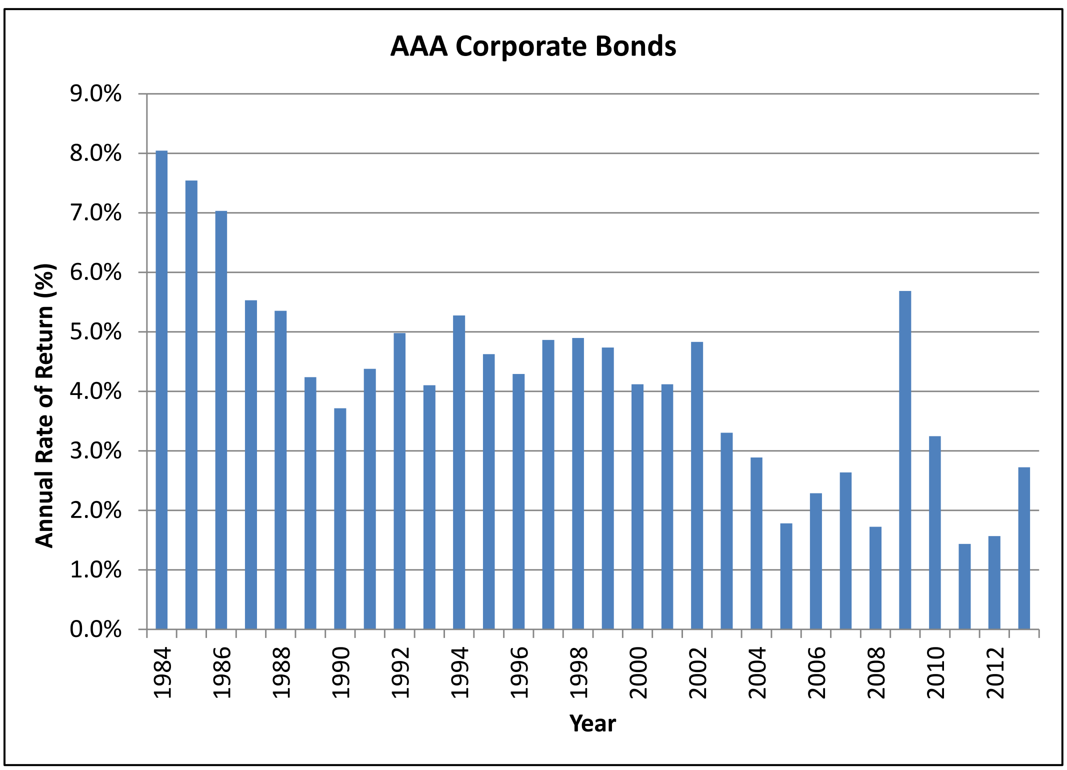

Figure 8D.2.9 Distribution of Annual Rate of Return on Corporate AAA Bonds

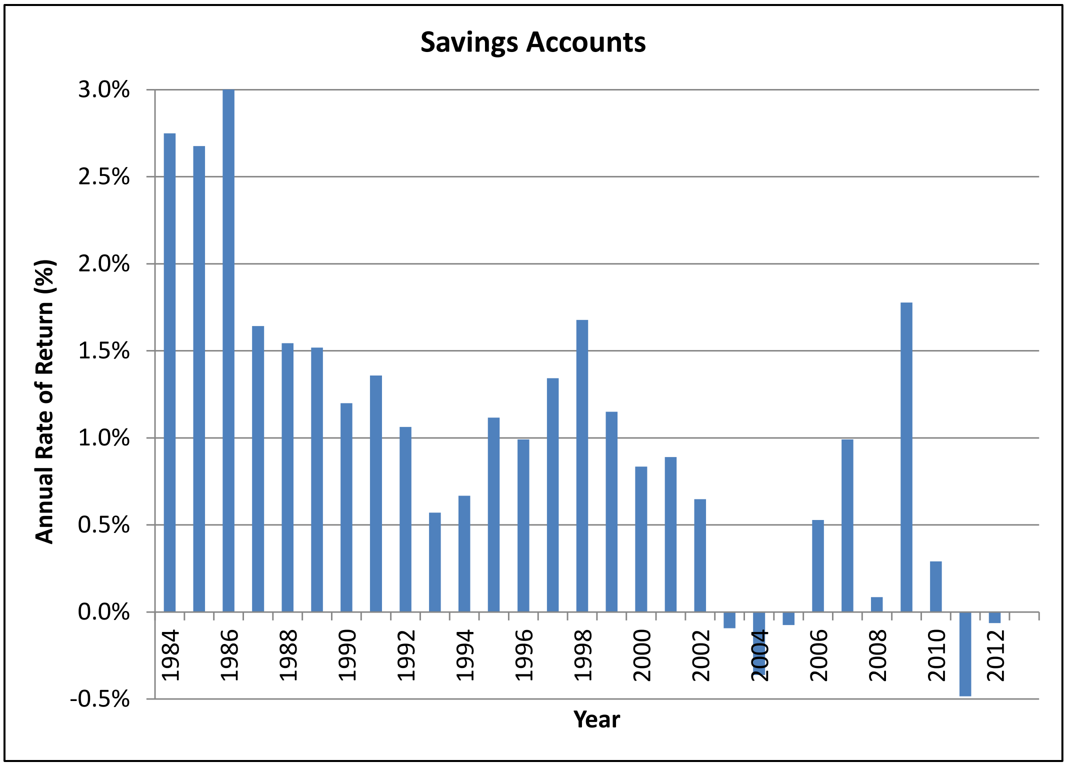

Figure 8D.2.10 Distribution of Annual Rate of Savings Accounts

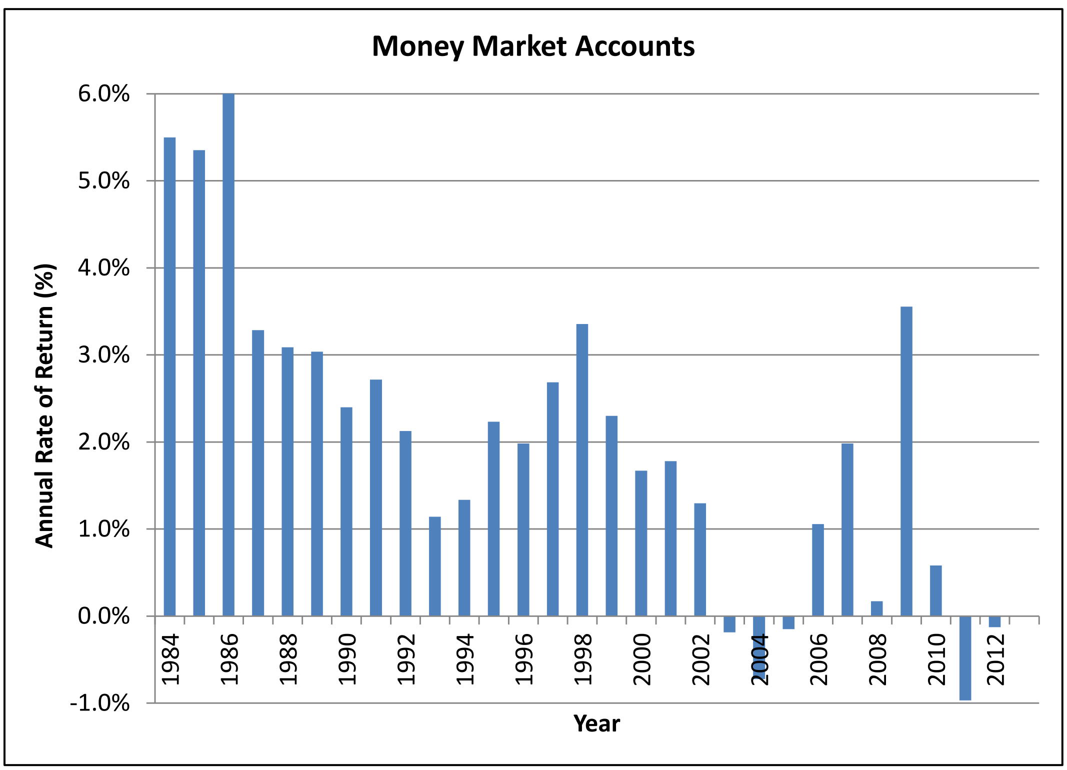

Figure 8D.2.11 Distribution of Annual Rate of Money Market Accounts

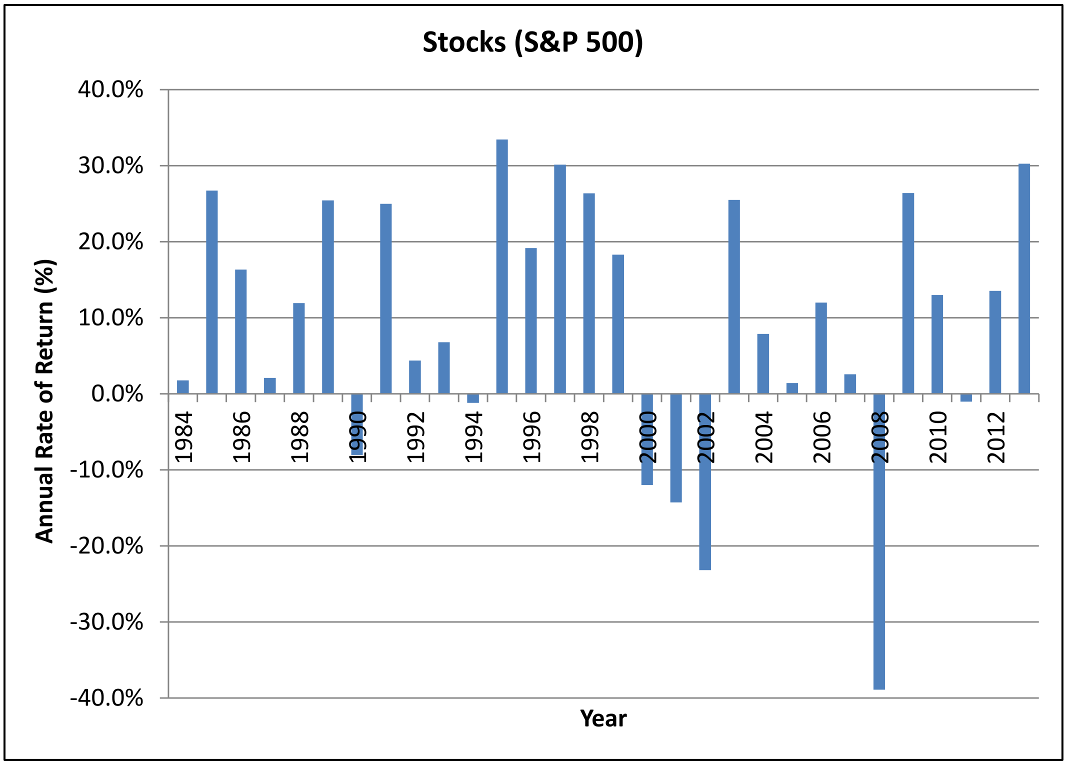

Figure 8D.2.12 Distribution of Annual Rate of Return on S&P 500

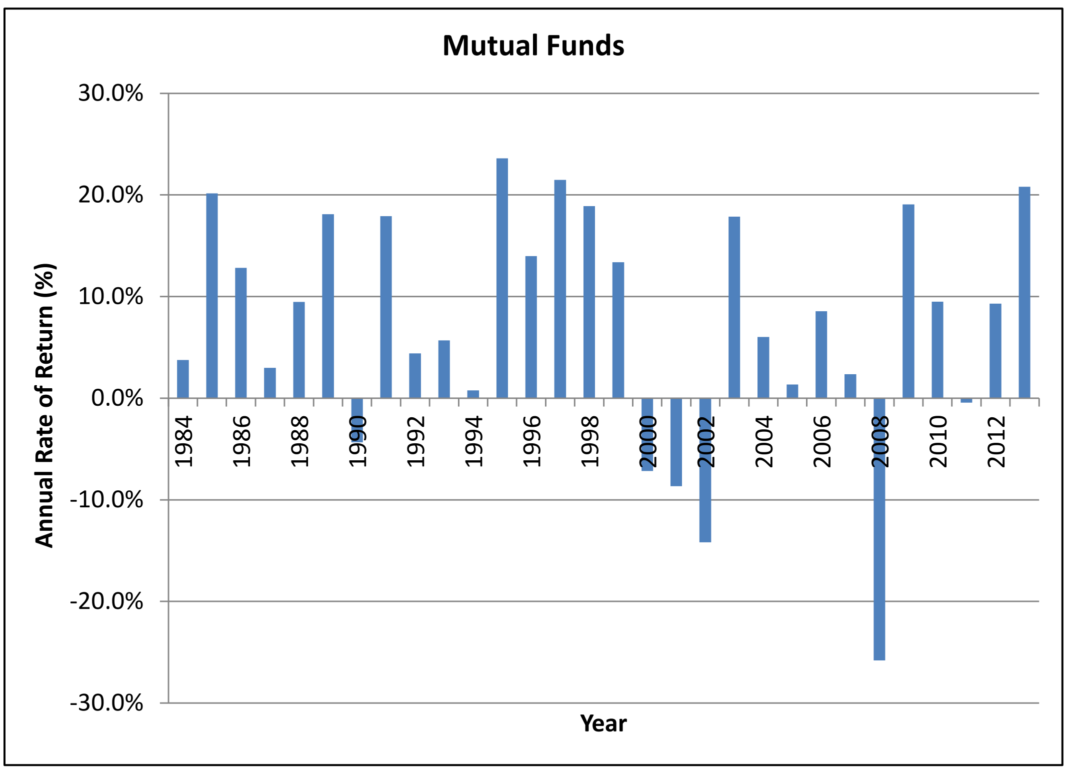

Figure 8D.2.13 Distribution of Annual Rate of Return on Mutual Funds

8D.3 DISTRIBUTION OF REAL EFFECTIVE DISCOUNT RATES BY INCOME GROUP

Figure 8D.3.1 and Table 8D.3.1 present the distributions of real discount rates for each income group.

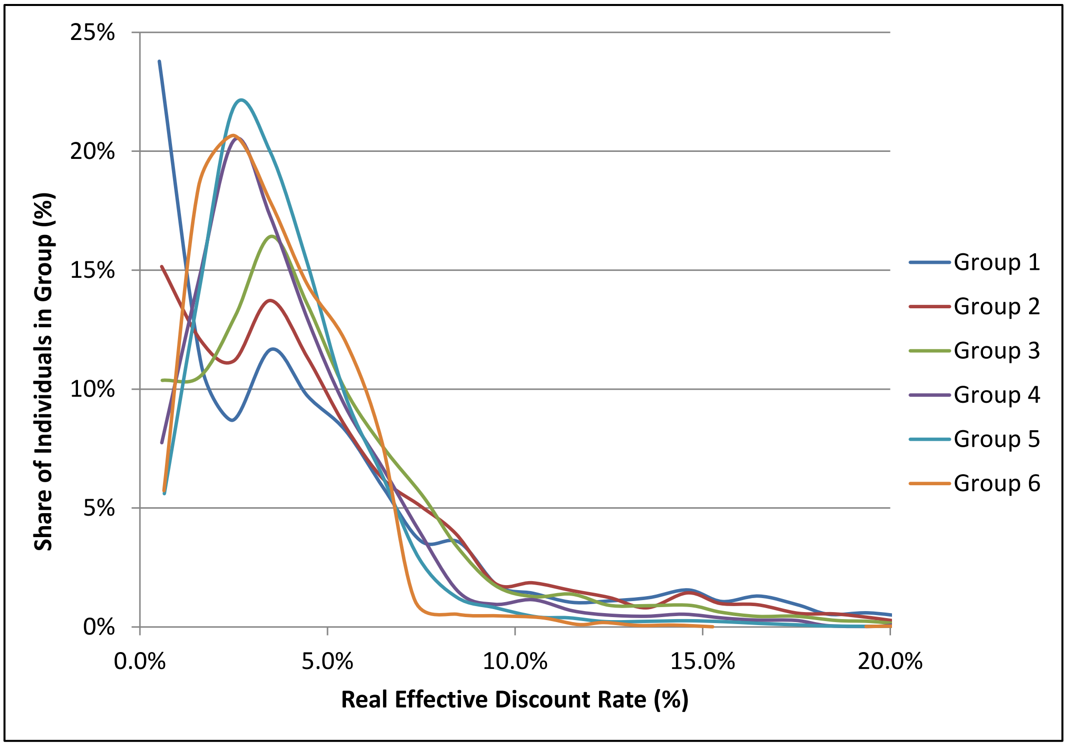

Figure 8D.3.1 Distribution of Real Discount Rates by Income Group

Table 8D.3.1 Distribution of Real Discount Rates by Income Group

DR Bin	Income Group 1 (1-20 percentile)		Income Group 2 (21-40 percentile)		Income Group 3 (41-60 percentile)		Income Group 4 (61-80 percentile)		Income Group 5 (81-90 percentile)		Income Group 6 (90-99 percentile)	
	rate	weight	rate	weight	rate	weight	rate	weight	rate	weight	rate	weight
0-1	0.5%	0.238	0.6%	0.152	0.6%	0.104	0.6%	0.077	0.6%	0.056	0.6%	0.057
1-2	1.6%	0.110	1.6%	0.120	1.6%	0.105	1.6%	0.146	1.6%	0.142	1.6%	0.185
2-3	2.5%	0.087	2.5%	0.112	2.6%	0.131	2.5%	0.205	2.5%	0.219	2.5%	0.207
3-4	3.5%	0.117	3.5%	0.137	3.5%	0.164	3.5%	0.173	3.5%	0.200	3.5%	0.178
4-5	4.5%	0.097	4.5%	0.113	4.5%	0.136	4.5%	0.129	4.5%	0.153	4.5%	0.144
5-6	5.5%	0.083	5.5%	0.084	5.5%	0.100	5.5%	0.093	5.5%	0.098	5.5%	0.120
6-7	6.5%	0.058	6.5%	0.062	6.5%	0.075	6.5%	0.067	6.5%	0.063	6.4%	0.079
7-8	7.5%	0.036	7.5%	0.051	7.6%	0.054	7.4%	0.041	7.4%	0.029	7.3%	0.011
8-9	8.5%	0.036	8.4%	0.039	8.4%	0.034	8.5%	0.015	8.4%	0.012	8.5%	0.005
9-10	9.5%	0.017	9.5%	0.018	9.5%	0.017	9.5%	0.010	9.5%	0.008	9.6%	0.005
10-11	10.5%	0.014	10.5%	0.019	10.5%	0.013	10.5%	0.011	10.6%	0.004	10.7%	0.004
11-12	11.5%	0.010	11.5%	0.015	11.5%	0.014	11.5%	0.007	11.4%	0.004	11.7%	0.001
12-13	12.5%	0.011	12.5%	0.012	12.5%	0.009	12.4%	0.005	12.4%	0.002	12.4%	0.002
13-14	13.6%	0.012	13.5%	0.008	13.5%	0.009	13.5%	0.004	13.5%	0.002	13.3%	0.001
14-15	14.6%	0.016	14.6%	0.014	14.6%	0.009	14.5%	0.005	14.6%	0.003	14.2%	0.001
15-16	15.5%	0.011	15.5%	0.010	15.5%	0.006	15.6%	0.004	15.6%	0.002	15.3%	0.000
16-17	16.5%	0.013	16.5%	0.009	16.5%	0.004	16.5%	0.003	16.5%	0.001	0.0%	0.000
17-18	17.5%	0.009	17.6%	0.006	17.5%	0.005	17.5%	0.003	17.6%	0.001	17.7%	0.001
18-19	18.4%	0.005	18.5%	0.005	18.6%	0.003	18.4%	0.001	18.2%	0.000	0.0%	0.000
19-20	19.4%	0.006	19.4%	0.004	19.4%	0.002	19.7%	0.000	19.7%	0.000	19.4%	0.000
20-21	20.6%	0.004	20.4%	0.002	20.5%	0.001	20.3%	0.001	20.5%	0.000	20.3%	0.000
21-22	21.4%	0.003	21.4%	0.002	21.4%	0.001	21.5%	0.001	0.0%	0.000	21.4%	0.000
22-23	22.5%	0.002	22.4%	0.001	22.6%	0.001	22.9%	0.000	22.8%	0.000	22.3%	0.000
23-24	23.6%	0.001	23.4%	0.001	23.6%	0.001	0.0%	0.000	0.0%	0.000	24.0%	0.000
24-25	24.6%	0.001	24.5%	0.000	24.6%	0.000	24.1%	0.000	24.3%	0.000	0.0%	0.000
25-26	25.4%	0.001	25.4%	0.001	25.5%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000
26-27	26.5%	0.001	26.5%	0.000	26.4%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000
27-28	27.8%	0.000	27.6%	0.000	27.8%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000
28-29	28.2%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000
29-23	29.9%	0.000	29.3%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000
>30	59.1%	0.001	142.7%	0.002	0.0%	0.000	53.3%	0.000	0.0%	0.000	0.0%	0.000

8D.4 DISTRIBUTIONS USED FOR COMMERCIAL DISCOUNT RATES

DOE derived commercial discount rates (*i.e.* weighted average cost of capital) for the life-cycle cost (LCC) analysis using the capital asset pricing model and firm-level data provided by Damodaran Online.[7] State and local government discount rates were estimated using the rate of return on 20-year municipal bonds, as provided by the Federal Reserve Board.[3] Separate distributions were constructed for each major industry. Figure 8D.4.1 through Figure 8D.4.10 show the probability distributions of commercial discount rates by industry.

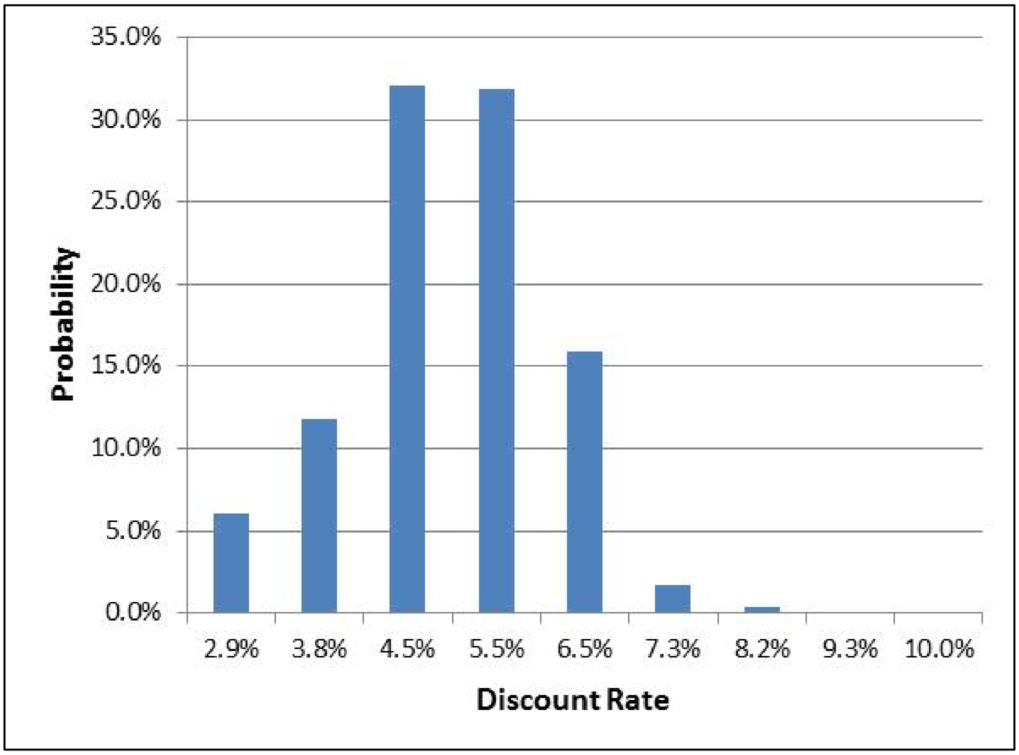

Figure 8D.4.1 Distribution of Commercial Discount Rates: Retail

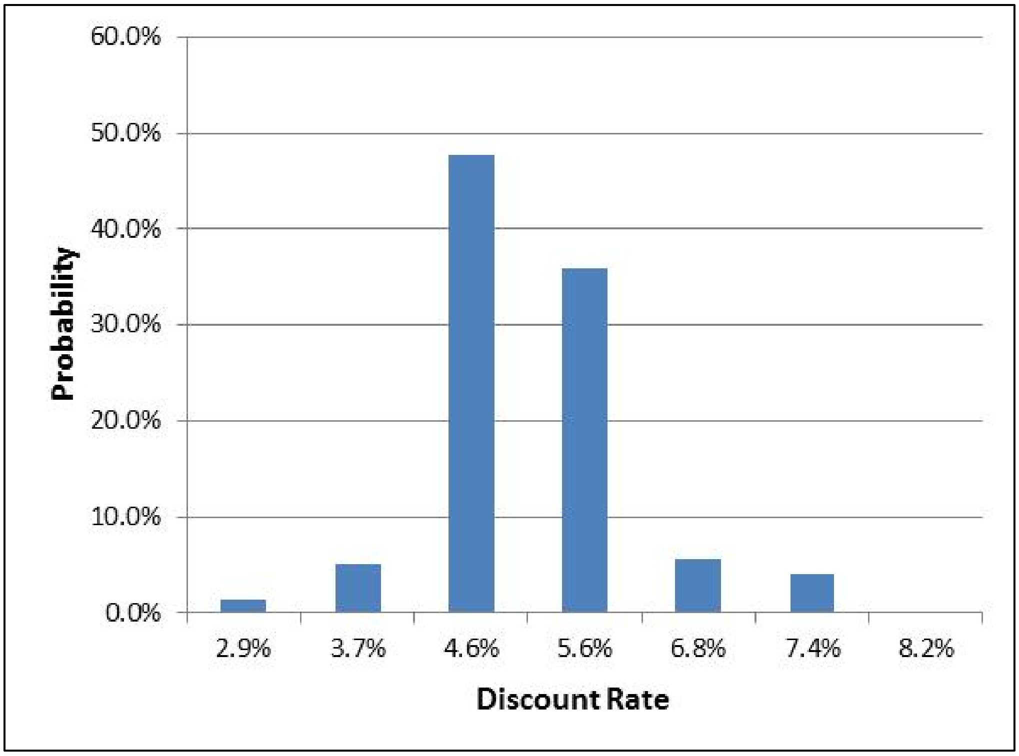

Figure 8D.4.2 Distribution of Commercial Discount Rates: Property

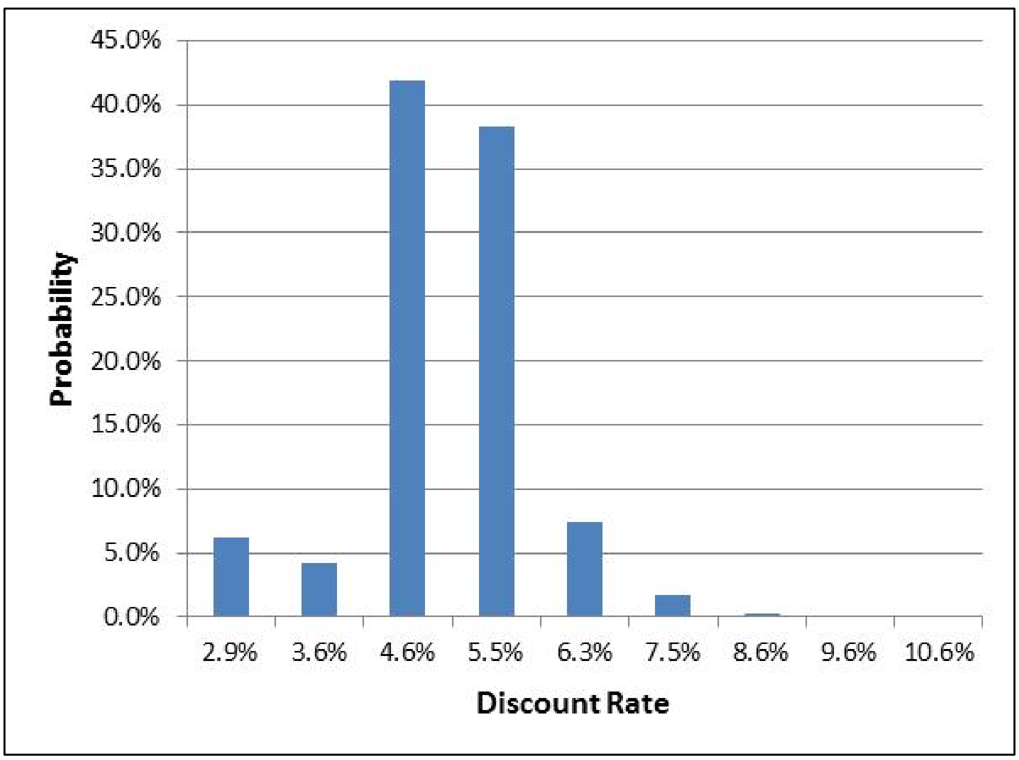

Figure 8D.4.3 Distribution of Commercial Discount Rates: Medical

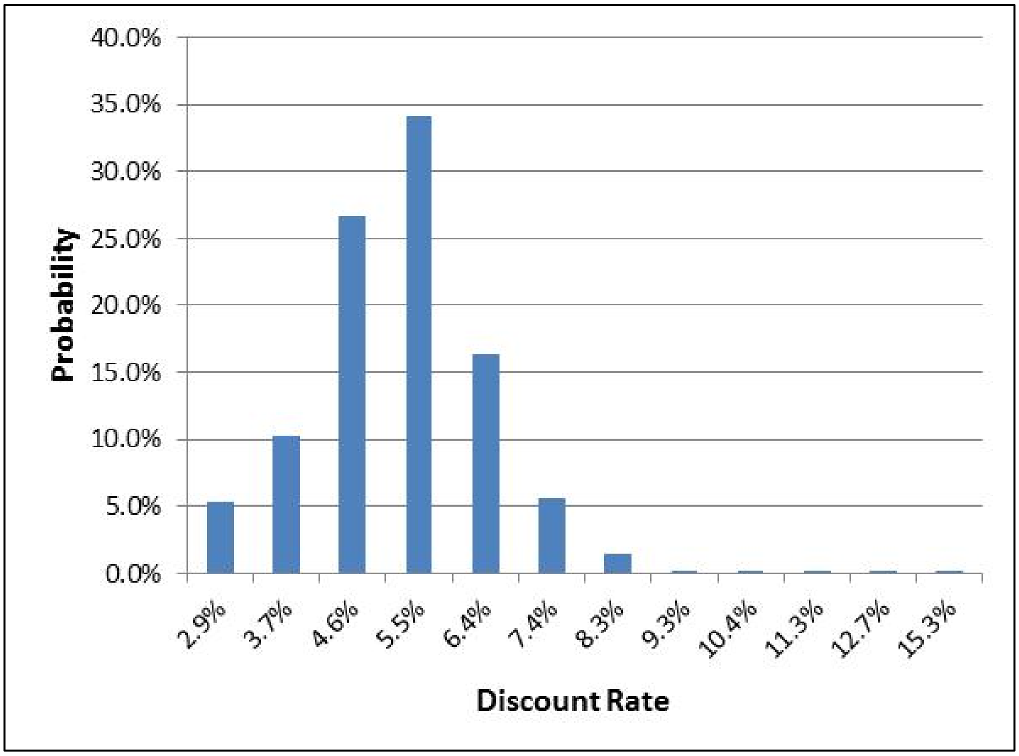

Figure 8D.4.4 Distribution of Commercial Discount Rates: Industrial

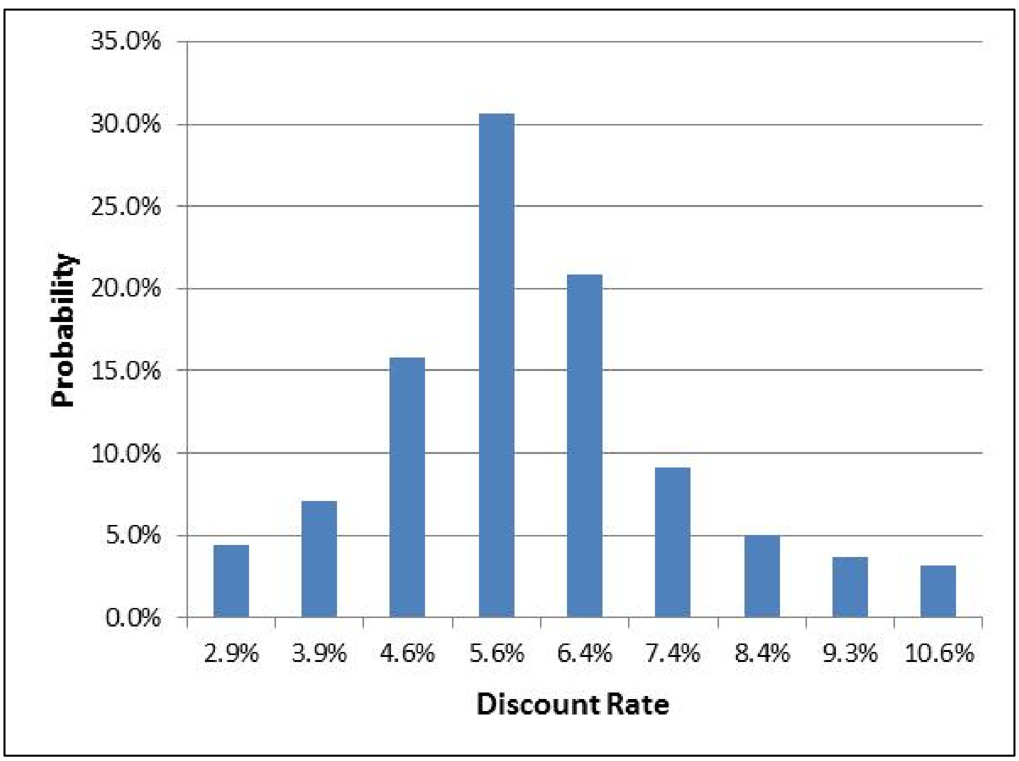

Figure 8D.4.5 Distribution of Commercial Discount Rates: Lodging

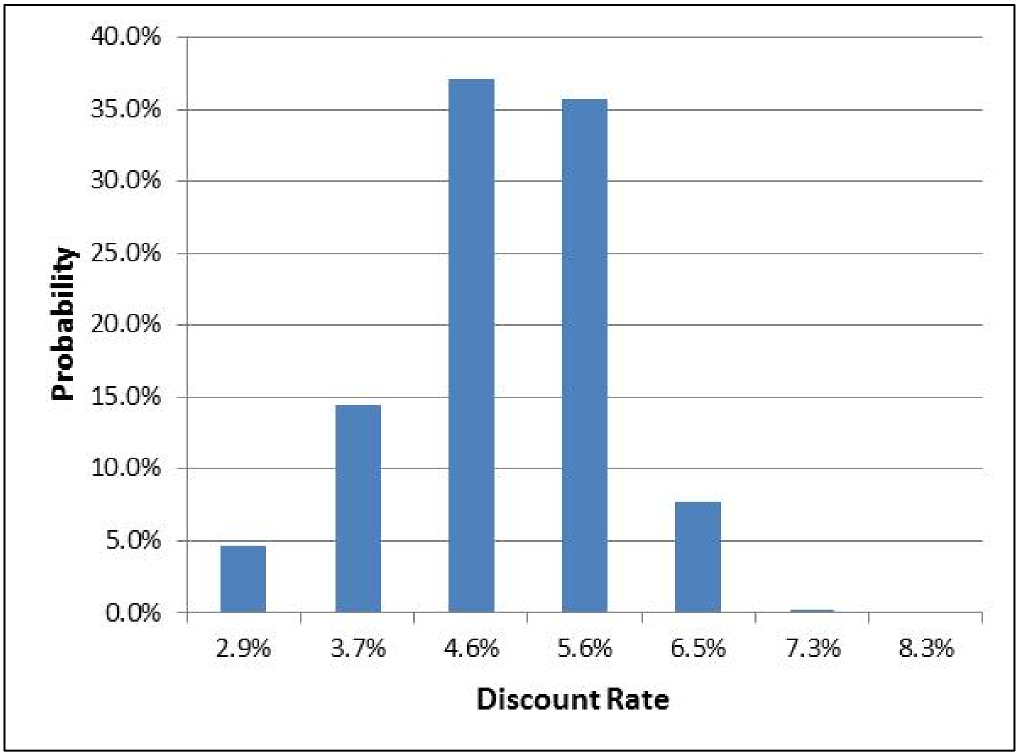

Figure 8D.4.6 Distribution of Commercial Discount Rates: Food Service

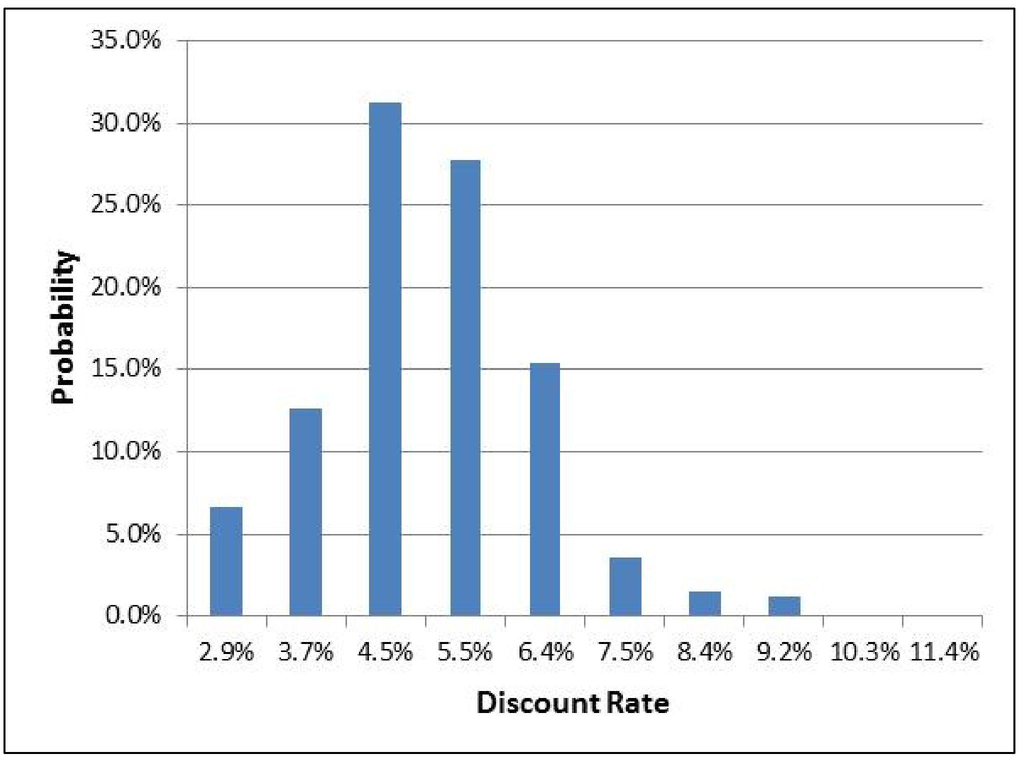

Figure 8D.4.7 Distribution of Commercial Discount Rates: Office

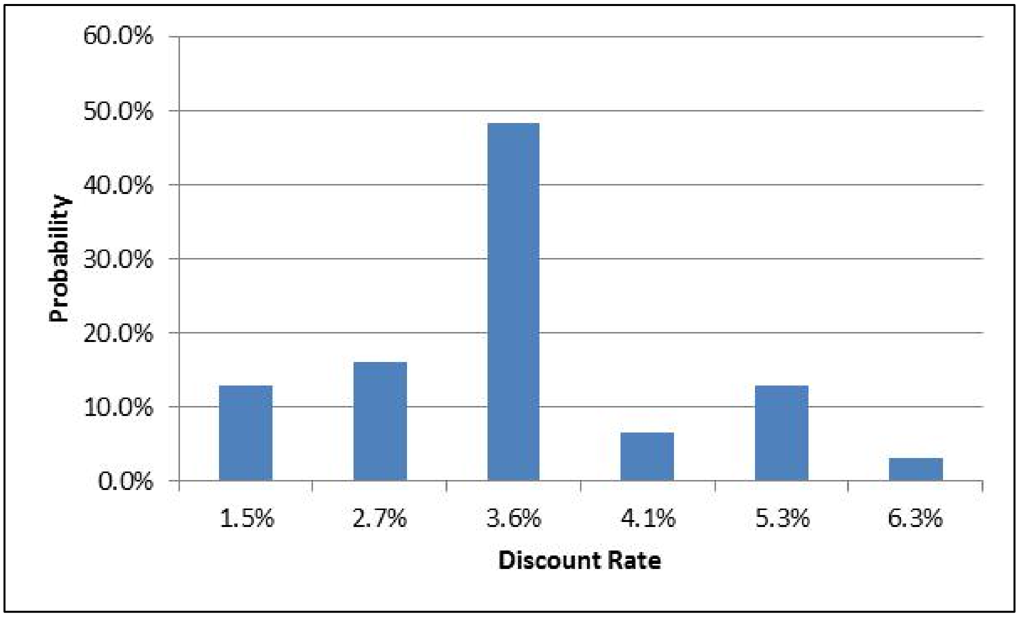

Figure 8D.4.8 Distribution of Commercial Discount Rates: State and Local Government

