TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT:

RESIDENTIAL CONVENTIONAL OVENS

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U.S. Department of Energy
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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 residential conventional cooking products. This NOPR TSD reports on the NOPR analyses conducted in support of the NOPR.

1.2 SUMMARY OF THE NATIONAL BENEFITS

DOE's analyses indicate that the proposed standards would save a significant amount of energy. The lifetime energy savings from residential conventional oven products purchased in the 30-year period that begins in the assumed year of compliance with the proposed standards (2019–2048), relative to the base case without the proposed standards, amount to 0.71 quadrillion Btu (quads).[a] This represents a savings of 11.2 percent relative to the energy use of these products in the base case.

The cumulative net present value (NPV) of total consumer costs and savings of the proposed standards for ovens in residential conventional cooking products ranges from $4.7 billion (at a 7-percent discount rate) to $11.0 billion (at a 3-percent discount rate). This NPV expresses the estimated total value of future operating-cost savings minus the estimated increased product costs for products purchased in 2019–2048.

In addition, the proposed standards would have significant environmental benefits. The energy savings described above are estimated to result in cumulative emission reductions of 41.1 million metric tons (Mt)[b] of carbon dioxide (CO_2), 221.2 thousand tons of methane, 29.5 thousand tons of sulfur dioxide (SO_2), 69 thousand tons of nitrogen oxides (NO_X), 0.52 thousand tons of nitrous oxide (N_2O), and 0.09 tons of mercury (Hg).[c]

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[a] A quad is equal to 10^{15} British thermal units (Btu). The quantity refers to full-fuel-cycle (FFC) energy savings. FFC energy savings includes the energy consumed in extracting, processing, and transporting primary fuels (i.e., coal, natural gas, petroleum fuels), and thus presents a more complete picture of the impacts of energy efficiency standards.

[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 2014 (AEO 2014) Reference case, which generally represents current legislation and environmental regulations for which implementing regulations were available as of October 31, 2013.

The cumulative reduction in CO2 emissions through 2030 amounts to 7.5 Mt, which is equivalent to the emissions resulting from the annual electricity use of 0.7 million homes.

The value of the CO2 reductions is calculated using a range of values per metric ton of CO2 (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 section IV.L. Using discount rates appropriate for each set of SCC values (see Table I-4), DOE estimates the present monetary value of the CO2 emissions reduction is between $0.3 billion and $4.1 billion, with a value of $1.3 billion using the central SCC case represented by $41.2/t in 2015.[e] DOE also estimates the present monetary value of the NOX emissions reduction, is $0.1 billion at a 7-percent discount rate and $0.2 billion at a 3-percent discount rate.[f]

Table 1.2.1 summarizes the national economic costs and benefits expected to result from the proposed standards for residential conventional ovens.

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[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, United States Government. May 2013; revised November 2013. http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf.

[e] The values only include CO_2 emissions, not CO_2 equivalent emissions; other gases with global warming potential are not included.

[f] 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 Energy Conservation Standards for Residential Conventional Ovens*

Category	Present Value Billion 2014$	Discount Rate
Benefits		
Operating Cost Savings	5.0	7%
	11.6	3%
CO_2 Reduction Monetized Value ($12.2.0/t case)**	0.3	5%
CO_2 Reduction Monetized Value ($41.2/t case)**	1.3	3%
CO_2 Reduction Monetized Value ($63.4/t case)**	2.1	2.5%
CO_2 Reduction Monetized Value ($121/t case)**	4.1	3%
NO_X Reduction Monetized Value†	0.1	7%
	0.2	3%
Total Benefits††	6.4	7%
	13.2	3%
Costs		
Incremental Installed Costs	0.3	7%
	0.6	3%
Total Net Benefits		
Including Emissions Reduction Monetized Value††	6.1	7%
	12.6	3%

* This table presents the costs and benefits associated with residential conventional ovens shipped in 2019−2048. These results include impacts to consumers which accrue after 2048 from the products purchased in 2019−2048. The results account for the incremental variable and fixed costs incurred by manufacturers due to any final standard, some of which may be incurred in preparation for the rule.

** The CO_2 values represent global monetized values of the SCC, in 2014$, 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 incorporate an escalation factor.

† The value for NO_X 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 3-percent discount rate ($40.5/t case).

The benefits and costs of these proposed standards, for products sold in 2019-2048, 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 new or amended standards (consisting primarily of operating cost savings from using less energy, minus increases in equipment 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.[g]

Although DOE believes that the values of operating savings and CO_2 emission reductions are both important, two issues are relevant. 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 time frames for analysis. The national operating cost savings is measured for the lifetime of residential conventional ovens shipped in 2019–2048. Because CO_2 emissions have a very long residence time in the atmosphere,[h] the SCC values in future years reflect future climate-related impacts resulting from the emission of CO_2 that continue well beyond 2100.

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[g] To convert the time-series of costs and benefits into annualized values, DOE calculated a present value in 2014, the year used for discounting the NPV of total consumer costs and savings. For the benefits, DOE calculated a present value associated with each year's shipments in the year in which the shipments occur (e.g., 2020 or 2030), and then discounted the present value from each year to 2014. The calculation uses discount rates of 3 and 7 percent for all costs and benefits except for the value of CO_2 reductions, for which DOE used case-specific discount rates. Using the present value, DOE then calculated the fixed annual payment over a 30-year period, starting in the compliance year that yields the same present value.

[h] The atmospheric lifetime of CO_2 is estimated of the order of 30–95 years. Jacobson, MZ (2005). "Correction to "Control of fossil-fuel particulate black carbon and organic matter, possibly the most effective method of slowing global warming."" J. Geophys. Res. 110. pp. D14105.

Estimates of annualized benefits and costs of the proposed 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 has a value of $41.2/t in 2015, the cost of the proposed standards is $33.5 million per year in increased equipment costs, while the benefits are $494 million per year in reduced equipment operating costs, $74 million in CO_2 reductions, and $9 million in reduced NO_X emissions. In this case, the net benefit amounts to $543 million per year. Using a 3-percent discount rate for all benefits and costs and the average SCC series that has a value of $41.2/t in 2015, the cost of the proposed standards is $33.1 million per year in increased equipment costs, while the benefits are $648 million per year in reduced operating costs, $74 million in CO_2 reductions, and $13 million in reduced NO_X emissions. In this case, the net benefit amounts to $701 million per year.

Table 1.2.2 Annualized Benefits and Costs of Proposed Energy Conservation Standards for Residential Conventional Ovens

	Discount Rate	Primary Estimate*	Low Net Benefits Estimate*	High Net Benefits Estimate*
		million 2014$/year		
Benefits				
Operating Cost Savings	7%	494	457	542
	3%	648	593	719
CO_2 Reduction Monetized Value ($12.2/t case)*	5%	21	20	24
CO_2 Reduction Monetized Value ($41.2/t case)*	3%	74	68	81
CO_2 Reduction Monetized Value ($63.4/t case)*	2.5%	108	100	119
CO_2 Reduction Monetized Value ($121/t case)*	3%	228	211	252
NO_X Reduction Monetized Value†	7%	9.24	8.66	10.11
	3%	13.43	12.46	14.80
Total Benefits††	7% plus CO_2 range	524 to 731	485 to 677	576 to 804
	7%	577	534	634
	3% plus CO_2 range	682 to 889	625 to 817	758 to 986
	3%	734	674	815
Costs				
Consumer Incremental Product Costs	7%	34	34	33
	3%	33	34	33
Net Benefits				
Total††	7% plus CO_2 range	491 to 697	451 to 642	543 to 771
	7%	543	499	601
	3% plus CO_2 range	649 to 856	592 to 783	725 to 953
	3%	701	640	783

* This table presents the annualized costs and benefits associated with residential conventional ovens shipped in 2019−2048. These results include benefits to consumers which accrue after 2048 from the products purchased in 2014−2043. The results account for the incremental variable and fixed costs incurred by manufacturers due to any final 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 2015[i] Reference case, Low Estimate, and High Estimate, respectively. In addition, incremental product costs reflect a medium decline rate in the Primary Estimate, a low decline rate in the Low Benefits Estimate, and a high decline rate f in the High Benefits Estimate.

** The CO_2 values represent global monetized values of the SCC, in 2014$, 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 incorporate an escalation factor.

† The value for NO_X 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 the average SCC with 3-percent discount rate ($41.2/t case). In the rows labeled "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

1.3 OVERVIEW OF STANDARDS FOR RESIDENTIAL CONVENTIONAL COOKING PRODUCTS

The National Appliance Energy Conservation Act of 1987 (NAECA), Pub. L. No. 100-12, amended EPCA to establish prescriptive standards for gas cooking products, requiring gas ranges and ovens with an electrical supply cord that are manufactured on or after January 1, 1990, not to be equipped with a constant burning pilot light. NAECA also directed DOE to conduct two cycles of rulemakings to determine if more stringent or additional standards were justified for kitchen ranges and ovens. (42 U.S.C. 6295 (h)(1)-(2))

DOE undertook the first cycle of these rulemakings and published a final rule on September 8, 1998, which found that no standards were justified for conventional electric cooking products at that time. In addition, partially due to the difficulty of conclusively demonstrating that elimination of standing pilots for conventional gas cooking products without an electrical supply cord was economically justified, DOE did not include amended standards for conventional gas cooking products in the final rule. 63 FR 48038. For the second cycle of rulemakings, DOE published the April 2009 Final Rule amending the energy conservation standards for conventional cooking products to prohibit constant burning pilots for all gas cooking products (i.e., gas cooking products both with or without an electrical supply cord) manufactured on or after April 9, 2012. DOE decided to not adopt energy conservation standards pertaining to the cooking efficiency of conventional electric cooking products because it

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[i] http://www.eia.gov/forecasts/AEO/

determined that such standards would not be technologically feasible and economically justified at that time. 74 FR 16040, 16041–44.[j]

EPCA also requires that, not later than 6 years after the issuance of a final rule establishing or amending a standard, DOE publish a NOPR proposing new standards or a notice of determination that the existing standards do not need to be amended. (42 U.S.C. 6295(m)(1))

1.4 PROCESS FOR SETTING ENERGY CONERVATION STANDARDS

Under EPCA, when DOE evaluates 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 on the consumers of the products subject to such a standard;

2) the savings in operating costs throughout the estimated average life of the covered product in the type (or class) compared to any increases in the price of, or in the initial charges for, or maintenance expenses of, the covered products which are likely to result from the imposition of the standard;

3) the total projected amount of energy, or as applicable, water, savings likely to result directly from the imposition of the standard;

4) any lessening of the utility or the performance of the covered products likely to result from the imposition of the standard;

5) the impact of any lessening of competition, as determined in writing by the Attorney General, that is likely to result from the imposition of the standard;

6) the need for national energy and water 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), (3)–(4).

DOE considers stakeholder participation to be a very important part of the process for setting energy conservation standards. Through formal public notifications (*i.e.*, *Federal Register*

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[j] As part of the April 2009 Final Rule, DOE decided not to adopt energy conservation standards pertaining to the cooking efficiency of microwave ovens. DOE also published a final rule on June 17, 2013 adopting energy conservation standards for microwave oven standby mode and off mode. 78 FR 36316. DOE is not considering energy conservation standards for microwave ovens as part of this rulemaking.

notices), DOE actively encourages the participation and interaction of all stakeholders during the comment period in each stage of the rulemaking. Beginning with the framework document and during subsequent comment periods, interactions among stakeholders provide a balanced discussion of the information that is required for the standards 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(m)(2)(B)) Any new or amended standard must be designed to achieve significant additional conservation of energy 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 involves two formal public notices, which DOE publishes in the *Federal Register*. The first notice is the NOPR, which presents the analyses of the impacts of potential amended energy conservation standards on consumers, manufacturers, and the Nation; DOE's weighting of these impacts of amended energy conservation standards; and the proposed energy conservation standards for the equipment. The second notice is the final rule, which presents a discussion of the comments received in response to the NOPR; the revised analyses; DOE's weighting of these impacts; the amended energy conservation standards DOE is adopting for each product; and the effective dates of the amended energy conservation standards.

On February 12, 2014, DOE published a request for information (RFI) notice to initiate the mandatory review process imposed by EPCA (the February 2014 RFI). As part of the RFI, DOE sought input from the public to assist with its determination on whether new or amended standards pertaining to conventional cooking products are warranted. 79 FR 8337. In making this determination, DOE must evaluate whether new or amended standards would (1) yield a significant savings in energy use and (2) be both technologically feasible and economically justified. (42 U.S.C. 6295(o)(3)(B)) The February 2014 RFI document is available at: http://www.regulations.gov/#!documentDetail;D=EERE-2014-BT-STD-0005-0001.

Table 1.4.1 Analyses Under the Process Rule[*]

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

[*] In the current rulemaking, DOE conducted the analyses listed under Preliminary Analyses as part of the NOPR analysis.

DOE developed spreadsheets for the engineering, Life-Cycle Cost (LCC) Payback Period (PBP), and national impact analyses for each product. The LCC spreadsheet calculates the LCC and PBP at various energy efficiency levels. The national impact analysis spreadsheet calculates the national energy savings and national net present values at various energy efficiency levels. This spreadsheet includes a model that forecasts the impacts of amended energy conservation standards at various levels on product shipments. All of these spreadsheets are available on the DOE website for residential conventional cooking products at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/57.

DOE can also provide quantitative outputs from its analyses in machine-readable format upon request. For example, outputs from trial runs of the LCC Monte Carlo simulations can be provided in such a format. DOE can also provide quantitative outputs from its analyses in machine-readable format upon request. For example, outputs from trial runs of the LCC Monte Carlo simulations can be provided in such a format.

1.5 STRUCTURE OF THE DOCUMENT

This TSD outlines the analytical approaches used in this rulemaking. The TSD consists of the following chapters and appendices.

Chapter 1	Introduction: provides an overview of the appliance standards program and how it applies to this rulemaking, and outlines the structure of the document.
Chapter 2	Analytical Framework: describes the rulemaking process.

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 increased manufacturer cost and increased efficiency.
Chapter 6	Markups for Equipment Price Determination: 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 Analysis: discusses the effects of standards on individual customers and users of the products and compares the LCC and PBP of products with and without higher efficiency standards.
Chapter 9	Shipments Analysis: estimates shipments of the products over the 30-year analysis period that is used in performing the national impact analysis (NIA).
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 different subgroups of consumers.
Chapter 12	Manufacturer Impact Analysis: discusses the effects of standards on the finances and profitability of product manufacturers.
Chapter 13	Emissions Impact Analysis: discusses the effects of standards on three pollutants—sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury—as well as carbon dioxide emissions.
Chapter 14	Monetization of Emission Reductions Benefits.

Chapter 15	Utility Impact Analysis: discusses certain effects of the considered on electric and gas utilities.
Chapter 16	Employment Impact Analysis: discusses the effects of standards on national employment.
Chapter 17	Regulatory Impact Analysis: discusses the impact of non-regulatory alternatives to efficiency standards.
Appendix 6A	Detailed Data for Equipment Price Markups
Appendix 7A	Conventional Ovens: Determination of Energy Using Components
Appendix 8A	User Instructions for Life-Cycle Cost and Payback Period Spreadsheet
Appendix 8B	Uncertainty and Variability in LCC Analysis
Appendix 8C	Lifetime Distributions
Appendix 8D	Distributions for Discount Rates
Appendix 10A	User Instructions for Shipments and National Impact Analysis Spreadsheets
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Appendix 12B	Government Regulatory Impact Model Overview
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Appendix 14B Technical Update of Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866

Appendix 15A Utility Impact Analysis Methodology

Appendix 17A Regulatory Impact Analysis: Supporting Materials

CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Section 6295(o)(2)(A) of the Energy Policy and Conservation Act (EPCA), Pub. L. 94-163, 42 U.S.C. 6291 *et seq*. requires the U.S. Department of Energy (DOE) to set forth energy conservation standards that achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. This chapter describes the general analytical framework that DOE uses in developing such standards, and in particular, new or amended energy conservation standards for residential conventional cooking products. The analytical framework is a description of the methodology, the analytical tools, and the 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 other knowledgeable experts within the field. 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.