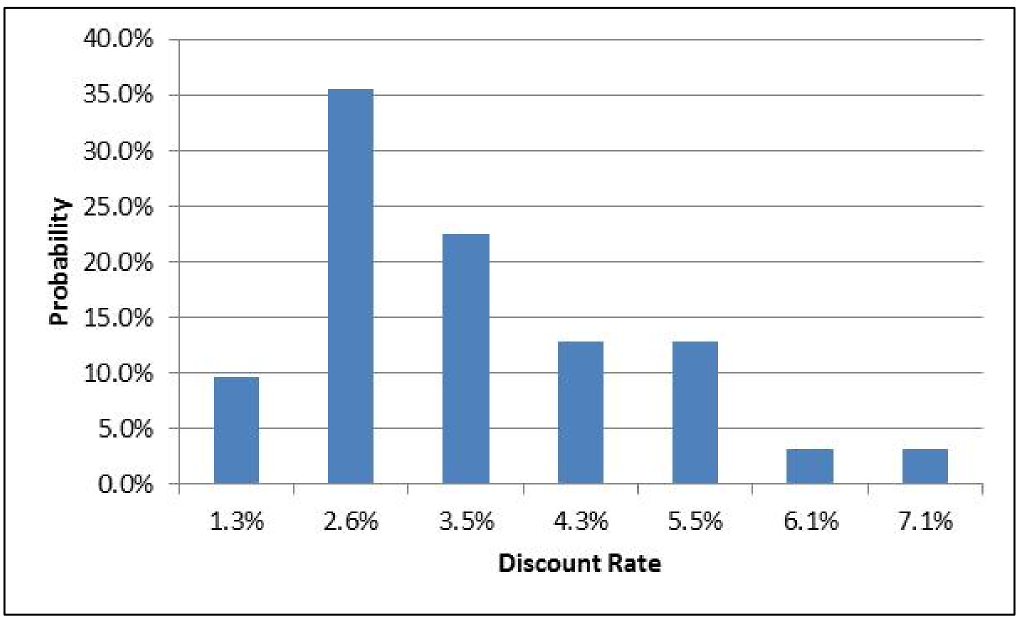

Figure 8D.4.9 Distribution of Commercial Discount Rates: Federal Government

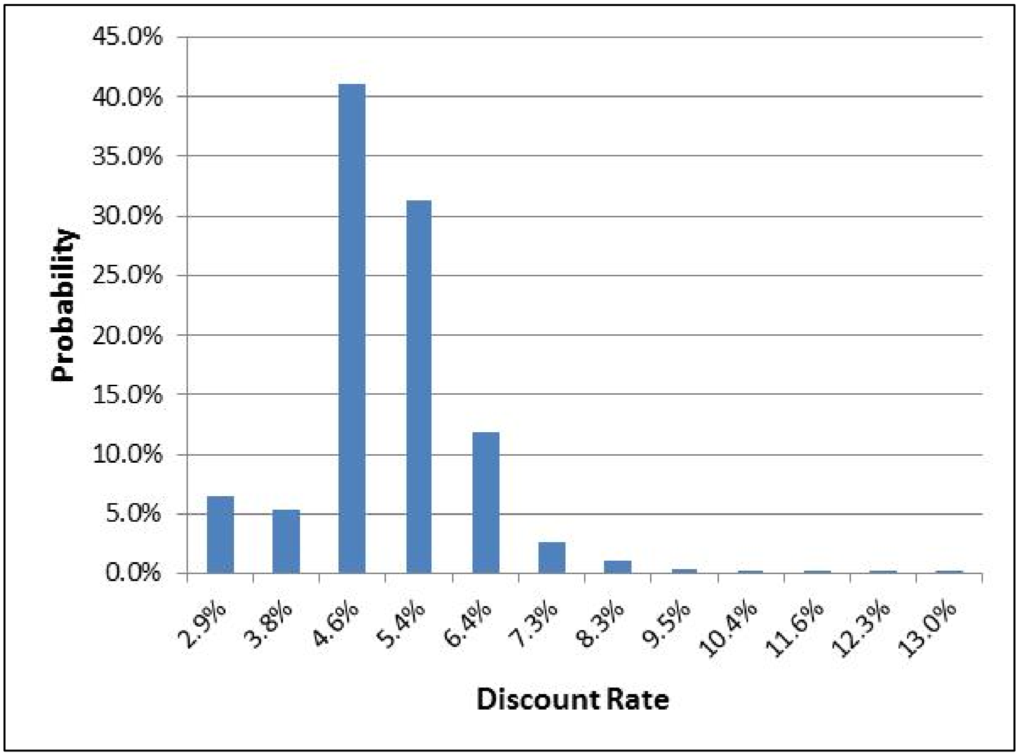

Figure 8D.4.10 Distribution of Commercial Discount Rates: Other

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APPENDIX 8E. LIFE-CYCLE COST ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR HEARTH PRODUCTS

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APPENDIX 8E. LIFE-CYCLE COST ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR HEARTH PRODUCTS

8E.1 INTRODUCTION

This appendix presents life-cycle cost (LCC) results using energy price projections from alternative economic growth scenarios. The scenarios are based on the High Economic Growth case and the Low Economic Growth case from Energy Information Administration (EIA)'s *Annual Energy Outlook 2014* (*AEO 2014*).[1]

This appendix describes the High and Low Economic Growth scenarios in further detail. See appendix 8A for details about how to generate LCC results for High Economic Growth and Low Economic Growth scenarios using the LCC spreadsheet.

8E.2 DESCRIPTION OF HIGH AND LOW ECONOMIC SCENARIOS

To generate LCC results reported in chapter 8, DOE uses the Reference case energy price projections from *AEO 2014*. The reference case is a business-as-usual estimate, given known market, demographic, and technological trends. For *AEO 2014*, EIA explored the impacts of alternative assumptions in other scenarios with different macroeconomic growth rates, world oil prices, rates of technology progress, and policy changes.

To reflect uncertainty in the projection of U.S. economic growth, EIA's *AEO 2014* uses High and Low Economic Growth scenarios to project the possible impacts of alternative economic growth assumptions on energy markets. The High Economic Growth scenario incorporates population, labor force and productivity growth rates that are higher than the Reference scenario, while these values are lower for the Low Economic Growth scenario. Economic output as measured by real GDP increases by 2.4 percent per year from 2012 through 2040, in the Reference case, 1.9 percent per year in the Low Economic Growth case, and 2.8 percent per year in the High Economic Growth case.[2]

In general, energy prices are higher in the High Economic Growth scenario and lower in the Low Economic Growth scenario than they are in the Reference Case. The energy price forecasts affect the operating cost savings at different efficiency levels. Figure 8E.2.1 through Figure 8E.2.3 show the national residential energy price trends for the Reference, High Economic Growth, and Low Economic Growth scenarios. *AEO 2014* projections stop in 2040. To estimate energy prices after 2040 in the high and low scenarios, DOE used the growth rate between 2030 and 2040, which are represented with a dashed line in the charts.

Because *AEO 2014* provides the price trends by census division, each sampled household is matched to the appropriate census division price trend. See appendix 8C for details about how energy price trends by census division are applied in the LCC analysis.

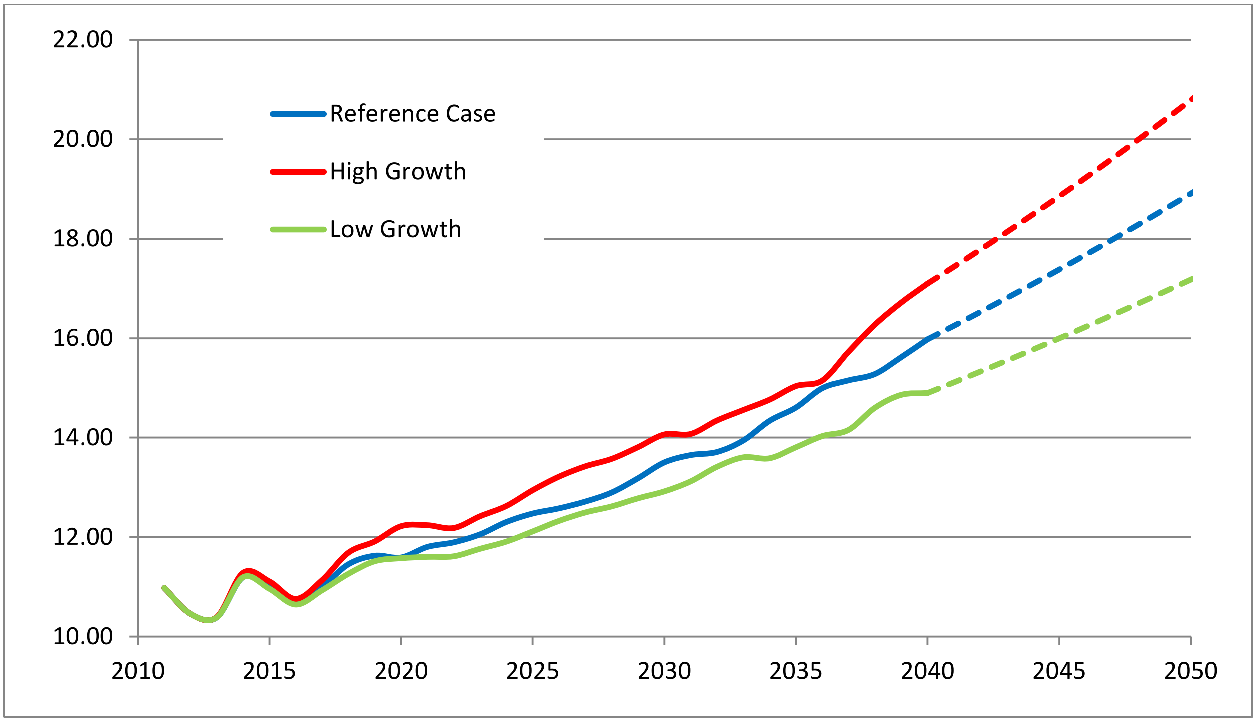

Figure 8E.2.1 Electricity Price Forecasts for Reference Case and High and Low Economic Growth Scenarios (National)

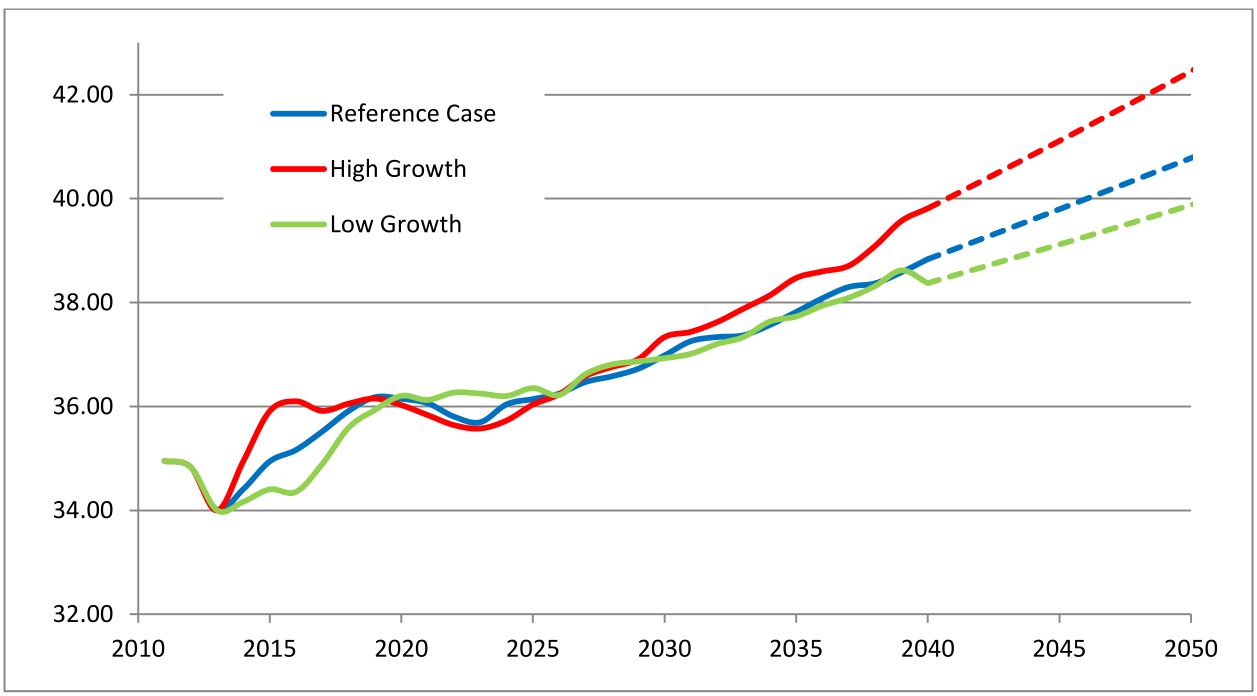

Figure 8E.2.2 Natural Gas Price Forecasts for Reference Case and High and Low Economic Growth Scenarios (National)

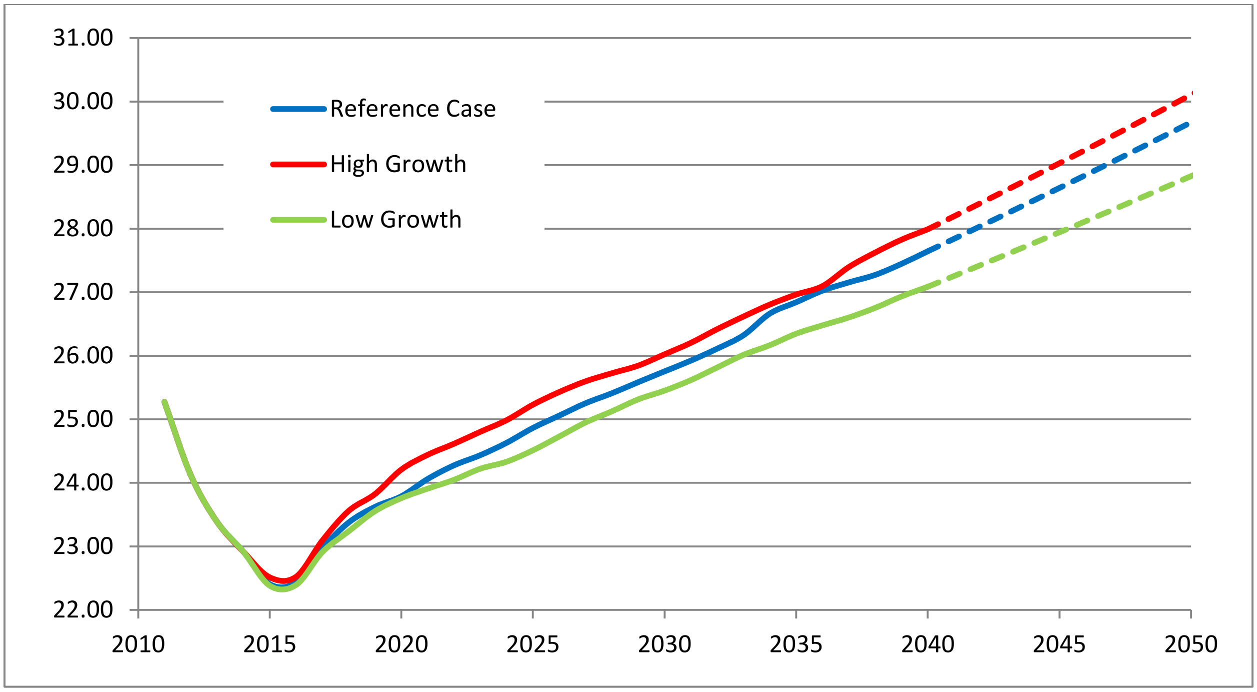

Figure 8E.2.3 LPG Price Forecasts for Reference Case and High and Low Economic Growth Scenarios (National)

8E.3 RESULTS

Table 8E.3.1 and Table 8E.3.2 summarize the LCC and PBP results for the High-Economic Growth scenario by efficiency level (EL) for hearth products. Table 8E.3.3 and Table 8E.3.4 summarize the LCC and PBP results for the Low Economic Growth scenario by EL for hearth products. Table 8E.3.5 compares average LCC savings and simple payback for these scenarios to the Reference case.

Table 8E.3.1 Average LCC and PBP Results by Efficiency Level for Hearth Product Ignition Systems: High Economic Growth Scenario

TSL	Efficiency Level	Average Costs 2013$				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	0	$166	$52	$625	$792	--	15.0
1	1	$268	$15	$179	$447	2.8	15.0

Note: The results for each TSL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8E.3.2 LCC Savings Relative to the Base Case Efficiency Distribution for Hearth Product Ignition Systems: High Economic Growth Scenario

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings* 2013$
1	1	22%	$175

* The calculation includes buildings with zero LCC savings (no impact).

Table 8E.3.3 Average LCC and PBP Results by Efficiency Level for Hearth Product Ignition Systems: Low Economic Growth Scenario

TSL	Efficiency Level	Average Costs 2013$				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	0	$166	$49	$584	$750	--	15.0
1	1	$268	$14	$170	$438	2.9	15.0

Note: The results for each TSL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8E.3.4 LCC Savings Relative to the Base Case Efficiency Distribution for Hearth Product Ignition Systems: Low Economic Growth Scenario

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings* 2013$
1	1	23%	$157

* The calculation includes buildings with zero LCC savings (no impact).

Table 8E.3.5 Comparison of Average LCC Savings and Simple Payback Period Results for Reference Case and High and Low Economic Growth Scenarios

EL	Efficiency Level	Average LCC Savings *2013$*			Simple Payback Period *Years*		
		High Growth	Low Growth	Reference Case	High Growth	Low Growth	Reference Case
1	Intermittent Pilot	$175	$157	$165	2.8	2.9	2.9

REFERENCES

1. U.S. Department of Energy-Energy Information Administration, *Annual Energy Outlook 2014 with Projections to 2040*, 2014. Washington, DC. <www.eia.gov/forecasts/aeo/>

2. Energy Information Administration, *Macroeconomic Activity Module for Annual Energy Outlook 2014*, 2014. Washington, DC. <www.eia.gov/forecasts/aeo/assumptions/pdf/macroeconomic.pdf>

APPENDIX 9A. RELATIVE PRICE ELASTICITY OF DEMAND FOR APPLIANCES

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APPENDIX 9A. RELATIVE PRICE ELASTICITY OF DEMAND FOR APPLIANCES

9A.1 INTRODUCTION

This appendix summarizes DOE's study of the price elasticity of demand for home appliances, including refrigerators, clothes washers and dishwashers. DOE chose this particular set of appliances because of the availability of data to determine a price elasticity. Section 9A.2 reviews the existing economics literature describing the impact of economic variables on the sale of durable goods. Section 9A.3 describes the market for home appliances and the changes that have occurred over the past 20 years. In section 9A.4, DOE summarizes the results of its regression analysis and presents estimates of the price elasticity of demand for the three appliances. In section 9A.5, DOE presents development of an 'effective' purchase price elasticity. DOE's interpretation of its results is presented in section 9A.6. Finally, section 9A.7 describes the data used in DOE's analysis.

9A.2 LITERATURE REVIEW

Relatively few studies measure the impact of price, income and efficiency on the sale of household appliances. This section briefly reviews the literature that describes the likely importance of these variables on the purchase of household appliances.

9A.2.1 Price

DOE reviewed many studies that sought to measure the impact of price on sales in a dynamic market. One study of the automobile market prior to 1970 finds the price elasticity of demand to decline over time. The author explains this as the result of buyers delaying purchases after a price increase but eventually making the purchase (Table 9A.2.1).[1] A contrasting study of household white goods also prior to 1970, finds the elasticity of demand to increase over time as more price-conscious buyers enter the market.[2] An analysis of refrigerator market survey data finds that consumer purchase probability decreases with survey asking price.[3] Estimates of the price elasticity of demand for different brands of the same product tend to vary. A review of 41 studies of the impact of price on market share found the average price elasticity to be -1.75.[4] The average estimate of price elasticity of demand reported in these studies is -0.33 in the appliance market and -0.47 in the combined automobile and appliance markets.

9A.2.2 Income

Higher income households are more likely to own household appliance.[5] The impact of income on appliance shipments is explored in two econometric studies of the automobile and appliance markets.[1, 2] The average income elasticity of demand is 0.50 in the appliance study cited in the literature review, much larger in the automobile study (Table 9A.2.1).

9A.2.3 Appliance Efficiency and Discount Rates

Many studies estimate the impact of appliance efficiency on consumers' choice of appliance. Typically, this impact is summarized by the implicit discount rate; that is, the rate consumers use to compare future savings in appliance operating costs against a higher initial purchase price of an appliance. One early and much cited study concludes that consumers use a 20 percent implicit discount rate when purchasing room air conditioners (Table 9A.2.1).[6] A survey of several studies of different appliances suggests that the consumer implicit discount rate has a broad range and averages about 37 percent.[7]

Table 9A.2.1 Estimates of the Impact of Price, Income and Efficiency on Automobile and Appliance Sales

Durable Good	Price Elasticity	Income Elasticity	Brand Price Elasticity	Implicit Discount Rate	Model	Data Years	Time Period
Automobiles[1]	-1.07	3.08	-	-	Linear Regression, stock adjustment	-	Short run
Automobiles[1]	-0.36	1.02	-	-	Linear Regression, stock adjustment	-	Long run
Clothes Dryers[2]	-0.14	0.26	-	-	Cobb-Douglas, diffusion	1947-1961	Mixed
Room Air Conditioners[2]	-0.37[8]	0.45	-	-	Cobb-Douglas, diffusion	1946-1962	Mixed
Dishwashers[2]	-0.42	0.79	-	-	Cobb-Douglas, diffusion	1947-1968	Mixed
Refrigerators[3]	-0.37	-	-	39%	Logit probability, survey data	1997	Short run
Various[4]	-	-	-1.76[9]	-	Multiplicative regression	-	Mixed
Room Air Conditioners[5]	-	-	-1.72	-	Non-linear diffusion	1949-1961	Short run
Clothes Dryers[5]	-	-	-1.32	-	Non-linear diffusion	1963-1970	Short run
Room Air Conditioners[6]	-	-	-	20%	Qualitative choice, survey data	-	-
Household Appliances[7]	-	-	-	37%[10]	Assorted	-	-

Sources: [1] S. Hymens. 1971; [2] P. Golder and G. Tellis, 1998; [3] D. Revelt and K. Train, 1997; [4] G. Tellis, 1988; [5] D. Jain and R. Rao; [6] J. Hausman; [7] K. Train, 1985.

Notes: [8] Logit probability results are not directly comparable to other elasticity estimates in this table.
[9] Average brand price elasticity across 41 studies.
[10] Averaged across several household appliance studies referenced in this work.

9A.3 VARIABLES DESCRIBING THE MARKET FOR REFRIGERATORS, CLOTHES WASHERS, AND DISHWASHERS

In this section DOE evaluates variables that appear to account for refrigerator, clothes washer and dishwasher shipments, including physical household/appliance variables and economic variables.

9A.3.1 Physical Household/Appliance Variables

Several variables influence the sale of refrigerators, clothes washers and dishwashers. The most important for explaining appliance sales trends are the annual number of new households formed (housing starts) and the number of appliances reaching the end of their operating life (replacements). Housing starts influence sales because new homes are often provided with, or soon receive, new appliances, including dishwashers and refrigerators. Replacements are correlated with sales because new appliances are typically purchased when old ones wear out. In principle, if households maintain a fixed number of appliances, shipments should equal housing starts plus appliance replacements.

9A.3.2 Economic variables

Appliance price, appliance operating cost and household income are important economic variables affecting shipments. Low prices and costs encourage household appliance purchases and a rise in income increases householder ability to purchase appliances. In principle, changes in economic variables should explain changes in the number of appliances per household.

During a 1980–2002 study period, annual shipments grew 69 percent for clothes washers, 81 percent for refrigerators and 105 percent for dishwashers (Table 9A.3.1). This rising shipments trend is explained in part by housing starts, which increased six percent and by appliance replacements, which rose between 49 percent and 90 percent, depending on the appliance, over the period (Table 9A.3.1).[a] For mature markets such as these, replacements exceed appliance sales associated with new housing construction.

Table 9A.3.1 Physical Household/Appliance Variables

	Shipments[i] (millions)			Housing Starts[ii] (millions)			Replacements[iii] (millions)		
Appliance	**1980**	**2002**	**Change**	**1980**	**2002**	**Change**	**1980**	**2002**	**Change**
Refrigerators	5.124	9.264	81%	1.723	1.822	6%	3.93	5.84	49%
Clothes Washers	4.426	7.492	69%	1.723	1.822	6%	3.66	5.50	50%
Dishwashers	2.738	5.605	105%	1.723	1.822	6%	1.99	3.79	90%

[i]Shipments: Number of units sold. **Sources:** AHAM Fact Book and Appliance Magazine.
[ii]Housing Starts: Annual number of new homes constructed. **Source:** U.S. Census.
[iii]Replacements: Average of annual lagged shipments, with lag equal to expected appliance operating life, ± 5 years.

Shipments increased somewhat more rapidly than housing starts and replacements. This is shown by comparing the beginning and end points of lines that represent "starts plus replacements" (uppermost solid line in Figure 9A.3.1) and "shipments" (diamond linked line in Figure 9A.3.1). In 1980, the "shipment" line begins below the "starts plus replacements" line. In 2002, the "shipments" line ends above the "starts plus replacements" line. This more rapid

[a] Appliance replacements are determined from the expected operating life of refrigerators (19 years), clothes washers (14 years), and dishwashers (12 years) and from past shipments. Replacements are further discussed in section 9-A.3. The dishwasher lifetime used in this analysis does not match the dishwasher used in the primary analysis.

increase in shipments, compared to housing starts plus replacements, suggests that the appliance per household ratio increased over the study period.

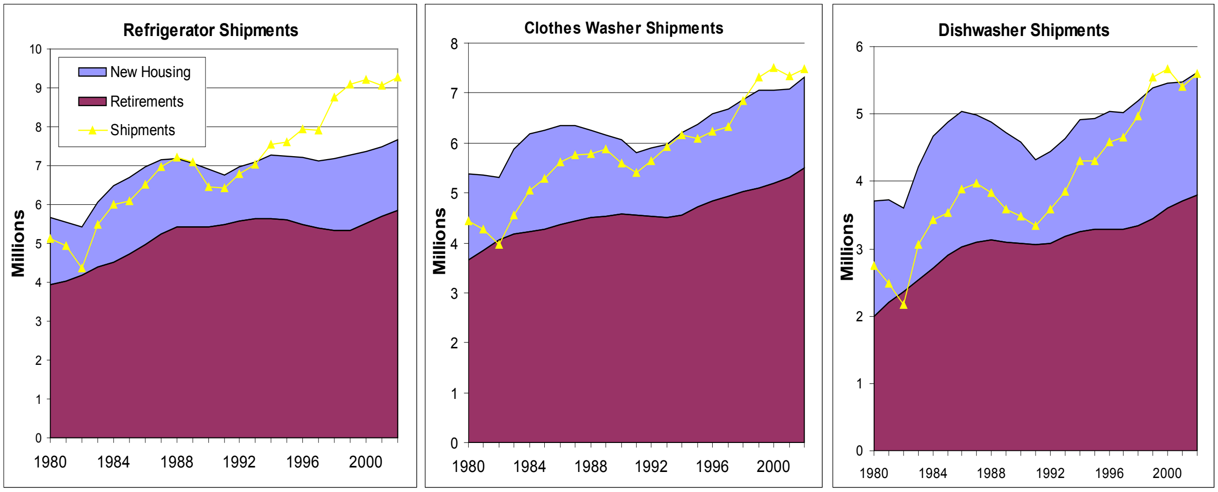

Figure 9A.3.1 Trends in Appliance Shipment, Housing Starts and Replacements

Economic variables, including price, cost and income, may explain this increase in appliances per household. Over the period, appliance prices decreased 40 percent to 50 percent, operating costs fell between 33 percent and 72 percent, and median household income rose 16 percent (Table 9A.3.2).

Table 9A.3.2 Economic Variables

	Price[i] (1999$)			Operating Cost[ii] (1999$)			Household Income[iii] (1999$)		
Appliance	**1980**	**2002**	**Change**	**1980**	**2002**	**Change**	**1980**	**2002**	**Change**
Refrigerators	1208	726	-40%	333	94	-72%	37,447	43,381	16%
Clothes Washers	779	392	-50%	262	175	-33%	37,447	43,381	16%
Dishwashers	713	369	-48%	183	95	-48%	37,447	43,381	16%

[i]Price: Shipment weighted retail sales price. **Sources:** AHAM Fact Book and Appliance Magazine.
[ii]Operating Cost: Annual electricity price times electricity consumption. **Source:** AHAM Fact Book.
[iii]Income: Mean Household income. **Source:** U.S. Census.

9A.4 REGRESSION ANALYSIS OF VARIABLES AFFECTING APPLIANCE SHIPMENTS

Few data are available to estimate the impact of economic variables on the demand for appliances. Industry operating cost data is incomplete—appliance energy use data are available for only 12 years of the 1980-2002 study period. Industry price data are also incomplete—available for only 8 years of the study period for each of the appliances.

The lack of data suggests that regression analysis can at best evaluate broad data trends, utilizing relatively few explanatory variables. This section begins by describing broad trends apparent in the economic and physical household data sets and then specifies a simple regression model to measure these trends, making assumptions to minimize the number of explanatory variables. Finally, results of the regression analysis are presented along with an estimate of the price elasticity of demand for appliances. In section 9A.4.5, DOE presents the results of regression analysis performed with more complex models, which are used to test assumptions underlying the simple model. These results support the specification of the simple model and the price elasticity of appliance demand estimated with that model.

9A.4.1 Broad Trends

In this section, DOE reviews trends in the physical household and economic data sets and posits a simple approach for estimating the price elasticity of appliance demand. As noted above, the physical household variables (housing starts and appliance replacements) explain most of the variability in appliance shipments during the study period (1980-2002).[b] DOE assumes the rest of the variability in shipments (referred to as "residual shipments") is explained by economic variables. Below, DOE presents a tabular method for measuring price elasticities.

To illustrate this tabular approach, DOE defines two new variables—residual shipments and total price. Residual shipments are defined as the difference between shipments and physical household demand (starts plus replacements). Total price, represented by the following equation, is defined as appliance price plus the present value of lifetime appliance operating cost:[c]

$$\boldsymbol{TP = PP + PVOC}$$

Eq. 9A.1

Where:

TP = total price,
PP = appliance purchase price, and
PVOC = present value of operating cost.

Over the study period, residual shipments increased in proportion to total shipments by 30 percent for refrigerators, 19 percent for clothes washers, and 23 percent for dishwashers. At the same time, total prices declined 47 percent, 45 percent and 48 percent for refrigerators, clothes washers, and dishwashers, respectively. Assuming that total price explains the entire change in per household appliance usage, a rough estimate is calculated of the total price elasticity of demand equal to -0.48 for refrigerators, -0.32 for clothes washers and -0.37 for dishwashers (Table 9A.4.1).

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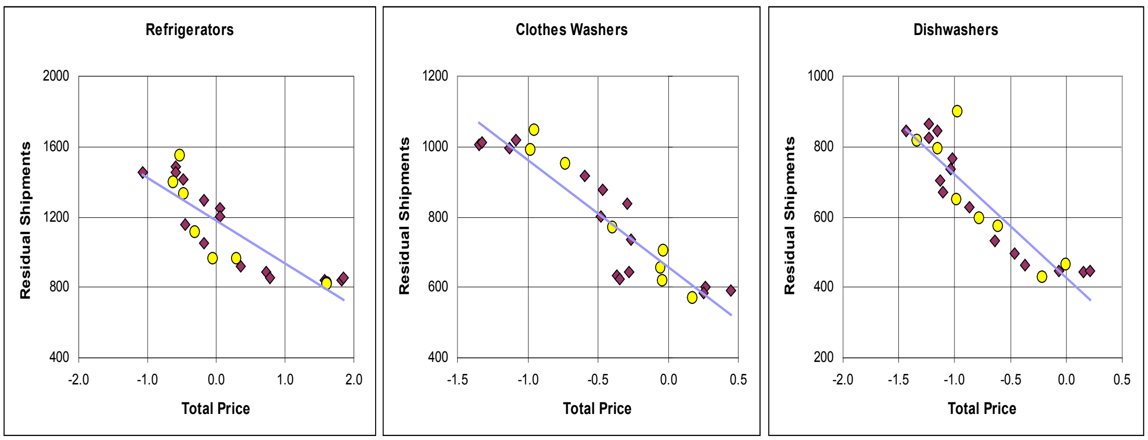
[b] A log regression of the form: Shipments = a + b • Housing Starts + c • Retirements, indicates that these two variables explain 89 percent of the variation in refrigerator shipments, 97 percent of the variation in clothes washer shipments, and 97 percent of the variation in dishwasher shipments.

[c] Present value operating cost is calculated assuming a 19-year operating life for refrigerators, 14-year operating life for clothes washers, and a 12-year operating life for dishwashers. A 37 percent discount rate is used to sum annual operating costs into a present value operating cost.

Table 9A.4.1 Estimate of Total Price Elasticity of Demand

	Residual Shipments (millions)				Total Price (1999$)			
Appliance	**1980**	**2002**	**Difference**	**Change**	**1980**	**2002**	**Change**	**Elasticity**
Refrigerators	-0.5	1.6	2.1	30%	1541	820	-61%	-0.48
Clothes Washers	-1.0	0.2	1.1	19%	1042	567	-59%	-0.32
Dishwashers	-1.0	-0.01	1.0	23%	896	464	-64%	-0.37

The negative correlation between total price and residual shipments suggested by these negative price elasticities is illustrated in a graph of residual shipments on the y-axis and total price on the x-axis (Figure 9A.4.1).



Yellow points are observed price data; red points are interpolated price data.

Figure 9A.4.1 Residual Shipments and Appliance Price

Household income rose during the study period, making it easier for households to purchase appliances. Assuming that a rise in income has a similar impact on shipments as a decline in price, the impact of income is incorporated by defining a third variable, termed *relative* price, which is calculated as total price divided by household income and represented by the following equation.[d]

$$RP = \frac{TP}{Income}$$

Eq. 9A.2

Where:

RP = relative price,
TP = total price, and
Income = household income.

[d] Recall that the income elasticity of demand cited in the literature review is 0.50 and the price elasticity of demand cited in the review averages -0.35. This suggests that combining the effects of income and price will yield an elasticity less negative than price elasticity alone.

The percent decline in *relative* price for the three appliances divided by the percent decline in residual shipments suggests a rough estimate of *relative* price elasticity equal to -0.40 for refrigerators, -0.26 for clothes washers and -0.30 for dishwashers (Table 9A.4.2).

Table 9A.4.2 Tabular Estimate of Relative Price Elasticity of Appliance Demand

	Residual Shipments (millions)			Relative Price (1999$)			
Appliance	**1980**	**2002**	**Change**	**1980**	**2002**	**Change**	**Elasticity**
Refrigerators	-0.532	1.597	30%	0.041	0.019	-74%	-0.40
Clothes Washers	-0.953	0.174	19%	0.028	0.013	-72%	-0.26
Dishwashers	-0.974	-0.005	23%	0.024	0.011	-76%	-0.30

9A.4.2 Specification of Model

The limited price data suggest it is appropriate to use a simple regression model to estimate the impact of economic variables on shipments, using few explanatory variables. The following equation, chosen for this analysis, includes one physical household variable (housing starts plus replacements) and one *relative* price variable (the sum of purchase price plus operating cost, divided by income).

$$\boldsymbol{Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor}$$

Eq. 9A.3

Where:

Ship = quantity of appliance sold,
RP = relative price,
Starts = number of new homes, and
Rplc = number of appliances at the end of their operating life.

The natural logs are taken of all variables so that the estimated coefficients for each variable in the model may be interpreted as the percent change in shipments associated with the percent change in the variable. Thus, the coefficient *b* in this model is interpreted as the *relative* price elasticity of demand for the three appliances.

DOE used the following combined regression equation to estimate an average price elasticity of demand across the three appliances, using pooled data in a single regression. A combined regression specification is justified, given the limited data available and the similarity in price and shipment behavior across appliances (see Figure 9A.4.1). Thus, the model represented by the combined regression equation is considered the basic model in DOE's analysis of appliance shipments.

$$\boldsymbol{Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor + d \times CW + e \times DW}$$

Eq. 9A.4

Where:

CW = quantity of clothes washers sold, and

DW = quantity of dishwashers sold.

9A.4.3 Discussion of Model

The most important assumption used to specify this model is that changes in economic variables over the study period—income, price, and operating cost—are responsible for all observed growth in residual appliance shipments. In other words, DOE assumes no impact from other possible factors, such as changing consumer preferences or increases in the quality of appliances. This assumption seems unlikely, but without additional data, the impact of this assumption on the price elasticity of demand cannot be measured. DOE effectively assumes that changes in consumer preferences and appliance characteristics, while affecting which models are purchased, have relatively little impact on the total number of appliances purchased in a year.

Three additional assumptions used to specify this model deserve comment. The *relative* price variable is specified in the model, assuming that (1) the correct implicit discount rate is used to combine appliance price and operating cost and that (2) rising income has the same impact on shipments as falling total price. The "starts + replacements" variable is specified, assuming (3) that starts and replacements have similar impacts on shipments.

To investigate the first assumption about discount rates, DOE calculated "present value operating cost" using a 20 percent implicit discount rate and performed a second regression analysis based on the models described in Eq. 9A.1 and Eq. 9A.2. The results of this analysis, presented in section 9A.4.5, indicate that the elasticity of *relative* price is fairly insensitive to changes in the discount rate.

To investigate the second and third assumptions, DOE specified a regression model separating income from total price and replacements from starts, thereby adding two additional explanatory variables to the basic model as shown in the following equation:

$$Ship = a + b \times TP + c \times Incone + d \times Start + e \times Rplc + f \times CW + g \times DW$$

Eq. 9A.5

The results of the regression analysis of this model are presented in section 9A.4.5. These results suggest that the elasticity of total price (coefficient *b*) is relatively insensitive to changes in the treatment of income and "starts + replacements" in the model.

9A.4.4 Analysis Results

The following sections describe results of analyses using both the individual and combined models for appliances and the effects of a lower consumer discount rate and disaggregated variables.

9A.4.4.1 Individual Appliance Model

The individual appliance regression equations are specified in Eq. 9A.6.

$$\boldsymbol{Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor}$$

Eq. 9A.6

In regression analysis of this model, the elasticity of *relative* price (*b*) is estimated to be -0.40 for refrigerators, -0.31 for clothes washers and -0.32 for dishwashers (Table 9A.4.3), averaging -0.35. These elasticities are similar to those reported in the literature survey for appliances (Table 9A.2.1). They are remarkably similar to the price elasticity calculated using a tabular approach (Table 9A.4.2).

The estimated coefficient associated with the "starts + replacements" variable is close to one. A coefficient equal to one for this variable would imply that, holding economic variables constant, shipments increase in direct proportion to an increase in "starts + replacements." The high R-squared values (above 95) and t-statistics (above 5) in the results provide a measure of confidence in this analysis, despite the very small data set.

Table 9A.4.3 Individual Appliance Model Results

	Refrigerator		Clothes Washer		Dishwasher	
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Intercept	-1.51	-7.26	-1.47	-8.23	-2.08	-16.78
Relative Price	-0.40	-6.60	-0.31	-5.69	-0.32	-7.03
Starts + Replacements	1.05	5.90	1.08	6.41	1.35	11.46
R^2	0.954		0.954		0.975	
Observations	23		23		23	

9A.4.4.2 Combined Appliance Model

The combined appliance regression equation is specified in Eq. 9A.7.

$$\boldsymbol{Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor + d \times CW + e \times DW}$$

Eq. 9A.7

This regression analysis indicates that the model fits the existing shipments data well (high R-squared) and that the variables included in the model are statistically significant (Table 9A.4.4). Estimated with this model, the elasticity of *relative* price is -0.34, close to the average value estimated in the individual appliance models (-0.35). It is also similar to elasticity estimates reported in the literature survey and calculated using the tabular approach in Table 9A.4.2.

Table 9A.4.4 Combined Appliance Model Result

Variable	Coefficient	t-statistic
Intercept	-1.60	-15.54
Relative Price	-0.34	-10.74
Starts + Replacements	1.21	13.95
CW	-0.20	-9.04
DW	-0.32	-6.58
R^2	0.983	
Observations	69	

9A.4.5 Additional Regression Specifications and Results

As described in section 9A.4.3, DOE used three assumptions to specify its appliance models. The first, made to aggregate appliance price and operating cost, is that the implicit price variable in the basic regression model is specified using a 37 percent implicit discount rate. The second states that the implicit price variable is defined assuming that rising income has the same impact on shipments as falling total price. The third states that the "starts + replacements" variable is defined assuming that housing starts have a similar impact on shipments as appliance replacements.

9A.4.5.1 Lower Consumer Discount Rate

To investigate the first assumption about discount rates, DOE calculated "present value operating cost" using a 20 percent implicit discount rate and performed a second regression analysis based on the models described in Eq. 9A.3 and Eq. 9A.4. The estimated coefficient associated with the *relative* price variable in these regressions is almost identical to the coefficients estimated for the same variable based on a 37 percent implicit discount rate. The elasticity of *relative* price calculated using a 20 percent discount rate is -0.33 in the combined regression and averages -0.35 for the three appliances (Table 9A.4.5). The elasticity of price calculated using a 37 percent discount rate is -0.34 in the combined regression and averages -0.35 for the three appliances. DOE concludes from this analysis that the elasticity of *relative* price is fairly insensitive to changes in the discount rate.

Table 9A.4.5 Combined and Individual Results, 20 percent discount rate

Three Appliances		
Variable	**Coefficient**	**t-Stat**
Intercept	-1.53	-14.61
Total Price / Income	-0.33	-10.69
Starts + Retirements	1.20	13.65
CW	-0.18	-8.69
DW	-0.32	-6.57
R^2	0.982	
Observations	69	

	Refrigerator		Clothes Washers		Dishwasher	
Variable	**Coefficient**	**t-Stat**	**Coefficient**	**t-Stat**	**Coefficient**	**t-Stat**
Intercept	-1.36	-6.26	-1.41	-7.49	-2.04	-17.23
Total Price / Income	-0.38	-6.50	-0.32	-5.29	-0.33	-7.30
Starts + Retirements	1.04	5.73	1.06	5.83	1.34	11.64
R^2		0.953		0.950		0.977
Observations		23		23		23

9A.4.5.2 Disaggregated Variables

To investigate the second and third assumptions, DOE constructed a regression model that separates income from total price and replacements from starts, thus adding two additional explanatory variables to the basic model (as shown earlier as Eq. 9A.5 and shown below).

$$Ship = a + b \times TP + c \times Income + d \times Start + e \times Rplc + f \times CW + g \times DW$$

Eq. 9A.8

The estimated coefficient associated with the total price variable in these regressions is almost identical to the coefficients estimated for the *relative* price variable reported above. The elasticity of total price in the above equation is -0.36 in the combined appliance regression and averages -0.35 for the three appliances (Table 9A.4.6). The elasticity of *relative* price based on the model described in Eq. 9A.4 is -0.34 in the combined regression (Table 9A.4.4) and averages -0.35 across the individual appliances (Table 9A.4.3). DOE concludes that the price elasticity calculated in this analysis is relatively insensitive to the specification of household income and "starts + replacements" variables in the model.

Table 9A.4.6 Disaggregated Regression Results, 37 percent discount rate

Three Appliances		
Variable	**Coefficient**	**t-Stat**
Intercept	-2.92	-1.26
Income	0.58	2.92
Total Price	-0.36	-7.06
Housing Starts	0.44	10.02
Retirements	0.62	8.12
CW	-0.24	-9.25
DW	-0.46	-7.68
R^2		0.985
Observations		69

	Refrigerator		Clothes Washers		Dishwasher	
Variable	**Coefficient**	**t-Stat**	**Coefficient**	**t-Stat**	**Coefficient**	**t-Stat**
Intercept	-6.19	-2.24	-6.64	-1.63	1.00	0.23
Income	0.89	3.80	0.87	2.31	0.20	0.52
Total Price	-0.35	-5.48	-0.27	-2.51	-0.43	-5.18
Housing Starts	0.41	7.38	0.25	3.29	0.62	8.24
Retirements	0.56	6.06	0.56	2.09	0.65	5.86
R^2		0.984		0.958		0.979
Observations		23		23		23

9A.5 LONG RUN IMPACTS

As noted above in Table 9A.2.1, the literature review provides price elasticities over short and long time periods, also referred to as short run and long run price elasticities. As noted in the first two rows of Table 9A.2.1, one source (*i.e.*, Hymans) shows that the price elasticity of demand is significantly different over the short run and long run for automobiles.[1] Because DOE's forecasts of shipments and national impacts due to standards is over a 30-year time period, consideration must be given to how the *relative* price elasticity is affected once a new standard takes effect.

DOE considers the *relative* price elasticities determined above in section 9A.4 to be short run elasticities. DOE was unable to identify sources specific to household durable goods, such as appliances, to indicate how short run and long run price elasticities differ. Therefore, to estimate how the *relative* price elasticity changes over time, DOE relied on the Hymans study pertaining to automobiles. Based on the Hymans study, Table 9A.5.1 shows how the automobile price elasticity of demand changes in the years following a purchase price change. With increasing years after the price change, the price elasticity becomes more inelastic until it reaches a terminal value around the tenth year after the price change.

Table 9A.5.1 Change in Price Elasticity of Demand for Automobiles following a Purchase Price Change

	Years Following Price Change					
	1	**2**	**3**	**5**	**10**	**20**
Price Elasticity of Demand	-1.20	-0.93	-0.75	-0.55	-0.42	-0.40
Relative Change in Elasticity to 1st year	1.00	0.78	0.63	0.46	0.35	0.33

Source: Hymans, 1971.

Based on the relative change in the automobile price elasticity of demand shown in Table 9A.5.1, DOE developed a time series of *relative* price elasticities for home appliances. Table 9A.5.2 presents the time series.

Table 9A.5.2 Change in Relative Price Elasticity for Home Appliances following a Purchase Price Change

	Years Following Price Change					
	1	**2**	**3**	**5**	**10**	**20**
Relative Change in Elasticity to 1st year	1.00	0.78	0.63	0.46	0.35	0.33
Relative Price Elasticity	-0.34	-0.26	-0.21	-0.16	-0.12	-0.11

9A.6 SUMMARY

This appendix describes the results of a literature search, tabular analysis, and regression analyses of the impact of price and other variables on appliance shipments. In the literature, DOE found only a few studies of appliance markets that are relevant to this analysis and no studies after 1980 using time series price and shipments data. The information that can be summarized from the literature suggests that the demand for appliances is price inelastic. Other information in the literature suggests that appliances are a normal good, such that rising incomes increase the demand for appliances. Finally, the literature suggests that consumers use relatively high implicit discount rates, when comparing appliance prices and appliance operating costs.

There are too few price and operating cost data available to perform complex analysis of dynamic changes in the appliance market. In this analysis, DOE used data available for refrigerators, clothes washers, and dishwashers to evaluate broad market trends and perform simple regression analysis.

These data indicate an increase in appliance shipments and a decline in appliance price and operating cost over the study period 1980-2002. Household income has also risen during this time. To simplify the analysis, DOE combined the available economic information into one variable, termed *relative* price, and used that variable in a tabular analysis of market trends and a regression analysis.

DOE's tabular analysis of trends in the number of appliances per household suggests that the price elasticity of demand for the three appliances is inelastic. Our regression analysis of these same variables suggests that the *relative* price elasticity of demand is -0.34. The price elasticity is consistent with estimates in the literature. Nevertheless, DOE stresses that the measure is based on a small data set, using very simple statistical analysis. More important, the measure is based on an assumption that economic variables, including price, income and operating costs, explain most of the trend in appliances per household in the United States since 1980. Changes in appliance quality and consumer preferences may have occurred during this period, but they are not accounted for in this analysis.

9A.7 DATA USED IN THE ANALYSIS

- **Appliance Shipments** are defined as the annual number of units shipped in millions. These data were collected from the Association of Home Appliance Manufacturers (AHAM)[8, 9] and Appliance Magazine[10] as annual values for each year, 1980–2002. AHAM was used for the period 1989–2002 while Appliance Magazine was used for the period 1980–1988.

- **Appliance Price** is defined as the shipments weighted retail sales price of the unit in 1999 dollars. Price values for 1980, 1985, 1986, 1991, 1993, 1994, 1998, and 2002 were collected from AHAM Fact Books.[11] Price values for other years were interpolated from these eight years of data.

- **Housing Starts** data were collected from the U.S. Census construction statistics (C25 reports) as annual values for each year, 1980–2002.[12]

- **Replacements**, driven by equipment retirements, are estimated with the assumption that some fraction of sales arise from consumers replacing equipment at the end of its useful life. Since each appliance has a different expected lifespan (19 years for refrigerators,[13] 14 years for clothes washers,[14] 12 years for dishwashers[15]), replacements are calculated differently for each appliance type. Replacements are estimated as the average of shipments 14–24 years previous for refrigerators, 9–19 years previous for clothes washers, and 7–17 years previous for dishwashers. Historical shipments data were collected from AHAM and Appliance Magazine.

- **Annual Electricity Consumption** (UEC) is defined as the energy consumption of the unit in kilowatt-hours. Electricity consumption depends on appliance capacity and efficiency. These data were provided by AHAM for 1980, 1990–1997 and 1999–2002.[9] Data were interpolated in the years for which data were not available.

- **Operating Cost** is the present value of the electricity consumption of an appliance over its expected lifespan. The lifespans of refrigerators, clothes washers and dishwashers are assumed to be 19, 14, and 12 years respectively. Discount rates of 20 percent[6] and 37 percent[16] were used, producing similar estimates of price elasticity. A study by Hausman recommended a discount rate of "about 20 percent" in its introduction and presented results ranging from 24.1 percent to 29 percent based on his calculations for room air conditioners. A study by Train suggests a range of implicit discount rates averaging 35 percent for appliances.

- **Income:** Median annual household income in 2003 dollars. These data were collected for each year, 1980–2002, from Table H-6 of the U.S. Census.[17]

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APPENDIX 10A. USER INSTRUCTIONS FOR NATIONAL IMPACT ANALYSIS SPREADSHEET MODEL

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APPENDIX 10A. USER INSTRUCTIONS FOR NATIONAL IMPACT ANALYSIS SPREADSHEET MODEL

10A.1 USER INSTRUCTIONS

The results obtained in this analysis can be examined and reproduced using the Microsoft Excel® spreadsheets accessible on the Internet from the Department of Energy's (DOE's) hearth products rulemaking page: www1.eere.energy.gov/buildings/appliance_standards/product.aspx?productid=83. From that page, follow the links to the Preliminary Analysis phase of the rulemaking and then to the analytical tools.

10A.2 STARTUP

The NIA spreadsheets enable the user to perform a National Impact Analysis (NIA) for hearth product ignition devices. To utilize the spreadsheet, the Department assumes that the user has access to a PC with a hardware configuration capable of running Windows 2003 or later. To use the NIA spreadsheets, the user requires Microsoft Excel® 2003 or later installed under the Windows operating system.

10A.3 DESCRIPTION OF NATIONAL IMPACT ANALYSIS WORKSHEETS

The NIA spreadsheets perform calculations to project the change in national energy use and net present value of financial impacts due to revised energy efficiency standards. The energy use and associated costs for a given standard level are determined by calculating the shipments and then calculating the energy use and costs for all hearth products shipped under that standard. The differences between the standards and base case can then be compared and the overall energy savings and net present values determined. The NIA spreadsheets consist of the following worksheets:

All Scenarios	Contains NPV, NES, and intermediate results for all product types, AEO economic scenarios, and discount rates. Also contains a summary pivot table of NES and NPV results by TSL for user-selected AEO economic scenario and discount rate parameters.
Summary	Contains a summary of disaggregated NIA and site NES results for all product types
Fireplace (vented)	Contains vented fireplace NIA calculations.
Fireplace (ventless)	Contains ventless fireplace NIA calculations.
Logs (vented)	Contains vented log set NIA calculations.
Logs (ventless)	Contains ventless log set NIA calculations.
Outdoor	Contains outdoor hearth product NIA calculations.
PC Inputs	Contains energy use, electricity use, retail price, installation cost, annual repair costs, and annual maintenance costs, for each product class.
Shipments	Includes historical and projected shipments data for each product type.
Price_Elasticity	Includes the price elasticity to account for the change in the percentage of consumers acquiring a hearth product divided by a change in the relative price.
Base-Case Shipments	Contains shipments projections by product type under the base case (no standard).
Lifetime	Includes the lifetime and the retirement function for each product type.
Energy Price	Contains energy prices for each product type by year.

10A.4 BASIC INSTRUCTIONS FOR OPERATING THE NATIONAL IMPACT ANALYSIS SPREADSHEETS

Basic instructions for operating the NIA spreadsheets are as follows:

1. Once the NIA spreadsheet file has been downloaded from the Department's web site, open the file using MS Excel. Click "Enable Macro" when prompted and then click on the tab for the worksheet User Inputs.
2. Use MS Excel's View/Zoom commands at the top menu bar to change the size of the display to make it fit your monitor.
3. The user can change the parameters in the sheet "Summary". The default parameters (shown in Figure 10A.4.1) are:

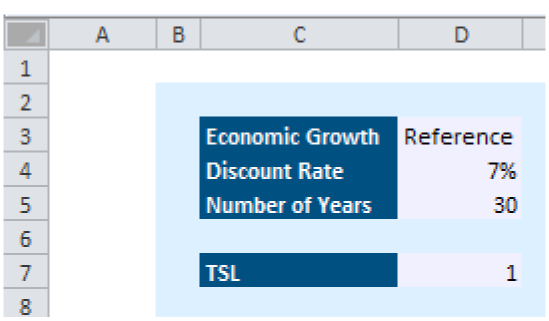

Figure 10A.4.1 The default user input parameters

a) Economic Growth Scenario: Set to “Reference” (AEO 2014 Reference Case). To change value, click on the pull down menu next to cell D3 “Economic Growth Scenario” and change to desired scenario (Reference, Low, or High).
b) Number of Years: Set to 30. To change value, click on the pull down menu next to cell D5 and change to desired analysis period (30 or 9 years). The year that analysis ends is automatically calculated based on the year standards in effect and analysis period.
c) Discount Rates: Set to 7%. To change value, click on the pull down menu next to cell D4 and change to desired value (7% or 3%).
d) TSL: Set to 1.

4. The spreadsheet automatically updates the analysis results based on user inputs: National Energy Savings, Net Present Values and intermediate results by product type, in cells H4 to M9.

   Note: Make sure that the spreadsheet is in automatic calculation mode. The calculation mode could be changed by (shown in Figure 10A.4.2):

   1. In Excel 2010 and later, go to the tab “Formulas” in the Office ribbon.
   2. Click on the button “Calculation Options” and select “Automatic”.

The results are automatically updated and are reported in the source energy savings matrix, net present value matrix, and summary table for each product class.

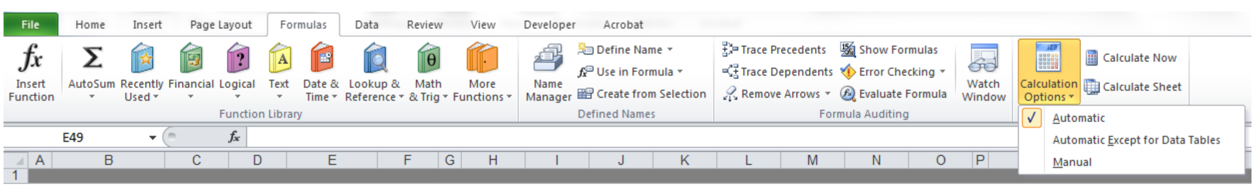

Figure 10A.4.2 Set the spreadsheet to automatic calculation mode

APPENDIX 10B. FULL FUEL CYCLE MULTIPLIERS

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APPENDIX 10B. FULL FUEL CYCLE MULTIPLIERS

10B.1 INTRODUCTION

This appendix summarizes the methods used to calculate full-fuel-cycle (FFC) energy savings expected to result from proposed standards. The FFC measure includes point-of-use (site) energy, the energy losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels. DOE's traditional approach encompassed only site energy and the energy losses associated with generation, transmission, and distribution of electricity. Per DOE's 2011 *Statement of Policy for Adopting Full Fuel Cycle Analyses*, DOE now uses FFC measures of energy use and emissions in its energy conservation standards analyses.[1] This appendix summarizes the methods used to incorporate the full-fuel-cycle impacts into the analysis.

This analysis uses several different terms to reference energy use. The physical sources of energy are the primary fuels such as coal, natural gas, liquid fuels, *etc*. Primary energy is equal to the heat content (Btu) of the primary fuels used to provide an end-use service. Site energy use is defined as the energy consumed at the point-of-use in a building or industrial process. Where natural gas and petroleum fuels are consumed at the site (for example in a hearth product), site energy is identical to primary energy, with both equal to the heat content of the primary fuel consumed. For electricity, site energy is measured in kWh. In this case the primary energy is equal to the quads of primary energy required to generate and deliver the site electricity. This primary energy is calculated by multiplying the site kWh times the site-to-power plant energy use factor, given in chapter 10. For the FFC analysis, the upstream energy use is defined as the energy consumed in extracting, processing, and transporting or distributing primary fuels. FFC energy use is the sum of primary energy at the site or power plant plus upstream energy use.

Both primary fuels and electricity are used in upstream activities. The treatment of electricity in fuel cycle analysis must distinguish between electricity generated by fossil fuels and uranium, and electricity generated from renewable fluxes (wind, solar and hydro). For the former, the upstream fuel cycle impacts are derived based on the amount of fuel consumed at the power plant. For the latter, no fuel *per se* is used, so there is no upstream component.

10B.2 METHODOLOGY

The mathematical approach is discussed in the paper *A Mathematical Analysis of Full Fuel Cycle Energy Use,* [2] and details on the fuel production chain analysis are presented in the paper *Projections of Full Fuel Cycle Energy and Emissions Metrics*.[3] The text below provides a brief summary of the methods used to calculate FFC energy.

When all energy quantities are normalized to the same units, the FFC energy use can be represented as the product of the primary energy use and an *FFC multiplier*. The FFC multiplier is defined mathematically as a function of a set of parameters representing the energy intensity and material losses at each production stage. These parameters depend only on physical data, so the calculations do not require any assumptions about prices or other economic data. While in general these parameter values may vary by geographic region, for this analysis national averages are used.

In the notation below, the indices x and y are used to indicate fuel type, with x=c for coal, x=g for natural gas, x=p for petroleum fuels, x=u for uranium and x=r for renewable fluxes. The fuel cycle parameters are:

- a_x is the quantity of fuel x burned per unit of electricity output, on average, for grid electricity. The calculation of a_x includes a factor to account for transmission and distribution system losses.
- b_y is the amount of grid electricity used in production of fuel y, in MWh per physical unit of fuel y.
- c_{xy} is the amount of fuel x consumed in producing one unit of fuel y.
- q_x is the heat content of fuel x (MBTU/physical unit)
- z_x(s) is the emissions intensity for fuel x (mass of pollutant s per physical unit of x)

The parameters are calculated as a function of time with an annual time step; hence, a time series of annual values is used to estimate the FFC energy and emissions savings in each year of the analysis period. Fossil fuel quantities are converted to energy units using the heat content factors q_x. To convert electricity in kWh to primary energy units, on-site electricity consumption is multiplied by the power sector primary energy use factor indicated in chapter 10. The power sector primary energy use factor is defined as the ratio of the total primary energy consumption by the electric power sector (in quadrillion BTUs) divided by the total electricity generation in each year.

The FFC multiplier is a dimensionless number denoted μ (mu). The upstream component of the energy savings is proportional to (μ-1). A separate multiplier is calculated for each fuel used on site. The fuel type is denoted by a subscript on the multiplier μ. A multiplier is also calculated for electricity reflecting the fuel mix used in its generation.

For DOE's appliance standards energy savings estimates, the FFC analysis methodology is designed to make use of data and projections published in the Annual Energy Outlook (AEO). Table 10B.2.1 provides a summary of the AEO data used as inputs to the different parameter calculations. The AEO does not provide all the information needed to estimate total energy use in the fuel production chain. The *Projections of Full Fuel Cycle Energy and Emissions Metrics* paper[3] describes the additional data sources used to complete the analysis. However, the time dependence in the FFC multipliers arises exclusively from variables taken from the AEO. The FFC analysis for this rulemaking used data from *AEO 2014*.[4]

Table 10B.2.1 Dependence of FFC Parameters on AEO Inputs

Parameter	Fuel	AEO Table	Variables
q_x	all	Conversion Factors	MMBTU per physical unit
a_x	all	Electricity Supply, Disposition, Prices, and Emissions	Generation by fuel type
		Energy Consumption by Sector and Source	Electric power sector energy consumption
b_c, c_{nc}, c_{pc}	coal	Coal Production by Region and Type	Production by coal type and sulfur content
b_p, c_{np}, c_{pp}	petroleum	Refining Industry Energy Consumption	Refining only energy use
		Liquid Fuels Supply and Disposition	Crude supply by source
		International Liquids Supply and Disposition	Crude oil imports
		Oil and Gas Supply	Crude oil domestic production
c_{nn}	natural gas	Oil and Gas Supply	US dry gas production
		Natural Gas Supply, Disposition and Prices	Pipeline, lease and plant fuel
z_x	all	Electricity Supply, Disposition, Prices and Emissions	Power sector emissions

10B.3 FULL-FUEL-CYCLE ENERGY MULTIPLIERS

Upstream energy multipliers are presented in Table 10B.3.1 for selected years. For years after 2040 (the last year in the AEO), DOE maintained the 2040 value. The multipliers are applied to site energy. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation over the forecast period.

Table 10B.3.1 Upstream Energy Multipliers (Based on AEO 2014)

	2021	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	1.044	1.045	1.046	1.047	1.047	1.047	1.047
Natural Gas	1.110	1.111	1.113	1.114	1.114	1.114	1.114

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APPENDIX 10C. NATIONAL IMPACT ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR HEARTH PRODUCTS

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APPENDIX 10C. NATIONAL IMPACT ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR HEARTH PRODUCTS

10C.1 INTRODUCTION

This appendix presents National Impact Analysis (NIA) results using energy price forecasts from alternative economic growth scenarios. The scenarios are based on the High Economic Growth case and the Low Economic Growth case from Energy Information Administration's (EIA's) *Annual Energy Outlook 2014* (*AEO 2014*).[1] To estimate energy prices after 2040 in the high and low scenarios, DOE used the growth rate between 2021 and 2040. See appendix 8C for details about alternative economic growth scenarios.

This appendix also describes the High and Low Economic Growth scenarios in further detail. See appendix 10A for details about how to generate NIA results for High Economic Growth and Low Economic Growth scenarios using the NIA spreadsheet.

10C.2 DESCRIPTION OF HIGH AND LOW ECONOMIC SCENARIOS

To generate NIA results reported in chapter 10, DOE uses the Reference case energy price and housing projections from *AEO 2014*. The reference case is a business-as-usual estimate, given known market, demographic, and technological trends. For *AEO 2014*, EIA explored the impacts of alternative assumptions in other scenarios with different macroeconomic growth rates, world oil prices, rates of technology progress, and policy changes.

To reflect uncertainty in the projection of U.S. economic growth, EIA's *AEO 2014* uses High and Low Economic Growth scenarios to project the possible impacts of alternative economic growth assumptions on energy markets.[2]

In general, energy prices are higher in the High Economic Growth scenario and lower in the Low Economic Growth scenario. See appendix 8E for details about the effect of these alternative economic scenarios on energy prices.

Because *AEO 2014* provides the price trends by census division, each sampled household is then matched to the appropriate census division price trend. See chapter 10 for details about how energy price trends by census division are applied in the NIA analysis.

In addition, the High and Low Economic Growth scenarios provide different housing starts projections that affect the hearth product shipments projections. Figure 10C.2.1 shows the shipments projections based on the different *AEO 2014* scenarios.

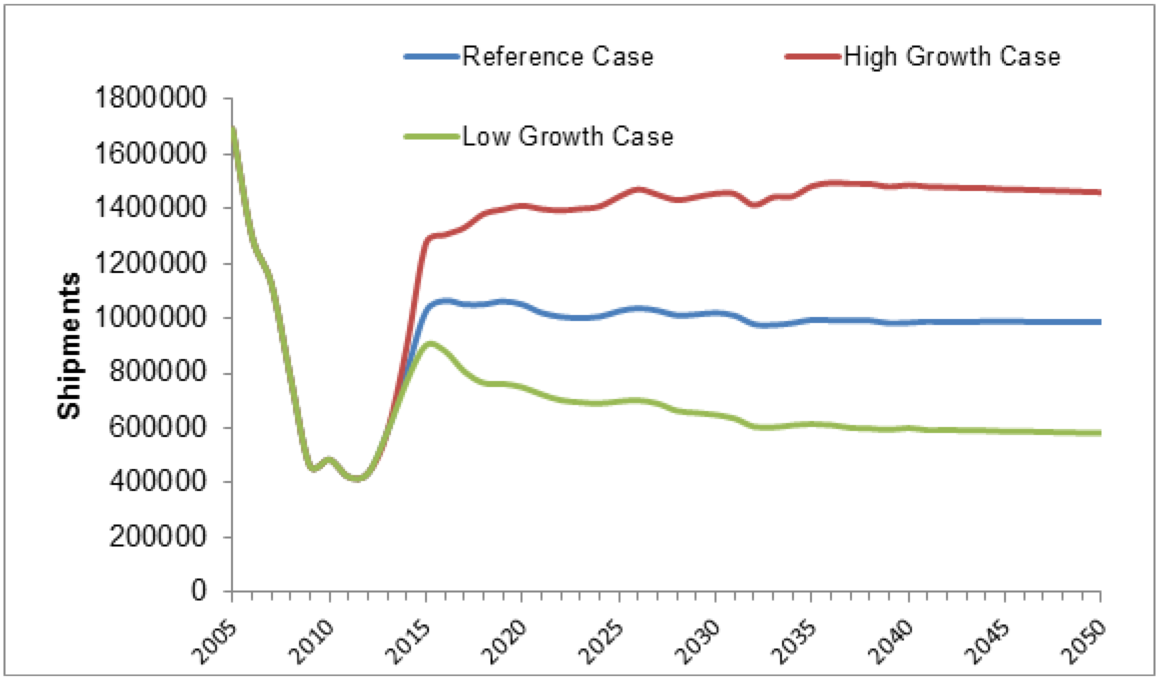

Figure 10C.2.1 Shipment Projections for Reference Case and High and Low Economic Growth Scenarios (Base Case)

10C.3 RESULTS

10C.3.1 National Energy Savings

Table 10C.3.1 through Table 10C.3.3 show the national energy savings (NES) results for the Trial Standard Levels (TSL) analyzed for hearth product ignition systems using the Reference case, High Economic Growth scenario, and Low Economic Growth scenario.

Table 10C.3.1 Full Fuel Cycle National Energy Savings (Quads) – Reference Case

Product Classes	Trial Standard Levels
	1
Hearth Products	0.69

Table 10C.3.2 Full Fuel Cycle National Energy Savings (Quads) – High Economic Growth

Product Classes	Trial Standard Levels
	1
Hearth Products	1.01

Table 10C.3.3 Full Fuel Cycle National Energy Savings (Quads) – Low Economic Growth

Product Classes	Trial Standard Levels
	1
Hearth Products	0.44

10C.3.2 Net Present Value of Consumer Impacts

Table 10C.3.4 through Table 10C.3.9 show the national present value (NPV) results for the TSLs analyzed for hearth product ignition systems using the Reference case, High Economic Growth scenario, and Low Economic Growth scenario.

Table 10C.3.4 Net Present Value, Discounted at 3 Percent (Billion 2013$) – Reference Case

Product Classes	Trial Standard Levels
	1
Hearth Products	3.1

Table 10C.3.5 Net Present Value, Discounted at 7 Percent (Billion 2013$) – Reference Case

Product Classes	Trial Standard Levels
	1
Hearth Products	1.0

Table 10C.3.6 Net Present Value, Discounted at 3 Percent (Billion 2013$) – High Economic Growth

Product Classes	Trial Standard Levels
	1
Hearth Products	4.9

Table 10C.3.7 Net Present Value, Discounted at 7 Percent (Billion 2013$) – High Economic Growth

Product Classes	Trial Standard Levels
	1
Hearth Products	1.6

Table 10C.3.8 Net Present Value, Discounted at 3 Percent (Billion 2013$) – Low Economic Growth

Product Classes	Trial Standard Levels
	1
Hearth Products	1.8

Table 10C.3.9 Net Present Value, Discounted at 7 Percent (Billion 2013$) – Low Economic Growth

Product Classes	Trial Standard Levels
	1
Hearth Products	0.6

10C.3.3 Summary

Table 10C.3.10 shows the NES and NPV results for each of the TSL for the Reference case and the High Economic Growth and Low Economic Growth scenarios. NES and NPV results are larger for High Economic Growth scenario and smaller for Low Economic Growth scenario compared to Reference case.

Table 10C.3.10 Comparison of Energy Savings and Net Present Value Results for Reference Case and High and Low Economic Growth Scenarios

		Trial Standard Level
		1
Reference	Full Fuel Cycle Energy Savings (quads)	0.69
	NPV 3% (billion 2013$)	3.1
	NPV 7% (billion 2013$)	1.0
High Economic Growth	Full Fuel Cycle Energy Savings (quads)	1.01
	NPV 3% (billion 2013$)	4.9
	NPV 7% (billion 2013$)	1.6
Low Economic Growth	Full Fuel Cycle Energy Savings (quads)	0.44
	NPV 3% (billion 2013$)	1.8
	NPV 7% (billion 2013$)	0.6

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APPENDIX 12A. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

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APPENDIX 12A. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

12A.1 INTRODUCTION AND PURPOSE

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards and other regulations on manufacturers. The basic mode of analysis is to estimate the change in the value of the industry or manufacturers(s) following a regulation or a series of regulations. The model structure also allows an analysis of multiple products with regulations taking effect over a period of time, and of multiple regulations on the same products.

Industry net present value is defined, for the purpose of this analysis, as the discounted sum of industry free cash flows plus a discounted terminal value. The model calculates the actual cash flows by year and then determines the present value of those cash flows both without an energy conservation standard (*i.e.*, the base case) and under different trial standard levels (*i.e.*, the standards case).

Outputs from the model consist of summary financial metrics, graphs of major variables, and, when appropriate, access to the complete cash flow calculation.

12A.2 MODEL DESCRIPTION

The basic structure of the GRIM is a standard annual cash flow analysis that uses manufacturer selling prices, manufacturing costs, a shipments forecast, and financial parameters as inputs and accepts a set of regulatory conditions as changes in costs and investments. The cash flow analysis is separated into two major blocks: income and cash flow. The income calculation determines net operating profit after taxes. The cash flow calculation converts net operating profit after taxes into an annual cash flow by including investment and non-cash items. Below are definitions of listed items on the printout of the output sheet of the GRIM.

(1) ***Unit sales:*** Total annual shipments for the industry were obtained from the national impact analysis spreadsheet.

(2) ***Revenues:*** Annual revenues are computed by multiplying products' unit prices at each efficiency level by the appropriate manufacturer markup.

(3) ***Material:*** The portion of cost of goods sold (COGS) that includes materials.

(4) ***Labor:*** The portion of COGS that includes direct labor, commissions, dismissal pay, bonuses, vacation, sick leave, social security contributions, fringe, and assembly labor up-time.

(5) ***Depreciation:*** The portion of overhead that includes an allowance for the total amount of fixed assets used to produce that one unit. Annual depreciation is computed as a percentage of COGS**.** While included in overhead, the depreciation is shown as a separate line item.

(6) ***Overhead:*** The portion of COGS that includes indirect labor, indirect material, energy use, maintenance, depreciation, property taxes, and insurance related to assets. While included in overhead, depreciation is shown as a separate line item.

(7) ***Standard SG&A:*** Selling, general, and administrative costs are computed as a percentage of revenues (2).

(8) ***R&D:*** GRIM separately accounts for ordinary research and development as a percentage of revenues (2).

(9) ***Product conversion costs:*** Product conversion costs are one-time investments in research, development, testing, marketing, and other costs focused on making products designs comply with the new energy conservation standard. The GRIM allocates these costs over the period between the standard's announcement and compliance dates.

(10) ***Stranded assets:*** In the year the standard becomes effective, a one-time write-off of stranded assets is accounted for.

(11) ***Earnings before interest and taxes (EBIT):*** Includes profits before deductions for interest paid and taxes.

(12) ***EBIT as a percentage of sales (EBIT/revenues):*** GRIM calculates EBIT as a percentage of sales to compare with the industry's average reported in financial statements.

(13) ***Taxes:*** Taxes on EBIT (11) are calculated by multiplying the tax rate contained in major assumptions by EBIT (11).

(14) ***Net operating profits after taxes (NOPAT):*** Computed by subtracting COGS ((3) to (6)), SG&A (7), R&D (8), product conversion costs (9), and taxes (13) from revenues (2).

(15) ***NOPAT repeated***: NOPAT is repeated in the statement of cash flows.

(16) ***Depreciation repeated***: Depreciation and stranded assets are added back into the statement of cash flows because they are non-cash expenses.