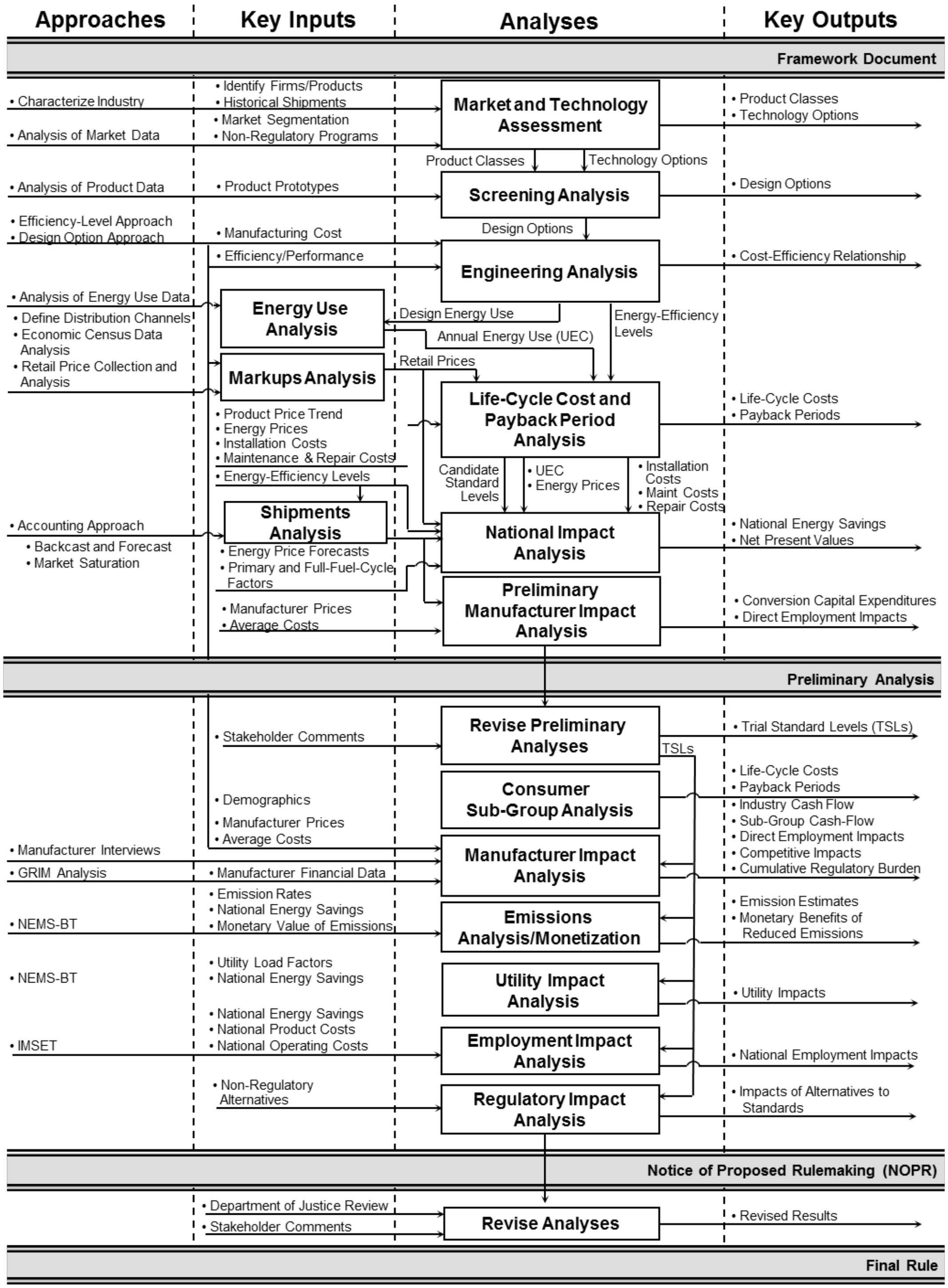

Figure 2.1 Flow Diagram of Analyses for the Rulemaking Process[a]

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[a] Note: This rulemaking published a request for information notice in place of the framework and bypassed the preliminary analysis stage and went straight to the NOPR analysis stage.

The analyses performed for this notice of proposed rulemaking (NOPR) and reported in this technical support document (TSD) are listed below.

- A market and technology assessment to characterize the relevant product markets and existing technology options, including prototype designs.
- A screening analysis to review each technology option to decide whether it is technologically feasible; is practical to manufacture, install, and service; would adversely affect product utility or product availability; or would have adverse effects on health and safety.
- An engineering analysis to develop cost-efficiency relationships, which indicate the manufacturer's cost of achieving increased efficiency.
- A markups analysis to develop distribution channel markups that relate the manufacturer production cost (MPC) 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.
- A life-cycle cost (LCC) and payback period (PBP) analysis 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 customer characteristics that might cause a standard to disproportionately affect particular customer subpopulations.
- A manufacturer impact analysis to estimate the financial impact of standards on manufacturers and to calculate impacts on costs, shipments, competition, employment, and manufacturing capacity.
- 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 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.

- 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 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the relevant product markets and existing technology options, including prototype designs, for the considered products.

2.2.1 Market 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, the industry structure, and market characteristics for the products. This activity assesses the industry and products both quantitatively and qualitatively based on publicly available information and encompasses the following: (1) manufacturer market share and characteristics, (2) existing regulatory and non-regulatory efficiency improvement initiatives, and (3) trends in product characteristics and retail markets. This information serves as resource material throughout the rulemaking.

The subjects addressed in the market assessment for residential conventional cooking products included manufacturers, trade associations, and the quantities and types of products sold and offered for sale. DOE examined both large and small and foreign and domestic residential conventional cooking product manufacturers. DOE also examined publicly available data from the key trade association for this product category, the Association of Home Appliance Manufacturers (AHAM). DOE reviewed shipment data collected by AHAM and *Appliance* magazine to evaluate annual shipment trends. Finally, DOE reviewed other energy efficiency programs from utilities, individual States, and other organizations. Chapter 3 of the NOPR TSD provides additional details on the market and technology assessment.

2.2.2 Technology Assessment

DOE typically uses information relating to existing and past technology options and prototype designs as inputs to determine what technologies manufacturers may 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 it believes are technologically feasible.

DOE developed its list of technologically feasible design options for residential conventional cooking products from trade publications and technical papers, and a review of the TSD published in support of the final rule published on April 8, 2009 (April 2009 Final Rule). 74 FR 16040. Because some options for improving product efficiency are available in existing units, product literature and direct examination provided additional information.

Chapter 3 of the NOPR TSD includes the detailed list of all technology options identified for residential conventional cooking products.

2.3 SCREENING ANALYSIS

The screening analysis examines various technologies as to whether they: (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. DOE developed an initial list of efficiency-enhancement options from the technologies identified as technologically feasible in the technology assessment. Then DOE reviewed the list to determine if these options are practicable to manufacture, install, and service, would adversely affect product utility or availability, or would have adverse impacts on health and safety. In the engineering analysis, DOE further considered efficiency enhancement options that it did not screen out in the screening analysis. Chapter 4 of the NOPR TSD contains details on the screening analysis for residential conventional cooking products.

2.4 ENGINEERING ANALYSIS

The engineering analysis (chapter 5 of the NOPR TSD) establishes the relationship between the MPC and the efficiency for each class of residential conventional cooking products. This relationship serves as the basis for cost/benefit calculations in terms of individual consumers, manufacturers, and the nation. The engineering analysis discusses the product classes DOE analyzed, the representative baseline units, the incremental efficiency levels, the methodology DOE used to develop the MPCs, the cost-efficiency curves, and the impact of efficiency improvements on the considered products. The engineering analysis considered technologies not eliminated in the screening analysis, designated as design options, in developing the cost-efficiency curves.

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.

To create the cost-efficiency relationship, DOE structured its engineering analysis using a design-option approach, supplemented by reverse engineering (physical teardowns and testing of existing products in the market) to identify the incremental cost and efficiency improvement associated with each design option or design option combination. DOE considered the cost-efficiency data presented in the TSD published in support of the April 2009 Final Rule (the 2009 TSD). DOE also conducted interviews with manufacturers of conventional cooking products to develop a deeper understanding of the various combinations of design options used to increase product efficiency, and their associated manufacturing costs. Chapter 5 of the NOPR TSD describes the methodology and results of the analysis used to derive the cost-efficiency relationships.

2.5 MARKUPS ANALYSIS

DOE performed a markups analysis to convert the manufacturer costs estimated in the engineering analysis to consumer prices, which then were used in the LCC and PBP and manufacturer impact analyses. DOE calculated markups for baseline products (baseline markups) and for more efficient products (incremental markups). The incremental markup relates the change in the MPC of higher efficiency models (the incremental cost increase) to the change in the retailer or distributor sales price.

To develop markups, DOE identified how the products are distributed from the manufacturer to the consumer. After establishing appropriate distribution channels, DOE relied on economic data from the U.S. Census Bureau and other sources to determine how prices are marked up as the products pass from the manufacturer to the consumer. Chapter 6 of the NOPR TSD provides details on DOE's development of markups for residential conventional cooking products.

2.6 ENERGY USE ANALYSIS

DOE performed an energy use analysis to assess the energy savings potential from higher efficiency levels, providing the basis for the energy savings values used in the LCC and subsequent analyses. The goal of the energy use characterization is to generate a range of energy use values that reflects actual product use in American homes. Chapter 7 of the NOPR TSD provides more detail about DOE's approach for characterizing energy use of residential conventional cooking products.

DOE relied on California RASS and FSEC studies[b] to establish the annual energy consumption of a cooking product. DOE determined a range of annual energy consumption of cooking products by utilizing the frequency of product usage data provided for each household in

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[b] Refer to Chapter 7 of the NOPR TSD for details about the studies.

the representative sample of U.S. households based on RECS 2009. DOE utilized the range in frequency of use to define the variability of the annual energy consumption.

2.7 LIFE-CYCLE COST AND PAYBACK PERIOD ANALSYIS

In determining whether an energy efficiency 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:

- LCC (life-cycle cost) is the total consumer cost of an appliance or product, generally over the life of the appliance or product. The LCC calculation includes total installed cost (equipment manufacturer selling price, distribution chain markups, sales tax, and installation costs), operating costs (energy, repair, and maintenance costs), equipment lifetime, and discount rate. Future operating costs are discounted to the time of purchase and summed over the lifetime of the appliance or product.
- PBP (payback period) 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. Inputs to the payback period calculation include the installed cost to the consumer and first-year operating costs.

DOE analyzed the net effect of potential amended dishwasher standards on consumers by determining the LCC and PBP using the engineering performance data, the energy use data, and the markups. 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 which allows DOE to identify the fraction of customers achieving LCC savings or incurring net cost at the considered efficiency levels.

Chapter 8 of the NOPR TSD describes the results from the LCC and PBP analyses.

2.8 SHIPMENTS ANALYSIS

DOE projected future shipments of residential conventional cooking products based on an analysis of key market drivers. Projections of shipments are needed to calculate the potential effects of standards on national energy use, NPV, and future manufacturer cash flows. DOE generated shipments projections for each product class. The projections estimate the total number of conventional cooking products shipped each year during the 30-year analysis period (2019–2048). To create the projections, DOE combined current-year shipments with results of a shipments model that incorporates key market drivers for residential conventional cooking products. Chapter 9 of this TSD provides additional details on the shipments analysis.

2.9 NATIONAL IMPACT ANALYSIS

The national impact analysis (NIA) assesses the net present value (NPV), to the nation, of total consumer life-cycle cost (LCC) and net energy savings (NES). DOE determined both the NPV and NES for the efficiency levels considered for the product classes analyzed. To make the analysis more accessible and transparent to all interested parties, DOE prepared a Microsoft Excel spreadsheet model to forecast NES and the national consumer economic costs and savings resulting from new standards. The spreadsheet model uses as inputs typical values (as opposed to probability distributions). To assess the effect of input uncertainty on NES and NPV results, DOE may conduct sensitivity analyses by running scenarios on specific input variables. Chapter 10 of the NOPR TSD provides additional details regarding the national impact analysis.

Several of the inputs for determining NES and NPV depend on the forecast trends in product energy efficiency. For the base case, DOE uses the efficiency distributions developed for the LCC analysis, and assumes some rate of change over the forecast period. In this analysis, DOE has used a roll-up scenario in developing its forecasts of efficiency trends after standards take effect. Under a roll-up scenario, all products that perform at levels below a prospective standard are moved, or rolled-up, to the minimum performance level allowed under the standard. Product efficiencies above the standard level under consideration would remain the same as before the revised standard takes effect. Because DOE has no reason to believe that implementation of standards would increase the demand for product that is more efficient than the minimum required, it did not incorporate an efficiency trend in the standards-case scenarios either.

2.9.1 National Energy Savings

The inputs for determining the national energy savings for each product class are: (1) annual energy consumption per unit, (2) shipments, (3) product stock, (4) national energy consumption, and (5) site-to-primary energy and full-fuel cycle conversion factors for energy. DOE calculated national energy consumption by multiplying the number of units, or stock, of each product class (by vintage, or age) by the unit energy consumption (also by vintage). DOE calculated annual NES based on the difference in national energy consumption for the base case (without new efficiency standards) and for each efficiency standard being considered.

DOE historically has presented NES in terms of primary energy savings. In response to the recommendations of a committee on “Point-of-Use and Full-Fuel-Cycle Measurement Approaches to Energy Efficiency Standards” appointed by the National Academy of Science, DOE announced its intention to use full-fuel-cycle (FFC) measures of energy use and greenhouse gas and other emissions in the national impact analyses and emissions analyses included in future energy conservation standards rulemakings. 76 FR 51281 (August 18, 2011). After evaluating the approaches discussed in the August 18, 2011 notice, DOE published a statement of amended policy in the *Federal Register* in which DOE explained its determination that NEMS is the most appropriate tool for its FFC analysis and its intention to use NEMS for that purpose. 77 FR 49701 (August 17, 2012). The approach used for the NOPR is described in appendix 10-A of the TSD.

2.9.2 Net Present Value of Consumer Benefit

The inputs for determining NPV of the total costs and benefits experienced by consumers are: (1) total annual installed cost, (2) total annual savings in operating costs, and (3) a discount factor. DOE calculated the difference in total installed cost between the base case and each TSL. Because the more efficient equipment bought in a standards case usually costs more than equipment bought in the base case, cost increases appear as negative values in the NPV.

DOE calculated net savings each year as the difference in total savings in operating costs and total increases in installed costs between the base case and each standards case. DOE expressed savings in operating costs as decreases associated with the lower energy consumption of equipment bought in the standards case compared to the base case. DOE calculated savings throughout the life of each equipment class, accounting for differences in yearly energy rates. DOE calculated NPV as the difference between the present value of operating cost savings and the present value of total installed costs. DOE used real discount rates of 3 percent and 7 percent to discount future costs and savings to present values.

Chapter 10 of the NOPR TSD provides additional details regarding the national impact analysis.

2.10 CONSUMER SUBGROUP ANALYSIS

The consumer subgroup analysis evaluates economic impacts on selected groups of consumers who might be adversely affected by a change in the national energy conservation standards for the considered products. DOE evaluates impacts on particular subgroups of consumers primarily by analyzing the LCC impacts and PBP for those particular consumers using the LCC spreadsheet model.

For this rulemaking, DOE analyzed as subgroups: (1) low-income households; and (2) households solely occupied by senior citizens. Chapter 11 of NOPR TSD describes the consumer subgroup analysis.

2.11 MANUFACTURER IMPACT ANALYSIS

The manufacturer impact analysis (MIA) assesses the impacts of new energy conservation standards on manufacturers of the considered products. Potential impacts include financial effects, both quantitative and qualitative, that might lead to changes in the manufacturing practices for these products.

DOE conducts the MIA in three phases, and will tailor the analytical framework based on interested parties' comments. In Phase I, DOE created a cooking products manufacturing industry profile and analyzed publicly available financial information to derive preliminary inputs for the GRIM. In Phase II, DOE prepared an industry cash flow model. In Phase III, industry and subgroup cash flow and NPV were assessed through the use of the Government Regulatory Impact Model (GRIM). Then, DOE assessed impacts on competition, manufacturing capacity, employment, and cumulative regulatory burden. DOE discusses its findings from the MIA in chapter 12 of the NOPR TSD.

2.12 EMISSIONS IMPACT ANALYSIS

In the emissions analysis, DOE estimates the reduction in power sector emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2) and mercury (Hg) from potential energy conservation standards for the considered products. In addition, DOE will estimate 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 full-fuel-cycle (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 conducts the emissions analysis using emissions factors for CO_2 and most of the other gases derived from data in the latest version of EIA's *Annual Energy Outlook (AEO)*. Combustion emissions of CH_4 and N_2O are estimated using emissions intensity factors published by the Environmental Protection Agency (EPA), GHG Emissions Factors Hub.[c]

EIA prepares the *Annual Energy Outlook* using NEMS. Each annual version of NEMS incorporates the projected impacts of existing air quality regulations on emissions. The text below refers to *AEO 2014*, which generally represents current legislation and environmental regulations, including recent government actions, for which implementing regulations were available as of October 31, 2013.