(17) ***Change in working capital***: Change in cash tied up in accounts receivable, inventory, and other cash investments necessary to support operations is calculated by multiplying working capital (as a percentage of revenues) by the change in annual revenues.

(18) ***Cash flow from operations***: Calculated by taking NOPAT (15), adding back non-cash items such as a depreciation (16), and subtracting the change in working capital (17).

(19) ***Ordinary capital expenditures:*** Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of revenues (2).

(20) ***Capital conversion costs:*** Capital conversion costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new product

designs can be fabricated and assembled under the new regulation. The GRIM allocates these costs over the period between the standard's announcement and compliance dates.

(21)* *Capital investment: Total investments in property, plant, and equipment are computed by adding ordinary capital expenditures (19) and capital conversion costs (20).

(22)* *Free cash flow: Annual cash flow from operations and investments; computed by subtracting capital investment (21) from cash flow from operations (18).

(23)* *Terminal value: Estimate of the continuing value of the industry after the analysis period. Computed by growing the free cash flow at a constant rate in perpetuity.

(24)* *Present value factor: Factor used to calculate an estimate of the present value of an amount to be received in the future.

(25)* *Discounted cash flow: Free cash flows (22) multiplied by the present value factor (24). For the end of 2050, the discounted cash flow includes the discounted terminal value (23).

(26)* *Industry value through the end of 2050: The sum of discounted cash flows (25).

Table 12A.2.1 Detailed Cash Flow Example

Base Case DCF

Navigatio

Industry Income Statement (in millions)	2013	Base Yr 2014	Ancmt Yr 2015	2016	2017	2018	PTAC Std 2019	2020	2021	2022	2023	2024	2025
Revenues	$ 226.742	$ 227.465	$ 230.291	$ 233.426	$ 237.012	$ 239.655	$ 242.694	$ 245.556	$ 248.429	$ 251.441	$ 254.830	$ 258.281	$ 261.517
Total Shipments	0.488	0.488	0.494	0.500	0.506	0.511	0.517	0.522	0.527	0.533	0.539	0.545	0.551
- Materials	$ 145.4	$ 145.8	$ 147.5	$ 149.4	$ 151.6	$ 153.2	$ 155.1	$ 156.8	$ 158.6	$ 160.4	$ 162.5	$ 164.6	$ 166.6
- Labor	$ 11.2	$ 11.2	$ 11.4	$ 11.6	$ 11.8	$ 12.0	$ 12.2	$ 12.3	$ 12.5	$ 12.7	$ 12.9	$ 13.1	$ 13.3
- Depreciation	$ 10.0	$ 10.1	$ 10.3	$ 10.4	$ 10.7	$ 10.8	$ 11.0	$ 11.2	$ 11.4	$ 11.5	$ 11.7	$ 12.0	$ 12.2
- Overhead	$ 12.0	$ 12.0	$ 12.2	$ 12.3	$ 12.5	$ 12.7	$ 12.8	$ 13.0	$ 13.2	$ 13.3	$ 13.5	$ 13.7	$ 13.9
- Standard SG&A	$ 34.0	$ 34.1	$ 34.5	$ 35.0	$ 35.6	$ 35.9	$ 36.4	$ 36.8	$ 37.3	$ 37.7	$ 38.2	$ 38.7	$ 39.2
- R&D	$ 6.8	$ 6.8	$ 6.9	$ 7.0	$ 7.1	$ 7.2	$ 7.3	$ 7.4	$ 7.5	$ 7.5	$ 7.6	$ 7.7	$ 7.8
- Product Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Earnings Before Interest and Taxes (EBIT)	$ 7.4	$ 7.4	$ 7.5	$ 7.6	$ 7.7	$ 7.8	$ 7.9	$ 8.0	$ 8.1	$ 8.2	$ 8.3	$ 8.4	$ 8.5
Per Unit EBIT ($)	$ 15.15	$ 15.18	$ 15.21	$ 15.23	$ 15.26	$ 15.29	$ 15.31	$ 15.34	$ 15.36	$ 15.39	$ 15.41	$ 15.44	$ 15.46
EBIT/Revenues (%)	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*
- Taxes	$ 2.5	$ 2.5	$ 2.6	$ 2.6	$ 2.6	$ 2.7	$ 2.7	$ 2.7	$ 2.8	$ 2.8	$ 2.8	$ 2.9	$ 2.9
Net Operating Profit after Taxes (NOPA	**$ 4.9**	**$ 4.9**	**$ 5.0**	**$ 5.0**	**$ 5.1**	**$ 5.2**	**$ 5.2**	**$ 5.3**	**$ 5.3**	**$ 5.4**	**$ 5.5**	**$ 5.6**	**$ 5.6**
Cash Flow Statement													
NOPAT	$ 4.9	$ 4.9	$ 5.0	$ 5.0	$ 5.1	$ 5.2	$ 5.2	$ 5.3	$ 5.3	$ 5.4	$ 5.5	$ 5.6	$ 5.6
+ Depreciation	$ 10.0	$ 10.1	$ 10.3	$ 10.4	$ 10.7	$ 10.8	$ 11.0	$ 11.2	$ 11.4	$ 11.5	$ 11.7	$ 12.0	$ 12.2
+ Loss on Disposal of Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Change in Working Capital	$ -	$ 0.1	$ 0.2	$ 0.2	$ 0.3	$ 0.2	$ 0.2	$ 0.2	$ 0.2	$ 0.2	$ 0.2	$ 0.2	$ 0.2
Cash Flows from Operations	$ 14.9	$ 14.9	$ 15.0	$ 15.3	$ 15.5	$ 15.8	$ 16.0	$ 16.3	$ 16.5	$ 16.7	$ 17.0	$ 17.3	$ 17.6
- Ordinary Capital Expenditures	$ 11.3	$ 11.4	$ 11.5	$ 11.7	$ 11.9	$ 12.0	$ 12.1	$ 12.3	$ 12.4	$ 12.6	$ 12.7	$ 12.9	$ 13.1
- Capital Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Free Cash Flow	**$ 3.6**	**$ 3.6**	**$ 3.5**	**$ 3.6**	**$ 3.7**	**$ 3.8**	**$ 3.9**	**$ 4.0**	**$ 4.1**	**$ 4.2**	**$ 4.3**	**$ 4.4**	**$ 4.5**
Discounted Cash Flow													
Free Cash Flow	$ 3.6	$ 3.6	$ 3.5	$ 3.6	$ 3.7	$ 3.8	$ 3.9	$ 4.0	$ 4.1	$ 4.2	$ 4.3	$ 4.4	$ 4.5
Terminal Value	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-
Present Value Factor	*0.000*	*1.000*	*0.922*	*0.849*	*0.783*	*0.722*	*0.665*	*0.613*	*0.565*	*0.521*	*0.480*	*0.442*	*0.408*
Discounted Cash Flow	**$ -**	**$ 3.6**	**$ 3.2**	**$ 3.0**	**$ 2.9**	**$ 2.8**	**$ 2.6**	**$ 2.4**	**$ 2.3**	**$ 2.2**	**$ 2.0**	**$ 1.9**	**$ 1.8**
INPV at Baseline $ 58.5													
Net PPE	$ 34.0	$ 35.3	$ 36.5	$ 37.8	$ 39.0	$ 40.1	$ 41.2	$ 42.3	$ 43.4	$ 44.4	$ 45.4	$ 46.4	$ 47.3
Net PPE as % of Sales	15.0%	15.5%	15.9%	16.2%	16.4%	16.7%	17.0%	17.2%	17.5%	17.7%	17.8%	18.0%	18.1%
Net Working Capital	$ 15.9	$ 15.9	$ 16.1	$ 16.3	$ 16.6	$ 16.8	$ 17.0	$ 17.2	$ 17.4	$ 17.6	$ 17.8	$ 18.1	$ 18.3
Return on Invested Capital (ROIC)	9.78%	9.56%	9.41%	9.28%	9.18%	9.06%	8.97%	8.88%	8.79%	8.72%	8.67%	8.62%	8.58%
Weighted Average Cost of Capital (WACC)	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%
Return on Sales (EBIT/Sales)	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%

This tab computes key parameters from an income statement based on unit sales, revenues and COGS, and initial financial inputs (parameters as a % of revenue). It also computes an INPV based on a discounted cash flow model.

APPENDIX 14A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

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APPENDIX 14A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866[a]

14A.1 EXECUTIVE SUMMARY

Under Executive Order 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the "social cost of carbon" (SCC) estimates presented here is to allow agencies to incorporate the social benefits of reducing carbon dioxide (CO_2) emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

This document presents a summary of the interagency process that developed these SCC estimates. Technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

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[a] Prepared by Interagency Working Group on Social Cost of Carbon, United States Government.
With participation by:
Council of Economic Advisers
Council on Environmental Quality
Department of Agriculture
Department of Commerce
Department of Energy
Department of Transportation
Environmental Protection Agency
National Economic Council
Office of Energy and Climate Change
Office of Management and Budget
Office of Science and Technology Policy
Department of the Treasury

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution.

Table 14A.1.1 Social Cost of CO_2, 2010 – 2050 (in 2007 dollars)

	Discount Rate			
	5%	3%	2.5%	3%
Year	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

14A.2 MONETIZING CARBON DIOXIDE EMISSIONS

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. We report estimates of the SCC in dollars per metric ton of carbon dioxide throughout this document.[b]

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

[b] In this document, we present all values of the SCC as the cost per metric ton of CO_2 emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of CO_2 and the mass of carbon is 3.67 (the molecular weight of CO_2 divided by the molecular weight of carbon = 44/12 = 3.67).

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Under Executive Order 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. Most federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the benefits from reduced (or costs from increased) emissions in any future year can be estimated by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions; we do not attempt to answer that question here.

An interagency group convened on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key inputs and assumptions in order to generate SCC estimates. Agencies that actively participated in the interagency process include the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury. This process was convened by the Council of Economic Advisers and the Office of Management and Budget, with active participation and regular input from the Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions that are grounded in the existing literature. In this way, key uncertainties and model differences can more transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are $5, $21, $35, and $65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socioeconomic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95^{th} percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of CO_2 in 2015 and \$26 per ton of CO_2 in 2020. See section 16-A.5 for the full range of annual SCC estimates from 2010 to 2050.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, we have set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, we will continue to explore the issues raised in this document and consider public comments as part of the ongoing interagency process.

14A.3 SOCIAL COST OF CARBON VALUES USED IN PAST REGULATORY ANALYSES

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing carbon dioxide emissions. In the final model year 2011 CAFE rule, the Department of Transportation (DOT) used both a "domestic" SCC value of \$2 per ton of CO_2 and a "global" SCC value of \$33 per ton of CO_2 for 2007 emission reductions (in 2007 dollars), increasing both values at 2.4 percent per year. It also included a sensitivity analysis at \$80 per ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in carbon dioxide emissions, while a global SCC value is meant to reflect the value of damages worldwide.

A 2008 regulation proposed by DOT assumed a domestic SCC value of \$7 per ton CO_2 (in 2006 dollars) for 2011 emission reductions (with a range of \$0-\$14 for sensitivity analysis), also increasing at 2.4 percent per year. A regulation finalized by DOE in October of 2008 used a domestic SCC range of \$0 to \$20 per ton CO_2 for 2007 emission reductions (in 2007 dollars). In addition, EPA's 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as "very preliminary" SCC estimates subject to revision. EPA's global mean values were \$68 and \$40 per ton CO_2 for discount rates of approximately 2 percent and 3 percent, respectively (in 2006 dollars for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted.

The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006 dollars) of \$55, \$33, \$19, \$10, and \$5 per ton of CO_2. The \$33 and \$5 values represented model-weighted means of the published estimates produced from the most recently available versions of three integrated assessment models—

DICE, PAGE, and FUND—at approximately 3 and 5 percent discount rates. The $55 and $10 values were derived by adjusting the published estimates for uncertainty in the discount rate (using factors developed by Newell and Pizer (2003)) at 3 and 5 percent discount rates, respectively. The $19 value was chosen as a central value between the $5 and $33 per ton estimates. All of these values were assumed to increase at 3 percent annually to represent growth in incremental damages over time as the magnitude of climate change increases.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and CO_2 tailpipe emission proposed rules.

14A.4 APPROACH AND KEY ASSUMPTIONS

Since the release of the interim values, the interagency group has reconvened on a regular basis to generate improved SCC estimates. Specifically, the group has considered public comments and further explored the technical literature in relevant fields. This section details the several choices and assumptions that underlie the resulting estimates of the SCC.

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable, since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Academy of Science (2009) points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. Throughout this document, we highlight a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC.

The U.S. Government will periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance. The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them and with a sincere promise to continue work to improve them.

14A.4.1 Integrated Assessment Models

We rely on three integrated assessment models (IAMs) commonly used to estimate the SCC: the FUND, DICE, and PAGE models.[c] These models are frequently cited in the peer-reviewed literature and used in the IPCC assessment. Each model is given equal weight in the SCC values developed through this process, bearing in mind their different limitations (discussed below).

These models are useful because they combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework. At the same time, they gain this advantage at the expense of a more detailed representation of the underlying climatic and economic systems. DICE, PAGE, and FUND all take stylized, reduced-form approaches (see NRC 2009 for a more detailed discussion; see Nordhaus 2008 on the possible advantages of this approach). Other IAMs may better reflect the complexity of the science in their modeling frameworks but do not link physical impacts to economic damages. There is currently a limited amount of research linking climate impacts to economic damages, which makes this exercise even more difficult. Underlying the three IAMs selected for this exercise are a number of simplifying assumptions and judgments reflecting the various modelers' best attempts to synthesize the available scientific and economic research characterizing these relationships.

The three IAMs translate emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. The emissions projections used in the models are based on specified socioeconomic (GDP and population) pathways. These emissions are translated into concentrations using the carbon cycle built into each model, and concentrations are translated into warming based on each model's simplified representation of the climate and a key parameter, climate sensitivity. Each model uses a different approach to translate warming into damages. Finally, transforming the stream of economic damages over time into a single value requires judgments about how to discount them.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. In PAGE, for example, the consumption-equivalent damages in each period are calculated as a fraction of GDP, depending on the temperature in that period relative to the pre-industrial average temperature in each region. In FUND, damages in each period also depend on the rate of temperature change from the prior period. In DICE, temperature affects both consumption and investment. We describe each model in greater detail here. In a later section, we discuss key gaps in how the models account for various scientific and

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[c] The DICE (Dynamic Integrated Climate and Economy) model by William Nordhaus evolved from a series of energy models and was first presented in 1990 (Nordhaus and Boyer 2000, Nordhaus 2008). The PAGE (Policy Analysis of the Greenhouse Effect) model was developed by Chris Hope in 1991 for use by European decision-makers in assessing the marginal impact of carbon emissions (Hope 2006, Hope 2008). The FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model, developed by Richard Tol in the early 1990s, originally to study international capital transfers in climate policy. is now widely used to study climate impacts (*e.g.*, Tol 2002a, Tol 2002b, Anthoff et al. 2009, Tol 2009).

economic processes (*e.g.* the probability of catastrophe, and the ability to adapt to climate change and the physical changes it causes).

The parameters and assumptions embedded in the three models vary widely. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches to quantifying damages taken by the key modelers in the field. An extensive review of the literature was conducted to select three sets of input parameters for these models: climate sensitivity, socioeconomic and emissions trajectories, and discount rates. A probability distribution for climate sensitivity was specified as an input into all three models. In addition, the interagency group used a range of scenarios for the socioeconomic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments. In DICE, these parameters are handled deterministically and represented by fixed constants; in PAGE, most parameters are represented by probability distributions. FUND was also run in a mode in which parameters were treated probabilistically.

The sensitivity of the results to other aspects of the models (*e.g.* the carbon cycle or damage function) is also important to explore in the context of future revisions to the SCC but has not been incorporated into these estimates. Areas for future research are highlighted at the end of this document.

The DICE Model

The DICE model is an optimal growth model based on a global production function with an extra stock variable (atmospheric carbon dioxide concentrations). Emission reductions are treated as analogous to investment in "natural capital." By investing in natural capital today through reductions in emissions—implying reduced consumption—harmful effects of climate change can be avoided and future consumption thereby increased.

For purposes of estimating the SCC, carbon dioxide emissions are a function of global GDP and the carbon intensity of economic output, with the latter declining over time due to technological progress. The DICE damage function links global average temperature to the overall impact on the world economy. It varies quadratically with temperature change to capture the more rapid increase in damages expected to occur under more extreme climate change, and is calibrated to include the effects of warming on the production of market and nonmarket goods and services. It incorporates impacts on agriculture, coastal areas (due to sea level rise), "other vulnerable market sectors" (based primarily on changes in energy use), human health (based on climate-related diseases, such as malaria and dengue fever, and pollution), non-market amenities (based on outdoor recreation), and human settlements and ecosystems. The DICE damage function also includes the expected value of damages associated with low probability, high impact "catastrophic" climate change. This last component is calibrated based on a survey of experts (Nordhaus 1994). The expected value of these impacts is then added to the other market and non-market impacts mentioned above.

No structural components of the DICE model represent adaptation explicitly, though it is included implicitly through the choice of studies used to calibrate the aggregate damage function. For example, its agricultural impact estimates assume that farmers can adjust land use decisions in response to changing climate conditions, and its health impact estimates assume improvements in healthcare over time. In addition, the small impacts on forestry, water systems, construction, fisheries, and outdoor recreation imply optimistic and costless adaptation in these sectors (Nordhaus and Boyer, 2000; Warren et al., 2006). Costs of resettlement due to sea level rise are incorporated into damage estimates, but their magnitude is not clearly reported. Mastrandrea's (2009) review concludes that "in general, DICE assumes very effective adaptation, and largely ignores adaptation costs."

Note that the damage function in DICE has a somewhat different meaning from the damage functions in FUND and PAGE. Because GDP is endogenous in DICE and because damages in a given year reduce investment in that year, damages propagate forward in time and reduce GDP in future years. In contrast, GDP is exogenous in FUND and PAGE, so damages in any given year do not propagate forward.[d]

The PAGE Model

PAGE2002 (version 1.4epm) treats GDP growth as exogenous. It divides impacts into economic, non-economic, and catastrophic categories and calculates these impacts separately for eight geographic regions. Damages in each region are expressed as a fraction of output, where the fraction lost depends on the temperature change in each region. Damages are expressed as power functions of temperature change. The exponents of the damage function are the same in all regions but are treated as uncertain, with values ranging from 1 to 3 (instead of being fixed at 2 as in DICE).

PAGE2002 includes the consequences of catastrophic events in a separate damage sub-function. Unlike DICE, PAGE2002 models these events probabilistically. The probability of a "discontinuity" (*i.e.*, a catastrophic event) is assumed to increase with temperature above a specified threshold. The threshold temperature, the rate at which the probability of experiencing a discontinuity increases above the threshold, and the magnitude of the resulting catastrophe are all modeled probabilistically.

Adaptation is explicitly included in PAGE. Impacts are assumed to occur for temperature increases above some tolerable level (2°C for developed countries and 0°C for developing countries for economic impacts, and 0°C for all regions for non-economic impacts), but

[d] Using the default assumptions in DICE 2007, this effect generates an approximately 25 percent increase in the SCC relative to damages calculated by fixing GDP. In DICE2007, the time path of GDP is endogenous. Specifically, the path of GDP depends on the rate of saving and level of abatement in each period chosen by the optimizing representative agent in the model. We made two modifications to DICE to make it consistent with EMF GDP trajectories (see next section): we assumed a fixed rate of savings of 20 percent, and we re-calibrated the exogenous path of total factor productivity so that DICE would produce GDP projections in the absence of warming that exactly matched the EMF scenarios.

adaptation is assumed to reduce these impacts. Default values in PAGE2002 assume that the developed countries can ultimately eliminate up to 90 percent of all economic impacts beyond the tolerable 2°C increase and that developing countries can eventually eliminate 50 percent of their economic impacts. All regions are assumed to be able to mitigate 25 percent of the non-economic impacts through adaptation (Hope 2006).

The FUND Model

Like PAGE, the FUND model treats GDP growth as exogenous. It includes separately calibrated damage functions for eight market and nonmarket sectors: agriculture, forestry, water, energy (based on heating and cooling demand), sea level rise (based on the value of land lost and the cost of protection), ecosystems, human health (diarrhea, vector-borne diseases, and cardiovascular and respiratory mortality), and extreme weather. Each impact sector has a different functional form, and is calculated separately for sixteen geographic regions. In some impact sectors, the fraction of output lost or gained due to climate change depends not only on the absolute temperature change but also on the rate of temperature change and level of regional income.[e] In the forestry and agricultural sectors, economic damages also depend on CO_2 concentrations.

Tol (2009) discusses impacts not included in FUND, noting that many are likely to have a relatively small effect on damage estimates (both positive and negative). However, he characterizes several omitted impacts as “big unknowns”: for instance, extreme climate scenarios, biodiversity loss, and effects on economic development and political violence. With regard to potentially catastrophic events, he notes, “Exactly what would cause these sorts of changes or what effects they would have are not well-understood, although the chance of any one of them happening seems low. But they do have the potential to happen relatively quickly, and if they did, the costs could be substantial. Only a few studies of climate change have examined these issues.”

Adaptation is included both implicitly and explicitly in FUND. Explicit adaptation is seen in the agriculture and sea level rise sectors. Implicit adaptation is included in sectors such as energy and human health, where wealthier populations are assumed to be less vulnerable to climate impacts. For example, the damages to agriculture are the sum of three effects: (1) those due to the rate of temperature change (damages are always positive); (2) those due to the level of temperature change (damages can be positive or negative depending on region and temperature); and (3) those from CO_2 fertilization (damages are generally negative but diminishing to zero).

Adaptation is incorporated into FUND by allowing damages to be smaller if climate change happens more slowly. The combined effect of CO_2 fertilization in the agricultural sector, positive impacts to some regions from higher temperatures, and sufficiently slow increases in temperature across these sectors can result in negative economic damages from climate change.

[e] In the deterministic version of FUND, the majority of damages are attributable to increased air conditioning demand, while reduced cold stress in Europe, North America, and Central and East Asia results in health benefits in those regions at low to moderate levels of warming (Warren et al., 2006).

Damage Functions

To generate revised SCC values, we rely on the IAM modelers' current best judgments of how to represent the effects of climate change (represented by the increase in global-average surface temperature) on the consumption-equivalent value of both market and non-market goods (represented as a fraction of global GDP). We recognize that these representations are incomplete and highly uncertain. But given the paucity of data linking the physical impacts to economic damages, we were not able to identify a better way to translate changes in climate into net economic damages, short of launching our own research program.

The damage functions for the three IAMs are presented in Figure 14A.4.1 and Figure 14A.4.2, using the modeler's default scenarios and mean input assumptions. There are significant differences between the three models both at lower (Figure 14A.4.2) and higher (Figure 14A.4.1) increases in global-average temperature.

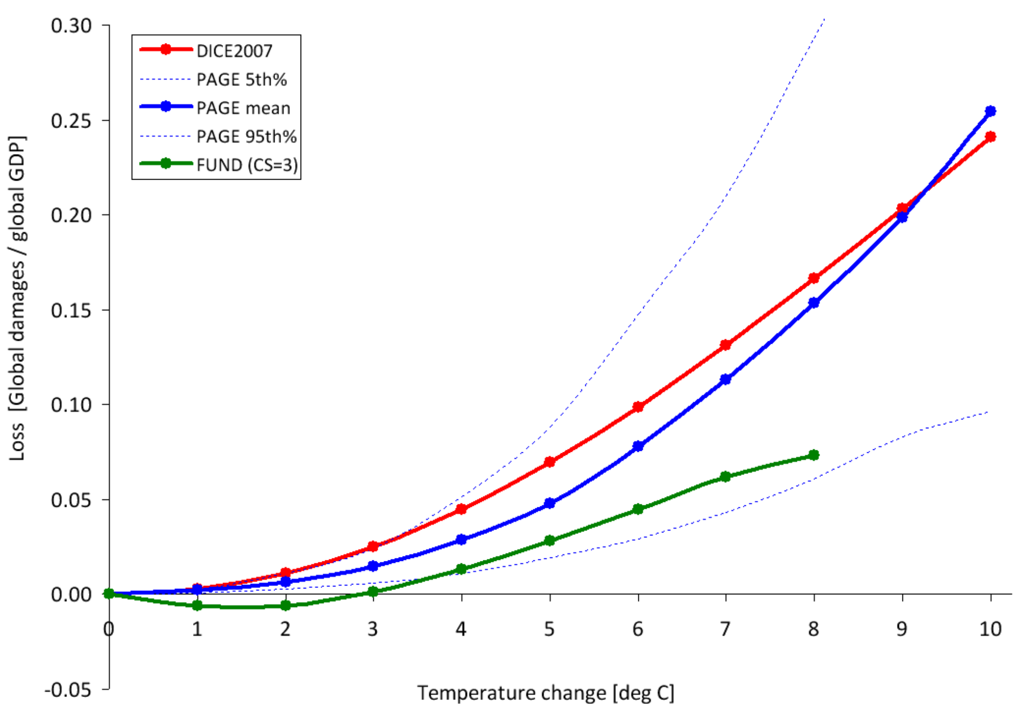

Figure 14A.4.1 Annual Consumption Loss as a Fraction of Global GDP in 2100 Due to an Increase in Annual Global Temperature in the DICE, FUND, and PAGE models[f]

[f] The x-axis represents increases in annual, rather than equilibrium, temperature, while the y-axis represents the annual stream of benefits as a share of global GDP. Each specific combination of climate sensitivity, socioeconomic, and emissions parameters will produce a different realization of damages for each IAM. The damage functions represented in Figures 1A and 1B are the outcome of default assumptions. For instance, under alternate assumptions, the damages from FUND may cross from negative to positive at less than or greater than 3 °C.

The lack of agreement among the models at lower temperature increases is underscored by the fact that the damages from FUND are well below the 5th percentile estimated by PAGE, while the damages estimated by DICE are roughly equal to the 95th percentile estimated by PAGE. This is significant because at higher discount rates we expect that a greater proportion of the SCC value is due to damages in years with lower temperature increases. For example, when the discount rate is 2.5 percent, about 45 percent of the 2010 SCC value in DICE is due to damages that occur in years when the temperature is less than or equal to 3 °C. This increases to approximately 55 percent and 80 percent at discount rates of 3 and 5 percent, respectively.

These differences underscore the need for a thorough review of damage functions—in particular, how the models incorporate adaptation, technological change, and catastrophic damages. Gaps in the literature make modifying these aspects of the models challenging, which highlights the need for additional research. As knowledge improves, the Federal government is committed to exploring how these (and other) models can be modified to incorporate more accurate estimates of damages.

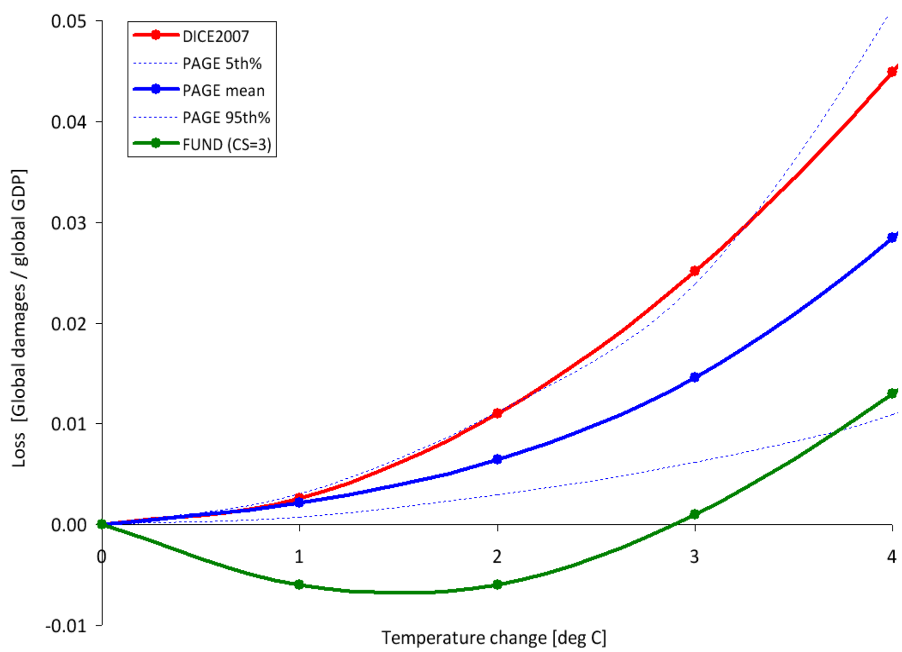

Figure 14A.4.2 Annual Consumption Loss for Lower Temperature Changes in DICE, FUND, and PAGE

14A.4.2 Global versus Domestic Measures of SCC

Because of the distinctive nature of the climate change problem, we center our current attention on a global measure of SCC. This approach is the same as that taken for the interim values, but it otherwise represents a departure from past practices, which tended to put greater emphasis on a domestic measure of SCC (limited to impacts of climate change experienced within U.S. borders). As a matter of law, consideration of both global and domestic values is generally permissible; the relevant statutory provisions are usually ambiguous and allow selection of either measure.[g]

Global SCC

Under current OMB guidance contained in Circular A-4, analysis of economically significant proposed and final regulations from the domestic perspective is required, while analysis from the international perspective is optional. However, the climate change problem is highly unusual in at least two respects. First, it involves a global externality: emissions of most greenhouse gases contribute to damages around the world even when they are emitted in the United States. Consequently, to address the global nature of the problem, the SCC must incorporate the full (global) damages caused by GHG emissions. Second, climate change presents a problem that the United States alone cannot solve. Even if the United States were to reduce its greenhouse gas emissions to zero, that step would be far from enough to avoid substantial climate change. Other countries would also need to take action to reduce emissions if significant changes in the global climate are to be avoided. Emphasizing the need for a global solution to a global problem, the United States has been actively involved in seeking international agreements to reduce emissions and in encouraging other nations, including emerging major economies, to take significant steps to reduce emissions. When these considerations are taken as a whole, the interagency group concluded that a global measure of the benefits from reducing U.S. emissions is preferable.

When quantifying the damages associated with a change in emissions, a number of analysts (*e.g.*, Anthoff, et al. 2009a) employ "equity weighting" to aggregate changes in consumption across regions. This weighting takes into account the relative reductions in wealth in different regions of the world. A per-capita loss of $500 in GDP, for instance, is weighted more heavily in a country with a per-capita GDP of $2,000 than in one with a per-capita GDP of $40,000. The main argument for this approach is that a loss of $500 in a poor country causes a greater reduction in utility or welfare than does the same loss in a wealthy nation. Notwithstanding the theoretical claims on behalf of equity weighting, the interagency group concluded that this approach would not be appropriate for estimating a SCC value used in domestic regulatory analysis.[h] For this reason, the group concluded that using the global (rather than domestic) value, without equity weighting, is the appropriate approach.

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[g] It is true that federal statutes are presumed not to have extraterritorial effect, in part to ensure that the laws of the United States respect the interests of foreign sovereigns. But use of a global measure for the SCC does not give extraterritorial effect to federal law and hence does not intrude on such interests.

[h] It is plausible that a loss of $X inflicts more serious harm on a poor nation than on a wealthy one, but development of the appropriate "equity weight" is challenging. Emissions reductions also impose costs, and hence a full account would have to consider that a given cost of emissions reductions imposes a greater utility or welfare loss on a poor nation than on a wealthy one. Even if equity weighting—for both the costs and benefits of emissions reductions—is appropriate when considering the utility or welfare effects of international action, the interagency group concluded that it should not be used in developing an SCC for use in regulatory policy at this time.

Domestic SCC

As an empirical matter, the development of a domestic SCC is greatly complicated by the relatively few region- or country-specific estimates of the SCC in the literature. One potential source of estimates comes from the FUND model. The resulting estimates suggest that the ratio of domestic to global benefits of emission reductions varies with key parameter assumptions. For example, with a 2.5 or 3 percent discount rate, the U.S. benefit is about 7-10 percent of the global benefit, on average, across the scenarios analyzed. Alternatively, if the fraction of GDP lost due to climate change is assumed to be similar across countries, the domestic benefit would be proportional to the U.S. share of global GDP, which is currently about 23 percent.[i]

On the basis of this evidence, the interagency workgroup determined that a range of values from 7 to 23 percent should be used to adjust the global SCC to calculate domestic effects. Reported domestic values should use this range. It is recognized that these values are approximate, provisional, and highly speculative. There is no a priori reason why domestic benefits should be a constant fraction of net global damages over time. Further, FUND does not account for how damages in other regions could affect the United States (*e.g.*, global migration, economic and political destabilization). If more accurate methods for calculating the domestic SCC become available, the Federal government will examine these to determine whether to update its approach.

14A.4.3 Valuing Non-CO_2 Emissions

While CO_2 is the most prevalent greenhouse gas emitted into the atmosphere, the U.S. included five other greenhouse gases in its recent endangerment finding: methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The climate impact of these gases is commonly discussed in terms of their 100-year global warming potential (GWP). GWP measures the ability of different gases to trap heat in the atmosphere (*i.e.*, radiative forcing per unit of mass) over a particular timeframe relative to CO_2. However, because these gases differ in both radiative forcing and atmospheric lifetimes, their relative damages are not constant over time. For example, because methane has a short lifetime, its impacts occur primarily in the near term and thus are not discounted as heavily as those caused by longer-lived gases. Impacts other than temperature change also vary across gases in ways that are not captured by GWP. For instance, CO_2 emissions, unlike methane and other greenhouse gases, contribute to ocean acidification. Likewise, damages from methane emissions are not offset by the positive effect of CO_2 fertilization. Thus, transforming gases into CO_2-equivalents using GWP, and then multiplying the carbon-equivalents by the SCC, would not result in accurate estimates of the social costs of non-CO_2 gases.

In light of these limitations, and the significant contributions of non-CO_2 emissions to climate change, further research is required to link non-CO_2 emissions to economic impacts. Such work would feed into efforts to develop a monetized value of reductions in non-CO_2 greenhouse gas emissions. As part of ongoing work to further improve the SCC estimates, the

[i] Based on 2008 GDP (in current US dollars) from the *World Bank Development Indicators Report*.

interagency group hopes to develop methods to value these other greenhouse gases. The goal is to develop these estimates by the time we issue revised SCC estimates for carbon dioxide emissions.

14A.4.4 Equilibrium Climate Sensitivity

Equilibrium climate sensitivity (ECS) is a key input parameter for the DICE, PAGE, and FUND models.[j] It is defined as the long-term increase in the annual global-average surface temperature from a doubling of atmospheric CO_2 concentration relative to pre-industrial levels (or stabilization at a concentration of approximately 550 parts per million (ppm)). Uncertainties in this important parameter have received substantial attention in the peer-reviewed literature.

The most authoritative statement about equilibrium climate sensitivity appears in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC):

> *Basing our assessment on a combination of several independent lines of evidence…including observed climate change and the strength of known feedbacks simulated in [global climate models], we conclude that the global mean equilibrium warming for doubling CO_2, or 'equilibrium climate sensitivity', is likely to lie in the range 2 °C to 4.5 °C, with a most likely value of about 3 °C. Equilibrium climate sensitivity is very likely larger than 1.5 °C.* [k]
>
> *For fundamental physical reasons as well as data limitations, values substantially higher than 4.5 °C still cannot be excluded, but agreement with observations and proxy data is generally worse for those high values than for values in the 2 °C to 4.5 °C range.* (Meehl et al., 2007, p 799)

After consulting with several lead authors of this chapter of the IPCC report, the interagency workgroup selected four candidate probability distributions and calibrated them to be consistent with the above statement: Roe and Baker (2007), log-normal, gamma, and Weibull. Table 14A.4.1 included below gives summary statistics for the four calibrated distributions.

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[j] The equilibrium climate sensitivity includes the response of the climate system to increased greenhouse gas concentrations over the short to medium term (up to 100-200 years), but it does not include long-term feedback effects due to possible large-scale changes in ice sheets or the biosphere, which occur on a time scale of many hundreds to thousands of years (*e.g.* Hansen et al. 2007).

[k] This is in accord with the judgment that it "is likely to lie in the range 2 °C to 4.5 °C" and the IPCC definition of "likely" as greater than 66 percent probability (Le Treut et al.2007). "Very likely" indicates a greater than 90 percent probability.

Table 14A.4.1 Summary Statistics for Four Calibrated Climate Sensitivity Distributions

	Roe & Baker	Log-normal	Gamma	Weibull
Pr(ECS < 1.5°C)	0.013	0.050	0.070	0.102
Pr(2°C < ECS < 4.5°C)	0.667	0.667	0.667	0.667
5^{th} percentile	1.72	1.49	1.37	1.13
10^{th} percentile	1.91	1.74	1.65	1.48
Mode	2.34	2.52	2.65	2.90
Median (50^{th} percentile)	3.00	3.00	3.00	3.00
Mean	3.50	3.28	3.19	3.07
90^{th} percentile	5.86	5.14	4.93	4.69
95^{th} percentile	7.14	5.97	5.59	5.17

Each distribution was calibrated by applying three constraints from the IPCC:

(1) a median equal to 3°C, to reflect the judgment of "a most likely value of about 3 °C";[1]
(2) two-thirds probability that the equilibrium climate sensitivity lies between 2 and 4.5 °C; and
(3) zero probability that it is less than 0°C or greater than 10°C (see Hegerl et al. 2006, p. 721).

We selected the calibrated Roe and Baker distribution from the four candidates for two reasons. First, the Roe and Baker distribution is the only one of the four that is based on a theoretical understanding of the response of the climate system to increased greenhouse gas concentrations (Roe and Baker 2007, Roe 2008). In contrast, the other three distributions are mathematical functions that are arbitrarily chosen based on simplicity, convenience, and general shape. The Roe and Baker distribution results from three assumptions about climate response: (1) absent feedback effects, the equilibrium climate sensitivity is equal to 1.2 °C; (2) feedback factors are proportional to the change in surface temperature; and (3) uncertainties in feedback factors are normally distributed. There is widespread agreement on the first point and the second and third points are common assumptions.