Because the on-site operation of conventional cooking 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,

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[c] http://www.epa.gov/climateleadership/inventory/ghg-emissions.html

DOE also accounts 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 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.[d] 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.[e] The court ordered EPA to continue administering CAIR. *AEO 2014* assumes that CAIR remains a binding regulation through 2040.[f]

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 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 HCl 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

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[d] 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).

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

[f] 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.

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, DOE believes that energy efficiency standards will reduce SO_2 emissions in 2016 and beyond.

CAIR established a cap on NO_X 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 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 the caps, so DOE estimates NO_X 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 will estimate 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 NO_x. The monetary benefits that DOE estimates for reductions in NO_x 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 NOPR TSD.

2.13 MONETIZING REDUCED CO_2 AND OTHER EMISSIONS

DOE considered the estimated monetary benefits likely to result from the reduced emissions of CO_2 and NO_X 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 Social Cost of Carbon (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 greenhouse gas (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 an update of its previous report in 2013.[g] 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 NO_X emissions resulting from the standard levels it considers. Estimates of monetary value for reducing NO_X from stationary sources range from $476 to $4,893 per ton in 2013$.[h] DOE calculated monetary benefits using a medium value for NO_X 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 the NOPR TSD.

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[g] *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. www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

[h] 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.

2.14 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). The utility impact analysis is based on output of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS). 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 alternative cases that implement a variety of efficiency-related policies.

Further detail is provided in chapter 15 of the NOPR TSD.

2.15 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.[i] 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 the NOPR TSD.

2.16 REGULATORY IMPACT ANALYSIS

In the NOPR stage, DOE prepared a regulatory impact analysis (RIA) pursuant to Executive Order 12866, Regulatory Planning and Review, 58 FR 51735, October 4, 1993. The

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[i] 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*).

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 the NOPR TSD.

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter provides a profile of the residential conventional cooking product, and specifically residential conventional oven, industries in the United States. The U.S. Department of Energy (DOE) developed the market and technology assessment presented in this chapter primarily from publicly available information. This assessment is helpful in identifying the major manufacturers and their product characteristics, which form the basis for the engineering and the life-cycle cost (LCC) analyses. Present and past industry structure and industry financial information help DOE in the process of conducting the manufacturer impact analysis.

3.2 PRODUCT DEFINITIONS

Title III, Part B of the Energy Policy and Conservation Act of 1975 (EPCA or the Act), Pub. L. 94-163 (42 U.S.C. 6291-6309, as codified) established the Energy Conservation Program for Consumer Products Other Than Automobiles, a program covering most major household appliances (collectively referred to as “covered products”), which includes kitchen ranges and ovens. DOE’s regulations define kitchen ranges and ovens, or “cooking products”, as consumer products that are used as the major household cooking appliances. They are designed to cook or heat different types of food by one or more of the following sources of heat: gas, electricity, or microwave energy. Each product may consist of a horizontal cooking top containing one or more surface units and/or one or more heating compartments. They must be one of the following classes: conventional ranges, conventional cooking tops, conventional ovens, microwave ovens, microwave/conventional ranges and other cooking products. (10 CFR 430.2) Each cooking product may consist of a horizontal cooking top containing one or more surface units[a] and/or one or more heating compartments. Based on these definitions, DOE has interpreted kitchen ranges and ovens to refer more generally to all types of cooking products including, for example, microwave ovens.

DOE notes that conventional ranges are defined in 10 CFR 430.2 as a class of kitchen ranges and ovens which is a household cooking appliance, consisting of a conventional cooking top and one or more conventional ovens. In this rulemaking, DOE is not considering gas and electric conventional ranges as a distinct product category and is not basing its product classes on that category. Instead, DOE plans to consider energy conservation standards for conventional cooking tops and conventional ovens separately. Because ranges consist of both a cooking top and oven, any potential cooking top or oven standards would apply to the individual components of the range.

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[a] The term surface unit refers to burners for gas cooking tops, electric resistance heating elements for electric cooking tops, and inductive heating elements for induction cooking tops.

As part of this rulemaking, DOE intends only to address energy conservation standards for conventional ovens, including conventional ovens that are a part of conventional ranges. DOE has decided to defer its decision regarding whether to adopt amended energy conservation standards for conventional cooking tops, pending further rulemaking. In both the cooking product test procedure NOPR published on January 30, 2013 (78 FR 6232, the January 2013 TP NOPR) and the cooking product test procedure supplemental NOPR (SNOPR) published on December 3, 2014 (79 FR 71894, the December 2014 TP SNOPR), DOE proposed amendments to the cooking products test procedure in Appendix I to subpart B of Title 10 of the CFR part 430 that would allow for the testing of active mode energy consumption of induction cooking tops. After reviewing public comments on the December 2014 TP SNOPR, conducting interviews with manufacturers, and performing additional analyses, DOE believes further study is required before a cooking top test procedure can be established that produces test results which measure energy use during a representative average use cycle, is repeatable, and reproducible, and is not unduly burdensome to conduct. For these reasons, this NOPR is limited to addressing energy conservation standards for conventional ovens. DOE intends to complete the rulemaking process for conventional cooking tops once additional key data and information become available.

3.3 PRODUCT CLASSES

DOE separated residential conventional cooking products into product classes. When evaluating and establishing energy conservation standards, DOE divides covered products into different product classes using the following criteria: (1) type of energy used, 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))

For conventional ovens, the product classes defined by DOE are based on energy source (*i.e.*, gas or electric). DOE initially considered product classes based on the list of classes defined by DOE in its 2009 *Final Rule Technical Support Document: Residential Dishwashers, Dehumidifiers, and Cooking Products and Commercial Clothes Washers* (2009 TSD), which was released as part of the most recent standards rulemaking.[b] DOE also considered whether additional product classes were warranted based on the amended and proposed test procedure for conventional cooking products discussed in section 3.4.

For **electric ovens**, the 2009 TSD determined that the type of oven-cleaning system is a utility feature that affects performance. DOE found that standard ovens and ovens using a catalytic continuous-cleaning process use roughly the same amount of energy. On the other hand, Self-clean ovens use a pyrolytic process that provides enhanced consumer utility with lower

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[b] Available online at http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0127-0097

overall energy consumption as compared to either standard or catalytically lined ovens. Thus, DOE defined the following product classes for electric ovens:

- Standard oven with or without a catalytic line; and
- Self-clean oven.

Based on DOE's review of conventional ovens and ranges available on the U.S. market, and based on manufacturer interviews and testing conducted as part of the engineering analysis described in Chapter 5 of the TSD, DOE notes that the self-cleaning function of the self-clean oven may employ methods other than a high temperature pyrolytic cycle to perform the cleaning action. Specifically, DOE is aware of a type of self-cleaning oven that uses a proprietary oven coating and water to perform a self-clean cycle with a shorter duration and at a significantly lower temperature setting. The self-cleaning cycle for these ovens, unlike catalytically- lined standard ovens that provide continuous cleaning during normal baking, still have a separate self-cleaning mode that is user-selectable and must be tested separately. Thus, DOE is clarifying that a self-cleaning electric or gas conventional oven is an oven that has a user-selectable mode separate from the normal baking mode, not intended to heat or cook food, which is dedicated to cleaning and removing cooking deposits from the oven cavity walls.

For **gas ovens**, for the same reasons as for electric ovens, DOE defined the following product classes:

- Standard oven with or without a catalytic line; and
- Self-clean oven.

As part of the most recent standards rulemaking for conventional cooking products, DOE decided to exclude residential conventional gas ovens with higher burner input rates, including products marketed as "commercial-style" or "professional-style," from consideration of energy conservation standards due to a lack of available data for determining efficiency characteristics of those products. DOE considers these products to be gas ovens with burner input rates greater than 22,500 Btu/h. 74 FR 16040, 16054 (Apr. 8, 2009); 72 FR 64432, 64444-45 (Nov. 15, 2007). DOE also stated that the current DOE cooking products test procedures may not adequately measure performance of gas cooking tops and ovens with higher burner input rates. 72 FR 64432, 64444-45 (Nov. 15, 2007).

For conventional gas ovens, based on DOE's review of the residential conventional gas ovens available on the market, residential-style gas ovens typically have an input rate of 16,000 to 18,000 Btu/h whereas residential gas ovens marketed as commercial-style typically have burner input rates ranging from 22,500 to 30,000 Btu/h.[c] Additional review of both the residential-style and commercial-style gas oven cavities indicated that there is significant overlap in oven cavity volume between the two oven types. Standard residential-style gas oven cavities

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[c] However, DOE noted that many gas ranges, while marketed as commercial- or professional-style and having multiple surface units with high input rates, did not have a gas oven with a burner input rate above 22,500 Btu/h.

ranged from 2.5 to 5.6 cubic feet (ft^3) in volume and gas oven marketed as commercial-style have cavity volumes ranging from 3.0 to 6.0 ft^3. Sixty percent of the commercial-style models surveyed had cavity volumes between 4.0 and 5.0 ft^3 while fifty percent of the standard models had cavity volumes between 4.0 and 5.0 ft^3. The primary differentiating factor between the two oven types was burner input rate, which is greater than 22,500 Btu/h for commercial-style gas ovens.

As discussed in section 3.4, DOE determined as part of the concurrent test procedure rulemaking that the test load for ovens as specified in the existing DOE test procedure, was appropriate for gas ovens with burner input rates greater than 22,500 Btu/h. 79 FR 71915–16 (Dec. 3, 2014). As a result, DOE conducted testing for this NOPR to determine whether conventional gas ovens with higher burner input rates warrant establishing a separate product class. DOE evaluated the cooking efficiency of the eight conventional gas ovens listed in Table 3.3.1. Five of these ovens had burners rated at 18,000 Btu/h or less and the remaining three had burner input rates ranging from 27,000 Btu/h to 30,000 Btu/h.

Table 3.3.1 Performance Characteristics of Gas Oven Test Sample

Test Unit #	**Type**	**Installation Configuration**	**Burner Input Rate (*Btu/h*)**	**Cavity Volume (*cubic feet* (*ft^3*))**	**Measured Cooking Efficiency**	**Normalized Cooking Efficiency****
1	Standard	Freestanding	18,000	4.8	6.6%	7.0%
2	Standard	Freestanding	18,000	4.8	6.0%	6.3%
3	Self-Clean	Freestanding	18,000	5.0	7.6%	8.1%
4	Standard	Freestanding	16,500	4.4	6.2%	6.2%
5	Self-Clean	Built-in	13,000	2.8	9.4%	8.3%
6	Standard *	Freestanding	28,000	5.3	4.3%	5.1%
7	Standard *	Slide-in	27,000	4.4	5.2%	5.2%
8	Standard *	Freestanding	30,000	5.4	3.9%	4.7%

* These products are marketed as commercial-style gas ovens.
** Measured cooking efficiency normalized to a fixed cavity volume of 4.3ft^3.

The measured cooking efficiencies for ovens with burner input rates above 22,500 Btu/h were lower than for ovens with ratings below 22,500 Btu/h, even after normalizing cooking efficiency to a fixed cavity volume. However, DOE also noted that the conventional gas ovens with higher burner input rates in DOE's test sample were marketed as commercial-style and had greater total thermal mass, including heavier racks and thicker cavity walls, even after normalizing for cavity volume. To determine whether the lower measured efficiency of these ovens was due to the higher input rate burners, DOE isolated the heating element from the thermal mass of the oven by placing 1-inch thick insulation on all surfaces inside the oven cavity, except for the bottom of the cavity where the burner was located, and ran tests according to the DOE test procedure. By adding insulation, heat transfer to the cavity walls was minimized and retained in the cavity to heat the test block. DOE selected test unit 3 and test unit 8 in Table 3.3.1 for test because of the similarity in cavity volume, their difference in efficiency, and their differing input rate (18,000 Btu/h and 30,000 Btu/h, respectively). Figure 3.3.1 displays the resulting test block temperature increase as a function of test time, measured with and without insulation lining the interior oven cavity walls.

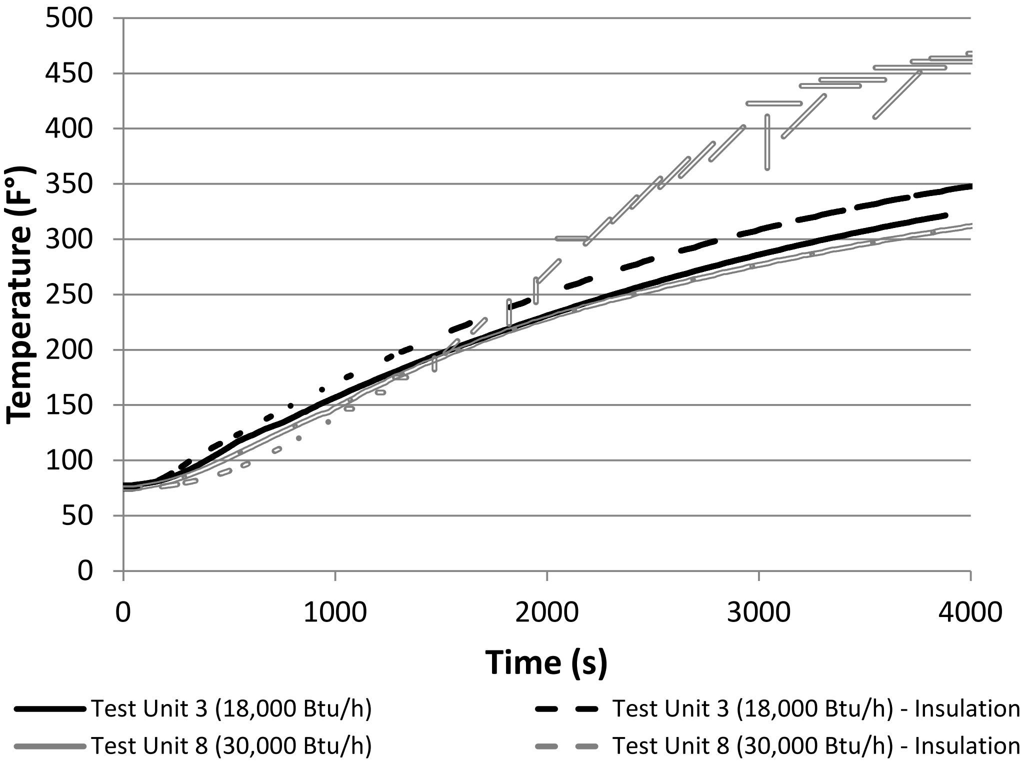

Figure 3.3.1 Test Load Temperature With and Without Insulation Lining the Interior Cavity Walls

Without the added insulation inside the oven cavity, the temperature rise in the test block was similar for each oven, despite the large difference in burner input rate. In contrast, by adding insulation inside the cavity, the test block temperature in the 30,000 Btu/h oven increased at a faster rate than in the 18,000 Btu/h oven. This suggests that much of the energy input to the 30,000 Btu/h oven goes to heating the added mass of the cavity, rather than the test load.

DOE also investigated the time it took each oven in the test sample to heat the test load to a final test temperature of 234 degrees Fahrenheit (°F) above its initial temperature, as specified in the DOE test procedure. As shown in Table 3.3.2, gas ovens with burner input rates greater than 22,500 Btu/h do not heat the test load significantly faster than the ovens with lower burner input rates, and two out of the three units with the higher burner input rates took longer than the average time to heat the test load. Therefore, DOE preliminarily concludes that there is no unique utility associated with faster cook times that is provided by gas ovens with burner input rates greater than 22,500 Btu/h.

Table 3.3.2 Gas Oven Test Times

Unit	Type	Burner Input Rate (*Btu/h*)	Bake Time to Reach 234°F Above Initial Temp (*min*)	Difference in Time from Avg (*min*)
1	Standard	18,000	43.6	-3.8
2	Standard	18,000	43.6	-3.8
3	Self-Clean	18,000	47.2	-0.2
4	Standard	16,500	44.9	-2.5
5	Self-Clean	13,000	48.9	1.5
6	Standard *	28,000	48.9	1.5
7	Standard *	27,000	45.4	-2.0
8	Standard *	30,000	57.2	9.8
		Average	47.4	-

* Test units 6, 7, and 8 are marketed as commercial-style ovens.

Based on DOE's testing, reverse engineering analyses, and discussions with manufacturers, DOE determined that the major differentiation between conventional gas ovens with lower burner input rates and those with higher input rates, including those marketed as commercial-style, was design and construction related to aesthetics rather than improved cooking performance. Further, DOE did not identify any utility conferred by commercial-style gas ovens. For the reasons discussed above, DOE is not proposing to establish a separate product class for conventional gas ovens with higher burner input rates.

As discussed in section 3.4, DOE amended its test procedure for conventional cooking products in a final rule on October 31, 2012 to include methods for measuring fan-only mode. 77 FR 65942. Fan-only mode is an active mode that is not user-selectable in which a fan circulates air internally or externally to the cooking product for a finite period of time after the end of the heating function. Table 3.3.3 and Table 3.3.4 list the fan-only mode duration and energy consumption measured for the gas and electric ovens in the DOE test sample described in chapter 5. The tables also specify the installation configuration of the oven and provide an estimate of the percentage of annual energy consumption due to fan-only mode operation alone.

Table 3.3.3 Gas Oven Measured Fan-Only Mode

Unit	Source	Type	Installation	Fan-Only Mode Duration (*min*)	Fan-Only Mode Energy Consumption Per Cycle (*kWh*)	% of Annual Energy Consumption
1	Gas	Standard	Freestanding	0.0	0.000	0
2	Gas	Standard	Freestanding	0.0	0.000	0
3	Gas	Self-Clean	Freestanding	0.0	0.000	0
4	Gas	Standard	Freestanding	0.0	0.000	0
5	Gas	Self-Clean	Built-in	4.5	0.001	0.1%
6	Gas	Standard	Freestanding	0.0	0.000	0
7	Gas	Standard	Slide-in	30.8	0.016	0.5%
8	Gas	Standard	Freestanding	0.0	0.000	0

Table 3.3.4 Electric Oven Measured Fan-Only Mode

Unit	Source	Type	Installation	Fan-Only Mode Duration (*min*)	Fan-Only Mode Energy Consumption Per Cycle (*kWh*)	% of Annual Energy Consumption
1	Electric	Self-Clean	Freestanding	0	0.000	0
2	Electric	Standard	Freestanding	0	0.000	0
3	Electric	Self-Clean	Built-in	6.71	0.002	0.2%
4	Electric	Standard	Built-in	69	0.032	2.4%
5	Electric	Self-Clean	Built-in	69	0.032	2.1%
6	Electric	Self-Clean	Built-in	66.84	0.031	1.8%
7	Electric	Self-Clean	Built-in	41.32	0.030	1.6%

Based on DOE’s testing of freestanding, built-in, and slide-in installation configurations for conventional gas and electric ovens, DOE noted that all of the built-in and slide-in ovens consumed energy in fan-only mode, whereas freestanding ovens did not. The energy consumption in fan-only mode for built-in and slide-in ovens ranged from approximately 1.3 to 37.6 watt-hours (Wh) per cycle (0.25 to 7.6 kWh/yr) and had fan-only mode durations ranging from 4.5 to 69 minutes. The percentage of annual energy consumption represented by fan-only mode was less than 1.0 percent for gas ovens and less than 3.0 percent for electric ovens.

Based on DOE’s reverse engineering analyses discussed in chapter 5 of this TSD, DOE noted that built-in and slide-in products had an additional exhaust fan and vent assembly that was not present in freestanding products. The additional energy required to exhaust air from the oven cavity is necessary for slide-in and built-in installation configurations to meet safety-related temperature requirements since the oven is enclosed in cabinetry. For these reasons, DOE proposes to include separate product classes for built-in/slide-in ovens.

The proposed product classes for this NOPR are listed in Table 3.3.5.

Table 3.3.5 Proposed Product Classes for Conventional Ovens

Product Class	Product Type	Sub-Category	Installation Type
1	Electric oven	Standard with or without a catalytic line	Freestanding
2			Built-in/Slide-in
3		Self-clean	Freestanding
4			Built-in/Slide-in
5	Gas oven	Standard with or without a catalytic line	Freestanding
6			Built-in/Slide-in
7		Self-clean	Freestanding
8			Built-in/Slide-in

3.4 PRODUCT TEST PROCEDURES

DOE's test procedures for conventional ranges, conventional cooking tops, and conventional ovens are codified at 10 CFR part 430, subpart B, appendix I (Appendix I).

DOE established the test procedures in a final rule published in the *Federal Register* on May 10, 1978. 43 FR 20108, 20120–28. DOE revised its test procedures for cooking products to more accurately measure their efficiency and energy use, and published the revisions as a final rule in 1997. 62 FR 51976 (Oct. 3, 1997). These test procedure amendments included: (1) a reduction in the annual useful cooking energy; (2) a reduction in the number of self-clean oven cycles per year; and (3) incorporation of portions of International Electrotechnical Commission (IEC) Standard 705-1988, "Methods for measuring the performance of microwave ovens for household and similar purposes," and Amendment 2-1993 for the testing of microwave ovens. Id. The test procedures for conventional cooking products establish provisions for determining estimated annual operating cost, cooking efficiency (defined as the ratio of cooking energy output to cooking energy input), and energy factor (EF) (defined as the ratio of annual useful cooking energy output to total annual energy input). 10 CFR 430.23(i); Appendix I.

Section 310 of the Energy Independence and Security Act of 2007 (EISA 2007) amended Section 325 of the EPCA to require that that the test procedures for cooking products[d] be amended to include measurement of standby mode and off mode power, taking into consideration the most current version of IEC Standard 62301 *Household electrical appliances – Measurement of standby power* (IEC Standard 62301) and IEC Standard 62087 *Methods of*

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[d] The term "cooking products" as used in this TSD refers to residential electric and gas kitchen ranges and ovens, including microwave ovens. See section 3.2 for additional information.

measurement for the power consumption of audio, video and related equipment.[e] (42 U.S.C. 6295(gg)) DOE conducted a rulemaking to address standby and off mode energy consumption, as well as certain active mode (*i.e.*, fan-only mode) testing provisions, for residential conventional cooking products. DOE published a final rule on October 31, 2012 (77 FR 65942, the October 2012 TP Final Rule), adopting standby and off mode provisions that satisfy the EPCA requirement that DOE include measures of standby mode and off mode energy consumption in its test procedures for residential products, if technically feasible. (42 U.S.C. 6295(gg)(2)(A)) In addition, DOE amended the test procedures to include methodology for the measurement of fan-only mode energy use. 77 FR 65942. The inclusion of methods to measure these additional modes allows for the calculation of integrated annual energy consumption (IAEC).

On January 30, 2013, DOE published a NOPR (78 FR 6232, the January 2013 TP NOPR) proposing amendments to Appendix I that would allow for testing the active mode energy consumption of induction cooking products; i.e., conventional cooking tops equipped with induction heating technology for one or more surface units on the cooking top. DOE proposed to incorporate induction cooking tops by amending the definition of "conventional cooking top" to include induction heating technology. Furthermore, DOE proposed to require for all cooking tops the use of test equipment compatible with induction technology. Specifically, DOE proposed to replace the solid aluminum test blocks currently specified in the test procedure for cooking tops with hybrid test blocks comprising two separate pieces: an aluminum body and a stainless steel base. 78 FR 6232, 6234 (Jan. 30, 2013).

On December 3, 2014, DOE published a supplemental NOPR (SNOPR) (the December 2014 TP SNOPR), in which DOE modified its proposal from the January 2013 TP NOPR to specify different test equipment that would allow for measuring the energy efficiency of induction cooking tops, and would include an additional test block size for electric surface units with large diameters (both induction and electric resistance). 79 FR 71894. In addition, DOE proposed methods to test non-circular electric surface units, electric surface units with flexible concentric cooking zones, and full-surface induction cooking tops. DOE further proposed amendments to add a larger test block size to test gas cooking top burners with higher input rates. *Id.*

In February and March of 2015, DOE conducted a series of interviews with manufacturers regarding the proposed cooking top test procedure. Manufacturers agreed that the hybrid test block method, as proposed, presented many issues which had not yet been addressed, and which left the repeatability and reproducibility of the test procedure in question. These concerns were similar to those expressed in written comments but came from a larger group of contributing manufacturers and included:

- Difficulty obtaining the hybrid test block materials;

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[e] IEC Standard 62087 does not cover any products for this rulemaking, and therefore was not considered.

- Difficulty obtaining and applying the thermal grease without more detailed specifications (i.e., thermal conductivity alone was not sufficient to identify a grease that performed according to DOE's descriptions in the SNOPR);
- Difficulty testing induction cooking tops that use different programming techniques to prevent overheating (some manufacturers still observed that power to the heating elements cut off prematurely during testing with the hybrid test block, despite adding thermal grease); and
- The need for larger test block sizes to test electric surface units having 12-inch and 13-inch diameters and gas surface units with high input rates.

For these reasons, DOE has decided to continue the energy conservation standards rulemaking for conventional ovens but to defer its decision regarding adoption of energy conservation standards for conventional cooking tops until a representative, repeatable and reproducible test method for cooking tops is finalized.

In the December 2014 TP SNOPR, DOE also proposed to incorporate methods for measuring conventional oven volume, to clarify that the existing oven test block must be used to test all ovens regardless of input rate, and to measure the energy consumption and efficiency of conventional ovens equipped with an oven separator. *Id.* DOE is proposing energy conservation standards for conventional ovens in this NOPR based on the proposed oven related test methods in the December 2014 TP SNOPR. DOE intends to update the standards rulemaking analyses based on any final amendments developed as part of the concurrent conventional oven test procedure rulemaking.

3.5 MANUFACTURER TRADE GROUPS

DOE recognizes the importance of trade groups in disseminating information and promoting the interests of the industry that they support. To gain insight into the residential cooking products industry, DOE researched various associations available to manufacturers, suppliers, and users of such equipment. DOE also used the member lists of these groups in the construction of an exhaustive database containing domestic manufacturers.

DOE identified one trade group that supports the residential cooking product industry, the Association of Home Appliance Manufacturers (AHAM).

3.5.1 Association of Home Appliance Manufacturers

AHAM[f], formed in 1967, aims to enhance the value of the home appliance industry through leadership, public education and advocacy. AHAM provides services to its members

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[f] For more information visit www.aham.org.

including government relations; certification programs for room air conditioners, dehumidifiers and room air cleaners; an active communications program; and technical services and research. In addition, AHAM conducts other market and consumer research studies and publishes a *Fact Book*. AHAM also develops and maintains technical standards for various appliances to provide uniform, repeatable procedures for measuring specific product characteristics and performance features.

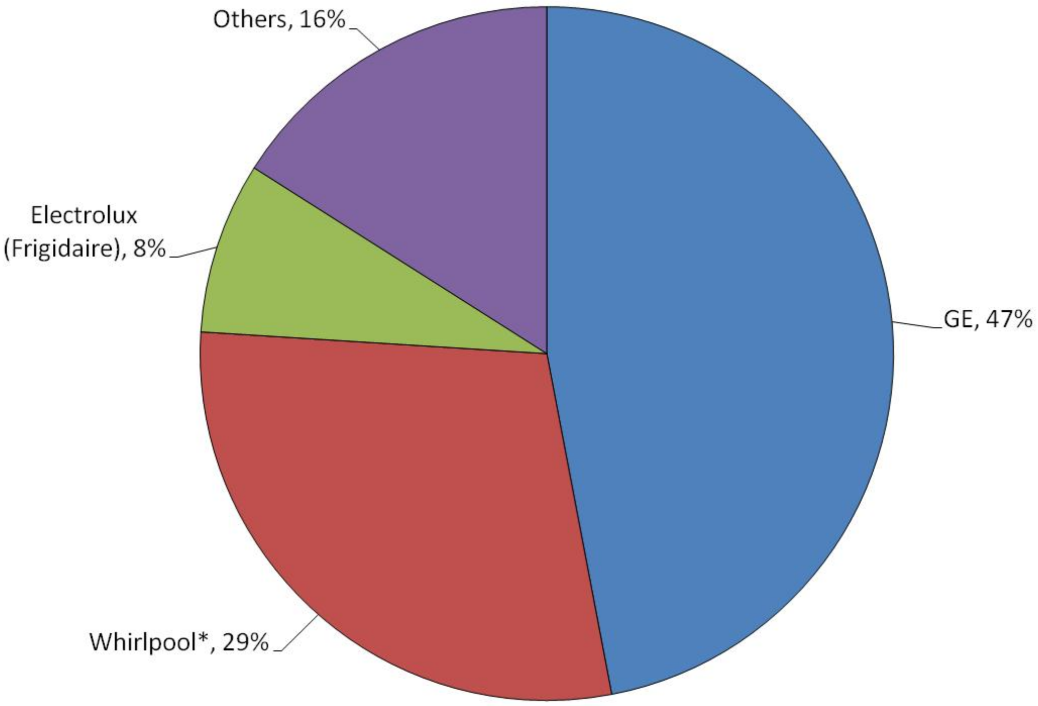
3.6 MANUFACTURER INFORMATION

The following section details information regarding domestic manufacturers of residential cooking products, including estimated market shares (section 3.6.1), industry mergers and acquisitions (section 3.6.2), potential small business impacts (section 3.6.3), and product distribution channels (section 3.6.4).

3.6.1 Manufacturers and Market Shares

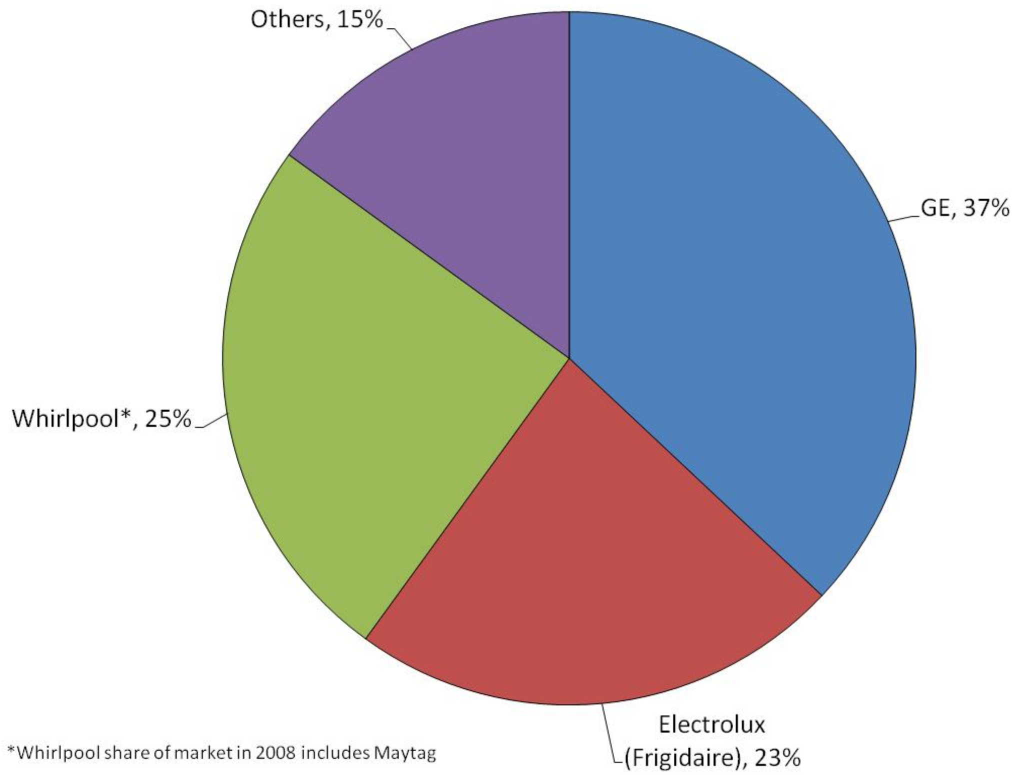
Using publicly available data (*e.g. Appliance Magazine* and market assessments done by third parties), DOE estimates the market shares for domestic manufacturers of each of the products contained in this standards rulemaking. Manufacturers may offer multiple brand names. Some of the brand names come from independent appliance manufacturers which have been acquired over time, and domestic manufacturers may put their brand on a product manufactured overseas. Companies included in this analysis may also be off-shore manufacturers that maintain a significant domestic presence via a U.S. entity.

DOE estimates that there are approximately 20 manufacturers of residential conventional cooking products supplying the domestic market. As discussed in section 3.6.2, Maytag Corporation (Maytag) and Whirlpool Corporation (Whirlpool) merged in 2006 but have continued to maintain both product lines to this date. In addition, AB Electrolux (Frigidaire) reached an agreement in September 2014 to purchase the appliance division of GE Consumer & Industrial (GE). Electrolux/GE and Whirlpool/Maytag represent roughly 85 percent of the electric and gas range products market. Figure 3.6.1 and Figure 3.6.2 illustrate the 2008 market shares for the domestic residential electric and gas range markets, respectively.