Second, the calibrated Roe and Baker distribution better reflects the IPCC judgment that "values substantially higher than 4.5°C still cannot be excluded." Although the IPCC made no quantitative judgment, the 95^{th} percentile of the calibrated Roe & Baker distribution (7.1 °C) is much closer to the mean and the median (7.2 °C) of the 95^{th} percentiles of 21 previous studies summarized by Newbold and Daigneault (2009). It is also closer to the mean (7.5 °C) and

[1] Strictly speaking, "most likely" refers to the mode of a distribution rather than the median, but common usage would allow the mode, median, or mean to serve as candidates for the central or "most likely" value and the IPCC report is not specific on this point. For the distributions we considered, the median was between the mode and the mean. For the Roe and Baker distribution, setting the median equal to 3°C, rather than the mode or mean, gave a 95^{th} percentile that is more consistent with IPCC judgments and the literature. For example, setting the mean and mode equal to 3°C produced 95^{th} percentiles of 5.6 and 8.6 °C, respectively, which are in the lower and upper end of the range in the literature. Finally, the median is closer to 3°C than is the mode for the truncated distributions selected by the IPCC (Hegerl, et al., 2006); the average median is 3.1 °C and the average mode is 2.3 °C, which is most consistent with a Roe and Baker distribution with the median set equal to 3 °C.

median (7.9 °C) of the nine truncated distributions examined by the IPCC (Hegerl, et al., 2006) than are the 95th percentiles of the three other calibrated distributions (5.2-6.0 °C).

Finally, we note the IPCC judgment that the equilibrium climate sensitivity "is very likely larger than 1.5°C." Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5 °C is almost 99 percent, is not inconsistent with the IPCC definition of "very likely" as "greater than 90 percent probability," it reflects a greater degree of certainty about very low values of ECS than was expressed by the IPCC.

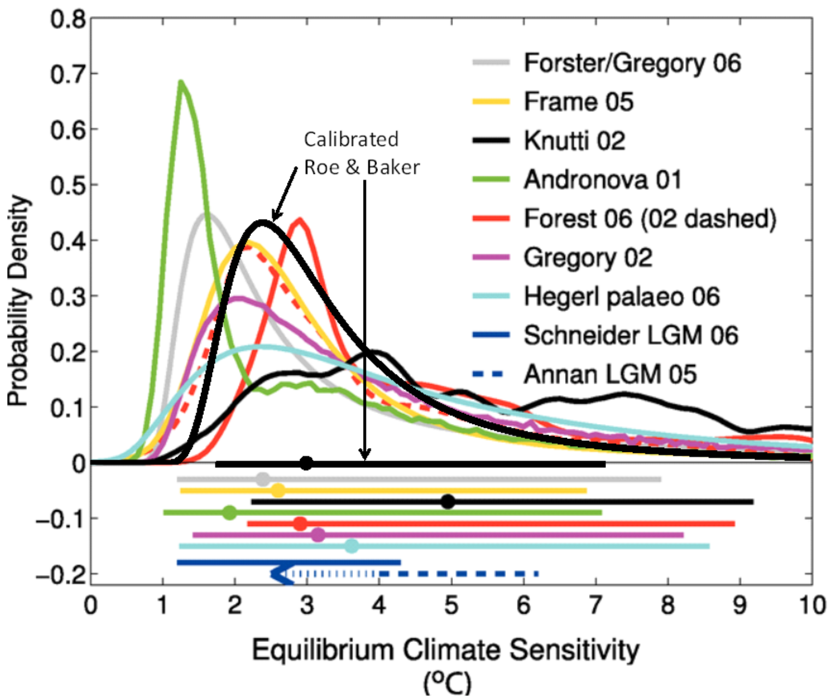

Figure 14A.4.3 Estimates of the Probability Density Function for Equilibrium Climate Sensitivity (°C)

To show how the calibrated Roe and Baker distribution compares to different estimates of the probability distribution function of equilibrium climate sensitivity in the empirical literature, Figure 14A.4.3 (above) overlays it on Figure 9.20 from the IPCC Fourth Assessment Report. These functions are scaled to integrate to unity between 0 °C and 10 °C. The horizontal bars show the respective 5 percent to 95 percent ranges; dots indicate the median estimate.[m]

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[m] The estimates based on instrumental data are from Andronova and Schlesinger (2001), Forest et al. (2002; dashed line, anthropogenic forcings only), Forest et al. (2006; solid line, anthropogenic and natural forcings), Gregory et al. (2002a), Knutti et al. (2002), Frame et al. (2005), and Forster and Gregory (2006). Hegerl et al. (2006) are based on multiple palaeoclimatic reconstructions of north hemisphere mean temperatures over the last 700 years. Also shown are the 5-95 percent approximate ranges for two estimates from the last glacial maximum (dashed, Annan et al. 2005; solid, Schneider von Deimling et al. 2006), which are based on models with different structural properties.

14A.4.5 Socioeconomic and Emissions Trajectories

Another key issue considered by the interagency group is how to select the set of socioeconomic and emissions parameters for use in PAGE, DICE, and FUND. Socioeconomic pathways are closely tied to climate damages because, all else equal, more and wealthier people tend to emit more greenhouse gases and also have a higher (absolute) willingness to pay to avoid climate disruptions. For this reason, we consider how to model several input parameters in tandem: GDP, population, CO_2 emissions, and non-CO_2 radiative forcing. A wide variety of scenarios have been developed and used for climate change policy simulations (*e.g.*, SRES 2000, CCSP 2007, EMF 2009). In determining which scenarios are appropriate for inclusion, we aimed to select scenarios that span most of the plausible ranges of outcomes for these variables.

To accomplish this task in a transparent way, we decided to rely on the recent Stanford Energy Modeling Forum exercise, EMF-22. EMF-22 uses ten well-recognized models to evaluate substantial, coordinated global action to meet specific stabilization targets. A key advantage of relying on these data is that GDP, population, and emission trajectories are internally consistent for each model and scenario evaluated. The EMF-22 modeling effort also is preferable to the IPCC SRES due to their age (SRES were developed in 1997) and the fact that 3 of 4 of the SRES scenarios are now extreme outliers in one or more variables. Although the EMF-22 scenarios have not undergone the same level of scrutiny as the SRES scenarios, they are recent, peer-reviewed, published, and publicly available.

To estimate the SCC for use in evaluating domestic policies that will have a small effect on global cumulative emissions, we use socioeconomic and emission trajectories that span a range of plausible scenarios. Five trajectories were selected from EMF-22 (see Table 14A.4.2 below). Four of these represent potential business-as-usual (BAU) growth in population, wealth, and emissions and are associated with CO_2 (only) concentrations ranging from 612 to 889 ppm in 2100. One represents an emissions pathway that achieves stabilization at 550 ppm CO_2e (i*i.e.*, CO_2-only concentrations of 425 – 484 ppm or a radiative forcing of 3.7 W/m^2) in 2100, a lower-than-BAU trajectory.[n] Out of the 10 models included in the EMF-22 exercise, we selected the trajectories used by MiniCAM, MESSAGE, IMAGE, and the optimistic scenario from MERGE. For the BAU pathways, we used the GDP, population, and emission trajectories from each of these four models. For the 550 ppm CO_2e scenario, we averaged the GDP, population, and emission trajectories implied by these same four models.

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[n] Such an emissions path would be consistent with widespread action by countries to mitigate GHG emissions, though it could also result from technological advances. It was chosen because it represents the most stringent case analyzed by the EMF-22 where all the models converge: a 550 ppm, not to exceed, full participation scenario.

Table 14A.4.2 Socioeconomic and Emissions Projections from Select EMF-22 Reference Scenarios

Reference Fossil and Industrial CO_2 Emissions ($GtCO_2$/yr)

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	26.6	31.9	36.9	40.0	45.3	60.1
MERGE Optimistic	24.6	31.5	37.6	45.1	66.5	117.9
MESSAGE	26.8	29.2	37.6	42.1	43.5	42.7
MiniCAM	26.5	31.8	38.0	45.1	57.8	80.5
550 ppm average	26.2	31.1	33.2	32.4	20.0	12.8

Reference GDP (using market exchange rates in trillion 2005$)[o]

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	38.6	53.0	73.5	97.2	156.3	396.6
MERGE Optimistic	36.3	45.9	59.7	76.8	122.7	268.0
MESSAGE	38.1	52.3	69.4	91.4	153.7	334.9
MiniCAM	36.1	47.4	60.8	78.9	125.7	369.5
550 ppm average	37.1	49.6	65.6	85.5	137.4	337.9

Global Population (billions)

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	6.1	6.9	7.6	8.2	9.0	9.1
MERGE Optimistic	6.0	6.8	7.5	8.2	9.0	9.7
MESSAGE	6.1	6.9	7.7	8.4	9.4	10.4
MiniCAM	6.0	6.8	7.5	8.1	8.8	8.7
550 ppm average	6.1	6.8	7.6	8.2	8.7	9.1

We explore how sensitive the SCC is to various assumptions about how the future will evolve without prejudging what is likely to occur. The interagency group considered formally assigning probability weights to different states of the world, but this proved challenging to do in an analytically rigorous way given the dearth of information on the likelihood of a full range of future socioeconomic pathways.

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[o] While the EMF-22 models used market exchange rates (MER) to calculate global GDP, it is also possible to use purchasing power parity (PPP). PPP takes into account the different price levels across countries, so it more accurately describes relative standards of living across countries. MERs tend to make low-income countries appear poorer than they actually are. Because many models assume convergence in per capita income over time, use of MER-adjusted GDP gives rise to projections of higher economic growth in low income countries. There is an ongoing debate about how much this will affect estimated climate impacts. Critics of the use of MER argue that it leads to overstated economic growth and hence a significant upward bias in projections of greenhouse gas emissions, and unrealistically high future temperatures (*e.g.*, Castles and Henderson 2003). Others argue that convergence of the emissions-intensity gap across countries at least partially offset the overstated income gap so that differences in exchange rates have less of an effect on emissions (Holtsmark and Alfsen, 2005; Tol, 2006). Nordhaus (2007b) argues that the ideal approach is to use superlative PPP accounts (*i.e.*, using cross-sectional PPP measures for relative incomes and outputs and national accounts price and quantity indexes for time-series extrapolations). However, he notes that it important to keep this debate in perspective; it is by no means clear that exchange-rate-conversion issues are as important as uncertainties about population, technological change, or the many geophysical uncertainties.

There are a number of caveats. First, EMF BAU scenarios represent the modelers' judgment of the most likely pathway absent mitigation policies to reduce greenhouse gas emissions, rather than the wider range of possible outcomes. Nevertheless, these views of the most likely outcome span a wide range, from the more optimistic (*e.g.*, abundant low-cost, low-carbon energy) to more pessimistic (*e.g.*, constraints on the availability of nuclear and renewables).[p] Second, the socioeconomic trajectories associated with a 550 ppm CO_2e concentration scenario are not derived from an assessment of what policy is optimal from a benefit-cost standpoint. Rather, it is indicative of one possible future outcome. The emission trajectories underlying some BAU scenarios (*e.g.*, MESSAGE's 612 ppm) also are consistent with some modest policy action to address climate change.[q] We chose not to include socioeconomic trajectories that achieve even lower GHG concentrations at this time, given the difficulty many models had in converging to meet these targets.

For comparison purposes, the Energy Information Agency in its 2009 Annual Energy Outlook projected that global carbon dioxide emissions will grow to 30.8, 35.6, and 40.4 gigatons in 2010, 2020, and 2030, respectively, while world GDP is projected to be $51.8, $71.0 and $93.9 trillion (in 2005 dollars using market exchange rates) in 2010, 2020, and 2030, respectively. These projections are consistent with one or more EMF-22 scenarios. Likewise, the United Nations' 2008 Population Prospect projects population will grow from 6.1 billion people in 2000 to 9.1 billion people in 2050, which is close to the population trajectories for the IMAGE, MiniCAM, and MERGE models.

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane, nitrous oxide, fluorinated greenhouse gases, and net land use CO_2 emissions out to 2100. These assumptions also are used in the three models while retaining the default radiative forcings due to other factors (*e.g.*, aerosols and other gases). See the Annex for greater detail.

14A.4.6 Discount Rate

The choice of a discount rate, especially over long periods of time, raises highly contested and exceedingly difficult questions of science, economics, philosophy, and law. Although it is well understood that the discount rate has a large influence on the current value of future damages, there is no consensus about what rates to use in this context. Because carbon dioxide emissions are long-lived, subsequent damages occur over many years. In calculating the SCC, we first estimate the future damages to agriculture, human health, and other market and non-market sectors from an additional unit of carbon dioxide emitted in a particular year in terms

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[p] For instance, in the MESSAGE model's reference case total primary energy production from nuclear, biomass, and non-biomass renewables is projected to increase from about 15 percent of total primary energy in 2000 to 54 percent in 2100. In comparison, the MiniCAM reference case shows 10 percent in 2000 and 21 percent in 2100.
[q] For example, MiniCAM projects if all non-US OECD countries reduce CO_2 emissions to 83 percent below 2005 levels by 2050 (per the G-8 agreement) but all other countries continue along a BAU path CO_2 concentrations in 2100 would drop from 794 ppmv in its reference case to 762 ppmv.

of reduced consumption (or consumption equivalents) due to the impacts of elevated temperatures, as represented in each of the three IAMs. Then we discount the stream of future damages to its present value in the year when the additional unit of emissions was released using the selected discount rate, which is intended to reflect society's marginal rate of substitution between consumption in different time periods.

For rules with both intra- and intergenerational effects, agencies traditionally employ constant discount rates of both 3 percent and 7 percent in accordance with OMB Circular A-4. As Circular A-4 acknowledges, however, the choice of discount rate for intergenerational problems raises distinctive problems and presents considerable challenges. After reviewing those challenges, Circular A-4 states, "If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent." For the specific purpose of developing the SCC, we adapt and revise that approach here.

Arrow et al. (1996) outlined two main approaches to determine the discount rate for climate change analysis, which they labeled "descriptive" and "prescriptive." The descriptive approach reflects a positive (non-normative) perspective based on observations of people's actual choices—*e.g.*, savings versus consumption decisions over time, and allocations of savings among more and less risky investments. Advocates of this approach generally call for inferring the discount rate from market rates of return "because of a lack of justification for choosing a social welfare function that is any different than what decision makers [individuals] actually use" (Arrow et al. 1996).

One theoretical foundation for the cost-benefit analyses in which the social cost of carbon will be used—the Kaldor-Hicks potential-compensation test—also suggests that market rates should be used to discount future benefits and costs, because it is the market interest rate that would govern the returns potentially set aside today to compensate future individuals for climate damages that they bear (*e.g.*, Just et al. 2004). As some have noted, the word "potentially" is an important qualification; there is no assurance that such returns will actually be set aside to provide compensation, and the very idea of compensation is difficult to define in the intergenerational context. On the other hand, societies provide compensation to future generations through investments in human capital and the resulting increase in knowledge, as well as infrastructure and other physical capital.

The prescriptive approach specifies a social welfare function that formalizes the normative judgments that the decision-maker wants explicitly to incorporate into the policy evaluation—*e.g.*, how inter-personal comparisons of utility should be made, and how the welfare of future generations should be weighed against that of the present generation. Ramsey (1928), for example, has argued that it is "ethically indefensible" to apply a positive pure rate of time preference to discount values across generations, and many agree with this view.

Other concerns also motivate making adjustments to descriptive discount rates. In particular, it has been noted that the preferences of future generations with regard to consumption versus environmental amenities may not be the same as those today, making the current market rate on consumption an inappropriate metric by which to discount future climate-related damages. Others argue that the discount rate should be below market rates to correct for market distortions and uncertainties or inefficiencies in intergenerational transfers of wealth, which in the Kaldor-Hicks logic are presumed to compensate future generations for damage (a potentially controversial assumption, as noted above) (Arrow et al. 1996, Weitzman 1999).

Further, a legitimate concern about both descriptive and prescriptive approaches is that they tend to obscure important heterogeneity in the population. The utility function that underlies the prescriptive approach assumes a representative agent with perfect foresight and no credit constraints. This is an artificial rendering of the real world that misses many of the frictions that characterize individuals' lives and indeed the available descriptive evidence supports this. For instance, many individuals smooth consumption by borrowing with credit cards that have relatively high rates. Some are unable to access traditional credit markets and rely on payday lending operations or other high-cost forms of smoothing consumption. Whether one puts greater weight on the prescriptive or descriptive approach, the high interest rates that credit-constrained individuals accept suggest that some account should be given to the discount rates revealed by their behavior.

We draw on both approaches but rely primarily on the descriptive approach to inform the choice of discount rate. With recognition of its limitations, we find this approach to be the most defensible and transparent given its consistency with the standard contemporary theoretical foundations of benefit-cost analysis and with the approach required by OMB's existing guidance. The logic of this framework also suggests that market rates should be used for discounting future consumption-equivalent damages. Regardless of the theoretical approach used to derive the appropriate discount rate(s), we note the inherent conceptual and practical difficulties of adequately capturing consumption trade-offs over many decades or even centuries. While relying primarily on the descriptive approach in selecting specific discount rates, the interagency group has been keenly aware of the deeply normative dimensions of both the debate over discounting in the intergenerational context and the consequences of selecting one discount rate over another.

Historically Observed Interest Rates

In a market with no distortions, the return to savings would equal the private return on investment, and the market rate of interest would be the appropriate choice for the social discount rate. In the real world risk, taxes, and other market imperfections drive a wedge between the risk-free rate of return on capital and the consumption rate of interest. Thus, the literature recognizes two conceptual discount concepts—the consumption rate of interest and the opportunity cost of capital.

According to OMB's Circular A-4, it is appropriate to use the rate of return on capital when a regulation is expected to displace or alter the use of capital in the private sector. In this case, OMB recommends Agencies use a discount rate of 7 percent. When regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services—

a lower discount rate of 3 percent is appropriate to reflect how private individuals trade-off current and future consumption.

The interagency group examined the economics literature and concluded that the consumption rate of interest is the correct concept to use in evaluating the benefits and costs of a marginal change in carbon emissions (see Lind 1990, Arrow et al 1996, and Arrow 2000). The consumption rate of interest also is appropriate when the impacts of a regulation are measured in consumption (-equivalent) units, as is done in the three integrated assessment models used for estimating the SCC.

Individuals use a variety of savings instruments that vary with risk level, time horizon, and tax characteristics. The standard analytic framework used to develop intuition about the discount rate typically assumes a representative agent with perfect foresight and no credit constraints. The risk-free rate is appropriate for discounting certain future benefits or costs, but the benefits calculated by IAMs are uncertain. To use the risk-free rate to discount uncertain benefits, these benefits first must be transformed into "certainty equivalents," that is the maximum certain amount that we would exchange for the uncertain amount. However, the calculation of the certainty-equivalent requires first estimating the correlation between the benefits of the policy and baseline consumption.

If the IAM projections of future impacts represent expected values (not certainty-equivalent values), then the appropriate discount rate generally does not equal the risk-free rate. If the benefits of the policy tend to be high in those states of the world in which consumption is low, then the certainty-equivalent benefits will be higher than the expected benefits (and vice versa). Since many (though not necessarily all) of the important impacts of climate change will flow through market sectors such as agriculture and energy, and since willingness to pay for environmental protections typically increases with income, we might expect a positive (though not necessarily perfect) correlation between the net benefits from climate policies and market returns. This line of reasoning suggests that the proper discount rate would exceed the riskless rate. Alternatively, a negative correlation between the returns to climate policies and market returns would imply that a discount rate below the riskless rate is appropriate.

This discussion suggests that both the post-tax riskless and risky rates can be used to capture individuals' consumption-equivalent interest rate. As a measure of the post-tax riskless rate, we calculate the average real return from Treasury notes over the longest time period available (those from Newell and Pizer 2003) and adjust for Federal taxes (the average marginal rate from tax years 2003 through 2006 is around 27 percent).[r] This calculation produces a real interest rate of about 2.7 percent, which is roughly consistent with Circular A-4's

[r] The literature argues for a risk-free rate on government bonds as an appropriate measure of the consumption rate of interest. Arrow (2000) suggests that it is roughly 3-4 percent. OMB cites evidence of a 3.1 percent pre-tax rate for 10-year Treasury notes in the A-4 guidance. Newell and Pizer (2003) find real interest rates between 3.5 and 4 percent for 30-year Treasury securities.

recommendation to use 3 percent to represent the consumption rate of interest.[s] A measure of the post-tax risky rate for investments whose returns are positively correlated with overall equity market returns can be obtained by adjusting pre-tax rates of household returns to risky investments (approximately 7 percent) for taxes, which yields a real rate of roughly 5 percent.[t]

The Ramsey Equation

Ramsey discounting also provides a useful framework to inform the choice of a discount rate. Under this approach, the analyst applies either positive or normative judgments in selecting values for the key parameters of the Ramsey equation: η (coefficient of relative risk aversion or elasticity of the marginal utility of consumption) and ρ (pure rate of time preference).[u] These are then combined with g (growth rate of per-capita consumption) to equal the interest rate at which future monetized damages are discounted: $\rho + \eta \cdot g$.[v] In the simplest version of the Ramsey model, with an optimizing representative agent with perfect foresight, what we are calling the "Ramsey discount rate," $\rho + \eta \cdot g$, will be equal to the rate of return to capital, *i.e.*, the market interest rate.

A review of the literature provides some guidance on reasonable parameter values for the Ramsey discounting equation, based on both prescriptive and descriptive approaches.

- η. Most papers in the climate change literature adopt values for η in the range of 0.5 to 3 (Weitzman cites plausible values as those ranging from 1 to 4), although not all authors

[s] The positive approach reflects how individuals make allocation choices across time, but it is important to keep in mind that we wish to reflect preferences for society as a whole, which generally has a longer planning horizon.
[t] Cambell et al (2001) estimates that the annual real return from stocks for 1900-1995 was about 7 percent. The annual real rate of return for the S&P 500 from 1950 – 2008 was about 6.8 percent. In the absence of a better way to population-weight the tax rates, we use the middle of the 20 – 40 percent range to derive a post-tax interest rate (Kotlikoff and Rapson 2006).
[u] The parameter ρ measures the *pure rate of time preference*: people's behavior reveals a preference for an increase in utility today versus the future. Consequently, it is standard to place a lower weight on utility in the future. The parameter η captures *diminishing marginal utility*: consumption in the future is likely to be higher than consumption today, so diminishing marginal utility of consumption implies that the same monetary damage will cause a smaller reduction of utility for wealthier individuals, either in the future or in current generations. If $\eta = 0$, then a one dollar increase in income is equally valuable regardless of level of income; if $\eta = 1$, then a one percent increase in income is equally valuable no matter the level of income; and if $\eta > 1$, then a one percent increase in income is less valuable to wealthier individuals.
[v] In this case, g could be taken from the selected EMF socioeconomic scenarios or alternative assumptions about the rate of consumption growth.

articulate whether their choice is based on prescriptive or descriptive reasoning.[w] Dasgupta (2008) argues that η should be greater than 1 and may be as high as 3, because η equal to 1 suggests savings rates that do not conform to observed behavior.

- ρ. With respect to the pure rate of time preference, most papers in the climate change literature adopt values for ρ in the range of 0 to 3 percent per year. The very low rates tend to follow from moral judgments involving intergenerational neutrality. Some have argued that to use any value other than ρ = 0 would unjustly discriminate against future generations (*e.g.*, Arrow et al. 1996, Stern et al. 2006). However, even in an inter-generational setting, it may make sense to use a small positive pure rate of time preference because of the small probability of unforeseen cataclysmic events (Stern et al. 2006).

- g. A commonly accepted approximation is around 2 percent per year. For the socioeconomic scenarios used for this exercise, the EMF models assume that g is about 1.5-2 percent to 2100.

Some economists and non-economists have argued for constant discount rates below 2 percent based on the prescriptive approach. When grounded in the Ramsey framework, proponents of this approach have argued that a ρ of zero avoids giving preferential treatment to one generation over another. The choice of η has also been posed as an ethical choice linked to the value of an additional dollar in poorer countries compared to wealthier ones. Stern et al. (2006) applies this perspective through his choice of ρ = 0.1 percent per year, η = 1 and g = 1.3 percent per year, which yields an annual discount rate of 1.4 percent. In the context of permanent income savings behavior, however, Stern's assumptions suggest that individuals would save 93 percent of their income.[x]

Recently, Stern (2008) revisited the values used in Stern et al. (2006), stating that there is a case to be made for raising η due to the amount of weight lower values place on damages far in the future (over 90 percent of expected damages occur after 2200 with η = 1). Using Stern's assumption that ρ = 0.1 percent, combined with a η of 1.5 to 2 and his original growth rate, yields a discount rate of greater than 2 percent.

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[w] Empirical estimates of η span a wide range of values. A benchmark value of 2 is near the middle of the range of values estimated or used by Szpiro (1986), Hall and Jones (2007), Arrow (2007), Dasgupta (2006, 2008), Weitzman (2007, 2009), and Nordhaus (2008). However, Chetty (2006) developed a method of estimating η using data on labor supply behavior. He shows that existing evidence of the effects of wage changes on labor supply imposes a tight upper bound on the curvature of utility over wealth (CRRA < 2) with the mean implied value of 0.71 and concludes that the standard expected utility model cannot generate high levels of risk aversion without contradicting established facts about labor supply. Recent work has jointly estimated the components of the Ramsey equation. Evans and Sezer (2005) estimate η = 1.49 for 22 OECD countries. They also estimate ρ = 1.08 percent per year using data on mortality rates. Anthoff, et al. (2009b) estimate η = 1.18, and ρ = 1.4 percent. When they multiply the bivariate probability distributions from their work and Evans and Sezer (2005) together, they find η = 1.47, and ρ = 1.07.

[x] Stern (2008) argues that building in a positive rate of exogenous technical change over time reduces the implied savings rate and that η at or above 2 are inconsistent with observed behavior with regard to equity. (At the same time, adding exogenous technical change—all else equal—would increase g as well.)

We conclude that arguments made under the prescriptive approach can be used to justify discount rates between roughly 1.4 and 3.1 percent. In light of concerns about the most appropriate value for η, we find it difficult to justify rates at the lower end of this range under the Ramsey framework.

Accounting for Uncertainty in the Discount Rate

While the consumption rate of interest is an important driver of the benefits estimate, it is uncertain over time. Ideally, we would formally model this uncertainty, just as we do for climate sensitivity. Weitzman (1998, 2001) showed theoretically and Newell and Pizer (2003) and Groom et al. (2006) confirm empirically that discount rate uncertainty can have a large effect on net present values. A main result from these studies is that if there is a persistent element to the uncertainty in the discount rate (*e.g.*, the rate follows a random walk), then it will result in an effective (or certainty-equivalent) discount rate that declines over time. Consequently, lower discount rates tend to dominate over the very long term (see Weitzman 1998, 1999, 2001; Newell and Pizer 2003; Groom et al. 2006; Gollier 2008; Summers and Zeckhauser 2008; and Gollier and Weitzman 2009).

The proper way to model discount rate uncertainty remains an active area of research. Newell and Pizer (2003) employ a model of how long-term interest rates change over time to forecast future discount rates. Their model incorporates some of the basic features of how interest rates move over time, and its parameters are estimated based on historical observations of long-term rates. Subsequent work on this topic, most notably Groom et al. (2006), uses more general models of interest rate dynamics to allow for better forecasts. Specifically, the volatility of interest rates depends on whether rates are currently low or high and the variation in the level of persistence over time.

While Newell and Pizer (2003) and Groom et al (2006) attempt formally to model uncertainty in the discount rate, others argue for a declining scale of discount rates applied over time (*e.g.*, Weitzman 2001, and the UK's "Green Book" for regulatory analysis). This approach uses a higher discount rate initially, but applies a graduated scale of lower discount rates further out in time.[y] A key question that has emerged with regard to both of these approaches is the trade-off between potential time inconsistency and giving greater weight to far future outcomes (see the EPA Science Advisory Board's recent comments on this topic as part of its review of their *Guidelines for Economic Analysis*).[z]

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[y] For instance, the UK applies a discount rate of 3.5 percent to the first 30 years; 3 percent for years 31 - 75; 2.5 percent for years 76 - 125; 2 percent for years 126 - 200; 1.5 percent for years 201 - 300; and 1 percent after 300 years. As a sensitivity, it recommends a discount rate of 3 percent for the first 30 years, also decreasing over time.

[z] Uncertainty in future damages is distinct from uncertainty in the discount rate. Weitzman (2008) argues that Stern's choice of a low discount rate was "right for the wrong reasons." He demonstrates how the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. Newbold and Daigneault, (2009) and Nordhaus (2009) find that Weitzman's result is sensitive to the functional forms chosen for climate sensitivity,

The Discount Rates Selected for Estimating SCC

In light of disagreement in the literature on the appropriate market interest rate to use in this context and uncertainty about how interest rates may change over time, we use three discount rates to span a plausible range of certainty-equivalent constant discount rates: 2.5, 3, and 5 percent per year. Based on the review in the previous sections, the interagency workgroup determined that these three rates reflect reasonable judgments under both descriptive and prescriptive approaches.

The central value, 3 percent, is consistent with estimates provided in the economics literature and OMB's Circular A-4 guidance for the consumption rate of interest. As previously mentioned, the consumption rate of interest is the correct discounting concept to use when future damages from elevated temperatures are estimated in consumption-equivalent units. Further, 3 percent roughly corresponds to the after-tax riskless interest rate. The upper value of 5 percent is included to represent the possibility that climate damages are positively correlated with market returns. Additionally, this discount rate may be justified by the high interest rates that many consumers use to smooth consumption across periods.

The low value, 2.5 percent, is included to incorporate the concern that interest rates are highly uncertain over time. It represents the average certainty-equivalent rate using the mean-reverting and random walk approaches from Newell and Pizer (2003) starting at a discount rate of 3 percent. Using this approach, the certainty equivalent is about 2.2 percent using the random walk model and 2.8 percent using the mean reverting approach.[aa] Without giving preference to a particular model, the average of the two rates is 2.5 percent. Further, a rate below the riskless rate would be justified if climate investments are negatively correlated with the overall market rate of return. Use of this lower value also responds to certain judgments using the prescriptive or normative approach and to ethical objections that have been raised about rates of 3 percent or higher.

14A.5 REVISED SCC ESTIMATES

Our general approach to estimating SCC values is to run the three integrated assessment models (FUND, DICE, and PAGE) using the following inputs agreed upon by the interagency group:

- A Roe and Baker distribution for the climate sensitivity parameter bounded between 0 and 10 with a median of 3 °C and a cumulative probability between 2 and 4.5 °C of two-thirds.
- Five sets of GDP, population, and carbon emissions trajectories based on EMF-22.
- Constant annual discount rates of 2.5, 3, and 5 percent.

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utility, and consumption. Summers and Zeckhauser (2008) argue that uncertainty in future damages can also work in the other direction by increasing the benefits of waiting to learn the appropriate level of mitigation required.

[aa] Calculations done by Pizer et al. using the original simulation program from Newell and Pizer (2003).

Because the climate sensitivity parameter is modeled probabilistically, and because PAGE and FUND incorporate uncertainty in other model parameters, the final output from each model run is a distribution over the SCC in year *t*.

For each of the IAMs, the basic computational steps for calculating the SCC in a particular year *t* are:

1. Input the path of emissions, GDP, and population from the selected EMF-22 scenarios, and the extrapolations based on these scenarios for post-2100 years.

2. Calculate the temperature effects and (consumption-equivalent) damages in each year resulting from the baseline path of emissions.

   a. In PAGE, the consumption-equivalent damages in each period are calculated as a fraction of the EMF GDP forecast, depending on the temperature in that period relative to the pre-industrial average temperature in each region.
   b. In FUND, damages in each period depend on both the level and the rate of temperature change in that period.
   c. In DICE, temperature affects both consumption and investment, so we first adjust the EMF GDP paths as follows: Using the Cobb-Douglas production function with the DICE2007 parameters, we extract the path of exogenous technical change implied by the EMF GDP and population paths, then we recalculate the baseline GDP path taking into account climate damages resulting from the baseline emissions path.

3. Add an additional unit of carbon emissions in year *t.* (The exact unit varies by model.)

4. Recalculate the temperature effects and damages expected in all years beyond *t* resulting from this adjusted path of emissions, as in step 2.

5. Subtract the damages computed in step 2 from those in step 4 in each year. (DICE is run in 10-year time steps, FUND in annual time steps, while the time steps in PAGE vary.)

6. Discount the resulting path of marginal damages back to the year of emissions using the agreed upon fixed discount rates.

7. Calculate the SCC as the net present value of the discounted path of damages computed in step 6, divided by the unit of carbon emissions used to shock the models in step 3.

8. Multiply by 12/44 to convert from dollars per ton of carbon to dollars per ton of CO_2 (2007 dollars) in DICE and FUND. (All calculations are done in tons of CO_2 in PAGE).

The steps above were repeated in each model for multiple future years to cover the time horizons anticipated for upcoming rulemaking analysis. To maintain consistency across the three IAMs, climate damages are calculated as lost consumption in each future year.

It is important to note that each of the three models has a different default end year. The default time horizon is 2200 for PAGE, 2595 for DICE, and 3000 for the latest version of FUND. This is an issue for the multi-model approach because differences in SCC estimates may arise simply due to the model time horizon. Many consider 2200 too short a time horizon because it could miss a significant fraction of damages under certain assumptions about the growth of marginal damages and discounting, so each model is run here through 2300. This step required a small adjustment in the PAGE model only. This step also required assumptions about GDP, population, and greenhouse gas emission trajectories after 2100, the last year for which these data are available from the EMF-22 models. (A more detailed discussion of these assumptions is included in the Annex.)

This exercise produces 45 separate distributions of the SCC for a given year, the product of 3 models, 3 discount rates, and 5 socioeconomic scenarios. This is clearly too many separate distributions for consideration in a regulatory impact analysis.

To produce a range of plausible estimates that still reflects the uncertainty in the estimation exercise, the distributions from each of the models and scenarios are equally weighed and combined to produce three separate probability distributions for SCC in a given year, one for each assumed discount rate. These distributions are then used to define a range of point estimates for the global SCC. In this way, no IAM or socioeconomic scenario is given greater weight than another. Because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context, we present SCCs based on the average values across models and socioeconomic scenarios for each discount rate.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC across models and socioeconomic and emissions scenarios at the 2.5, 3, and 5 percent discount rates. The fourth value is included to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95^{th} percentile at a 3 percent discount rate. (The full set of distributions by model and scenario combination is included in the Annex.) As noted above, the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range.

As previously discussed, low probability, high impact events are incorporated into the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high-temperature outcomes, which in turn lead to higher projections of damages. Although FUND does not include catastrophic damages (in contrast to the other two models), its probabilistic treatment of the equilibrium climate sensitivity parameter will directly affect the non-catastrophic damages that are a function of the rate of temperature change.

In Table 14A.5.1, we begin by presenting SCC estimates for 2010 by model, scenario, and discount rate to illustrate the variability in the SCC across each of these input parameters. As expected, higher discount rates consistently result in lower SCC values, while lower discount rates result in higher SCC values for each socioeconomic trajectory. It is also evident that there are differences in the SCC estimated across the three main models. For these estimates, FUND produces the lowest estimates, while PAGE generally produces the highest estimates.

Table 14A.5.1 Disaggregated Social Cost of CO_2 Values by Model, Socioeconomic Trajectory, and Discount Rate for 2010 (in 2007 dollars)

	Discount rate:	**5%**	**3%**	**2.5%**	**3%**
Model	*Scenario*	Avg	Avg	Avg	95th
DICE	IMAGE	10.8	35.8	54.2	70.8
	MERGE	7.5	22.0	31.6	42.1
	Message	9.8	29.8	43.5	58.6
	MiniCAM	8.6	28.8	44.4	57.9
	550 Average	8.2	24.9	37.4	50.8
PAGE	IMAGE	8.3	39.5	65.5	142.4
	MERGE	5.2	22.3	34.6	82.4
	Message	7.2	30.3	49.2	115.6
	MiniCAM	6.4	31.8	54.7	115.4
	550 Average	5.5	25.4	42.9	104.7
FUND	IMAGE	-1.3	8.2	19.3	39.7
	MERGE	-0.3	8.0	14.8	41.3
	Message	-1.9	3.6	8.8	32.1
	MiniCAM	-0.6	10.2	22.2	42.6
	550 Average	-2.7	-0.2	3.0	19.4

These results are not surprising when compared to the estimates in the literature for the latest versions of each model. For example, adjusting the values from the literature that were used to develop interim SCC values to 2007 dollars for the year 2010 (assuming, as we did for the interim process, that SCC grows at 3 percent per year), FUND yields SCC estimates at or near zero for a 5 percent discount rate and around $9 per ton for a 3 percent discount rate. There are far fewer estimates using the latest versions of DICE and PAGE in the literature: Using similar adjustments to generate 2010 estimates, we calculate a SCC from DICE (based on Nordhaus 2008) of around $9 per ton for a 5 percent discount rate, and a SCC from PAGE (based on Hope 2006, 2008) close to $8 per ton for a 4 percent discount rate. Note that these comparisons are only approximate since the literature generally relies on Ramsey discounting, while we have assumed constant discount rates.[bb]

[bb] Nordhaus (2008) runs DICE2007 with $\rho = 1.5$ and $\eta = 2$. The default approach in PAGE2002 (version 1.4epm) treats ρ and η as random parameters, specified using a triangular distribution such that the min, mode, and max = 0.1, 1, and 2 for ρ, and 0.5, 1, and 2 for η, respectively. The FUND default value for η is 1, and Tol generates SCC

The SCC estimates from FUND are sensitive to differences in emissions paths but relatively insensitive to differences in GDP paths across scenarios, while the reverse is true for DICE and PAGE. This likely occurs because of several structural differences among the models. Specifically in DICE and PAGE, the fraction of economic output lost due to climate damages increases with the level of temperature alone, whereas in FUND the fractional loss also increases with the rate of temperature change. Furthermore, in FUND increases in income over time decrease vulnerability to climate change (a form of adaptation), whereas this does not occur in DICE and PAGE. These structural differences among the models make FUND more sensitive to the path of emissions and less sensitive to GDP compared to DICE and PAGE.

Figure 14A.5.1 shows that IMAGE has the highest GDP in 2100 while MERGE Optimistic has the lowest. The ordering of global GDP levels in 2100 directly corresponds to the rank ordering of SCC for PAGE and DICE. For FUND, the correspondence is less clear, a result that is to be expected given its less direct relationship between its damage function and GDP.