*Whirlpool share of market in 2008 includes Maytag

Figure 3.6.1 2008 Market Shares for the Domestic Electric Range Market[1]



*Whirlpool share of market in 2008 includes Maytag

Figure 3.6.2 2008 Market Shares for the Domestic Gas Range Market[2]

In addition to the manufacturers presented above, manufacturers of ovens, cooking tops, and ranges also include BSH Home Appliances Corporation (Bosch-Siemens) (which acquired Thermador Corporation), Danby Products Inc. (Danby) Fagor America Inc. (Fagor), Haier America Trading, LLC (Haier) (which acquired Fisher & Paykel), LG Electronics, Inc. (LG), Miele, Inc. (Miele), Samsung Electronics America, Inc. (Samsung), Sub-Zero Freezer Company, Inc. (Sub-Zero) (which acquired the residential division of the Wolf Appliance Company (Wolf)), , and Viking Range Corporation (Viking). DOE also identified 9 small business manufacturers, including Acme Kitchenettes Corp. (Acme), American Range, Brown Stove Works, Inc. (Brown Stove), Capital Cooking Equipment, Inc. (Capital), Dacor, Inc. (Dacor), Evo, Inc. (Evo), Kenyon International, Inc. (Kenyon), Peerless-Premier Appliance Co. (Peerless-Premier), and Felix Storch, Inc. (Summit). Table 3.6.1 lists these manufacturers.

Table 3.6.1 Major and Other Range, Oven and Cooking Top Manufacturers

Major Manufacturers	Other Manufacturers	Small Manufacturers
GE/Electrolux	Bosch-Siemens	Acme Kitchenettes
Whirlpool/Maytag	Danby	American Range
	Fagor	Brown Stove
	Haier (Fisher & Paykel)	Capital
	LG	Dacor
	Miele	Evo
	Samsung	Kenyon
	Sub-Zero	Peerless-Premier
	Viking	Summit

3.6.2 Mergers and Acquisitions

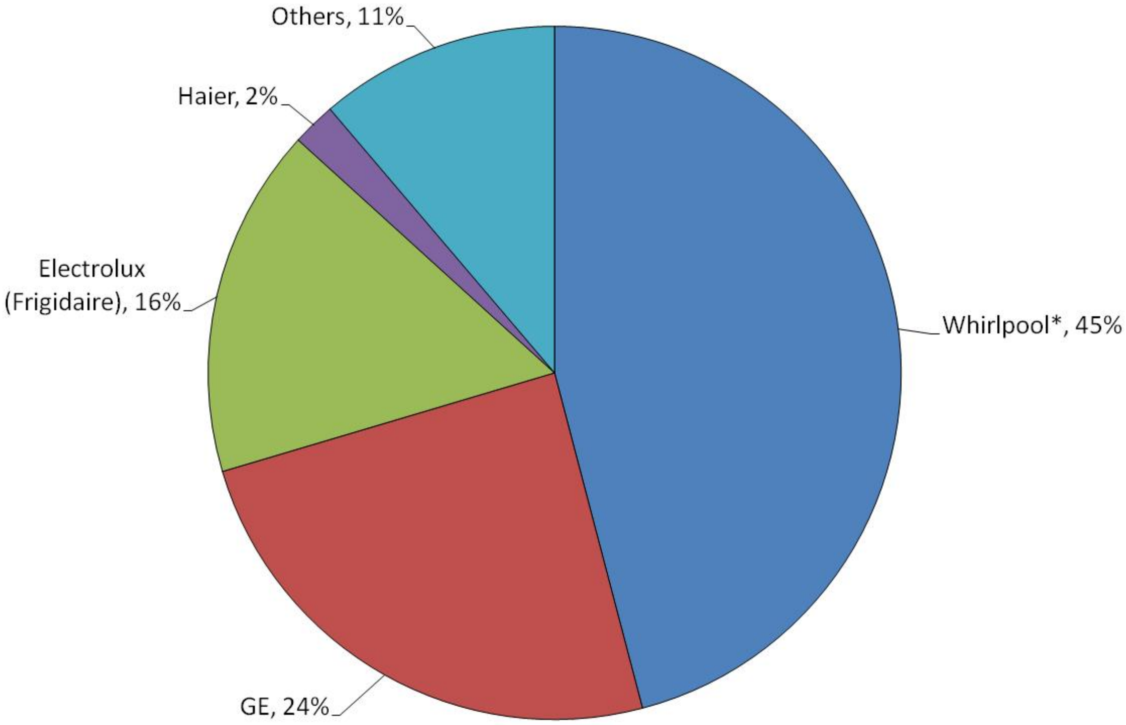
DOE described the merger between Whirlpool and Maytag, which was completed on March 31, 2006, in chapter 3 of the 2009 TSD. In September of 2014, Electrolux reached an agreement to purchase GE's appliances business for \$3.3 billion. This move will double Electrolux's annual appliance sales in North America to over \$10 billion.[3]

Due to mergers and acquisitions, the home appliance industry continues to consolidate. While this phenomenon varies from product to product within the industry, the large market shares of a few companies provide evidence in support of this characterization.

According to the September 2009 issue of *Appliance Magazine*, two manufacturers comprise 85 percent of the core appliance market share. "Core appliances" include dishwashers, clothes dryers, freezers, ranges, refrigerators, and clothes washers. Table 3.6.2 lists these core appliance manufacturers, and Figure 3.6.3 illustrates the breakdown of 2008 market shares in the core appliance category.

Table 3.6.2 Core Appliance Manufacturers

Core Appliance Manufacturers
Whirlpool (Maytag)
GE/Electrolux (Frigidaire)



*Whirlpool share of market in 2008 includes Maytag

Figure 3.6.3 2008 Core Appliance Market Shares[4]

3.6.3 Small Business Impacts

DOE considers the possibility of small businesses being impacted by the promulgation of energy conservation standards for residential cooking products. At this time, DOE is aware of nine small cooking products manufacturers, defined by the Small Business Association (SBA) as having 750 employees or fewer, who produce products that fall under this rulemaking and who, therefore, would be impacted by a minimum efficiency standard. These small business manufacturers are listed in Table 3.6.1. DOE evaluated the potential impacts on these small businesses as part of the manufacturer impact analysis (MIA), which it conducted as a part of the NOPR analysis. For further information on the cooking products small businesses, see chapter 12 of the TSD.

3.6.4 Distribution Channels

Understanding the distribution channels of products covered by this rulemaking is an important facet of the market assessment. DOE gathered information regarding the distribution channels for residential cooking products from publicly available sources.

For residential appliances, including cooking products, the majority of consumers purchase their appliances directly from retailers. These retailers include: (1) home improvement, appliance, and department stores; (2) Internet retailers; (3) membership warehouse clubs; and (4) kitchen remodelers. The AHAM *Fact Book 2005* reports that home improvement stores claim nearly one out of every four dollars spent on appliances.[5]

Home appliance retailers generally obtain products directly from manufacturers. The AHAM *Fact Book 2003* shows that over 93 percent of residential appliances are distributed from the manufacturer directly to a retailer.[6]

3.7 REGULATORY PROGRAMS

The following section details current regulatory programs mandating energy conservation standards for residential conventional cooking products. Section 3.7.1 discusses Federal energy conservation standards, section 3.7.2 reviews standards under EISA 2007. In addition, section 3.7.3 reviews standards in Canada that may impact the companies servicing the North American market, section 3.7.4 reviews conventional oven regulations in the European Union, and section 3.7.5 reviews foreign standby power regulatory programs.

3.7.1 Federal Energy Conservation Standards

The National Appliance Energy Conservation Act of 1987 (NAECA) (42 U.S.C. 6291-6309) amended EPCA to establish prescriptive standards for gas cooking products, requiring gas cooking tops, ranges, and ovens with an electrical supply cord not to be equipped with constant burning pilots and directed DOE to conduct two cycles of rulemakings to determine if more stringent standards are justified. (42 U.S.C. 6295 (h)(1)-(2))

DOE undertook the first cycle of these rulemakings and published a final rule on September 8, 1998, which found that no standards were justified for conventional electric cooking products at that time. In addition, partially due to the difficulty of conclusively demonstrating that elimination of standing pilots for conventional gas cooking products without an electrical supply cord was economically justified, DOE did not include amended standards for conventional gas cooking products in the final rule. 63 FR 48038. For the second cycle of rulemakings, DOE published the April 2009 Final Rule amending the energy conservation standards for cooking products to prohibit constant burning pilots for all gas cooking products (i.e., gas cooking products both with or without an electrical supply cord) manufactured on or after April 9, 2012. As noted in the April 2009 Final Rule, DOE considered standards for conventional cooking tops and conventional ovens separately, and noted that any cooking top or oven standard would apply to the individual components of the conventional range. 74 FR 16040, 16053. DOE decided to not adopt energy conservation standards pertaining to the cooking efficiency of conventional electric cooking products because it determined that such standards would not be technologically feasible and economically justified at that time. 74 FR 16040, 16041–44.[g]

3.7.2 Energy Independence and Security Act of 2007

On December 19, 2007, the President signed into law EISA 2007, which contains numerous amendments to EPCA. Section 325 of EPCA is amended by section 310 of EISA 2007 to require DOE to regulate standby mode and off mode energy consumption as part of an energy conservation standard for all covered products, including residential ranges and ovens, for which a final rule is adopted after July 10, 2010. (42 U.S.C. 6295(gg)(1)(A)) Off mode is defined by EISA 2007 as "the condition in which an energy-using product – (I) is connected to a main power source; and (II) is not providing any standby or active mode function." (42 U.S.C. 6295(gg)(1)(A)(ii)) Active mode refers to the main (cooking) function, while standby is defined by EISA 2007 as "the condition in which an energy-using product (I) is connected to a main power source; and (II) offers 1 or more of the following user-oriented or protective functions: (aa) To facilitate the activation or deactivation of other functions (including active mode) by remote switch (including remote control), internal sensor, or timer. (bb) Continuous functions, including information or status displays (including clocks) or sensor-based functions." (*Id*.; 42 U.S.C. 6295(gg)(1)(A)(iii))

For the April 2009 Final Rule, DOE stated that it did not have any data on standby power consumption in conventional cooking products (*i.e.*, electric and gas cooking tops and ovens) that indicate the potential for significant energy savings. For this reason, DOE did not consider regulating standby and off mode power for conventional cooking products as part of the April 2009 Final Rule.

As discussed in section 3.4, DOE published the October 2012 Final Rule to amend the test procedures for conventional cooking products in Appendix I to adopt standby and off mode provisions that satisfy the EISA 2007 amendments to EPCA. (42 U.S.C.6295(gg)(2)(A)) For this rulemaking, DOE is considering energy conservation standards for conventional cooking products that would include standby and off mode energy consumption.

3.7.3 Canadian Energy Conservation Standards

Canada's Energy Efficiency Regulations (hereafter Regulations) mandate minimum energy conservation standards for certain residential conventional cooking products, including electric and gas ranges, cooking tops, and ovens. Like U.S. DOE standards, Canadian Regulations require that gas cooking products, including ranges, ovens, and cooking tops, with

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[g] As part of the April 2009 Final Rule, DOE decided not to adopt energy conservation standards pertaining to the cooking efficiency of microwave ovens. DOE also published a final rule on June 17, 2013 adopting energy conservation standards for microwave oven standby mode and off mode. 78 FR 36316. DOE is not considering energy conservation standards for microwave ovens as part of this rulemaking.

an electrical supply cord not be equipped with constant burning pilots. Table 3.7.1 presents the Regulations for electric cooking products.

Table 3.7.1 Canadian Energy Conservation Standards for Electric Cooking Products

Cooking Product Classification	**Maximum Allowable Energy Consumption *(kWh/year)****
Free-standing or built-in ranges with one or more surface elements and one or more ovens	2.0V + 458
Built-in or wall-mounted ranges without surface elements and with one or more ovens	2.0V + 200
Counter-mounted ranges without ovens and with one or more surface elements on a conventional (*i.e.*, not modular) cooking top	258

* Where V = volume of oven in liters

3.7.4 European Union Energy Conservation Standards

The European Union (EU) recently enacted the Commission Regulation (EC) No. 66/2014 of January 14, 2014, implementing Directive 2009/125/EC of the European Parliament and of the Council with regards to design requirements for residential conventional ovens. Annex I of the regulation specifies the following requirements:

Residential conventional ovens shall comply with maximum Energy Efficiency Index[h] limits indicated in Table 3.7.2.

Table 3.7.2 European Union Energy Conservation Standards: Energy Efficiency Index Limits for Cavities of Ovens

	Residential Gas & Electric Ovens
From 1 year after the entry into force	$EEI_{cavity} < 146$
From 2 years after the entry into force	$EEI_{cavity} < 121$
From 5 years after the entry into force	$EEI_{cavity} < 96$

From 5 years after entry into force, for multi-cavity ovens, at least one cavity shall comply with the maximum Energy Efficiency Index as indicated in Table 3.7.2 as applicable from 5 years after entry into force whereas the other cavities shall comply with the maximum Energy Efficiency Index as indicated in Table 1 as applicable from 2 years after entry into force.

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[h] The Energy Efficiency Index compares the energy consumption of an oven with the standard energy consumption of an average 2012 oven with the same cavity volume

3.7.5 Foreign Standby Power Regulatory Programs

The International Energy Agency (IEA) has raised awareness of standby power through publications, international conferences, and policy advice to governments. In 1999, the IEA developed the "1-Watt Plan," which proposed reducing standby power internationally in electronic devices and which advocates that all countries harmonize energy policies and adopt the same definition and test procedure. The IEA has advocated a 1 W requirement for all consumer electrical products (unless specifically excluded) in standby mode. The IEA also stated that IEC Standard 62301 provides an internationally sanctioned definition and test procedure for standby power, which is now widely specified and used.[i]

The EU recently enacted the EC No. 1275/2008 of December 17, 2008, implementing design requirements for standby and off mode power for electrical and electronic household and office equipment, including conventional cooking products. Annex II of the regulation specifies the following maximum power requirements:

1. One year after this Regulation has come into force:

(a) Power consumption in 'off mode':

> Power consumption of equipment in any off-mode condition shall not exceed [1.00] W.

(b) Power consumption in 'standby mode(s)':

> The power consumption of equipment in any condition providing only a reactivation function, or providing only a reactivation function and a mere indication of enabled reactivation function, shall not exceed [1.00] W.
>
> The power consumption of equipment in any condition providing only information or status display, or providing only a combination of reactivation function and information or status display, shall not exceed [2.00] W.

(c) Availability of off mode and/or standby mode

> Equipment shall, except where this is inappropriate for the intended use, provide off mode and/or standby mode and/or another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source.

2. Four years after this Regulation has come into force:

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[i] For more information, visit www.iea.org/.

(a) Power consumption in ‘off mode’:

Power consumption of equipment in any off-mode condition shall not exceed [0.50] W.

(b) Power consumption in ‘standby mode(s)’:

The power consumption of equipment in any condition providing only a reactivation function, or providing only a reactivation function and a mere indication of enabled reactivation function, shall not exceed [0.50] W.

The power consumption of equipment in any condition providing only information or status display, or providing only a combination of reactivation function and information or status display, shall not exceed [1.00] W.

(c) Availability of off mode and/or standby mode

Equipment shall, except where this is inappropriate for the intended use, provide off mode and/or standby mode and/or another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source.

(d) Power management

When equipment is not providing the main function, or when other energy-using product(s) are not dependent on its functions, equipment shall, unless inappropriate for the intended use, offer a power management function, or a similar function, that switches equipment after the shortest possible period of time appropriate for the intended use of the equipment, automatically into:

— standby mode, or

— off mode, or

— another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source. The power management function shall be activated before delivery.

3.8 HISTORICAL SHIPMENTS

Awareness of annual product shipment trends is an important aspect of the market assessment and in the development of the standards rulemaking. DOE reviewed data collected by the U.S. Census Bureau, EPA, and AHAM to evaluate residential appliance product shipment trends and the value of these shipments, which were used during the shipments analysis (chapter 9 of this TSD.)

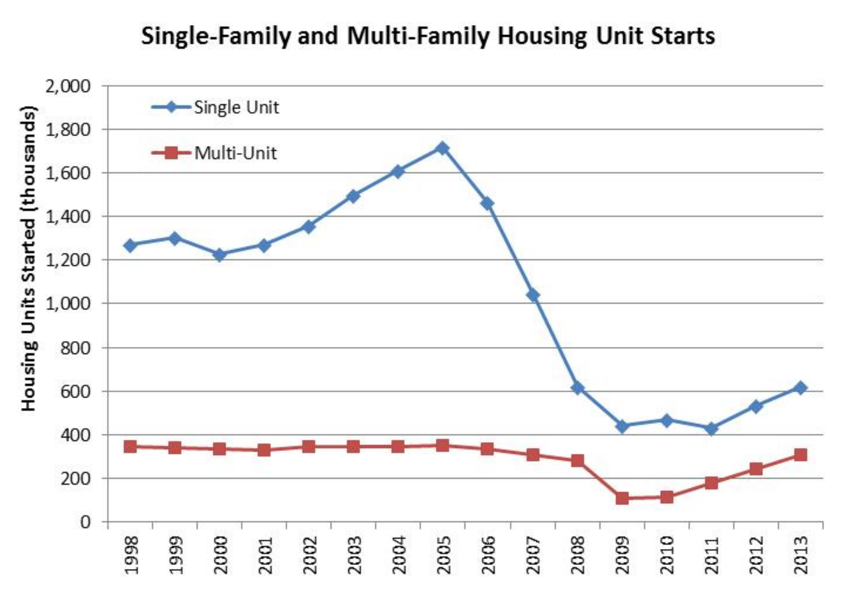
3.8.1 New Home Starts

Trends in new home starts may directly affect shipments of certain home appliances. While there is certainly both a replacement and remodeling market for some appliances including cooking products, these products are also fixtures in virtually all new homes.

Table 3.8.1 presents the number of new single-family and multi-family housing units started in the United States from 1998–2013. Over the period from 2000–2005, single-family home starts increased nearly 40 percent, to 1,716,000 units annually. However, between 2005 and 2010, single-family home starts decreased 73 percent, to 471,000 units annually. Multi-family unit starts remained relatively stable during the period 1998–2005 at around 340,000 units annually. Between 2005 and 2010, multi-family units decreased 67.1 percent to 116,000 units annually. Over the period from 2010–2013, multi-family units have rebounded to near their pre-2005 levels, while single-family units remain significantly lower.

Table 3.8.1 New Privately Owned Single-Family and Multi-Family Housing Unit Starts in the United States from 1998–2013 (Thousands)[7]

Year	Single Unit	Multi-Unit
2013	618	307
2012	535	245
2011	431	178
2010	471	116
2009	445	109
2008	622	284
2007	1046	309
2006	1465	336
2005	1716	353
2004	1611	345
2003	1499	349
2002	1359	346
2001	1273	329
2000	1231	338
1999	1302	339
1998	1271	346



3.8.2 Unit Shipments

AHAM's *Fact Book* provides annual unit shipments for conventional cooking products from 1995 to 2005. Shipments for 2006 through 2010 were obtained from the January 2011 *Appliance Market Research Report*'s "U.S. Appliance Shipment Statistics January 2011." The two sources contain consistent shipment values for the overlapping years 2000 through 2005. Shipments for 2011 and 2012 were taken from Appliance Magazine's "Full-Year Appliance Industry Shipment Statistics" reports for the respective years. Table 3.8.2 presents the annual shipments of conventional cooking products for the period from 1995 to 2012.

Table 3.8.2 Industry Shipments of Cooking Products (Domestic and Import in Thousands of Units)[8, 9, 10, 11]

	Cooking Products							
	Electric Ranges				Gas Ranges			
Year	Free-Standing	Built-In	Surface Cooking Units	Total	Free-Standing	Built-In	Surface Cooking Units	Total
2012*				4,319				2,598
2011*				4,318				2,625
2010*				4,449				2,790
2009*				4,333				2,598
2008*				5,106				2,843
2007*				5,991				3,334
2006*				6,228				3,726
2005	4,685	973	542	6,201	3,139	64	560	3,762
2004	4,612	963	570	6,145	3,124	67	528	3,719
2003	4,238	841	543	5,622	2,897	67	455	3,419
2002	4,030	780	528	5,338	2,781	71	416	3,268
2001	3,842	726	498	5,066	2,580	72	384	3,036
2000	3,826	706	494	5,026	2,729	70	377	3,176
1999	3,785	705	493	4,983	2,698	72	367	3,137
1998	3,481	652	506	4,639	2,543	71	336	2,950
1997	3,177	617	446	4,240	2,391	73	280	2,744
1996	3,123	614	418	4,155	2,366	72	272	2,710
1995	2,931	598	389	3,917	2,391	84	240	2,715

* Disaggregated shipments data for electric and gas ranges was unavailable for 2006–2012.

3.8.3 Value of Shipments

Table 3.8.3 provides the value of shipments for the household cooking appliance industry from 2002–2011 based upon data from the U.S. Census Bureau's *Annual Survey of*

Manufacturers (ASM).[j] The ASM expresses all dollar values in nominal dollars; *i.e.*, 2011 data are expressed in 2011 dollars, and 2010 data are expressed in 2010 dollars. The value of shipments has declined by nearly 12 percent over the 10-year period.

Table 3.8.3 Household Cooking Appliance Manufacturing Statistics by Year[12]

Year	**Value of Shipments in Nominal Dollars *($1,000)***
2011	3,809,552
2010	3,740,373
2009	3,798,353
2008	3,884,230
2007	4,786,768
2006	4,864,268
2005	5,114,677
2004	4,798,227
2003	4,691,713
2002	4,327,308

The overall increase in shipment volumes combined with an overall decrease in the shipment values indicates that the U.S. cooking appliance industry is very competitive.

According to data presented in the AHAM *Fact Book 2003*, many old appliances are still being used after consumers purchase new units of same product. Table 3.8.4 presents the various methods by which consumers dispose of their older appliances.

Table 3.8.4 Disposition of Previous Appliance (Percentage)[13]

Product	**Kept It**	**Left with Previous Home**	**Sold / Gave Away**	**Recycling Facility**	**Left at Curb for Disposal**	**Retailer Took Away**
Ranges	6	37	21	13	8	15
Built-In Ranges	4	46	11	15	12	13

3.8.4 Imports and Exports

There is a large market for the import and export of home appliances. Each month AHAM publishes import and export data for certain home appliances. These data are released by the U.S. Census Bureau and aggregated by a third party. On the whole, major appliance unit imports decreased 9.7 percent in 2009 as compared to 2008. Major appliance unit exports decreased 17.5 percent over the same period.

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[j] Available online at http://www.census.gov/manufacturing/asm/.

Table 3.8.5 shows selected import data from AHAM's *Import/Export Trade Report – December 2009*.[14] For non-portable cooking products, both the number and value of units imported decreased significantly from 2008–2009. For and electric stoves, ranges, and ovens, the number of units imported increased over the 1-year period, while the value of those units decreased. Overall, the value of major appliance imports decreased 9.2 percent from 2008–2009.

Table 3.8.5 2008–2009 Imports of Appliances Covered by this Rulemaking[15]

Appliance Description	Jan. – Dec. 2009	Jan. – Dec. 2008		Jan. – Dec. 2009	Jan. – Dec. 2008	
	Units		% Change	*$ Mil (Nominal)*		% Change
Non-portable cooking products	948,264	1,021,795	-7.2	244.736	277.779	-11.9
Electric stoves, ranges, and ovens	2,496,531	2,396,020	4.2	504.189	533.056	-5.4

Table 3.8.6 shows selected export data from AHAM's *Import/Export Trade Report – December 2009*.[16] For the 1-year period from 2008–2009, both the number and value of unit exports of non-portable cooking products and electric stoves, ranges, and ovens decreased. For the same time period, the number and value of coin-operated washing machines and microwave oven exports decreased. Overall, the total value of exports decreased 18.9 percent.

Table 3.8.6 2008–2009 Exports of Appliances Covered by this Rulemaking[17]

Appliance Description	Jan. – Dec. 2009	Jan. – Dec. 2008		Jan. – Dec. 2009	Jan. – Dec. 2008	
	Units		% Change	*$ Mil (Nominal)*		% Change
Non-portable cooking products	95,237	126,022	-24.4	53.372	69.763	-23.5
Electric stoves, ranges, and ovens	477,448	524,362	-8.9	274.984	303.672	-9.4

3.9 MARKET SATURATION

AHAM's *Fact Book 2005* and the January 2010 *Appliance Market Research Report* present the market saturation for conventional cooking products. The percentage of U.S. households with electric ranges and/or cooking tops and gas ranges and/or cooking tops has remained relatively steady since 2001. Table 3.9.1 presents the percentage of U.S. households with each product.

Table 3.9.1 Percentage of U.S. Households with Residential Conventional Cooking Products[18, 19]

Year	Electric Ranges / Cooking Tops	Gas Ranges / Cooking Tops
2008	61.0	40.0
2007	60.0	40.0
2006	60.0	39.0
2005	60.0	39.0
2004	61.0	39.0
2003	61.0	39.0
2002	62.0	38.0
2001	61.0	40.0
1990	62.6	38.7
1982*	58.0	42.7
1970*	40.6	57.7

*Cooking tops not included in 1970 or 1982 data

3.10 INDUSTRY COST STRUCTURE

DOE developed the household appliance industry cost structure from publicly available information from the ASM, (Table 3.10.1 and Table 3.10.2) and the U.S. Securities and Exchange Commission (SEC) 10-K reports filed by publicly owned manufacturers (summarized in Table 3.10.3). Table 3.10.1 presents the home cooking appliance industry employment levels and earnings from 2002-2011. The statistics illustrate a steady decline in the number of production and non-production workers in the industry. Consequently, the annual payroll for all employees also declines, although not as significantly as the number of employees, for this time period.

Table 3.10.1 Household Cooking Appliance Industry Employment and Earnings [20]

Year	Production Workers *('000)*	All Employees *('000)*	Payroll for All Employees *($1,000)*
2011	8.8	9.9	366,199
2010	8.7	9.8	346,539
2009	8.7	10.0	352,709
2008	10.4	11.8	407,454
2007	13.1	15.5	465,854
2006	12.7	14.4	439,673
2005	14.3	16.4	518,033
2004	14.4	17.0	515,637
2003	14.5	17.3	491,283
2002	14.7	18.0	498,003

Table 3.10.2 presents the costs of materials and industry payroll as a percentage of value of shipments from 2002–2011. The cost of materials as a percentage of value of shipments has fluctuated slightly over the 10-year period. Ranging from as high as 77.4 percent in 2008 to as low as 59.3 percent in 2011. DOE notes that fluctuations in raw material costs are common from year to year. The cost of payroll for production workers as a percentage of value of shipments has declined since 2002. Similarly, the cost of total payroll as a percentage of value of shipments has also declined since 2002.

Table 3.10.2 Household Cooking Appliance Industry Census Data [21]

Year	Cost of Materials as a Percentage of Value of Shipments (%)	Cost of Payroll for Production Workers as a Percentage of Value of Shipments (%)	Cost of Total Payroll (Production + Admin.) as a Percentage of Value of Shipments (%)
2011	59.3	7.1	9.6
2010	62.0	6.9	9.3
2009	60.2	6.8	9.3
2008	77.4	8.1	10.5
2007	64.3	7.4	9.7
2006	66.8	7.0	9.0
2005	67.9	8.0	10.1
2004	67.3	8.1	10.7
2003	63.2	7.5	10.5
2002	64.6	8.0	11.5

Table 3.10.3 presents the industry cost structure derived from SEC 10-K reports of publicly owned home appliance manufacturers. DOE averaged the financial data from 2002–2007 of several companies to obtain an industry average. Each financial statement entry is presented as a percentage of total revenues.

Table 3.10.3 Industry Cost Structure Using SEC Data

Financial Statement Entry	Percent of Revenues
Tax Rate	19.5%
Selling, general and administrative	11.2%
Capital expenditure	3.3%
Research and development	2.4%
Depreciation and amortization	3.0%
Net plant, property and equipment	16.2%
Working capital	4.5%

A detailed financial analysis of each of the products covered by this rulemaking is presented in the MIA. (See chapter 12 of this TSD.) This analysis identifies key financial inputs including cost of capital, working capital, depreciation, and capital expenditures.

3.11 INVENTORY LEVELS AND CAPACITY UTILIZATION RATES

Table 3.11.1 shows the year-end inventory for the household cooking appliance industry, according to the ASM. Both in dollars and as a percentage of value of shipments, the end-of-year inventory for the industry has declined since 2002. These data illustrate a general trend of domestic manufacturers retaining less of their inventories over time since 2002.

Table 3.11.1 Household Cooking Appliance Industry Census Data [22]

Year	End-of-Year Inventory ($1,000)	End-of-Year Inventory as a Percentage of Value of Shipments (%)
2011	324,175	8.5%
2010	303,768	8.1%
2009	295,928	7.8%
2008	388,156	10.0%
2007	557,181	11.6%
2006	385,467	7.9%
2005	432,427	8.5%
2004	410,325	8.6%
2003	390,220	8.3%
2002	431,456	10.0%

DOE obtained full production capacity utilization rates from the U.S. Census Bureau, *Survey of Plant Capacity* from 2002–2006. Table 3.11.2 presents utilization rates for the household cooking appliance industry. Full production capacity is defined as the maximum level of production an establishment could attain under normal operating conditions. In the *Survey of Plant Capacity* report, the full production utilization rate is a ratio of the actual level of operations to the full production level. The full production capacity utilization rate for household cooking appliances show a fluxuation in utilization from 2002–2006, although in 2006, the last year the utilization rates are available, the utilization rate is higher than in previous years.

Table 3.11.2 Full Production Capacity Utilization Rates[23]

Year	Household Cooking Appliance Industry Utilization Rates (%)
2006	65
2005	57
2004	61
2003	57
2002	56

3.12 TECHNOLOGY ASSESSMENT

This section provides a technology assessment for residential conventional ovens. Contained in this technology assessment are details about product characteristics and operation (section 3.12.1), an examination of possible technological improvements for each product (section 3.12.2), and a characterization of the product efficiency levels currently commercially available (section 3.12.3).

3.12.1 Product Operations and Components

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

Residential cooking products are appliances that enable the homeowner to heat and cook foods by means of transfer of input energy to the food load. Input energy may be electricity, gas, or a combination of the two. In conventional and ovens, the cooking vessel is placed inside a cavity within which the energy transfer to the food load takes place. Ranges incorporate both an oven and a cooking top in a single unit.

Gas ovens are appliances designed to bake, roast, or broil foods within an insulated cavity by means of the combustion of natural gas or propane. The major components of the oven include the cavity, the gas burners, an ignition system, and a control system. If the oven incorporates a convection cooking mode, one or more fans are situated within the cavity to provide a means for forced-air distribution.

The oven cavity is a formed sheet metal enclosure with provision for holding cooking racks at varying positions. The interior surface of the cavity may be bare metal (stainless steel), or it may have a porcelain coating for durability and cleanability. Additives in the porcelain coating can provide catalytic conversion of food spilled on the surface under normal cooking temperatures, thus enabling a continuous cleaning process. Alternatively, the oven may have features that allow it to be operated under a special self-clean mode, which heats the cavity to higher temperatures than those used for cooking. In the process, food spills are pyrolized, leaving an ash residue that is easily wiped off when the cavity cools down.

Accessories such as lights and sensors for control of cooking processes are located within the cavity, while an insulated glass window in the oven door allows observation of the cooking processes without requiring the door to be opened (which would incur substantial heat loss). The outside of the cavity is wrapped with insulation to minimize heat loss to ambient surroundings. The space between the cavity and the outer sheet metal enclosure which is filled by the insulation typically is made as small as practically possible in order to maximize the cavity volume.

Gas burners are situated at the bottom of the cavity for the bake function and the top for broiling. They are typically shielded by baffles or covers to protect the burners from spills and to help distribute heat evenly. Broil elements may also be of a radiant type in which the combustion of the fuel-air mixture heats a perforated ceramic matrix or a metal mesh. As the ceramic or metal heats, it emits infrared radiation that can produce heating and surface browning of the cooking load. Combustion products from each burner and gases released during the cooking process are vented from the top of the cavity.

As with gas cooking tops, gas ovens cannot have a constant burning pilot ignition system (10 CFR 430.32(j)(1)–(2)). Ignition may be achieved through the use of a hot surface igniter or an intermittently actuated spark igniter used to light the pilot when the oven controls are turned on. With hot surface ignition, a ceramic heating element is placed in a location where the incoming gas-air mixture will impinge on it. As the element is heated electrically, its resistance goes down and current draw goes up. A bi-metallic gas valve in electrical series with the igniter deforms as its corresponding current increases, allowing gas flow as long as the hot surface igniter is energized by the burner controller. For spark ignition, the pilot serves to heat a thermally-actuated switch that keeps the main gas valve open.