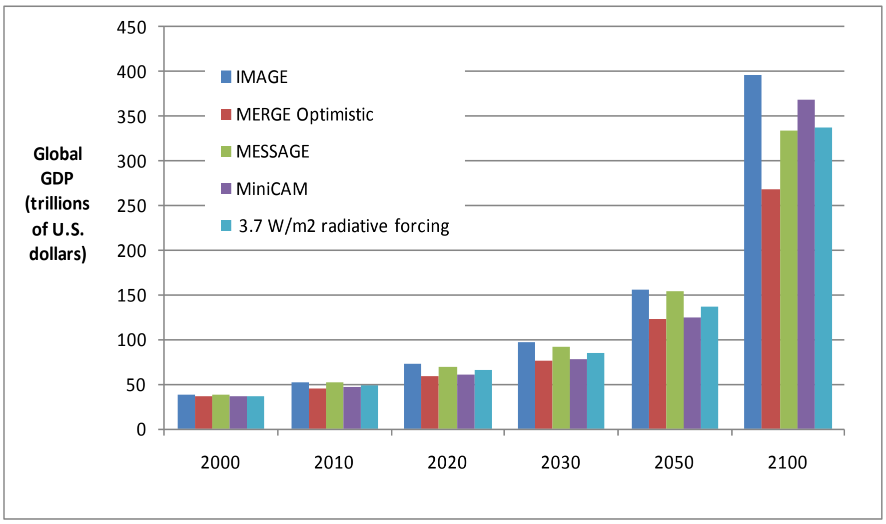

Figure 14A.5.1 Level of Global GDP across EMF Scenarios

Table 14A.5.2 shows the four selected SCC values in five-year increments from 2010 to 2050. Values for 2010, 2020, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using a simple linear interpolation.

estimates for values of ρ = 0, 1, and 3 in many recent papers (*e.g.* Anthoff et al. 2009). The path of per-capita consumption growth, g, varies over time but is treated deterministically in two of the three models. In DICE, g is endogenous. Under Ramsey discounting, as economic growth slows in the future, the large damages from climate change that occur far out in the future are discounted at a lower rate than impacts that occur in the nearer term.

Table 14A.5.2 Social Cost of CO_2, 2010 – 2050 (in 2007 dollars)

Discount Year	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that this approach allows us to estimate the growth rate of the SCC directly using DICE, PAGE, and FUND rather than assuming a constant annual growth rate as was done for the interim estimates (using 3 percent). This helps to ensure that the estimates are internally consistent with other modeling assumptions. Table 14A.5.3 illustrates how the growth rate for these four SCC estimates varies over time. The full set of annual SCC estimates between 2010 and 2050 is reported in the Annex.

Table 14A.5.3 Changes in the Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Growth Rate (%)	**5%** Avg	**3%** Avg	**2.5%** Avg	**3.0%** 95th
2010-2020	3.6%	2.1%	1.7%	2.2%
2020-2030	3.7%	2.2%	1.8%	2.2%
2030-2040	2.7%	1.8%	1.6%	1.8%
2040-2050	2.1%	1.4%	1.1%	1.3%

While the SCC estimate grows over time, the future monetized value of emissions reductions in each year (the SCC in year *t* multiplied by the change in emissions in year *t*) must be discounted to the present to determine its total net present value for use in regulatory analysis. Damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency—*i.e.*, future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate. For example, climate damages in the year 2020 that are calculated using a SCC based on a 5 percent discount rate also should be discounted back to the analysis year using a 5 percent discount rate.[cc]

14A.6 LIMITATIONS OF THE ANALYSIS

As noted, any estimate of the SCC must be taken as provisional and subject to further refinement (and possibly significant change) in accordance with evolving scientific, economic, and ethical understandings. During the course of our modeling, it became apparent that there are several areas in particular need of additional exploration and research. These caveats, and additional observations in the following section, are necessary to consider when interpreting and applying the SCC estimates.

Incomplete treatment of non-catastrophic damages. The impacts of climate change are expected to be widespread, diverse, and heterogeneous. In addition, the exact magnitude of these impacts is uncertain because of the inherent complexity of climate processes, the economic behavior of current and future populations, and our inability to accurately forecast technological change and adaptation. Current IAMs do not assign value to all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature (some of which are discussed above) because of lack of precise information on the nature of damages and because the science incorporated into these models understandably lags behind the most recent research. Our ability to quantify and monetize impacts will undoubtedly improve with time. But it is also likely that even in future applications, a number of potentially significant damage categories will remain non-monetized. (Ocean acidification is one example of a potentially large damage from CO_2 emissions not quantified by any of the three models. Species and wildlife loss is another example that is exceedingly difficult to monetize.)

Incomplete treatment of potential catastrophic damages. There has been considerable recent discussion of the risk of catastrophic impacts and how best to account for extreme scenarios, such as the collapse of the Atlantic Meridional Overturning Circulation or the West Antarctic Ice Sheet, or large releases of methane from melting permafrost and warming oceans. Weitzman (2009) suggests that catastrophic damages are extremely large—so large, in fact, that the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. However, Nordhaus (2009) concluded that the conditions under which Weitzman's results hold "are limited and do not apply to a wide range of potential uncertain scenarios."

Using a simplified IAM, Newbold and Daigneault (2009) confirmed the potential for large catastrophe risk premiums but also showed that the aggregate benefit estimates can be highly sensitive to the shapes of both the climate sensitivity distribution and the damage function at high temperature changes. Pindyck (2009) also used a simplified IAM to examine high-

[cc] However, it is possible that other benefits or costs of proposed regulations unrelated to CO_2 emissions will be discounted at rates that differ from those used to develop the SCC estimates.

impact, low-probability risks, using a right-skewed gamma distribution for climate sensitivity as well as an uncertain damage coefficient, but in most cases found only a modest risk premium. Given this difference in opinion, further research in this area is needed before its practical significance can be fully understood and a reasonable approach developed to account for such risks in regulatory analysis. (The next section discusses the scientific evidence on catastrophic impacts in greater detail.)

Uncertainty in extrapolation of damages to high temperatures: The damage functions in these IAMs are typically calibrated by estimating damages at moderate temperature increases (*e.g.*, DICE was calibrated at 2.5 °C) and extrapolated to far higher temperatures by assuming that damages increase as some power of the temperature change. Hence, estimated damages are far more uncertain under more extreme climate change scenarios.

Incomplete treatment of adaptation and technological change: Each of the three integrated assessment models used here assumes a certain degree of low- or no-cost adaptation. For instance, Tol assumes a great deal of adaptation in FUND, including widespread reliance on air conditioning; so much so, that the largest single benefit category in FUND is the reduced electricity costs from not having to run air conditioning as intensively (NRC 2009).

Climate change also will increase returns on investment to develop technologies that allow individuals to cope with adverse climate conditions, and IAMs to do not adequately account for this directed technological change.[dd] For example, scientists may develop crops that are better able to withstand higher and more variable temperatures. Although DICE and FUND have both calibrated their agricultural sectors under the assumption that farmers will change land use practices in response to climate change (Mastrandrea, 2009), they do not take into account technological changes that lower the cost of this adaptation over time. On the other hand, the calibrations do not account for increases in climate variability, pests, or diseases, which could make adaptation more difficult than assumed by the IAMs for a given temperature change. Hence, models do not adequately account for potential adaptation or technical change that might alter the emissions pathway and resulting damages. In this respect, it is difficult to determine whether the incomplete treatment of adaptation and technological change in these IAMs understate or overstate the likely damages.

Risk aversion: A key question unanswered during this interagency process is what to assume about relative risk aversion with regard to high-impact outcomes. These calculations do not take into account the possibility that individuals may have a higher willingness to pay to reduce the likelihood of low-probability, high-impact damages than they do to reduce the likelihood of higher-probability, but lower-impact, damages with the same expected cost. (The inclusion of the 95th percentile estimate in the final set of SCC values was largely motivated by this concern.) If individuals do show such a higher willingness to pay, a further question is whether that fact should be taken into account for regulatory policy. Even if individuals are not

[dd] However these research dollars will be diverted from whatever their next best use would have been in the absence of climate change (so productivity/GDP would have been still higher).

risk-averse for such scenarios, it is possible that regulatory policy should include a degree of risk-aversion.

Assuming a risk-neutral representative agent is consistent with OMB's Circular A-4, which advises that the estimates of benefits and costs used in regulatory analysis are usually based on the average or the expected value and that "emphasis on these expected values is appropriate as long as society is 'risk neutral' with respect to the regulatory alternatives. While this may not always be the case, [analysts] should in general assume 'risk neutrality' in [their] analysis."

Nordhaus (2008) points to the need to explore the relationship between risk and income in the context of climate change across models and to explore the role of uncertainty regarding various parameters in the results. Using FUND, Anthoff et al (2009) explored the sensitivity of the SCC to Ramsey equation parameter assumptions based on observed behavior. They conclude that "the assumed rate of risk aversion is at least as important as the assumed rate of time preference in determining the social cost of carbon." Since Circular A-4 allows for a different assumption on risk preference in regulatory analysis if it is adequately justified, we plan to continue investigating this issue.

14A.7 A FURTHER DISCUSSION OF CATASTROPHIC IMPACTS AND DAMAGE FUNCTIONS

As noted above, the damage functions underlying the three IAMs used to estimate the SCC may not capture the economic effects of all possible adverse consequences of climate change and may therefore lead to underestimates of the SCC (Mastrandrea 2009). In particular, the models' functional forms may not adequately capture: (1) potentially discontinuous "tipping point" behavior in Earth systems, (2) inter-sectoral and inter-regional interactions, including global security impacts of high-end warming, and (3) limited near-term substitutability between damage to natural systems and increased consumption.

It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling. In the meantime, we discuss some of the available evidence.

Extrapolation of climate damages to high levels of warming

The damage functions in the models are calibrated at moderate levels of warming and should therefore be viewed cautiously when extrapolated to the high temperatures found in the upper end of the distribution. Recent science suggests that there are a number of potential climatic "tipping points" at which the Earth system may exhibit discontinuous behavior with potentially severe social and economic consequences (*e.g.*, Lenton et al, 2008, Kriegler et al., 2009). These tipping points include the disruption of the Indian Summer Monsoon, dieback of the Amazon Rainforest and boreal forests, collapse of the Greenland Ice Sheet and the West Antarctic Ice Sheet, reorganization of the Atlantic Meridional Overturning Circulation, strengthening of El Niño-Southern Oscillation, and the release of methane from melting permafrost. Many of these tipping points are estimated to have thresholds between about 3 °C and 5 °C (Lenton et al., 2008). Probabilities of several of these tipping points were assessed through expert elicitation in 2005–2006 by Kriegler et al. (2009); results from this study are highlighted in Table 14A.7.1. Ranges of probability are averaged across core experts on each topic.

As previously mentioned, FUND does not include potentially catastrophic effects. DICE assumes a small probability of catastrophic damages that increases with increased warming, but the damages from these risks are incorporated as expected values (*i.e.*, ignoring potential risk aversion). PAGE models catastrophic impacts in a probabilistic framework (see Figure 14A.4.1), so the high-end output from PAGE potentially offers the best insight into the SCC if the world were to experience catastrophic climate change. For instance, at the 95th percentile and a 3 percent discount rate, the SCC estimated by PAGE across the five socioeconomic and emission trajectories of $113 per ton of CO_2 is almost double the value estimated by DICE, $58 per ton in 2010. We cannot evaluate how well the three models account for catastrophic or non-catastrophic impacts, but this estimate highlights the sensitivity of SCC values in the tails of the distribution to the assumptions made about catastrophic impacts.

Table 14A.7.1 Probabilities of Various Tipping Points from Expert Elicitation

Possible Tipping Points	Duration before effect is fully realized (in years)	Additional Warming by 2100		
		0.5-1.5 C	**1.5-3.0 C**	**3-5 C**
Reorganization of Atlantic Meridional Overturning Circulation	about 100	0-18%	6-39%	18-67%
Greenland Ice Sheet collapse	at least 300	8-39%	33-73%	67-96%
West Antarctic Ice Sheet collapse	at least 300	5-41%	10-63%	33-88%
Dieback of Amazon rainforest	about 50	2-46%	14-84%	41-94%
Strengthening of El Niño-Southern Oscillation	about 100	1-13%	6-32%	19-49%
Dieback of boreal forests	about 50	13-43%	20-81%	34-91%
Shift in Indian Summer Monsoon	about 1	Not formally assessed		
Release of methane from melting permafrost	Less than 100	Not formally assessed.		

PAGE treats the possibility of a catastrophic event probabilistically, while DICE treats it deterministically (that is, by adding the expected value of the damage from a catastrophe to the aggregate damage function). In part, this results in different probabilities being assigned to a catastrophic event across the two models. For instance, PAGE places a probability near zero on a catastrophe at 2.5 °C warming, while DICE assumes a 4 percent probability of a catastrophe at 2.5 °C. By comparison, Kriegler et al. (2009) estimate a probability of at least 16-36 percent of crossing at least one of their primary climatic tipping points in a scenario with temperatures about 2-4 °C warmer than pre-Industrial levels in 2100.

It is important to note that crossing a climatic tipping point will not necessarily lead to an economic catastrophe in the sense used in the IAMs. A tipping point is a critical threshold across which some aspect of the Earth system starts to shifts into a qualitatively different state (for instance, one with dramatically reduced ice sheet volumes and higher sea levels). In the IAMs, a catastrophe is a low-probability environmental change with high economic impact.

Failure to incorporate inter-sectoral and inter-regional interactions

The damage functions do not fully incorporate either inter-sectoral or inter-regional interactions. For instance, while damages to the agricultural sector are incorporated, the effects of changes in food supply on human health are not fully captured and depend on the modeler's choice of studies used to calibrate the IAM. Likewise, the effects of climate damages in one region of the world on another region are not included in some of the models (FUND includes the effects of migration from sea level rise). These inter-regional interactions, though difficult to quantify, are the basis for climate-induced national and economic security concerns (*e.g.*, Campbell et al., 2007; U.S. Department of Defense 2010) and are particularly worrisome at higher levels of warming. High-end warming scenarios, for instance, project water scarcity affecting 4.3-6.9 billion people by 2050, food scarcity affecting about 120 million additional people by 2080, and the creation of millions of climate refugees (Easterling et al., 2007; Campbell et al., 2007).

Imperfect substitutability of environmental amenities

Data from the geological record of past climate changes suggests that 6 °C of warming may have severe consequences for natural systems. For instance, during the Paleocene-Eocene Thermal Maximum about 55.5 million years ago, when the Earth experienced a geologically rapid release of carbon associated with an approximately 5 °C increase in global mean temperatures, the effects included shifts of about 400-900 miles in the range of plants (Wing et al., 2005), and dwarfing of both land mammals (Gingerich, 2006) and soil fauna (Smith et al., 2009).

The three IAMs used here assume that it is possible to compensate for the economic consequences of damages to natural systems through increased consumption of non-climate goods, a common assumption in many economic models. In the context of climate change, however, it is possible that the damages to natural systems could become so great that no increase in consumption of non-climate goods would provide complete compensation (Levy et al., 2005). For instance, as water supplies become scarcer or ecosystems become more fragile and less bio-diverse, the services they provide may become increasingly more costly to replace.

Uncalibrated attempts to incorporate the imperfect substitutability of such amenities into IAMs (Sterner and Persson, 2008) indicate that the optimal degree of emissions abatement can be considerably greater than is commonly recognized.

14A.8 CONCLUSION

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are \$5, \$21, \$35, and \$65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socioeconomic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of CO_2 in 2015 and \$26 per ton of CO_2 in 2020.

We noted a number of limitations to this analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking climate impacts to economic damages makes this modeling exercise even more difficult. It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling.

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14A.9 ANNEX

Table 14A.9.1 Annual SCC Values: 2010–2050 (in 2007 dollars)

Discount Rate Year	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	4.7	21.4	35.1	64.9
2011	4.9	21.9	35.7	66.5
2012	5.1	22.4	36.4	68.1
2013	5.3	22.8	37.0	69.6
2014	5.5	23.3	37.7	71.2
2015	5.7	23.8	38.4	72.8
2016	5.9	24.3	39.0	74.4
2017	6.1	24.8	39.7	76.0
2018	6.3	25.3	40.4	77.5
2019	6.5	25.8	41.0	79.1
2020	6.8	26.3	41.7	80.7
2021	7.1	27.0	42.5	82.6
2022	7.4	27.6	43.4	84.6
2023	7.7	28.3	44.2	86.5
2024	7.9	28.9	45.0	88.4
2025	8.2	29.6	45.9	90.4
2026	8.5	30.2	46.7	92.3
2027	8.8	30.9	47.5	94.2
2028	9.1	31.5	48.4	96.2
2029	9.4	32.1	49.2	98.1
2030	9.7	32.8	50.0	100.0
2031	10.0	33.4	50.9	102.0
2032	10.3	34.1	51.7	103.9
2033	10.6	34.7	52.5	105.8
2034	10.9	35.4	53.4	107.8
2035	11.2	36.0	54.2	109.7
2036	11.5	36.7	55.0	111.6
2037	11.8	37.3	55.9	113.6
2038	12.1	37.9	56.7	115.5
2039	12.4	38.6	57.5	117.4
2040	12.7	39.2	58.4	119.3
2041	13.0	39.8	59.0	121.0
2042	13.3	40.4	59.7	122.7
2043	13.6	40.9	60.4	124.4
2044	13.9	41.5	61.0	126.1
2045	14.2	42.1	61.7	127.8
2046	14.5	42.6	62.4	129.4
2047	14.8	43.2	63.0	131.1
2048	15.1	43.8	63.7	132.8
2049	15.4	44.4	64.4	134.5
2050	15.7	44.9	65.0	136.2

This Annex provides additional technical information about the non-CO_2 emission projections used in the modeling and the method for extrapolating emissions forecasts through 2300 and shows the full distribution of 2010 SCC estimates by model and scenario combination.

14A.9.1 Other (non-CO_2) gases

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane (CH_4), nitrous oxide (N_2O), fluorinated gases, and net land use CO_2 emissions to 2100. These assumptions are used in all three IAMs while retaining each model's default radiative forcings (RF) due to other factors (*e.g.*, aerosols and other gases). Specifically, to obtain the RF associated with the non-CO_2 EMF emissions only, we calculated the RF associated with the EMF atmospheric CO_2 concentrations and subtracted them from the EMF total RF.[ee] This approach respects the EMF scenarios as much as possible and at the same time takes account of those components not included in the EMF projections. Since each model treats non-CO_2 gases differently (*e.g.*, DICE lumps all other gases into one composite exogenous input), this approach was applied slightly differently in each of the models.

FUND: Rather than relying on RF for these gases, the actual emissions from each scenario were used in FUND. The model default trajectories for CH_4, N_20, SF_6, and the CO_2 emissions from land were replaced with the EMF values.

PAGE: PAGE models CO_2, CH_4, sulfur hexafluoride (SF_6), and aerosols and contains an "excess forcing" vector that includes the RF for everything else. To include the EMF values, we removed the default CH_4 and SF_6 factors[ff], decomposed the excess forcing vector, and constructed a new excess forcing vector that includes the EMF RF for CH_4, N_20, and fluorinated gases, as well as the model default values for aerosols and other factors. Net land use CO_2 emissions were added to the fossil and industrial CO_2 emissions pathway.

DICE: DICE presents the greatest challenge because all forcing due to factors other than industrial CO_2 emissions is embedded in an exogenous non-CO_2 RF vector. To decompose this exogenous forcing path into EMF non-CO_2 gases and other gases, we relied on the references in DICE2007 to the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) and the discussion of aerosol forecasts in the IPCC's Third Assessment Report (TAR) and in AR4, as explained below. In DICE2007, Nordhaus assumes that exogenous forcing from all non-CO_2 sources is -0.06 W/m^2 in 2005, as reported in AR4, and increases linearly to 0.3 W/m^2 in 2105, based on GISS projections, and then stays constant after that time.

According to AR4, the RF in 2005 from CH_4, N_20, and halocarbons (approximately similar to the F-gases in the EMF-22 scenarios) was 0.48 + 0.16 + 0.34 = 0.98 W/m^2 and RF from total aerosols was -1.2 W/m^2. Thus, the -.06 W/m^2 non-CO_2 forcing in DICE can be

[ee] Note EMF did not provide CO_2 concentrations for the IMAGE reference scenario. Thus, for this scenario, we fed the fossil, industrial, and land CO_2 emissions into MAGICC (considered a "neutral arbiter" model, which is tuned to emulate the major global climate models) and the resulting CO_2 concentrations were used. Note also that MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (*i.e.*, we add up the land use emissions from the other three models and divide by 4).

[ff] Both the model default CH_4 emissions and the initial atmospheric CH_4 is set to zero to avoid double counting the effect of past CH_4 emissions.

decomposed into: 0.98 W/m^2 due to the EMF non-CO_2 gases, -1.2 W/m^2 due to aerosols, and the remainder, 0.16 W/m^2, due to other residual forcing.

For subsequent years, we calculated the DICE default RF from aerosols and other non-CO_2 gases based on the following two assumptions:

(1) RF from aerosols declines linearly from 2005 to 2100 at the rate projected by the TAR and then stays constant thereafter; and
(2) With respect to RF from non-CO_2 gases not included in the EMF-22 scenarios, the share of non-aerosol RF matches the share implicit in the AR4 summary statistics cited above and remains constant over time.

Assumption (1) means that the RF from aerosols in 2100 equals 66 percent of that in 2000, which is the fraction of the TAR projection of total RF from aerosols (including sulfates, black carbon, and organic carbon) in 2100 vs. 2000 under the A1B SRES emissions scenario. Since the SRES marker scenarios were not updated for the AR4, the TAR provides the most recent IPCC projection of aerosol forcing. We rely on the A1B projection from the TAR because it provides one of the lower aerosol forecasts among the SRES marker scenarios and is more consistent with the AR4 discussion of the post-SRES literature on aerosols:

> *Aerosols have a net cooling effect and the representation of aerosol and aerosol precursor emissions, including sulfur dioxide, black carbon and organic carbon, has improved in the post-SRES scenarios. Generally, these emissions are projected to be lower than reported in SRES.*[gg]

Assuming a simple linear decline in aerosols from 2000 to 2100 also is more consistent with the recent literature on these emissions. For example, the figure below shows that the sulfur dioxide emissions peak over the short term of some SRES scenarios above the upper bound estimates of the more recent scenarios.[hh] Recent scenarios project sulfur emissions to peak earlier and at lower levels compared to the SRES in part because of new information about present and planned sulfur legislation in some developing countries, such as India and China.[ii] The lower-bound projections of the recent literature have also shifted downward slightly compared to the SRES scenario (IPCC 2007).

With these assumptions, the DICE aerosol forcing changes from -1.2 in 2005 to -0.792 in 2105 W/m^2; forcing due to other non-CO_2 gases not included in the EMF scenarios declines from 0.160 to 0.153 W/m^2.

[gg] AR4 Synthesis Report, p. 44, www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf
[hh] See Smith, S.J., R. Andres, E. Conception, and J. Lurz, 2004: Historical sulfur dioxide emissions, 1850-2000: methods and results. Joint Global Research Institute, College Park, 14 pp.
[ii] See Carmichael, G., D. Streets, G. Calori, M. Amann, M. Jacobson, J. Hansen, and H. Ueda, 2002: Changing trends in sulphur emissions in Asia: implications for acid deposition, air pollution, and climate. Environmental Science and Technology, 36(22):4707- 4713; Streets, D., K. Jiang, X. Hu, J. Sinton, X.-Q. Zhang, D. Xu, M. Jacobson, and J. Hansen, 2001: Recent reductions in China's greenhouse gas emissions. Science, 294(5548): 1835-1837.

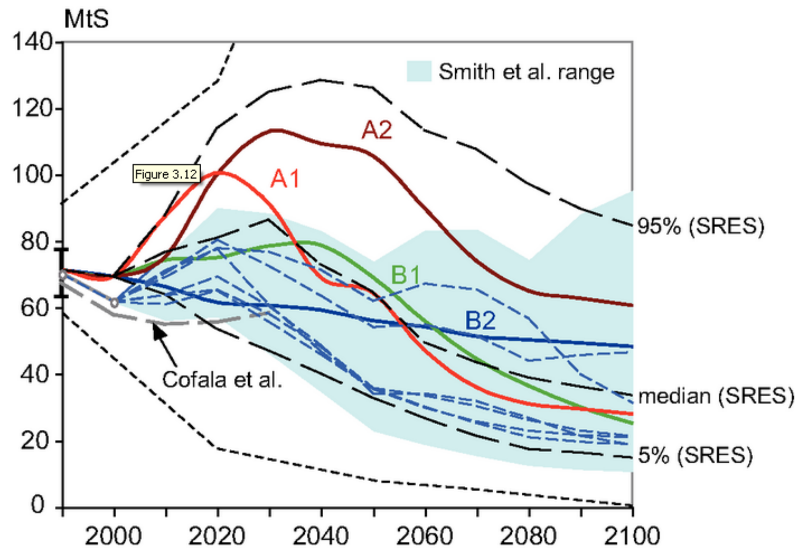

Figure 14A.9.2 Sulfur Dioxide Emission Scenarios

Notes: Thick colored lines depict the four SRES marker scenarios and black dashed lines show the median, 5[th], and 95[th] percentile of the frequency distribution for the full ensemble of 40 SRES scenarios. The blue area (and the thin dashed lines in blue) illustrates individual scenarios and the range of Smith et al. (2004). Dotted lines indicate the minimum and maximum of SO_2 emissions scenarios developed pre-SRES.
Source: IPCC (2007), AR4 WGIII 3.2,
www.ipcc.ch/publications_and_data/ar4/wg3/en/ch3-ens3-2-2-4.html.

Although other approaches to decomposing the DICE exogenous forcing vector are possible, initial sensitivity analysis suggests that the differences among reasonable alternative approaches are likely to be minor. For example, adjusting the TAR aerosol projection above to assume that aerosols will be maintained at 2000 levels through 2100 reduces average SCC values (for 2010) by approximately 3 percent (or less than $2); assuming all aerosols are phased out by 2100 increases average 2010 SCC values by 6-7 percent (or $0.50-$3)–depending on the discount rate. These differences increase slightly for SCC values in later years but are still well within 10 percent of each other as far out as 2050.

Finally, as in PAGE, the EMF net land use CO_2 emissions are added to the fossil and industrial CO_2 emissions pathway.

14A.9.2 Extrapolating Emissions Projections to 2300

To run each model through 2300 requires assumptions about GDP, population, greenhouse gas emissions, and radiative forcing trajectories after 2100, the last year for which these projections are available from the EMF-22 models. These inputs were extrapolated from 2100 to 2300 as follows:

1. Population growth rate declines linearly, reaching zero in the year 2200.
2. GDP/per capita growth rate declines linearly, reaching zero in the year 2300.
3. The decline in the fossil and industrial carbon intensity (CO_2/GDP) growth rate over 2090-2100 is maintained from 2100 through 2300.
4. Net land use CO_2 emissions decline linearly, reaching zero in the year 2200.
5. Non-CO_2 radiative forcing remains constant after 2100.

Long run stabilization of GDP per capita was viewed as a more realistic simplifying assumption than a linear or exponential extrapolation of the pre-2100 economic growth rate of each EMF scenario. This is based on the idea that increasing scarcity of natural resources and the degradation of environmental sinks available for assimilating pollution from economic production activities may eventually overtake the rate of technological progress. Thus, the overall rate of economic growth may slow over the very long run. The interagency group also considered allowing an exponential decline in the growth rate of GDP per capita. However, since this would require an additional assumption about how close to zero the growth rate would get by 2300, the group opted for the simpler and more transparent linear extrapolation to zero by 2300.

The population growth rate is also assumed to decline linearly, reaching zero by 2200. This assumption is reasonably consistent with the United Nations long run population forecast, which estimates global population to be fairly stable after 2150 in the medium scenario (UN 2004).[jj] The resulting range of EMF population trajectories (figure below) also encompass the UN medium scenario forecasts through 2300—global population of 8.5 billion by 2200, and 9 billion by 2300.

Maintaining the decline in the 2090-2100 carbon intensity growth rate (*i.e.*, CO_2 per dollar of GDP) through 2300 assumes that technological improvements and innovations in the areas of energy efficiency and other carbon reducing technologies (possibly including currently unavailable methods) will continue to proceed at roughly the same pace that is projected to occur towards the end of the forecast period for each EMF scenario. This assumption implies that total cumulative emissions in 2300 will be between 5,000 and 12,000 GtC, which is within the range of the total potential global carbon stock estimated in the literature.

Net land use CO_2 emissions are expected to stabilize in the long run, so in the absence of any post 2100 projections, the group assumed a linear decline to zero by 2200. Given no a priori reasons for assuming a long run increase or decline in non-CO_2 radiative forcing, it is assumed to remain at the 2100 levels for each EMF scenario through 2300.

Figures below show the paths of global population, GDP, fossil and industrial CO_2 emissions, net land CO_2 emissions, non-CO_2 radiative forcing, and CO_2 intensity (fossil and industrial CO_2 emissions/GDP) resulting from these assumptions.

[jj] United Nations. 2004. *World Population to 2300*.
www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf

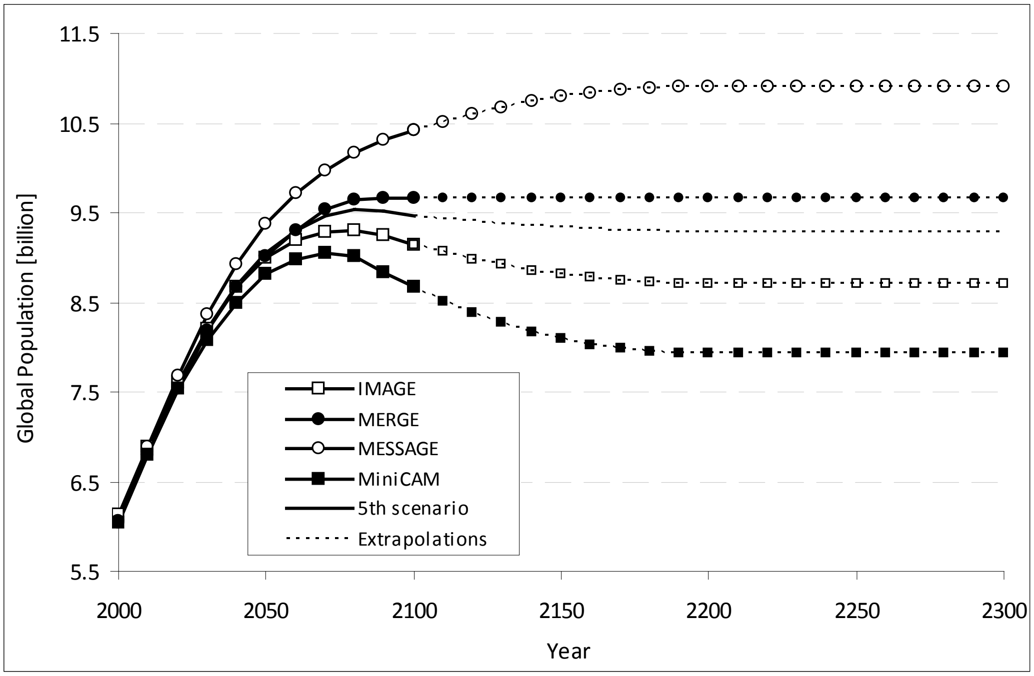

Figure 14A.9.3 Global Population, 2000-2300 (Post-2100 extrapolations assume the population growth rate changes linearly to reach a zero growth rate by 2200.)

Note: In the fifth scenario, 2000-2100 population is equal to the average of the population under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

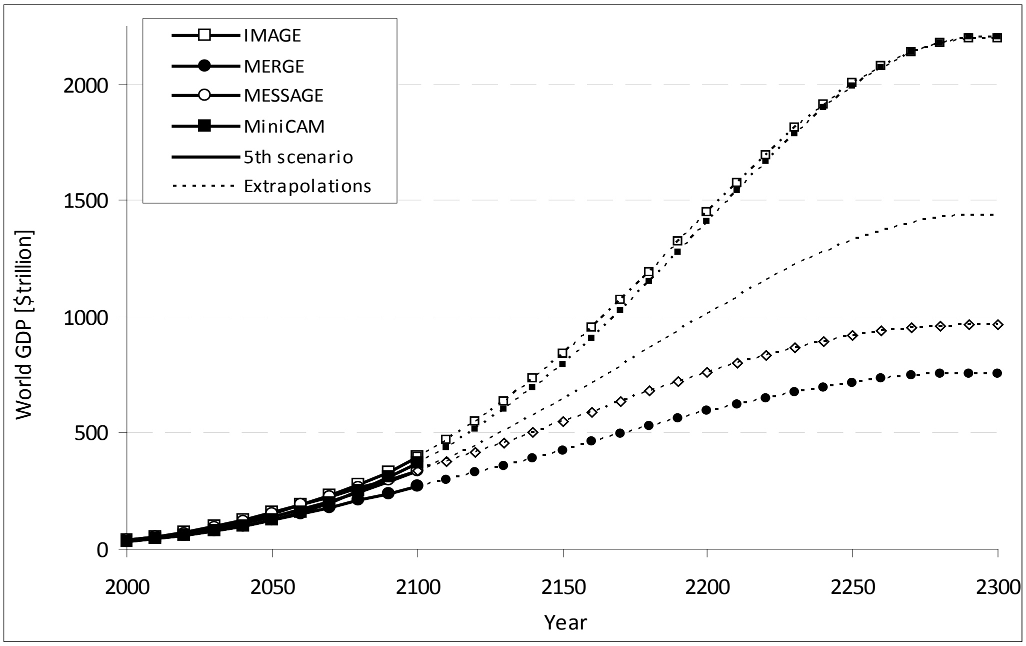

Figure 14A.9.4 World GDP, 2000-2300 (Post-2100 extrapolations assume GDP per capita growth declines linearly, reaching zero in the year 2300)

Note: In the fifth scenario, 2000-2100 GDP is equal to the average of the GDP under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

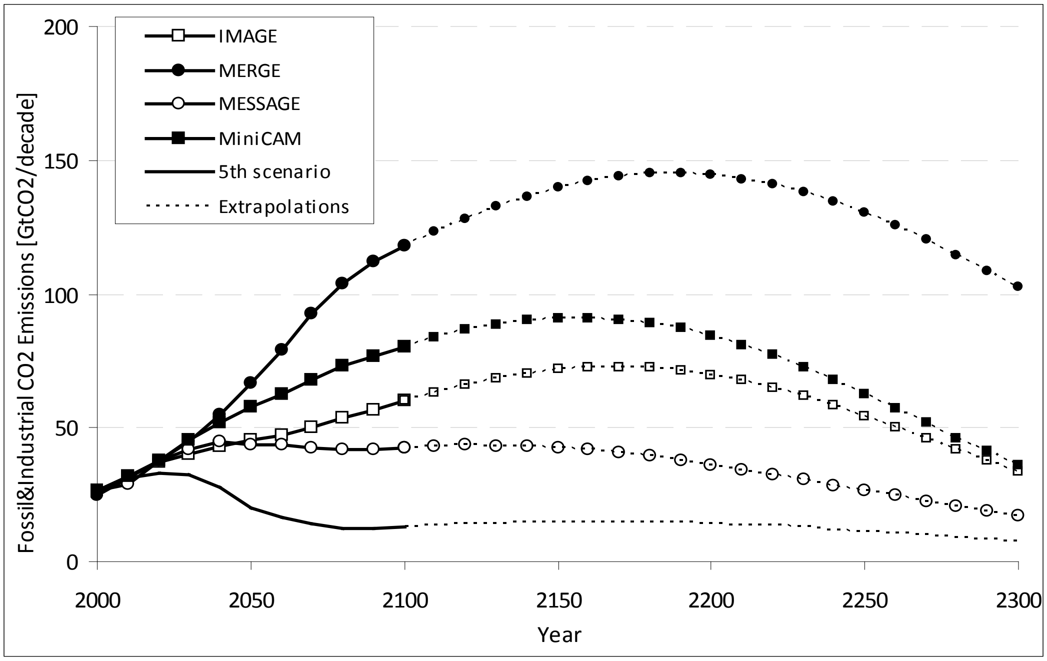

Figure 14A.9.5 Global Fossil and Industrial CO_2 Emissions, 2000-2300 (Post-2100 extrapolations assume growth rate of CO_2 intensity (CO_2/GDP) over 2090-2100 is maintained through 2300)

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

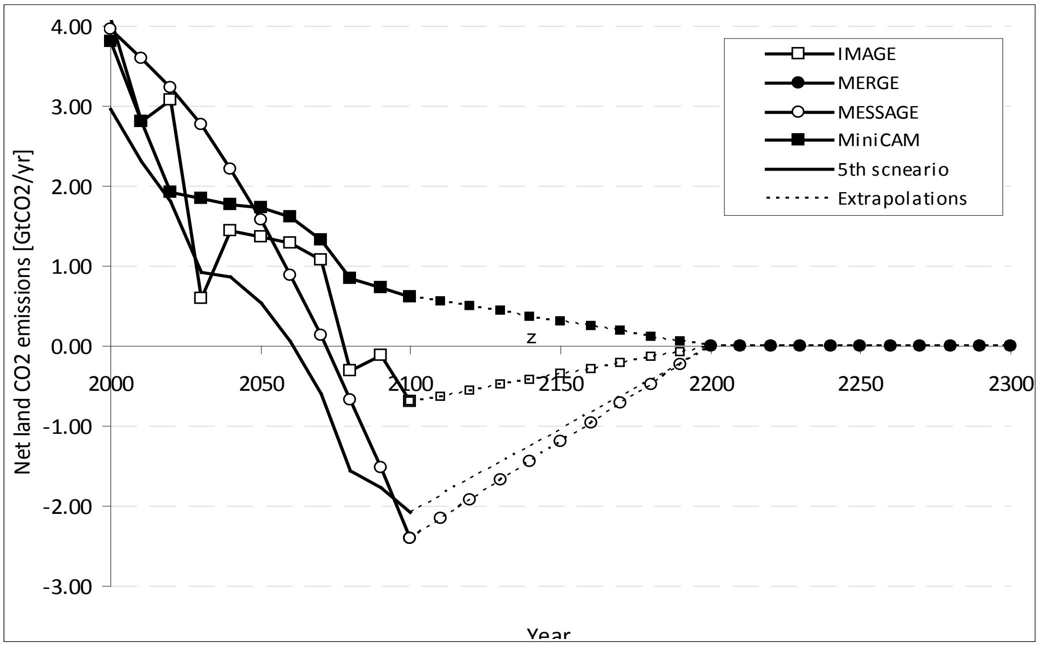

Figure 14A.9.6 Global Net Land Use CO_2 Emissions, 2000-2300 (Post-2100 extrapolations assume emissions decline linearly, reaching zero in the year 2200)[kk]

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

[kk] MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (*i.e.*, we add up the land use emissions from the other three models and divide by 4).

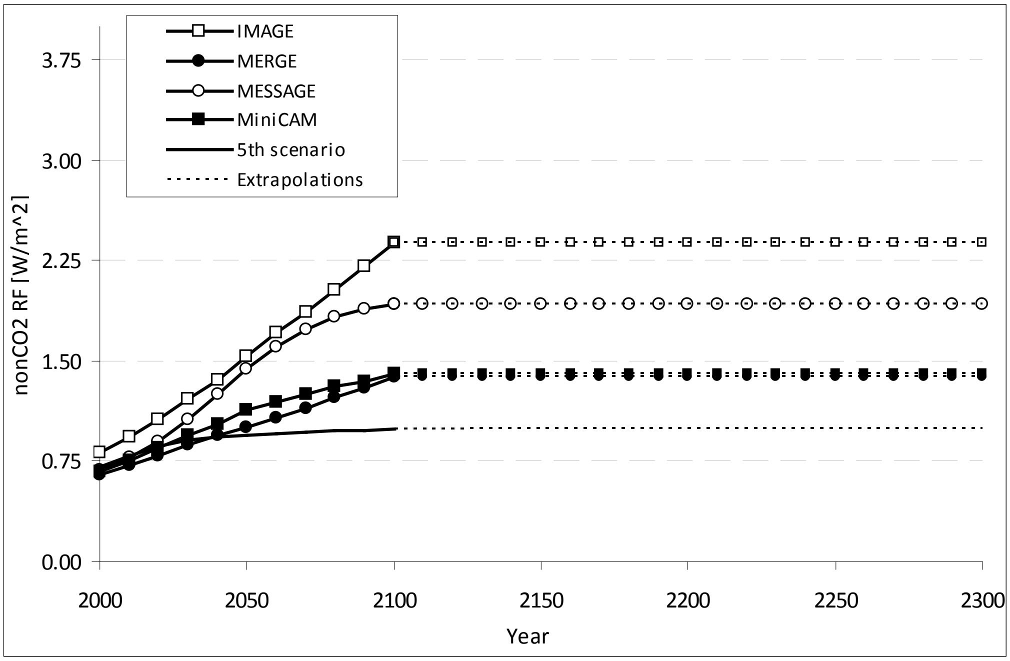

Figure 14A.9.7 Global Non-CO_2 Radiative Forcing, 2000-2300 (Post-2100 extrapolations assume constant non-CO_2 radiative forcing after 2100)

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

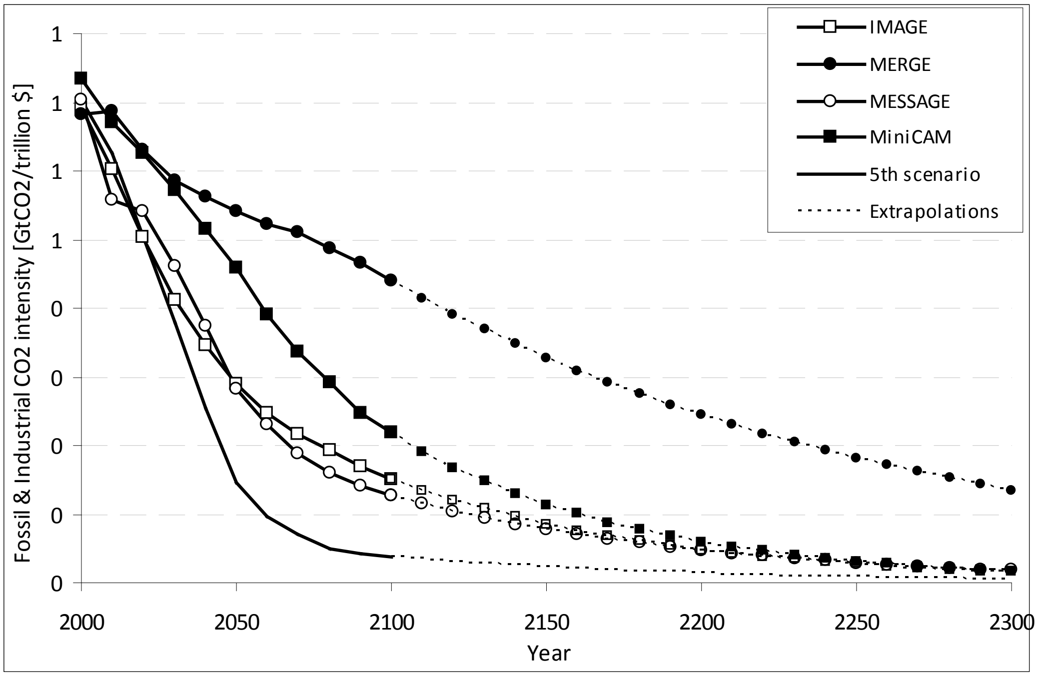

Figure 14A.9.8 Global CO_2 Intensity (fossil & industrial CO_2 emissions/GDP), 2000-2300 (Post-2100 extrapolations assume decline in CO_2/GDP growth rate over 2090-2100 is maintained through 2300)

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

Table 14A.9.2 2010 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	**PAGE**									
IMAGE	3.3	5.9	8.1	13.9	28.8	65.5	68.2	147.9	239.6	563.8
MERGE optimistic	1.9	3.2	4.3	7.2	14.6	34.6	36.2	79.8	124.8	288.3
Message	2.4	4.3	5.8	9.8	20.3	49.2	50.7	114.9	181.7	428.4
MiniCAM base	2.7	4.6	6.4	11.2	22.8	54.7	55.7	120.5	195.3	482.3
5th scenario	2.0	3.5	4.7	8.1	16.3	42.9	41.5	103.9	176.3	371.9

Scenario	**DICE**									
IMAGE	16.4	21.4	25	33.3	46.8	54.2	69.7	96.3	111.1	130.0
MERGE optimistic	9.7	12.6	14.9	19.7	27.9	31.6	40.7	54.5	63.5	73.3
Message	13.5	17.2	20.1	27	38.5	43.5	55.1	75.8	87.9	103.0
MiniCAM base	13.1	16.7	19.8	26.7	38.6	44.4	56.8	79.5	92.8	109.3
5th scenario	10.8	14	16.7	22.2	32	37.4	47.7	67.8	80.2	96.8

Scenario	**FUND**									
IMAGE	-33.1	-18.9	-13.3	-5.5	4.1	19.3	18.7	43.5	67.1	150.7
MERGE optimistic	-33.1	-14.8	-10	-3	5.9	14.8	20.4	43.9	65.4	132.9
Message	-32.5	-19.8	-14.6	-7.2	1.5	8.8	13.8	33.7	52.3	119.2
MiniCAM base	-31.0	-15.9	-10.7	-3.4	6	22.2	21	46.4	70.4	152.9
5th scenario	-32.2	-21.6	-16.7	-9.7	-2.3	3	6.7	20.5	34.2	96.8

Table 14A.9.3 2010 Global SCC Estimates at 3 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	**PAGE**									
IMAGE	2.0	3.5	4.8	8.1	16.5	39.5	41.6	90.3	142.4	327.4
MERGE optimistic	1.2	2.1	2.8	4.6	9.3	22.3	22.8	51.3	82.4	190.0
Message	1.6	2.7	3.6	6.2	12.5	30.3	31	71.4	115.6	263.0
MiniCAM base	1.7	2.8	3.8	6.5	13.2	31.8	32.4	72.6	115.4	287.0
5th scenario	1.3	2.3	3.1	5	9.6	25.4	23.6	62.1	104.7	222.5
Scenario	**DICE**									
IMAGE	11.0	14.5	17.2	22.8	31.6	35.8	45.4	61.9	70.8	82.1
MERGE optimistic	7.1	9.2	10.8	14.3	19.9	22	27.9	36.9	42.1	48.8
Message	9.7	12.5	14.7	19	26.6	29.8	37.8	51.1	58.6	67.4
MiniCAM base	8.8	11.5	13.6	18	25.2	28.8	36.9	50.4	57.9	67.8
5th scenario	7.9	10.1	11.8	15.6	21.6	24.9	31.8	43.7	50.8	60.6
Scenario	**FUND**									
IMAGE	-25.2	-15.3	-11.2	-5.6	0.9	8.2	10.4	25.4	39.7	90.3
MERGE optimistic	-24.0	-12.4	-8.7	-3.6	2.6	8	12.2	27	41.3	85.3
Message	-25.3	-16.2	-12.2	-6.8	-0.5	3.6	7.7	20.1	32.1	72.5
MiniCAM base	-23.1	-12.9	-9.3	-4	2.4	10.2	12.2	27.7	42.6	93.0
5th scenario	-24.1	-16.6	-13.2	-8.3	-3	-0.2	2.9	11.2	19.4	53.6

Table 14A.9.4 2010 Global SCC Estimates at 5 Percent Discount Rate (2007\$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	**PAGE**									
IMAGE	0.5	0.8	1.1	1.8	3.5	8.3	8.5	19.5	31.4	67.2
MERGE optimistic	0.3	0.5	0.7	1.2	2.3	5.2	5.4	12.3	19.5	42.4
Message	0.4	0.7	0.9	1.6	3	7.2	7.2	17	28.2	60.8
MiniCAM base	0.3	0.6	0.8	1.4	2.7	6.4	6.6	15.9	24.9	52.6
5th scenario	0.3	0.6	0.8	1.3	2.3	5.5	5	12.9	22	48.7
Scenario	**DICE**									
IMAGE	4.2	5.4	6.2	7.6	10	10.8	13.4	16.8	18.7	21.1
MERGE optimistic	2.9	3.7	4.2	5.3	7	7.5	9.3	11.7	12.9	14.4
Message	3.9	4.9	5.5	7	9.2	9.8	12.2	15.4	17.1	18.8
MiniCAM base	3.4	4.2	4.7	6	7.9	8.6	10.7	13.5	15.1	16.9
5th scenario	3.2	4	4.6	5.7	7.6	8.2	10.2	12.8	14.3	16.0
Scenario	**FUND**									
IMAGE	-11.7	-8.4	-6.9	-4.6	-2.2	-1.3	0.7	4.1	7.4	17.4
MERGE optimistic	-10.6	-7.1	-5.6	-3.6	-1.3	-0.3	1.6	5.4	9.1	19.0
Message	-12.2	-8.9	-7.3	-4.9	-2.5	-1.9	0.3	3.5	6.5	15.6
MiniCAM base	-10.4	-7.2	-5.8	-3.8	-1.5	-0.6	1.3	4.8	8.2	18.0
5th scenario	-10.9	-8.3	-7	-5	-2.9	-2.7	-0.8	1.4	3.2	9.2

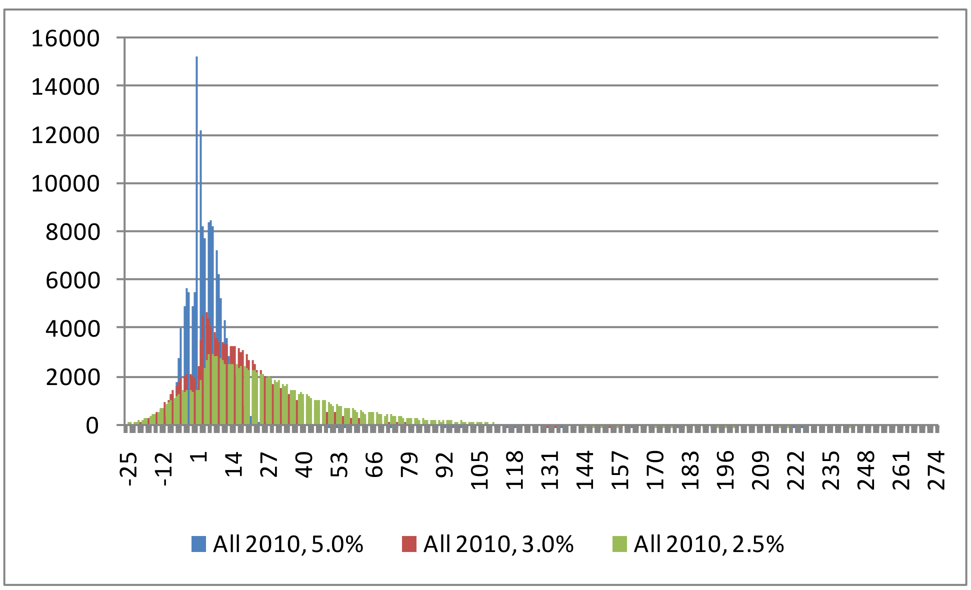

Figure 14A.9.9 Histogram of Global SCC Estimates in 2010 (2007\$/ton CO_2), by discount rate

* The distribution of SCC values ranges from -\$5,192 to \$66,116, but the X-axis has been truncated at approximately the 1st and 99th percentiles to better show the data.

Table 14A.9.5 Additional Summary Statistics of 2010 Global SCC Estimates

Discount Rate		Scenario		
		DICE	PAGE	FUND
5%	Mean	9	6.5	-1.3
	Variance	13.1	136	70.1
	Skewness	0.8	6.3	28.2
	Kurtosis	0.2	72.4	1,479.00
3%	Mean	28.3	29.8	6
	Variance	209.8	3,383.70	16,382.50
	Skewness	1.1	8.6	128
	Kurtosis	0.9	151	18,976.50
2.50%	Mean	42.2	49.3	13.6
	Variance	534.9	9,546.00	#######
	Skewness	1.2	8.7	149
	Kurtosis	1.1	143.8	23,558.30

APPENDIX 14B. TECHNICAL UPDATE OF SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

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APPENDIX 14B. TECHNICAL UPDATE OF SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

14B.1 PREFACE

The following text is reproduced almost verbatim from the May 2013 report of the Interagency Working Group on the Social Cost of Carbon of the United States Government. Minor changes were made to the working group's report to make it more consistent with the rest of this technical support document.

14B.2 PURPOSE

The purpose of this document is to update the schedule of social cost of carbon (SCC) [a] estimates from the 2010 interagency technical support document (TSD) (Interagency Working Group on Social Cost of Carbon 2010).[1] E.O. 13563 commits the Administration to regulatory decision making "based on the best available science."[b] Additionally, the interagency group recommended in 2010 that the SCC estimates be revisited on a regular basis or as model updates that reflect the growing body of scientific and economic knowledge become available.[c] New versions of the three integrated assessment models used by the U.S. government to estimate the SCC (DICE, FUND, and PAGE), are now available and have been published in the peer reviewed literature. While acknowledging the continued limitations of the approach taken by the interagency group in 2010 (documented in the original 2010 TSD), this document provides an update of the SCC estimates based solely on the latest peer-reviewed version of the models, replacing model versions that were developed up to ten years ago in a rapidly evolving field. It does not revisit other assumptions with regard to the discount rate, reference case socioeconomic and emission scenarios, or equilibrium climate sensitivity. Improvements in the way damages are modeled are confined to those that have been incorporated into the latest versions of the models by the developers themselves in the peer-reviewed literature. The Environmental Protection Agency (EPA), in collaboration with other Federal agencies such as the Department of Energy (DOE), continues to investigate potential improvements to the way in which economic damages associated with changes in CO_2 emissions are quantified.

Section 14B.3 summarizes the major updates relevant to SCC estimation that are contained in the new versions of the integrated assessment models released since the 2010 interagency report. Section 14B.4 presents the updated schedule of SCC estimates for 2010 – 2050 based on these versions of the models.

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[a] In this document, we present all values of the SCC as the cost per metric ton of CO_2 emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of CO_2 and the mass of carbon is 3.67.

[b] www.whitehouse.gov/sites/default/files/omb/inforeg/eo12866/eo13563_01182011.pdf

[c] See p. 1, 3, 4, 29, and 33 (Interagency Working Group on Social Cost of Carbon 2010).[1]

14B.3 SUMMARY OF MODEL UPDATES

This section briefly summarizes changes integrated into the most recent versions of the three integrated assessment models (IAMs) used by the interagency group in 2010. We focus on describing those model updates that are relevant to estimating the social cost of carbon. For example, both the DICE and PAGE models now include an explicit representation of sea level rise damages. Other revisions to PAGE include: updated adaptation assumptions, revisions to ensure damages are constrained GDP, updated regional scaling of damages, and a revised treatment of potentially abrupt shifts in climate damages. In the most recent version of DICE, the model's simple carbon cycle has been updated to be more consistent with a relatively more complex climate model. The FUND model includes updated damage functions for sea level rise impacts, the agricultural sector, and reduced space heating requirements, as well as changes to the response of temperature to the buildup of GHG concentrations and the inclusion of indirect effects of methane emissions. Changes made to parts of the models that are superseded by the interagency working group's modeling assumptions – regarding climate sensitivity, discounting, and socioeconomic variables – are not discussed.

14B.3.1 DICE

Changes in the DICE model relevant for the SCC estimates developed by the interagency working group include: 1) updated parameter values for the carbon cycle model, 2) an explicit representation of sea level dynamics, and 3) a re-calibrated damage function that includes an explicit representation of economic damages from sea level rise. Changes were also made to other parts of the DICE model—including the equilibrium climate sensitivity parameter, the rate of change of total factor productivity, and the elasticity of the marginal utility of consumption—but these components of DICE are superseded by the interagency working group's assumptions and so will not be discussed here. More details on DICE2007 can be found in Nordhaus (2008)[2] and on DICE2010 in Nordhaus (2010)[3] and the associated on-line appendix containing supplemental information.

14B.3.1.1 Carbon Cycle Parameters

DICE uses a three-box model of carbon stocks and flows to represent the accumulation and transfer of carbon among the atmosphere, the shallow ocean and terrestrial biosphere, and the deep ocean. These parameters are "calibrated to match the carbon cycle in the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC)" (Nordhaus 2008 p 44).[2d] Carbon cycle transfer coefficient values in DICE2010 are based on re-calibration of the model to match the newer version of MAGICC (Nordhaus 2010 p 2).[3] For example, in DICE2010 in each decade, 12 percent of the carbon in the atmosphere is transferred to the shallow ocean, 4.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 94.8 percent remains in the shallow ocean, and 0.5 percent is transferred to the deep ocean. For comparison, in DICE 2007, 18.9 percent of the carbon in the atmosphere is transferred to the shallow ocean each

[d] MAGICC is a simple climate model initially developed within the U.S. National Center for Atmospheric Research that has been used heavily by the Intergovernmental Panel on Climate Change (IPCC) to emulate projections from much more sophisticated state of the art earth system simulation models (Randall et al. 2007).[4]

decade, 9.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 85.3 percent remains in the shallow ocean, and 5 percent is transferred to the deep ocean.

The implication of these changes for DICE2010 is in general a weakening of the ocean as a carbon sink and therefore a higher concentration of carbon in the atmosphere than in DICE2007, for a given path of emissions. All else equal, these changes will generally increase the level of warming and therefore the SCC estimates in DICE2010 relative to those from DICE2007.

14B.3.1.2 Sea Level Dynamics

A new feature of DICE2010 is an explicit representation of the dynamics of the global average sea level anomaly to be used in the updated damage function (discussed below). This section contains a brief description of the sea level rise (SLR) module; a more detailed description can be found on the model developer's website.[e] The average global sea level anomaly is modeled as the sum of four terms that represent contributions from: 1) thermal expansion of the oceans, 2) melting of glaciers and small ice caps, 3) melting of the Greenland ice sheet, and 4) melting of the Antarctic ice sheet.

The parameters of the four components of the SLR module are calibrated to match consensus results from the IPCC's Fourth Assessment Report.[4,f] The rise in sea level from thermal expansion in each time period (decade) is 2 percent of the difference between the sea level in the previous period and the long run equilibrium sea level, which is 0.5 meters per degree Celsius (°C) above the average global temperature in 1900. The rise in sea level from the melting of glaciers and small ice caps occurs at a rate of 0.008 meters per decade per °C above the average global temperature in 1900.

The contribution to sea level rise from melting of the Greenland ice sheet is more complex. The equilibrium contribution to SLR is 0 meters for temperature anomalies less than 1 °C and increases linearly from 0 meters to a maximum of 7.3 meters. The contribution to SLR in each period is proportional to the difference between the previous period's sea level anomaly and the equilibrium sea level anomaly, where the constant of proportionality increases with the temperature anomaly in the current period.

The contribution to SLR from the melting of the Antarctic ice sheet is -0.001 meters per decade when the temperature anomaly is below 3 °C and increases linearly to a maximum rate of 0.025 meters per decade at a temperature anomaly of 6 °C.

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[e] Documentation on the new sea level rise module of DICE is available on William Nordhaus' website at: www.econ.yale.edu/.

[f] For a review of post-IPCC AR4 research on sea level rise, see Nicholls et al. (2011)[5] and NAS (2011).[6]

14B.3.1.3 Re-calibrated Damage Function

Economic damages from climate change in the DICE model are represented by a fractional loss of gross economic output in each period. A portion of the remaining economic output in each period (net of climate change damages) is consumed and the remainder is invested in the physical capital stock to support future production, so each period's climate damages will reduce consumption in that period and in all future periods due to the lost investment. The fraction of output in each period that is lost due to climate change impacts is represented as one minus a fraction, which is one divided by a quadratic function of the temperature anomaly, producing a sigmoid ("S"-shaped) function. The loss function in DICE2010 has been expanded by adding a quadratic function of SLR to the quadratic function of temperature. In DICE2010 the temperature anomaly coefficients have been recalibrated to avoid double-counting damages from sea level rise that were implicitly included in these parameters in DICE2007.

The aggregate damages in DICE2010 are illustrated by Nordhaus (2010 p 3),[3] who notes that "…damages in the uncontrolled (baseline) (*i.e.*, reference) case … in 2095 are $12 trillion, or 2.8 percent of global output, for a global temperature increase of 3.4 ^{o}C above 1900 levels." This compares to a loss of 3.2 percent of global output at 3.4 ^{o}C in DICE2007. However, in DICE2010 (as downloaded from the homepage of William Nordhaus), annual damages are lower in most of the early periods but higher in later periods of the time horizon than would be calculated using the DICE2007 damage function. Specifically, the percent difference between damages in the base run of DICE2010 and those that would be calculated using the DICE2007 damage function starts at +7 percent in 2005, decreases to a low of -14 percent in 2065, then continuously increases to +20 percent by 2300 (the end of the interagency analysis time horizon), and to +160 percent by the end of the model time horizon in 2595. The large increases in the far future years of the time horizon are due to the permanence associated with damages from sea level rise, along with the assumption that the sea level is projected to continue to rise long after the global average temperature begins to decrease. The changes to the loss function generally decrease the interagency working group SCC estimates slightly, all else equal.

14B.3.2 FUND

FUND version 3.8 includes a number of changes over the previous version 3.5 used in the interagency report. Documentation supporting FUND and the model's source code for all versions of the model is available from the model authors.[g] Notable changes, due to their impact on the estimates of expected SCC, are adjustments to the space heating, agriculture, and sea level rise damage functions in addition to changes to the temperature response function and the inclusion of indirect effects from methane emissions.[h] We discuss each of these in turn.

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[g] www.fund-model.org/. This report uses version 3.8 of the FUND model, which represents a modest update to the most recent version of the model to appear in the literature (version 3.7) (Anthoff and Tol, 2013).[7] For the purpose of computing the SCC, the relevant changes are associated with improving consistency with IPCC AR4 by adjusting the atmospheric lifetimes of CH4 and N2O and incorporating the indirect forcing effects of CH4, along with making minor stability improvements in the sea wall construction algorithm.

[h] The other damage sectors (water resources, space cooling, land loss, migration, ecosystems, human health, and extreme weather) were not the subject of significant updates.

14B.3.2.1 Space Heating

In FUND, the damages associated with the change in energy needs for space heating are based on the estimated impact due to one degree of warming. These baseline damages are scaled based on the forecasted temperature anomaly's deviation from the one degree benchmark and adjusted for changes in vulnerability due to economic and energy efficiency growth. In FUND 3.5, the function that scales the base year damages adjusted for vulnerability allows for the possibility that in some simulations the benefits associated with reduced heating needs may be an unbounded convex function of the temperature anomaly. In FUND 3.8, the form of the scaling has been modified to ensure that the function is everywhere concave, meaning that for every simulation there will exist an upper bound on the benefits a region may receive from reduced space heating needs. The new formulation approaches a value of two in the limit as the temperature anomaly increases, or in other words, assuming no decrease in vulnerability, the reduced expenditures on space heating at any level of warming will not exceed two times the reductions experienced at one degree of warming. Since the reduced need for space heating represents a benefit of climate change in the model, or a negative damage, this change will increase the estimated SCC. This update accounts for a significant portion of the difference in the expected SCC estimates reported by the two versions of the model when run probabilistically.

14B.3.2.2 Sea Level Rise and Land Loss

The FUND model explicitly includes damages associated with the inundation of dry land due to sea level rise. The amount of land lost within a region is dependent upon the proportion of the coastline being protected by adequate sea walls and the amount of sea level rise. In FUND 3.5 the function defining the potential land lost in a given year due to sea level rise is linear in the rate of sea level rise for that year. This assumption implicitly assumes that all regions are well represented by a homogeneous coastline in length and a constant uniform slope moving inland. In FUND 3.8 the function defining the potential land lost has been changed to be a non-linear function of sea level rise, thereby assuming that the slope of the shore line is not constant moving inland, with a positive first derivative. The effect of this change is to typically reduce the vulnerability of some regions to sea level rise based land loss, therefore having an effect of lowering the expected SCC estimate. The model has also been updated to assume that the value of dry land at risk of inundation is not uniform across a region but will be a decreasing function of protection measure, thereby implicitly assuming that the most valuable land will be protected first.

14B.3.2.3 Agriculture

In FUND, the damages associated with the agricultural sector are measured as proportional to the sector's value. The fraction is made up of three additively separable components that represent the effects from carbon fertilization, the rate of temperature change, and the level of the temperature anomaly. In both FUND 3.5 and FUND 3.8, the fraction of the sector's value lost due to the level of the temperature anomaly is modeled as a quadratic function with an intercept of zero. In FUND 3.5, the linear and quadratic coefficients are modeled as the ratio of two normal distributions. Within this specification, as draws from the distribution in the denominator approached zero the share of the sector's value "lost" approaches (+/-) infinity independent of the temperature anomaly itself. In FUND 3.8, the linear and quadratic coefficients are drawn directly from truncated normal distributions so that they remain in the range $[0,\infty)$ and $(-\infty,0]$, respectively, where the means for the new distributions are set equal to the ratio of the means from the normal distributions used in the previous version. In general the impact of this change has been to increase the likelihood that increases in the temperature level will have either larger positive or negative effects on the agricultural sector relative to the previous version (through eliminating simulations in which the "lost" value approached (+/-) infinity). The net effect of this change on the SCC estimates is difficult to predict.

14B.3.2.4 Temperature Response Model

The temperature response model translates changes in global levels of radiative forcing into the current expected temperature anomaly. In FUND, a given year's increase in the cumulative temperature anomaly is based on a mean reverting function where the mean equals the equilibrium temperature anomaly that would eventually be reached if that year's level of radiative forcing were sustained. The rate of mean reversion defines the rate at which the transient temperature approaches the equilibrium. In FUND 3.5, the rate of temperature response is defined as a decreasing linear function of equilibrium climate sensitivity to capture the fact that the progressive heat uptake of the deep ocean causes the rate to slow at higher values of the equilibrium climate sensitivity. In FUND 3.8, the rate of temperature response has been updated to a quadratic function of the equilibrium climate sensitivity. This change reduces the sensitivity of the rate of temperature response to the level of the equilibrium climate sensitivity. Therefore in FUND 3.8, the temperature response will typically be faster than in the previous version. The overall effect of this change is likely to increase estimates of the SCC as higher temperatures are reached during the timeframe analyzed and as the same damages experienced in the previous version of the model are now experienced earlier and therefore discounted less.

14B.3.2.5 Methane

The IPCC notes a series of indirect effects of methane emissions, and has developed methods for proxying such effects when computing the global warming potential of methane (Forster et al. 2007).[8] FUND 3.8 now includes the same methods for incorporating the indirect effects of methane emissions. Specifically, the average atmospheric lifetime of methane has been set to 12 years to account for the feedback of CH4 emissions on its own lifetime. The radiative forcing associated with atmospheric methane has also been increase by 40% to account for its net impact on ozone production and increase in stratospheric water vapor. The general effect of this increased radiative forcing will be to increase the estimated SCC values, where the degree to which this occurs will be dependent upon the relative curvature of the damage functions with respect to the temperature anomaly.

14B.3.3 PAGE

PAGE09 (Hope 2012)[9] includes a number of changes from PAGE2002, the version used in the 2009 SCC interagency report. The changes that most directly affect the SCC estimates include: explicitly modeling the impacts from sea level rise, revisions to the damage function to ensure damages are constrained by GDP, a change in the regional scaling of damages, a revised treatment for the probability of a discontinuity within the damage function, and revised assumptions on adaptation. The model also includes revisions to the carbon cycle feedback and the calculation of regional temperatures. More details on PAGE2009 can be found in three working papers (Hope 2011a, 2011b, 2011c).[10, 11, 12] A description of PAGE2002 can be found in Hope (2006).[13]

14B.3.3.1 Sea Level Rise

While PAGE2002 aggregates all damages into two categories – economic and non-economic impacts - PAGE2009 adds a third explicit category: damages from sea level rise. In the previous version of the model, damages from sea level rise were subsumed by the other damage categories. PAGE09 models damages from sea level rise as increasing less than linearly with sea level based on the assumption that low-lying shoreline areas will be associated with higher damages than current inland areas. Damages from the economic and non-economic sector were adjusted to account for the introduction of this new category.

14B.3.3.2 Revised Damage Function to Account for Saturation

In PAGE09, small initial economic and non-economic benefits (negative damages) are modeled for small temperature increases, but all regions eventually experience positive economic damages from climate change, where damages are the sum of additively separable polynomial functions of temperature and sea level rise. Damages transition from this polynomial function to a logistic path once they exceed a certain proportion of remaining Gross Domestic Product (GDP) to ensure that damages do not exceed 100 percent of GDP. This differs from PAGE2002, which allowed Eastern Europe to potentially experience large benefits from temperature increases, and which also did not bound the possible damages that could be experienced.

14B.3.3.3 Regional Scaling Factors

As in the previous version of PAGE, the PAGE09 model calculates the damages for the European Union (EU) and then, assumes that damages for other regions are proportional based on a given scaling factor. The scaling factor in PAGE09 is based on the length of a region's coastline relative to the EU (Hope 2011b).[11] Because of the long coastline in the EU, other regions are, on average, less vulnerable than the EU for the same sea level and temperature increase, but all regions have a positive scaling factor. PAGE2002 based its scaling factors on four studies reported in the IPCC's third assessment report, and allowed for benefits from temperature increase in Eastern Europe, smaller impacts in developing countries, and higher damages in developing countries.

14B.3.3.4 Probability of a Discontinuity

In PAGE2002, the damages associated with a "discontinuity" were modeled as an expected value. That is, additional damages from an extreme event, such as extreme melting of the Greenland ice sheet, were multiplied by the probability of the event occurring and added to the damage estimate. In PAGE09, the probability of "discontinuity" is treated as a discrete event for each year in the model. The damages for each model run are estimated with or without a discontinuity occurring, rather than as an expected value. A large-scale discontinuity becomes possible when the temperature rises beyond some threshold value between 2 and 4°C. The probability that a discontinuity will occur beyond this threshold then increases by between 10 and 30 percent for every 1°C rise in temperature beyond the threshold. If a discontinuity occurs, the EU loses an additional 5 to 25 percent of its GDP (drawn from a triangular distribution with a mean of 15 percent) in addition to other damages, and other regions lose an amount determined by the regional scaling factor. The threshold value for a possible discontinuity is lower than in PAGE2002, while the rate at which the probability of a discontinuity increases with the temperature anomaly and the damages that result from a discontinuity are both higher than in PAGE2002. The model assumes that only one discontinuity can occur and that the impact is phased in over a period of time, but once it occurs, its effect is permanent.

14B.3.3.5 Adaptation

As in PAGE2002, adaptation is available to increase the tolerable level of temperature change and can help mitigate any climate change impacts that still occur. In PAGE this adaptation is the same regardless of the temperature change or sea level rise and is therefore akin to what is more commonly considered a reduction in vulnerability. It is modeled by modifying the temperature change and sea level rise used in the damage function or by reducing the damages by some percentage. PAGE09 assumes a smaller decrease in vulnerability than the previous version of the model and assumes that it will take longer for this change in vulnerability to be realized. In the aggregated economic sector, at the time of full implementation, this adaptation will mitigate all damages up to a temperature increase of 1°C, and for temperature anomalies between 1°C and 3°C, it will reduce damages by 15-30 percent (depending on the region). However, it takes 20 years to fully implement this adaptation. In PAGE2002, adaptation was assumed to reduce economic sector damages up to 3°C by 50-90 percent after 20 years. Beyond 3°C, no adaptation is assumed to be available to mitigate the impacts of climate change. For the non-economic sector, in PAGE09 adaptation is available to reduce 15 percent of the damages due to a temperature increase between 0°C and 2°C and is assumed to take 40 years to fully implement, instead of 25 percent of the damages over 20 years assumed in PAGE2002. Similarly, adaptation is assumed to alleviate 25-50 percent of the damages from the first 0.20 to 0.25 meters of sea level rise but is assumed to be ineffective thereafter. Hope (2011c)[12] estimates that the less optimistic assumptions regarding the ability to offset impacts of temperature and sea level rise via adaptation increase the SCC by approximately 30 percent.

14B.3.3.6 Other Noteworthy Changes

Two other changes in the model are worth noting. A revised carbon cycle feedback is introduced to simulate decreased CO_2 absorption by the terrestrial biosphere and ocean as the temperature rises. This feedback is linear in the average global and annual temperature anomaly but is capped at a maximum value. In the previous version of PAGE, an additional amount was added to the CO_2 emissions each period to account for a decrease in ocean absorption and a loss of soil carbon. Also updated is the method by which the average global and annual temperature anomaly is downscaled to determine annual average regional temperature anomalies to be used in the regional damage functions. In the previous version of PAGE, the scaling was determined solely based on regional difference in emissions of sulfate aerosols. In PAGE09, this regional temperature anomaly is further adjusted using an additive factor that is based on the average absolute latitude of a region relative to the area weighted average absolute latitude of the Earth's landmass.

14B.4 REVISED SCC ESTIMATES

The updated versions of the three integrated assessment models were run using the same methodology detailed in the 2010 TSD.[1] The approach along with the inputs for the socioeconomic emissions scenarios, equilibrium climate sensitivity distribution, and discount rate remains the same. This includes the five reference scenarios based on the EMF-22 modeling exercise, the Roe and Baker equilibrium climate sensitivity distribution calibrated to the Fourth Assessment Report of the IPCC, and three constant discount rates of 2.5, 3, and 5 percent.

As was previously the case, the use of three models, three discount rates, and five scenarios produces 45 separate distributions for the SCC. The approach laid out in the TSD applied equal weight to each model and socioeconomic scenario in order to reduce the dimensionality down to three separate distributions representative of the three discount rates. The interagency group selected four values from these distributions for use in regulatory analysis. Three values are based on the average SCC across models and socio-economic-emissions scenarios at the 2.5, 3, and 5 percent discount rates, respectively. The fourth value was chosen to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, the 95th percentile of the SCC estimates at a 3 percent discount rate was chosen. (A detailed set of percentiles by model and scenario combination is available in the Annex.) As noted in the original TSD, "the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate" (TSD, p. 25). However, for purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance and value of including all four SCC values.

Table 14B.4.1 shows the four selected SCC estimates in five year increments from 2010 to 2050. Values for 2010, 2020, 2030, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using basic linear interpolation. The full set of annual SCC estimates between 2010 and 2050 is reported in the Annex.

Table 14B.4.1 Revised Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per ton of CO_2)

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

The SCC estimates using the updated versions of the models are higher than those reported in the TSD due to the changes to the models outlined in the previous section. Figure 14B.4.2 illustrates where the four SCC values for 2020 fall within the full distribution for each discount rate based on the combined set of runs for each model and scenario (150,000 estimates in total for each discount rate). In general, the distributions are skewed to the right and have long tails. The Figure also shows that the lower the discount rate, the longer the right tail of the distribution.

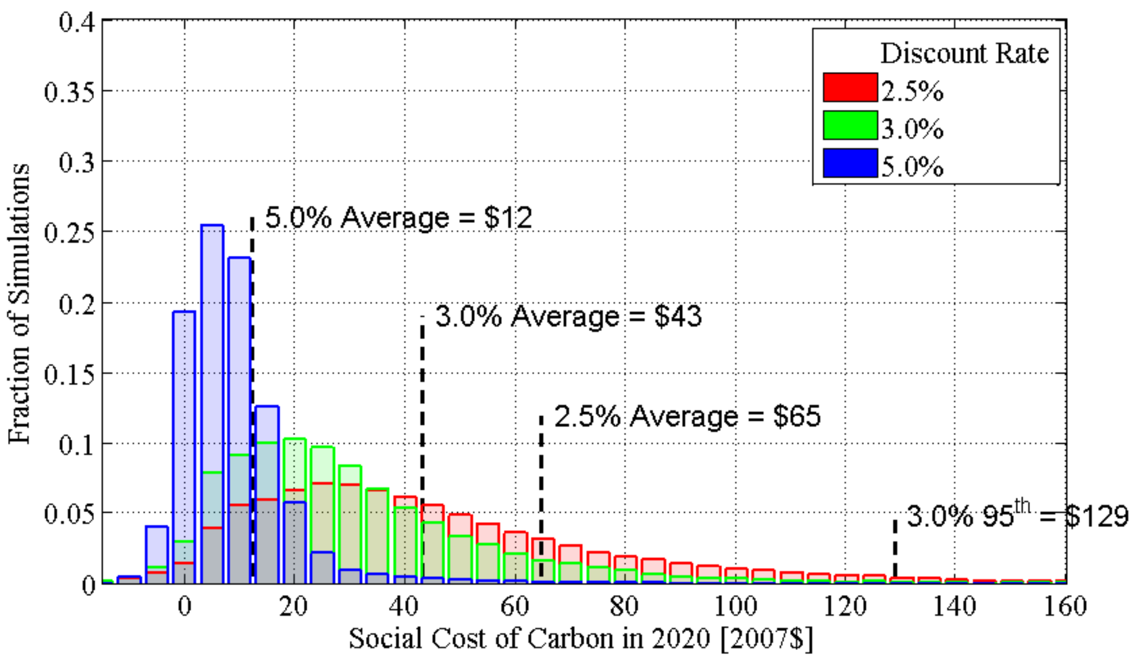

Figure 14B.4.2 Distribution of SCC Estimates for 2020 (in 2007$ per ton CO_2)

As was the case in the original TSD, the SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. The approach taken by the interagency group is to allow the growth rate to be determined endogenously by the models through running them for a set of perturbation years out to 2050. Table 14B.4.2 illustrates how the growth rate for these four SCC estimates varies over time.