Like gas ovens, **electric ovens** are designed to bake, roast, or broil food. The cavity is similar to those of gas ovens as well, in that the surface finishes may be bare or porcelainized, with or without the catalytic properties. In addition, electric ovens may incorporate a self-clean mode for pyrolysis of food matter on in the interior surfaces. Accessories and insulation tend to be similar between gas and electric ovens, and electric ovens also incorporate venting, although the demands of such venting are lower than those for gas ovens since there are no combustion products.

The heat source for the cooking process is typically provided by radiant elements. Bake elements are located at the bottom of the cavity, and may be either exposed or covered to provide spill protection and improve cleanability. Broil elements are situated at the top of the cavity. Far less common than radiant elements, halogen elements are also used to promote faster cooking.

An additional cooking feature on many electric ovens and certain gas ovens is convection mode, in which hot air within the cavity is circulated by means of one or more fans to speed the cooking process, promote surface crisping, and increase cooking uniformity.

Supplemental heating of this recirculated air may be accomplished by means of a radiant heating element located near the fan.

Additional electrically-powered components in electric ovens may include cavity lights, electronic controls incorporating various types of displays, and cooking sensors.

3.12.2 Technology Options

In order to gain a deeper understanding of the technological improvements used to increase the efficiency of residential conventional ovens, DOE identified several possible technologies and examined the most common improvements used in today's market.

DOE considered technologies identified in the following sources: (1) 2009 TSD from the most recent energy conservation standards rulemaking for residential conventional cooking products; (2) the 1996 *Technical Support Document for Residential Cooking Products* (1996 TSD), which was released as part of the previous standards rulemaking.[k] (3) information provided by trade publications; and (4) design data identified in manufacturer product offerings.

For **gas and electric ovens**, DOE considered the technologies listed in Table 3.12.1.

Table 3.12.1 Technology Options for Gas and Electric Ovens

1. Bi-radiant oven (electric only)
2. Forced convection
3. Halogen lamp oven (electric only)
4. Improved and added insulation
5. Improved door seals
6. Low-standby-loss electronic controls
7. No oven-door window
8. Oven separator
9. Electronic spark ignition (gas only)
10. Reduced conduction losses
11. Optimized burner and cavity design
12. Reduced vent rate
13. Reflective surfaces

Bi-radiant oven (electric only)

A bi-radiant electric oven system was developed by Purdue University for Oak Ridge National Laboratory in the late 1970s.[24] The objective of the project was to develop an electric oven that offered significant energy savings without compromising food quality. The bi-radiant oven has three important features which provide improved performance: (1) the cavity walls are highly reflective rather than absorptive, thereby allowing these surfaces to operate at cooler

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[k] Available online at http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0070-0053

temperatures; (2) the heating elements, similar in construction to those in conventional ovens but operating at much lower temperatures, provide a prescribed, balanced radiant flux to the top and bottom surfaces of the food product; and (3) the baking and roasting utensils have a highly absorptive finish.

The bi-radiant oven was tested under a variety of cooking conditions (including the DOE test procedure) and also modeled (using computer thermal analysis programs) to determine its performance. It demonstrated a greater than 50-percent increase in efficiency over that of a conventional oven. In addition, the separate upper and lower heating elements required by the oven provided more flexibility in baking and roasting.

As noted in the 2009 TSD, several important practical concerns have to be addressed by manufacturers in order to realize the demonstrated energy savings: (1) the oven lining material must be durable enough to maintain the low-emissivity (less than 0.1) cavity surface; (2) microprocessor controls must be used; and (3) as mentioned earlier, the baking and roasting utensils must have a highly absorptive exterior. However, given the assumption that all of these criteria are met, the previous rulemakings analyses assumed a 50-percent efficiency increase.

Forced convection

A forced convection oven uses a fan to distribute warm air evenly throughout the oven cavity. The use of forced circulation can reduce fuel consumption by cooking food more quickly, at lower temperatures, and in larger quantities than a natural convection oven of the same size and rating. The fan is placed within the rear cabinet wall and a protective screen is placed around it. The screen prevents any items being placed in the oven from “knocking” into the fan and causing damage. The screen may also assist in distributing the heated air evenly throughout the cavity. Cooking times can be reduced by using forced convection cooking.[25] As a result, forced convection is widely used in electric ovens.

Additionally, ovens can use convection heating elements in addition to resistance and other types of elements to speed up the cooking process. By utilizing different cooking elements where they are most effective, such combination ovens can reduce the time and energy consumption required to cook food.

In the previous rulemaking, DOE used estimates from manufacturers, researchers, published reports[26,27] and interested parties[28] to determine a relative cooking efficiency increase due to forced convection of 23 percent for gas self-clean ovens, 4.8 percent for gas standard ovens, and 2.4 percent for both standard and self-clean electric ovens. Additionally, DOE estimated that an increase in electrical energy consumption of approximately 15 watt-hours (Wh) would result from operation of the convection fan motor.

As described further in chapter 5, DOE performed testing on conventional ovens in support of this NOPR to determine the improvement in EF associated with forced convection. Included in the DOE test sample were four gas ovens and two electric ovens equipped with forced convection. DOE compared the measured energy consumption of each oven in bake mode to the average energy consumption of bake mode and convection mode (including energy consumption due to the fan motor) as specified in the test procedure. The absolute increase in EF resulting from the use of forced convection in conventional ovens is 0.003 for gas ovens and 0.005 for electric ovens. This translates to the relative increase in cooking efficiencies as shown in Table 3.12.2 below.

Table 3.12.2 Relative Percentage Increase in Cooking Efficiency due to Forced Convection

Forced Convection Oven Type	**Relative Percentage Increase in Cooking Efficiency[*] (%)**
Gas Standard Oven	3.5
Gas Self-Clean Oven	4.7
Electric Standard Oven	4.5
Electric Self-Clean Oven	5.8

[*] Measured cooking efficiency normalized to a fixed cavity volume of 3.9 ft^3.

Halogen lamp oven (electric only)

Halogen elements, similar to those used in electric cooking tops, can also be used in electric ovens. This oven type was first introduced in Europe, but according to U.S. manufacturers, its acceptance has been slow in the United States. Manufacturers stated in previous rulemakings that the cooking performance of the halogen lamp oven is relatively poor compared to that of a conventional oven, though it might be advantageous for certain broiling applications.

Alternatively, a conventional oven can use halogen elements in addition to resistance and/or convection elements to speed up the cooking process. By utilizing different cooking elements when they are most effective, combination ovens can reduce the time and energy consumption required to cook food. However, no data were found or submitted to demonstrate how efficiently halogen elements alone perform relative to conventional ovens.

Improved and added insulation

The efficiency of an oven can be increased by either improving the insulation or adding more insulation to the cabinet walls and oven door. Most standard models have 2 inches of low-density (~1.09 pounds (lb)/ft^3) fiberglass insulation in the cabinet walls and door, while most self-clean ovens use 2 inches of high-density (~1.90 lb/ft^3) insulation. Insulation is added primarily to pass UL surface temperature tests, which explains why self-clean ovens, which require high temperatures for pyrolysis, tend to have a more effective insulation package.

Since the DOE test procedure does not require maintaining heat in the oven over an extended period of time, manufacturers stated in the previous rulemakings that increasing the thickness or density of the oven’s insulation will demonstrate no energy savings. But data provided by several sources indicate that small energy savings can be realized under the conditions of the DOE test procedure.

The following sources were used in the 1996 TSD to establish the efficiency increase from using a denser insulation (1.09 to 1.90 lb/ft^3): (1) manufacturers' data provided by AHAM; (2) the costing analysis of design options for residential appliances prepared by ADM Associates for LBNL;[29] (3) the energy efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association;[30] and (4) the 1980 DOE engineering analysis for residential appliances.[31] Averaging the data from these sources results in an efficiency increase of 4.9 percent for standard gas ovens and 5.2 percent for standard electric ovens.

As noted in the 2009 TSD, two sources of data were available which showed an increase in efficiency due to adding more insulation (2 to 4 inches): (1) manufacturers' data provided by AHAM for the 1996 TSD and (2) the 1980 DOE engineering analysis for residential appliances.[32] Averaging these data points results in an efficiency increase of approximately 1.4 percentage points. However, GRI reported no change in energy consumption by adding insulation.[33]

Improved door seals

Door seals for standard ovens generally consist of a strip of silicone rubber, while self-clean ovens usually incorporate fiberglass seals. These seals are attached to the oven front frame and act as a seal for the door, which serves to reduce the loss of hot oven air through the door. Because some venting is required for proper cooking performance, a complete seal on the oven is undesirable. But the oven door seals can be improved further without sealing the oven completely.

As noted in the 2009 TSD, data from the energy efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association[34] were used to estimate the efficiency increase from improving the door seals. The data indicated that an approximately 7-percent increase in efficiency was possible for standard electric ovens and both standard and self-clean gas ovens. However, more recent data by GRI[35] show efficiency increases much less than the 7-percent value previously reported. A value of 1 percent, therefore, was used for the standard and self-clean gas oven analysis. The GRI report also pointed out the need for sufficient air flow though the oven cavity for proper heating and moisture conditions while cooking.

Low-standby-loss electronic controls

Electronic controls may consume power even when the conventional oven is not performing its intended function. Depending on the implementation of the controller, standby power is required to enable the electronic controls to detect user input without the user first having to turn on a mechanical power switch or to enable displays, illuminate switches, etc. Reducing the standby power consumption of electronic controls would reduce the annual energy consumption of the conventional oven, but would not impact the energy consumption of the conventional oven during active mode operation. Since clocks are incorporated into the majority of both gas and electric ovens, DOE considered options for reducing the standby power consumption of electronic controls while maintaining the clock feature.

A potential area for standby power improvements is the power supplies on the control board. Typically, conventional ovens incorporate unregulated plus regulated control board power supplies (also referred to as a linear power supply). The unregulated portion consists of a small transformer, a bridge rectifier, and an electrolytic capacitor. Voltage regulators then step down the voltage(s) to the level(s) required by the control logic, display, and cooking sensor. This approach results in a rugged power supply which is reliable, but typically has an efficiency of about 40 percent.

Switching power supplies offer the highest conversion efficiencies of up to 75 percent for switch mode power supply designs in appliance applications for power supply sizes similar to those of conventional ovens[1]. They also offer the lowest no-load standby losses (0.2 W or less), although a higher part count and greater complexity may also result in lower overall reliability and take greater care to implement. For example, among other issues, a switching power supply can be prone to causing electromagnetic interference. Based on DOE's reverse engineering analyses, discussed in detail in chapter 5 of this TSD, DOE observed that just less than 40 percent of the conventional cooking products in DOE's test sample incorporated switching power supplies. DOE research suggests that the component prices for switch mode power supplies and traditional linear power supplies are currently nearly equivalent.

No oven-door window

Most ovens and ranges come equipped with windows in the door. Using the window, the contents of the oven can be viewed without opening the oven door. But oven-door windows allow more energy to be lost through the door and, thus, reduce the efficiency of the oven. It could be argued, however, that having no window in the door necessitates frequent door openings to check the contents of the oven. The lost energy caused by these door openings could offset any energy savings that would result from eliminating the door window.

As noted in the 2009 TSD, GRI issued a topical report[36] which discussed this technology option. GRI's experimental tests showed a small savings in annual energy usage for both standard and self-clean ovens. However, they reported there could actually be a net energy loss due to consumer practices, which would be a function of the number of times a consumer would open the door to inspect the food while cooking. With four door openings per test according to the DOE test procedure, a standard oven would realize a net energy savings of 34 kBtu/yr. For a self-clean oven, however, GRI calculated a net energy loss of 3 kBtu/yr.

Oven separator (electric only)

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[1] Information on design and efficiencies of switch mode power supplies is available from Power Integrations: http://ac-dc.power.com/applications/major-appliances/.

For loads that do not require the entire oven volume, an oven separator can be used to reduce the cavity volume that is used for cooking. With less oven volume to heat, the energy used to cook an item would be reduced. The oven separator considered here is the type that can be easily and quickly installed by the user. The side walls of the oven cavity would be fitted with "slots" that guide and hold the separator into position, and a switch to indicate when the separator has been installed. The oven would also require at least two separate heating elements to heat the two cavities. Different pairs of "slots" would be spaced throughout the oven cavity so that the user could select different positions to place the separator.

Based on DOE's review of products available on the market, DOE noted that at least one manufacturer offers a conventional electric oven that incorporates an oven separator. Based on DOE's testing of this unit, DOE observed a 13 to 18 percent relative increase in cooking efficiency associated with an oven separator.

Electronic spark ignition (gas only)

Based on DOE's review of products on the market and its reverse engineering analyses, DOE notes that gas ovens generally incorporate an electric "glo-bar" ignition system. The glo-bar ignition system uses a ceramic "glo"-type igniter. When the thermostat is set to a specific temperature, line voltage is applied to the igniter. Once energized, the igniter draws typically slightly over three amps and heats to a high temperature. In series with the igniter is a safety valve that is electrically activated. Once the igniter current drops to a pre-determined amperage, the safety valve opens, allowing gas to flow to the oven burner. The hot glo-bar igniter then ignites the oven burner. Because the safety valve remains open only when the glo-bar igniter is drawing the correct current, the igniter must continually draw power to keep the burner ignited.[37] Based on DOE's testing, the glo-bar ignition system consumed between 300 W and 450 W. Thus the electrical energy consumption of a glo-bar ignition system is significant (0.136 kWh and 0.217 kWh per cycle, with an average of 0.184 kWh per cycle).

DOE notes that the energy consumption could be reduced by replacing glo-bar ignition systems with an electronic spark ignition system. These igniters are controlled by switches that may be rotary-actuated so that when the burner valve is turned to the light position, a "starter" signal is sent to the control module. Alternatively, the signal can be generated by electronic controls on the user interface of the oven. Once the signal is received, the control module activates the spark igniters. The control module may be unsupervised, using a sensor located at the burner (often the igniter itself) to sense when the flame has been accidentally extinguished. The burner switches do not need to be re-activated, as the sensor sends a signal back to the control module to reactivate the igniters. Though they cost more, unsupervised ignition systems are preferred over systems that use supervised control modules since they prevent the need to check accidentally extinguished flames. DOE also identified battery-powered ignition systems as an alternative that does not require line power. Battery-powered ignition systems have been incorporated successfully in conventional ovens available on the U.S. market. Such intermittent spark ignition systems discussed above consume negligible amounts of electricity. Since the control module is powered directly from line voltage, there are no 24-volt transformer losses associated with it. The spark igniter is activated for an extremely short time period so that its cumulative on-time during the course of a year, and thus its electricity consumption, is negligible.

Reduced conduction losses

Conduction losses from the oven can be reduced by upgrading the oven door. This upgrade includes an additional thermal break and a modified inner panel. In the 1996 rulemaking, manufacturers stated that with existing instrumentation, the DOE test procedure cannot measure the small energy gains that can be obtained by attempting to reduce conduction losses.

However, manufacturers' data provided by AHAM for the 1996 TSD indicated that a very small efficiency increase is possible. The data indicate that only an absolute percentage point increase of 0.05 is expected from reducing conduction losses. No other data were obtained to demonstrate whether the efficiency increase should be any higher or lower.

Optimized burner and cavity design

As discussed in chapter 5 of this TSD, DOE testing and reverse engineering analyses revealed that gas cooking top efficiency was correlated to burner design (*e.g.*, grate weight, flame angle, distance from burner ports to the cooking surface). For example, DOE's testing indicated that reducing the thermal mass of the oven cavity can increase cooking efficiency. Energy is absorbed by the oven components as the oven warms to its operating temperature. By reducing the amount of material used in constructing the oven, the amount of energy that is absorbed is reduced and hence the efficiency increases. One method of achieving this thermal mass reduction is to reduce the gauge of sheet metal used in constructing the oven. Because oven cavity and burner design are interdependent, DOE is considering optimized burner and cavity design as a technology option for increasing efficiency for gas ovens consistent with products available on the market rather than the reduced thermal mass technology option considered for the previous rulemaking. Based on its testing, DOE believes that a 30.1 percent relative increase in cooking efficiency can be achieved through optimized burner and cavity design.

Reduced vent rate

Oven vents function primarily to remove the moisture present during the baking process. Self-clean ovens have reduced vent diameters to limit the air flow in accordance with combustion safety regulations during the high-temperature cleaning cycle. For safety reasons for the combustion process, the vent rate found in self-clean ovens cannot be reduced any further. But the vent rate of standard ovens can be reduced to the vent rate of self-clean ovens. This can be accomplished by either reducing the vent-tube size or adding a baffle. A reduction in vent rate causes a corresponding increase in efficiency.