Table 14B.4.2 Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Rate (%)	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010-2020	1.2%	3.2%	2.4%	4.3%
2020-2030	3.4%	2.1%	1.7%	2.4%
2030-2040	3.0%	1.8%	1.5%	2.0%
2040-2050	2.6%	1.6%	1.3%	1.5%

The future monetized value of emission reductions in each year (the SCC in year t multiplied by the change in emissions in year t) must be discounted to the present to determine its total net present value for use in regulatory analysis. As previously discussed in the original TSD, damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency – *i.e.*, future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate.

14B.5 OTHER MODEL LIMITATIONS OR RESEARCH GAPS

The 2010 interagency SCC technical support report discusses a number of important limitations for which additional research is needed. In particular, the document highlights the need to improve the quantification of both non-catastrophic and catastrophic damages, the treatment of adaptation and technological change, and the way in which inter-regional and inter-sectoral linkages are modeled. It also discusses the need to more carefully assess the implications of risk aversion for SCC estimation as well as the inability to perfectly substitute between climate and non-climate goods at higher temperature increases, both of which have implications for the discount rate used. EPA, DOE, and other agencies continue to engage in long-term research work on modeling and valuation of climate impacts that we expect will inform improvements in SCC estimation in the future.

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ANNEX

Table 14B.5.1 Annual SCC Values: 2010-2050 (2007$/ton CO_2)

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	11	33	52	90
2011	11	34	54	94
2012	11	35	55	98
2013	11	36	56	102
2014	11	37	57	106
2015	12	38	58	109
2016	12	39	60	113
2017	12	40	61	117
2018	12	41	62	121
2019	12	42	63	125
2020	12	43	65	129
2021	13	44	66	132
2022	13	45	67	135
2023	13	46	68	138
2024	14	47	69	141
2025	14	48	70	144
2026	15	49	71	147
2027	15	49	72	150
2028	15	50	73	153
2029	16	51	74	156
2030	16	52	76	159
2031	17	53	77	163
2032	17	54	78	166
2033	18	55	79	169
2034	18	56	80	172
2035	19	57	81	176
2036	19	58	82	179
2037	20	59	84	182
2038	20	60	85	185
2039	21	61	86	188
2040	21	62	87	192
2041	22	63	88	195
2042	22	64	89	198
2043	23	65	90	200
2044	23	65	91	203
2045	24	66	92	206
2046	24	67	94	209
2047	25	68	95	212
2048	25	69	96	215
2049	26	70	97	218
2050	27	71	98	221

Table 14B.5.2 202 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95^{th}	99th
Scenario	PAGE									
IMAGE	6	11	15	27	58	129	139	327	515	991
MERGE	4	6	9	16	34	78	82	196	317	649
MESSAGE	4	8	11	20	42	108	107	278	483	918
MiniCAM Base	5	9	12	22	47	107	113	266	431	872
5th Scenario	2	4	6	11	25	85	68	200	387	955
Scenario	DICE									
IMAGE	25	31	37	47	64	72	92	123	139	161
MERGE	14	18	20	26	36	40	50	65	74	85
MESSAGE	20	24	28	37	51	58	71	95	109	221
MiniCAM Base	20	25	29	38	53	61	76	102	117	135
5th Scenario	17	22	25	33	45	52	65	91	106	126
Scenario	FUND									
IMAGE	-17	-1	5	17	34	44	59	90	113	176
MERGE	-7	2	7	16	30	35	49	72	91	146
MESSAGE	-19	-4	2	12	27	32	46	70	87	135
MiniCAM Base	-9	1	8	18	35	45	59	87	108	172
5th Scenario	-30	-12	-5	6	19	24	35	57	72	108

Table 14B.5.3 SCC Estimates at 3 Percent Discount Rate (2007$/ton CO2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	4	7	10	18	38	91	95	238	385	727
MERGE	2	4	6	11	23	56	58	142	232	481
MESSAGE	3	5	7	13	29	75	74	197	330	641
MiniCAM Base	3	5	8	14	30	73	75	184	300	623
5th Scenario	1	3	4	7	17	58	48	136	264	660
Scenario	DICE									
IMAGE	16	21	24	32	43	48	60	79	90	102
MERGE	10	13	15	19	25	28	35	44	50	58
MESSAGE	14	18	20	26	35	40	49	64	73	83
MiniCAM Base	13	17	20	26	35	39	49	65	73	85
5th Scenario	12	15	17	22	30	34	43	58	67	79
Scenario	FUND									
IMAGE	-14	-3	1	9	20	25	35	54	69	111
MERGE	-8	-1	3	9	18	22	31	47	60	97
MESSAGE	-16	-5	-1	6	16	18	28	43	55	88
MiniCAM Base	-9	-1	3	10	21	27	35	53	67	107
5th Scenario	-22	-10	-5	2	10	13	20	33	42	63

Table 14B.5.4 2020 Global SCC Estimates at 5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario					PAGE					
IMAGE	1	2	2	5	10	28	27	71	123	244
MERGE	1	1	2	3	7	17	17	45	75	153
MESSAGE	1	1	2	4	9	24	22	60	106	216
MiniCAM Base	1	1	2	3	8	21	21	54	94	190
5th Scenario	0	1	1	2	5	18	14	41	78	208
Scenario					DICE					
IMAGE	6	8	9	11	14	15	18	22	25	27
MERGE	4	5	6	7	9	10	12	15	16	18
MESSAGE	6	7	8	10	12	13	16	20	22	25
MiniCAM Base	5	6	7	8	11	12	14	18	20	22
5th Scenario	5	6	6	8	10	11	14	17	19	21
Scenario					FUND					
IMAGE	-9	-5	-3	-1	2	3	6	11	15	25
MERGE	-6	-3	-2	0	3	4	7	12	16	27
MESSAGE	-10	-6	-4	-1	2	2	5	9	13	23
MiniCAM Base	-7	-3	-2	0	3	4	7	11	15	26
5th Scenario	-11	-7	-5	-2	0	0	3	6	8	14

APPENDIX 17A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

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APPENDIX 17A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

17A.1 INTRODUCTION

This appendix contains sections discussing the following topics:

- Projections of annual market share increases for the alternative policies;
- NIA-RIA Integrated Model;
- XENERGY penetration curves used to analyze consumer rebates, including:
    - Background material,
    - DOE's adjustment of these curves for this analysis, and
    - The method DOE used for interpolating the curves;
- Detailed tables of rebates offered for the considered products; and
- Background material on Federal and state tax credits for appliances.

17A.2 MARKET SHARE ANNUAL INCREASES BY POLICY

Table 17A.2.1 through Table 17A.2.5 show the annual increases in market shares of hearth products meeting the target efficiency levels for the proposed TSL (TSL 1). DOE used these market share increases as inputs to the NIA-RIA spreadsheet model.

Table 17A.2.1 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Hearth Products: Fireplace (vented) (TSL 1)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Voluntary Energy Efficiency Targets	Bulk Government Purchases
2021	7.9%	4.8%	2.4%	3.2%	0.0%
2022	7.9%	4.8%	2.4%	6.3%	0.0%
2023	7.9%	4.8%	2.4%	9.2%	0.0%
2024	7.9%	4.8%	2.4%	12.1%	0.0%
2025	7.9%	4.8%	2.4%	14.8%	0.0%
2026	7.9%	4.8%	2.4%	17.4%	0.0%
2027	7.9%	4.8%	2.4%	19.9%	0.0%
2028	7.9%	4.8%	2.4%	22.4%	0.0%
2029	7.9%	4.8%	2.4%	24.7%	0.0%
2030	7.9%	4.8%	2.4%	27.0%	0.0%
2031	7.9%	4.8%	2.4%	27.2%	0.0%
2032	7.9%	4.8%	2.4%	27.3%	0.0%
2033	7.9%	4.8%	2.4%	27.6%	0.0%
2034	7.9%	4.8%	2.4%	27.7%	0.0%
2035	7.9%	4.8%	2.4%	27.9%	0.0%
2036	7.9%	4.8%	2.4%	28.1%	0.0%
2037	7.9%	4.8%	2.4%	28.3%	0.0%
2038	7.9%	4.8%	2.4%	28.4%	0.0%
2039	7.9%	4.8%	2.4%	28.6%	0.0%
2040	7.9%	4.8%	2.4%	28.7%	0.0%
2041	7.9%	4.8%	2.4%	28.9%	0.0%
2042	7.9%	4.8%	2.4%	29.0%	0.0%
2043	7.9%	4.8%	2.4%	29.2%	0.0%
2044	7.9%	4.8%	2.4%	29.3%	0.0%
2045	7.9%	4.8%	2.4%	29.4%	0.0%
2046	7.9%	4.8%	2.4%	29.6%	0.0%
2047	7.9%	4.8%	2.4%	29.7%	0.0%
2048	7.9%	4.8%	2.4%	29.8%	0.0%
2049	7.9%	4.8%	2.4%	30.0%	0.0%
2050	7.9%	4.8%	2.4%	30.1%	0.0%

Table 17A.2.2 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Hearth Products: Fireplace (ventless) (TSL 1)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Voluntary Energy Efficiency Targets	Bulk Government Purchases
2021	10.8%	6.5%	3.2%	1.7%	0.0%
2022	10.8%	6.5%	3.2%	3.4%	0.0%
2023	10.8%	6.5%	3.2%	5.0%	0.0%
2024	10.8%	6.5%	3.2%	6.5%	0.0%
2025	10.8%	6.5%	3.2%	7.9%	0.0%
2026	10.8%	6.5%	3.2%	9.3%	0.0%
2027	10.8%	6.5%	3.2%	10.6%	0.0%
2028	10.8%	6.5%	3.2%	11.8%	0.0%
2029	10.8%	6.5%	3.2%	13.0%	0.0%
2030	10.8%	6.5%	3.2%	14.1%	0.0%
2031	10.8%	6.5%	3.2%	14.1%	0.0%
2032	10.8%	6.5%	3.2%	14.1%	0.0%
2033	10.8%	6.5%	3.2%	14.1%	0.0%
2034	10.8%	6.5%	3.2%	14.1%	0.0%
2035	10.8%	6.5%	3.2%	14.1%	0.0%
2036	10.8%	6.5%	3.2%	14.1%	0.0%
2037	10.8%	6.5%	3.2%	14.1%	0.0%
2038	10.8%	6.5%	3.2%	14.1%	0.0%
2039	10.8%	6.5%	3.2%	14.1%	0.0%
2040	10.8%	6.5%	3.2%	14.1%	0.0%
2041	10.8%	6.5%	3.2%	14.1%	0.0%
2042	10.8%	6.5%	3.2%	14.1%	0.0%
2043	10.8%	6.5%	3.2%	14.1%	0.0%
2044	10.8%	6.5%	3.2%	14.1%	0.0%
2045	10.8%	6.5%	3.2%	14.1%	0.0%
2046	10.8%	6.5%	3.2%	14.1%	0.0%
2047	10.8%	6.5%	3.2%	14.1%	0.0%
2048	10.8%	6.5%	3.2%	14.1%	0.0%
2049	10.8%	6.5%	3.2%	14.1%	0.0%
2050	10.8%	6.5%	3.2%	14.1%	0.0%

Table 17A.2.3 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Hearth Products: Logs (vented) (TSL 1)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Voluntary Energy Efficiency Targets	Bulk Government Purchases
2021	4.7%	2.8%	1.4%	4.1%	0.0%
2022	4.7%	2.8%	1.4%	7.9%	0.0%
2023	4.7%	2.8%	1.4%	11.3%	0.0%
2024	4.7%	2.8%	1.4%	14.3%	0.0%
2025	4.7%	2.8%	1.4%	17.0%	0.0%
2026	4.7%	2.8%	1.4%	19.5%	0.0%
2027	4.7%	2.8%	1.4%	21.9%	0.0%
2028	4.7%	2.8%	1.4%	24.1%	0.0%
2029	4.7%	2.8%	1.4%	26.3%	0.0%
2030	4.7%	2.8%	1.4%	28.3%	0.0%
2031	4.7%	2.8%	1.4%	28.7%	0.0%
2032	4.7%	2.8%	1.4%	29.0%	0.0%
2033	4.7%	2.8%	1.4%	29.4%	0.0%
2034	4.7%	2.8%	1.4%	29.7%	0.0%
2035	4.7%	2.8%	1.4%	30.0%	0.0%
2036	4.7%	2.8%	1.4%	30.3%	0.0%
2037	4.7%	2.8%	1.4%	30.6%	0.0%
2038	4.7%	2.8%	1.4%	30.9%	0.0%
2039	4.7%	2.8%	1.4%	31.2%	0.0%
2040	4.7%	2.8%	1.4%	31.5%	0.0%
2041	4.7%	2.8%	1.4%	31.8%	0.0%
2042	4.7%	2.8%	1.4%	32.0%	0.0%
2043	4.7%	2.8%	1.4%	32.3%	0.0%
2044	4.7%	2.8%	1.4%	32.6%	0.0%
2045	4.7%	2.8%	1.4%	32.8%	0.0%
2046	4.7%	2.8%	1.4%	33.1%	0.0%
2047	4.7%	2.8%	1.4%	33.4%	0.0%
2048	4.7%	2.8%	1.4%	33.6%	0.0%
2049	4.7%	2.8%	1.4%	33.9%	0.0%
2050	4.7%	2.8%	1.4%	34.1%	0.0%

Table 17A.2.4 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Hearth Products: Logs (ventless) (TSL 1)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Voluntary Energy Efficiency Targets	Bulk Government Purchases
2021	4.2%	2.5%	1.3%	0.8%	0.0%
2022	4.2%	2.5%	1.3%	1.8%	0.0%
2023	4.2%	2.5%	1.3%	8.2%	0.0%
2024	4.2%	2.5%	1.3%	13.4%	0.0%
2025	4.2%	2.5%	1.3%	17.5%	0.0%
2026	4.2%	2.5%	1.3%	21.0%	0.0%
2027	4.2%	2.5%	1.3%	24.1%	0.0%
2028	4.2%	2.5%	1.3%	26.8%	0.0%
2029	4.2%	2.5%	1.3%	29.4%	0.0%
2030	4.2%	2.5%	1.3%	31.7%	0.0%
2031	4.2%	2.5%	1.3%	31.7%	0.0%
2032	4.2%	2.5%	1.3%	31.7%	0.0%
2033	4.2%	2.5%	1.3%	31.7%	0.0%
2034	4.2%	2.5%	1.3%	31.7%	0.0%
2035	4.2%	2.5%	1.3%	31.7%	0.0%
2036	4.2%	2.5%	1.3%	31.7%	0.0%
2037	4.2%	2.5%	1.3%	31.7%	0.0%
2038	4.2%	2.5%	1.3%	31.7%	0.0%
2039	4.2%	2.5%	1.3%	31.7%	0.0%
2040	4.2%	2.5%	1.3%	31.7%	0.0%
2041	4.2%	2.5%	1.3%	31.7%	0.0%
2042	4.2%	2.5%	1.3%	31.7%	0.0%
2043	4.2%	2.5%	1.3%	31.7%	0.0%
2044	4.2%	2.5%	1.3%	31.7%	0.0%
2045	4.2%	2.5%	1.3%	31.7%	0.0%
2046	4.2%	2.5%	1.3%	31.7%	0.0%
2047	4.2%	2.5%	1.3%	31.7%	0.0%
2048	4.2%	2.5%	1.3%	31.7%	0.0%
2049	4.2%	2.5%	1.3%	31.7%	0.0%
2050	4.2%	2.5%	1.3%	31.7%	0.0%

Table 17A.2.5 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Hearth Products: Outdoor (TSL 1)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Voluntary Energy Efficiency Targets	Bulk Government Purchases
2021	5.5%	3.3%	1.6%	1.7%	0.0%
2022	5.5%	3.3%	1.6%	3.6%	0.0%
2023	5.5%	3.3%	1.6%	6.7%	0.0%
2024	5.5%	3.3%	1.6%	11.3%	0.0%
2025	5.5%	3.3%	1.6%	15.4%	0.0%
2026	5.5%	3.3%	1.6%	19.3%	0.0%
2027	5.5%	3.3%	1.6%	23.0%	0.0%
2028	5.5%	3.3%	1.6%	26.5%	0.0%
2029	5.5%	3.3%	1.6%	29.8%	0.0%
2030	5.5%	3.3%	1.6%	32.8%	0.0%
2031	5.5%	3.3%	1.6%	33.1%	0.0%
2032	5.5%	3.3%	1.6%	33.3%	0.0%
2033	5.5%	3.3%	1.6%	33.5%	0.0%
2034	5.5%	3.3%	1.6%	33.8%	0.0%
2035	5.5%	3.3%	1.6%	34.0%	0.0%
2036	5.5%	3.3%	1.6%	34.2%	0.0%
2037	5.5%	3.3%	1.6%	34.4%	0.0%
2038	5.5%	3.3%	1.6%	34.6%	0.0%
2039	5.5%	3.3%	1.6%	34.8%	0.0%
2040	5.5%	3.3%	1.6%	34.9%	0.0%
2041	5.5%	3.3%	1.6%	35.1%	0.0%
2042	5.5%	3.3%	1.6%	35.3%	0.0%
2043	5.5%	3.3%	1.6%	35.5%	0.0%
2044	5.5%	3.3%	1.6%	35.6%	0.0%
2045	5.5%	3.3%	1.6%	35.8%	0.0%
2046	5.5%	3.3%	1.6%	36.0%	0.0%
2047	5.5%	3.3%	1.6%	36.1%	0.0%
2048	5.5%	3.3%	1.6%	36.3%	0.0%
2049	5.5%	3.3%	1.6%	36.4%	0.0%
2050	5.5%	3.3%	1.6%	36.6%	0.0%

17A.3 NIA-RIA INTEGRATED MODEL

For this analysis, DOE used its integrated NIA-RIA[a] model approach that built on the NIA model discussed in Chapter 10 and documented in Appendix 10A.The resulting integrated NIA-RIA model featured both the NIA analysis inputs and results and the RIA inputs and had the capability to generate results for each of the RIA policies. A separate module produced results summaries for the tables and figures in the RIA document. For the RIA methodology documentation in Chapter 17, the module created summaries of parameters calculated by the model for the consumer rebates policy, generated its penetration curves (discussed in section 17A.4.3 below), and reported market share impacts for the rebate and tax credit policies for hearth products. For the RIA results reported in Chapter 17, the module produced graphs of the market share increases resulting from each of the policies analyzed and created summary tables for the national energy savings (NES) and net present value (NPV) results. This module also generated tables of market share increases for each policy reported in section 17A.2 of this appendix.

17A.4 CONSUMER REBATE POLICY MARKET PENETRATION CURVES

This section first discusses the theoretical basis for the market penetration curves that DOE used to analyze the Consumer Rebates policy. Next it discusses the adjustments it made to the maximum penetration rates. It then refers to the method it used to develop an interpolated penetration curve for hearth products that meet the target efficiency level. The resulting curve for hearth products is in Chapter 17.

17A.4.1 Introduction

XENERGY, Inc.[b], developed a re-parameterized, mixed-source information diffusion model to estimate market impacts induced by financial incentives for purchasing energy efficient appliances.[1] The basic premise of the mixed-source model is that information diffusion drives the adoption of technology.

Extensive economic literature describes the diffusion of new products as technologies evolve. Some research focuses primarily on developing analytical models of diffusion patterns applicable to individual consumers or to technologies from competing firms.[2, 3, 4] One study records researchers' attempts to investigate the factors that drive diffusion processes.[5] Because a new product generally has its own distinct characteristics, few studies have been able to conclusively develop a universally applicable model. Some key findings, however, generally are accepted in academia and industry.

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[a] NIA = national impact analysis; RIA = regulatory impact analysis
[b] XENERGY is now owned by KEMA, Inc. (www.kema.com)

One accepted finding is that, regardless of their economic benefits and technological merits, new technologies are unlikely to be adopted by all potential users. For many products, a ceiling must be placed on the adoption rate. A second conclusion is that not all adopters purchase new products at the same time: some act quickly after a new product is introduced; others wait for the product to mature. Third, diffusion processes can be characterized approximately by asymmetric S-curves that depict three stages of diffusion: starting, accelerating, and decreasing (as the adoption ceiling is approached).

A so-called epidemic model of diffusion is used widely in marketing and social studies. The epidemic model assumes that (1) all consumers place identical value on the benefits of a new product, and (2) the cost of a new product is constant or declines monotonically over time. What induces a consumer to purchase a new product is information about the availability and benefits of the product. In other words, information diffusion drives consumers' adoption of a new product.[3] The model incorporates information diffusion from both internal sources (spread by word of mouth from early adopters to prospective adopters) and external sources (the "announcement effect" produced by government agencies, institutions, or commercial advertising). The model incorporates both internal and external sources by combining a logistic function with an exponential function.[4,5]

The relative degree of influence from the internal and external sources determines the general shape of the diffusion curve for a specific product.[4,5] If adoption of a product is influenced primarily by external sources of information (the announcement effect), for instance, a high rate of diffusion occurs at the beginning of the process. In this scenario, external sources provide immediate information exposure to a significant number of prospective adopters. In contrast, internal sources (such as a network of prospective adopters) are relatively small in size and reach, producing a more gradual exposure to prospective adopters. Graphically speaking, information diffusion dominated by external sources is represented by a concave curve (the exponential curve in Figure 17A.4.1). If adoption of a new product is influenced most strongly by internal sources of information, the number of adopters increases gradually, forming a convex curve (the logistic curve in Figure 17A.4.1).

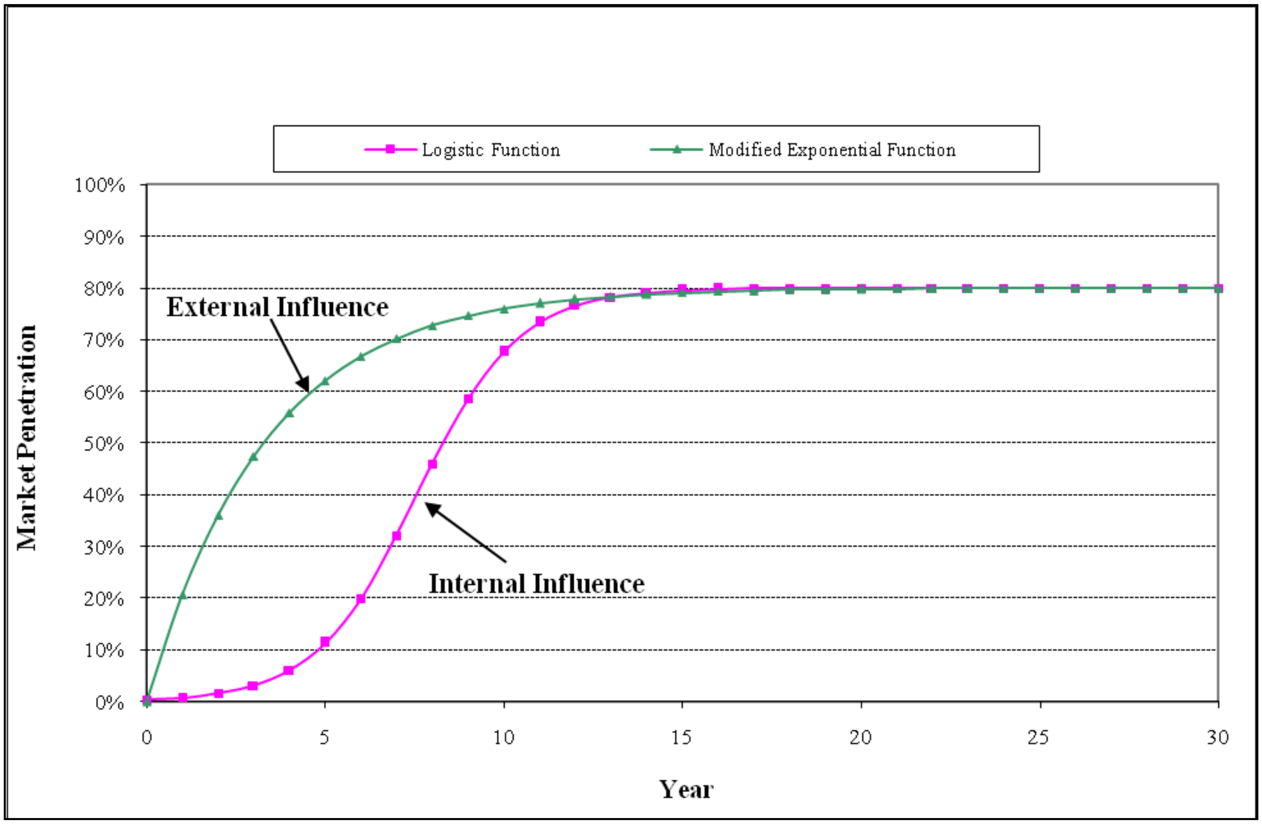

Figure 17A.4.1 S-Curves Showing Effects of External and Internal Sources on Adoption of New Technologies

17A.4.2 Adjustment of XENERGY Penetration Curves

In consultation with the primary authors of the 2002 XENERGY study who later conducted similar California studies, DOE made some adjustments to XENERGY's original implementation (penetration) curves.[6] The experiences with utility programs since the XENERGY study indicate that incentive programs have difficulty achieving penetration rates as high as 80 percent. Consumer response is limited by barriers created by consumer utility issues and other non-economic factors. DOE therefore adjusted the maximum penetration parameters for some of the curves from 80 percent to the following levels:

Moderate Barriers:	70%
High Barriers:	60%
Extremely High Barriers:	50%

The *low barriers* and *no barriers* curves (the latter used only when a product has a very high base-case-market share) remained, respectively, with 80 percent and 100 percent as their maximum penetration rates. For the interpolated penetration curves (discussed below), DOE set the *no barriers* and *extremely high barriers* curves as the upper and lower bounds, respectively, for any benefit/cost ratio points higher or lower than the curves. It set another constraint such that the policy case market share cannot be great than 100 percent, as might occur for products with high base case market shares of the target-level technology.

17A.4.3 Interpolation of Penetration Curves

As discussed above, the XENERGY penetration (implementation) curves followed a functional form to estimate the market implementation rate caused by energy efficiency measures such as consumer rebates.[c] The XENERGY report presents five reference market implementation curves that vary according to the level of market barriers to technology penetration.[1] Such curves have been used by DOE in the Regulatory Impact Analyses for rulemakings for appliance energy efficiency standards to estimate market share increases in response to rebate programs.[d] They provide a framework for evaluating technology penetration, yet require matching the studied market to the curve that best represents it. This approximate matching can introduce some inaccuracy to the analysis.

Blum et al (2011, Appendix A)[7]presents an alternative approach to such evaluation: a method to estimate market implementation rates more accurately by performing interpolations of the reference curves. The referred report describes the market implementation rate function and the reference curves, the method to calibrate the function to a given market, and the limitations of the method.

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[c] Chapter 17 refers to these curves as *penetration curves*. This section, in references to the original source, uses the term *implementation curve*.

[d] DOE has also used this method to estimate market share increases resulting from consumer tax credit and manufacturer tax credit programs, since the effects of tax credits on markets can be considered proportional to the rebate impacts.

17A.5 CONSUMER REBATE PROGRAMS

DOE performed a search for rebate programs that offered incentives for hearth products. Some organizations nationwide, comprising electric utilities and regional agencies, offer rebate programs for this equipment. Table 17A.5.2 provides the organizations' names, states, rebate amounts, and program websites. If there is more than one entry for an organization, it offers different rebates in different states. When an organization offers rebates through several utilities, it is represented only once in each table.

DOE relied on the data it gathered from 8 rebates programs offered by 6 organizations (see Table 17A.5.2) to calculate a market representative rebate amount for hearth product ignition modules. First DOE calculated a market average rebate value for hearth products as the simple average of the rebate amounts offered by the programs. Then – because the programs target consumers shopping for a whole hearth product unit – DOE scaled down the market average rebate value it calculated from the available programs, to estimate a rebate amount that would be offered to consumers willing to purchase a hearth product unit with intermittent pilot. DOE estimated that amount by multiplying the market average rebate value by the ratio of the price of the efficient ignition module divided by the price of the (entire) hearth product. Table 17A.5.1 presents the values DOE used for this calculation.

Table 17A.5.1 Calculation Steps of the Representative Rebate Value

	2013$
Market average rebate value	140.62
Hearth product unit price	308.00
Ignition module price	81.10
Rebate amount	37.03

Table 17A.5.2 Rebates for Hearth Products

Organization	State	Rebate	Website
Columbia Gas of Kentucky	KY	$100	www.columbiagasky.com/en/ways-to-save/warmwise-energy-saving-solutions/natural-gas-appliance-rebate-program
Columbia Gas of Kentucky	KY	$100	www.columbiagasky.com/en/ways-to-save/warmwise-energy-saving-solutions/natural-gas-appliance-rebate-program
Austin Utilities	MN	$75	www.austinutilities.com/pages/residential-conserve-incentives/
CenterPoint Energy	MN	$75	www.centerpointenergy.com/services/naturalgas/buildersandtradeallies/residentialdealersanddistributors/rebateprograms/7ea971be83d63410VgnVCM10000026a10d0aRCRD/HO/
Owatonna Public Utilities	MN	$75	www.owatonnautilities.com/residential-customers/residential-rebates
Cascade Natural Gas	WA	$200	www.cngconserve.com/savings-for-your-home
Cascade Natural Gas	WA	$300	www.cngconserve.com/savings-for-your-home
Puget Sound Energy	WA	$200	https://pse.com/savingsandenergycenter/ForHomes/Pages/Fireplace-Rebate.aspx

17A.6 FEDERAL AND STATE TAX CREDITS

This section summarizes the Federal and State tax credits available to consumers who purchase energy efficient appliances. This section also describes tax credits available to manufacturers who produce certain energy efficient appliances.

17A.6.1 Federal Tax Credits for Consumers

EPACT 2005 included Federal tax credits for consumers who installed efficient air conditioners or heat pumps; gas, oil and propane furnaces and boilers; furnace fans; and/or gas, oil, or electric heat pump water heaters in new or existing homes.[8, 9] These tax credits were in effect in 2006 and 2007, expired in 2008, and were reinstated for 2009–2010 by the American Recovery and Reinvestment Act (ARRA).[10] There was a $1,500 cap on the credit per home, including the amount received for insulation, windows, and air and duct sealing. Congress extended this provision for 2011, with some modifications to eligibility requirements, and reductions in the cap to $500 per home. The American Taxpayer Relief Act of 2012 extended, with some modifications, residential tax credits for air conditioners, heat pumps, furnaces, and water heaters placed in service between January 1, 2012 and December 31, 2013.[8, 11]
The tax credit for furnace fans was $50 in 2011, after which it expired.

The importance of the Federal tax credits has been emphasized in research in the residential heating industry on the impacts of the relatively large credits that were available for HVAC (heating, ventilating, and air conditioning) equipment. In a survey of HVAC distributors conducted by Vermont Energy Investment Corporation, respondents indicated that the ample credit had had a notable impact on sales of higher-efficiency heating and cooling equipment. Some distributors combined the Federal tax credits with manufacturer rebates and utility program rebates for a greater consumer incentive. However, when the amount of the Federal tax credit was reduced, smaller utility rebate incentives had not induced the same levels of equipment sales increases. The decrease in incentive size from a $1,500 cap in 2009-2010 to a $500 cap in 2011, during a period when the economy continued to be sluggish, resulted in a decline in total sales of residential HVAC products. Distributors stated that an incentive needed to cover 25 to 75 percent of the incremental cost of the efficient equipment to influence consumer choice. The industry publication "2011 HVAC Review and Outlook" noted a decline in sales of air conditioning units with >14 SEER in 2011 and a return in sales of units with >16 SEER to 2009 levels (after an increase in 2010). The large majority of distributor observed no impacts from the utility programs with their lower rebate amounts available in 2011. Distributors also commented on the advantages of the Federal tax credit being nationwide in contrast to utility rebate programs that target regional markets.[12, 13]

In an effort to evaluate the potential impact of a Federal appliance tax credit program, DOE reviewed Internal Revenue Service (IRS) data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. It estimated the percentage of taxpayers who filed Form 5695, *Residential Energy Credits.*[14] It also estimated the percentage of taxpayers with entries under Form 5695's section 3, *Residential energy property costs*, line 3b, *qualified natural gas, propane, or oil furnace or hot water boiler*. DOE reasoned that the percentage of taxpayers with an entry on Line 3b could serve as a rough indication of the potential of taxpayer participation in a Federal tax credit program for furnaces during the initial program years. DOE found that of all residential taxpayers filing tax returns, 0.8 percent in 2006 and 0.6 percent in 2007, claimed a credit for a furnace or boiler. DOE further found that the percentages of those filing Form 5695 for <u>any</u> qualifying energy property expenditure (which also included installation of efficient windows, doors and roofs) were 3.1 and 3.2 percent in 2006 and 2007 respectively.

DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. While this tax credit was available from 1979 through 1985, DOE located data for only the first three years of the program.[15, 16, 17] For those three years - 1979, 1980, and 1981 - the percentages of taxpayers filing Form 5695 were 6.4 percent, 5.2 percent, and 4.9 percent. Given that the data from this earlier tax credit program were not disaggregated by type of energy property, this data series served only to indicate a possible trend of greater participation in the initial program year, followed by slightly smaller participation in subsequent years. However, DOE did not find detailed analysis of this program to indicate the possible reasons for such a trend. Also, this trend varies from the more stable trend shown in the EPAct 2005 energy tax credit program data for its first two program years.

As discussed in Chapter 17, DOE analyzed the percentage of participation in consumer tax credit programs using its estimates of consumer participation in rebate programs that was based on benefit/cost data specific to hearth products. Hence it was difficult to compare these detailed estimates to the more general data analysis described above from the existing Federal tax credit program, or to use the IRS data analysis in its consumer tax credit analysis.

17A.6.2 Federal Tax Credits for Manufacturers

EPACT 2005 provided Federal Energy Efficient Appliance Credits to manufacturers that produced high-efficiency refrigerators, clothes washers, and dishwashers in 2006 and 2007.[18] The Emergency Economic Stabilization Act of 2008[19] amended the credits and extended them through 2010. The credits were extended again to 2011 with modifications in the eligibility requirements. Manufacturer tax credits were extended again, by the American Taxpayer Relief Act of 2012, for clothes washers, refrigerators, and dishwashers manufactured between January 1, 2012 and December 31, 2013.

Manufacturers who produce these appliances receive the credits for increasing their production of qualifying appliances. These credits had several efficiency tiers in 2011. For 2012-2013, credits for the higher tiers remain but were eliminated for the lowest (least efficient) tiers for clothes washers and dishwashers.[11] The credit amounts applied to each unit manufactured. The credit to manufacturers of qualifying clothes washers, refrigerators and dishwashers was capped at $75 million for the period of 2008-2010. However, the most efficient refrigerator (30%) and clothes washer (2.2 MEF/4.5 wcf) models was not subject to the cap. The credit to manufacturers was capped at $25 million for 2011, with the most efficient refrigerators (35%) and clothes washers (2.8 MEF/3.5 WCF) exempted from this cap.[20]

17A.6.3 State Tax Credits

The States of Oregon and Montana have offered consumer tax credits for efficient appliances for several years, and the States of Kentucky, Michigan and Indiana began offering such credits in 2009. The Oregon Department of Energy (ODOE) has disaggregated data on taxpayer participation in credits for eligible products. (See the discussion in Chapter 17 on tax credit data for clothes washers.) Montana’s Department of Revenue does not disaggregate participation data by appliance, although DOE reviewed Montana's overall participation trends and found them congruent with its analysis of Oregon's clothes washer tax credits.

Oregon’s Residential Energy Tax Credit (RETC) was created in 1977. The Oregon legislature expanded the RETC program in 1997 to include residential refrigerators, clothes washers, and dishwashers, which significantly increased participation in the program. The program subsequently added credits for high-efficiency heat pump systems, air conditioners, and water heaters (2001); furnaces and boilers (2002); and duct/air sealing, fuel cells, heat recovery, and renewable energy equipment. Beginning in 2012 a Tax Credit Extension Bill (HB3672) eliminated refrigerators, clothes washers, dishwashers, air conditioners, and boilers from the RETC program, leaving credits for water heaters, furnaces, heat pumps, tankless water heaters, and heat pump water heaters.[21, 22] Those technologies recognized by the Oregon Department of

Energy as "premium efficiency" are eligible for tax credit of $0.60 per kWh saved in the first year (up to $1,500).[21, 23]

Montana has had an Energy Conservation Tax Credit for residential measures since 1998.[24] The tax credit covers various residential energy and water efficient products, including split system central air conditioning; package system central air conditioning; split system air source heat pumps; package system heat pumps; natural gas, propane, or oil furnaces; hot water boilers; advanced main air circulating fans; heat recovery ventilators; gas, oil, or propane water heaters; electric heat pump water heaters; low-flow showerheads and faucets; light fixtures; and controls. In 2002 the amount of the credit was increased from 5 percent of product costs (up to $150) to 25 percent (up to $500) per taxpayer. The credit can be used for products installed in new construction or remodeling projects. The tax credit covers only that part of the cost and materials that exceed established standards of construction.

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