As noted in the 2009 TSD, Manufacturers stated as part of the previous rulemakings that reduced vent rates should only be considered for standard electric ovens. The vent diameters of standard and self-clean gas ovens are not significantly different, since both oven types need to maintain a satisfactory combustion environment. With regard to standard electric ovens, manufacturers asserted that vent sizes are unique to the design of the oven. The vent size is critical in maintaining the oven's proper cooking and safety performance. According to the manufacturers, mandating a specific vent rate would require most oven models to be redesigned in order to maintain their proper performance.

But manufacturers' data provided by AHAM for the 1996 TSD indicated that the vent size of both standard electric and standard gas ovens could be reduced. Since all self-clean ovens are already designed with this technology, no new improvements are required by the industry to incorporate this technology option. Averaging the manufacturers' data with data obtained from the costing analysis of design options for residential appliances prepared by ADM Associates for LBNL[38] results in an increase of approximately 0.62 absolute percentage points for standard electric ovens and 0.5 absolute percentage points for standard gas ovens.

Reflective surfaces

Oven efficiency can be improved by incorporating reflective surfaces onto the walls of the oven cavity. Reflective surfaces improve the oven's performance by reflecting and retaining infrared radiation within the oven cavity, thus increasing the percentage of heat available to be transferred to the food load.

GRI performed tests on this technology option which resulted in a decrease in energy efficiency.[39] The reflective surface interfered with the convective currents and the thermostat, thus fooling the thermostat into cycling. GRI reported that increased reflectance from the chrome-plated inner surface of the oven caused repeated thermostat cycling that "might have contributed to the higher energy consumption," which resulted in a 12.61-percent decrease in energy efficiency. ADL also commented that the reflected radiation is different from the normal radiation emitted by the oven cavities currently in use.[40]

Based on these studies, it is uncertain whether, or how much, energy savings are realizable with this technology option. A smarter controller for the oven seems to be a reasonable fix for the thermostat cycling problem. However, there is a general lack of sophistication in the technology to maintain clean, reflective surfaces over the lifetime of the product. Manufacturers stated in the previous rulemaking that reflective surfaces degrade throughout the life of the oven, particularly for self-clean ovens.

3.12.3 Energy Efficiency

In preparation for the screening and engineering analyses, DOE gathered data on the energy efficiency of residential conventional ovens currently available in the marketplace. While this section is not intended to provide a complete characterization of the energy efficiency of all appliances currently available and in use, it does provide an overview of the energy efficiency of each product covered by this rulemaking.

Although not completely representative of the current U.S. cooking products market, Natural Resources Canada (NRCan) publishes a database of electric cooking appliance performance as measured by the applicable Canadian Standards Association (CSA) test procedures. The CSA test procedures for cooking appliances are equivalent to the existing DOE test procedures in Appendix I, except that they do not include the active mode fan-only mode, standby mode, and off mode testing provisions adopted in the October 2012 TP Final Rule discussed in section 3.4. The NRCan database covers products available in the Canadian market, which overlaps with the U.S. market. Data from the NRCan database are presented as the distribution of listed models as a function of annual energy consumption.

Figure 3.12.1 displays the annual energy consumption of electric ovens listed in the NRCan database. Because annual energy consumption is a function of cavity volume, DOE also presented the data from the NRCan database to show the distribution of annual energy consumption versus cavity volume in Figure 3.12.2.

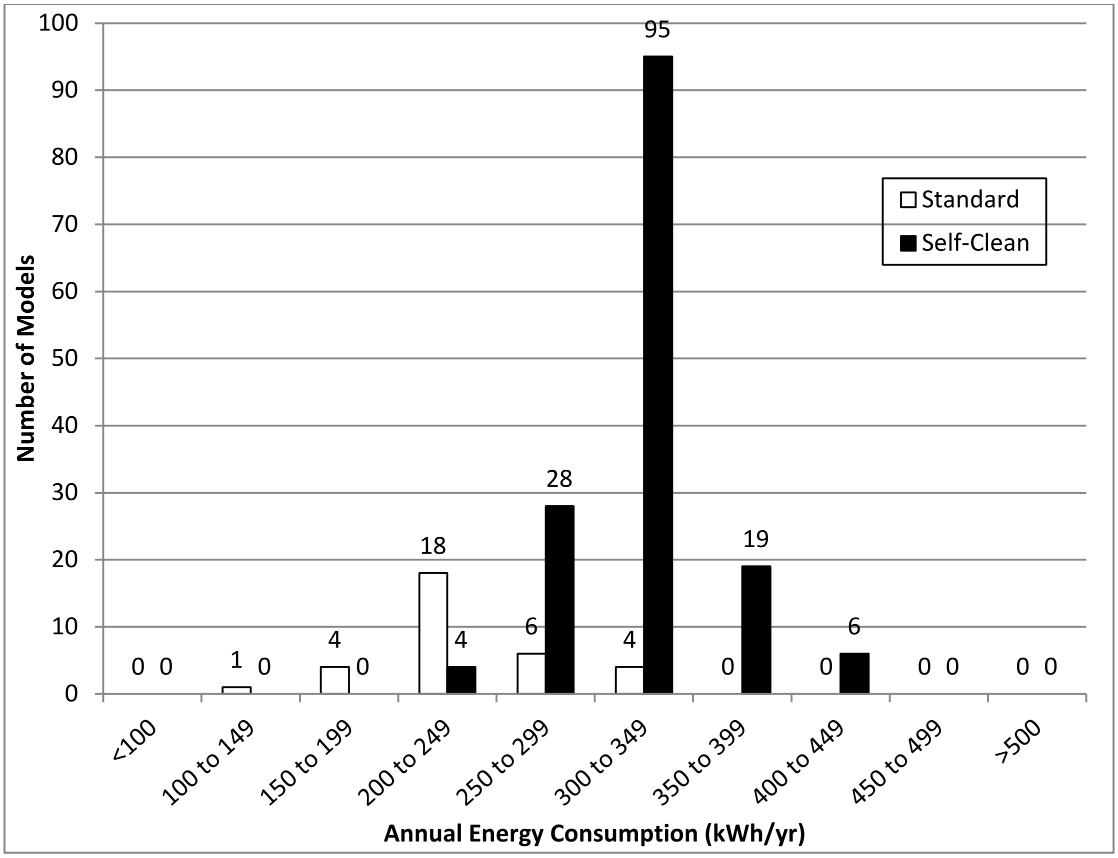

Figure 3.12.1 Electric Ovens in the NRCan Database – Number of Models as a Function of Annual Energy Consumption [41]

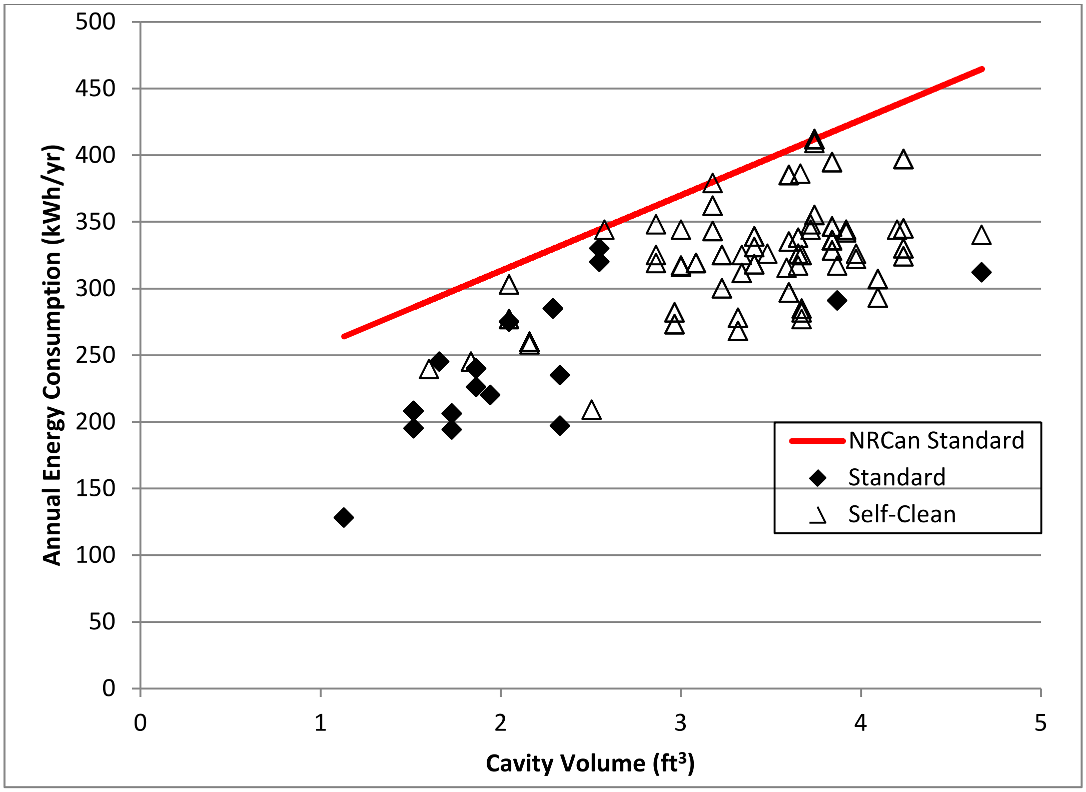

Figure 3.12.2 Electric Ovens in the NRCan Database – Annual Energy Consumption versus Cavity Volume[42]

REFERENCES

1 “The Share-of-Market Picture for 2008.” *32nd Annual Portrait of the U.S. Appliance Industry*, *Appliance Magazine*, September 2009.

2 *Ibid.*

3 “Electrolux takes on Whirlpool in U.S. with $3.3 billion GE Appliances buy,” Reuters, September 8, 2014, http://www.reuters.com/article/2014/09/08/us-general-electric-divestiture-idUSKBN0H30AG20140908. (Accessed October 13, 2014).

4 “The Share-of-Market Picture for 2008.” 2009. *Op. Cit.*

5 Association of Home Appliance Manufacturers (AHAM) *Fact Book* 2005.

6 AHAM *Fact Book* 2003.

7 U.S. Census Bureau. “New Residential Construction.” Available online at www.census.gov/construction/nrc/ (Accessed July 15, 2014).

8 AHAM *Fact Book* 2005.

9 “U.S. Appliance Shipment Statistics Monthly: January 2011”. *Appliance Magazine Market Research Report*, January 2011.

10 “2011 Full-Year Appliance Industry Shipment Statistics”. *Appliance Magazine Market Research Report*, March 2012.

11 “2012 Full-Year Appliance Industry Shipment Statistics & Year-In-Review”. *Appliance Magazine Market Research Report*, March 2013.

12 U.S. Census Bureau. 2011. Statistics

13 AHAM *Fact Book* 2003.

14 AHAM. *Import/Export Trade Report – December 2009*. 2010.

15 *Ibid*.

16 *Ibid*.

17 *Ibid*.

18 AHAM *Fact Book*. 2005.

---

19 “U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels”. *Appliance Magazine Market Research Report*, January 2010.

20 U.S. Census Bureau. 2006. “Statistics for Industry Groups and Industries: 2006 and Earlier Years.” *2006 Annual Survey of Manufacturers* (*ASM*), December 2006.

21 *Ibid.*

22 *Ibid.*

23 U.S. Census Bureau, *Survey of Plant Capacity: 2006 to 1994.*

24 D. DeWitt and M. Peart. 1982. *Bi-Radiant Oven: A Low-Energy Oven System*. Purdue University, West Lafayette, IN. Prepared for Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/Sub-80/0082/1, ORNL/Sub-80/0082/2, ORNL/Sub-80/0082/3, March 1982.

25 Whirlpool Corporation Product Literature. Available online at http://www.whirlpool.com/kitchen-1/cooking-2/wall-ovens-3/-[WOD93EC0AS]-1020949/WOD93EC0AS/ . (Accessed January 13, 2015.)

26 ORTECH. 1989. *Op. cit.*

27 Gas Research Institute (GRI). 1994. *Topical Report: Technical Input to NAECA Rulemaking for Gas-Fired Ranges*. Prepared by Battelle, Columbus, OH, American Gas Association Laboratories, Cleveland, OH, and ADL, Cambridge, MA for Gas Appliance Technology Center, Chicago, IL. Comment No. 001 to the NOPR, GRI-94/0195, July 1994.

28 ADL. 1994. *Op. cit.*

29 ADM. 1987. *Op. cit.*

30 ORTECH. 1989. *Op. cit.*

31 U.S. DOE. 1980. *Op. cit.*

32 *Ibid.*

33 GRI. 1994. *Op. cit.*

34 ORTECH. 1989. *Op. cit.*

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35 GRI. 1994. *Op. cit.*

36 *Ibid.*

37 P. Seibold. 1995. Personal Communications. Norton Company. Worcester, MA, March 1995.

38 ADM. 1987. *Op. cit.*

39 GRI. 1994. *Op. cit.*

40 ADL. 1994. *Op. cit.*

41 *Ibid.*

42 *Ibid.*

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 residential conventional ovens[a] (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 reduce energy consumption of the products covered in this rulemaking. The goal of the screening analysis is to identify any technologies that will be eliminated from further consideration in the rulemaking analyses.

For both electric and gas ovens, the corresponding candidate technology options are assessed based on DOE analysis as well as inputs from interested parties, including manufacturers, trade organizations, and energy efficiency advocates. Technology options that are judged to be viable approaches for improving energy efficiency are retained as inputs to the subsequent engineering analysis, and are designated as design options. Technology options that are not incorporated in commercial products or in working prototypes, or that fail to meet certain criteria as to practicability to manufacture, install and service, as to impacts on product utility or availability, or as to health or safety will be eliminated from consideration in accordance with *Energy Conservation Program for Consumer Products: Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products*. 61 FR at 36974 (July 15, 1996). The rationale for either screening out or retaining each technology option is detailed in the following sections.

4.2 DISCUSSION OF TECHNOLOGY OPTIONS

For residential conventional ovens, the screening criteria specified in section 4.1 were applied to the technology options to either retain or eliminate each technology from the engineering analysis.

4.2.1 Screened-Out Technology Options

The technologies identified in the market and technology assessment were evaluated pursuant to the criteria set out in The Energy Policy and Conservation Act, as amended (EPCA or the Act). (42 U.S.C. 6291–6309) EPCA provides criteria for prescribing new or amended standards, which will achieve the maximum improvement in energy efficiency the Secretary of Energy determines is technologically feasible. (42 U.S.C. 6295(o)(2)(A)) It also establishes

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[a] The term “conventional ovens” refers to residential electric and gas ovens or the oven component of a range, but not microwave ovens.

guidelines for determining whether a standard is economically justified. (42 U.S.C. 6295(o)(2)(B)) In view of the EPCA requirements for determining whether a standard is technologically feasible and economically justified, appendix A to subpart C of Title 10 Code of Federal Regulations part 430 (10 CFR part 430), *Procedures, Interpretations and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products* (the "Process Rule"), sets forth procedures to guide DOE in the consideration and promulgation of new or revised product efficiency standards under EPCA. These procedures elaborate on the statutory criteria provided in 42 U.S.C. 6295 and in part eliminate problematic technologies early in the process of revising an energy efficiency standard. Under the guidelines, DOE eliminates from consideration technologies that present unacceptable problems with respect to the following four factors:

(1) Technological feasibility. If it is determined that a technology has not been incorporated in commercial products or in working prototypes, then that technology will not be considered further.

(2) Practicability to manufacture, install, and service. If it is determined that mass production of a technology in commercial products and reliable installation and servicing of the technology could not be achieved on the scale necessary to serve the relevant market at the time of the effective date of the standard, then that technology will not be considered further.

(3) Impacts on product utility to consumers. If a technology is determined to have significant adverse impact on the utility of the product to significant subgroups of consumers, 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 be considered further.

(4) Safety of technologies. If it is determined that a technology will have significant adverse impacts on health or safety, it will not be considered further.

The following sections detail the technology options that were screened out for each product class covered by this rulemaking and the reasons why each were eliminated.

4.2.1.1 Electric and Gas Ovens

For electric and gas ovens, DOE screened out added insulation, bi-radiant oven, halogen lamp oven, no oven door window, and reflective surfaces, for the reasons that follow.

Added insulation

Although some analyses indicated energy consumption could be reduced by increasing the thickness of the insulation in the cabinet walls and doors from 2 inches to 4 inches, consumer utility would be negatively impacted, since the oven cavity volume would have to be reduced to maintain standardized exterior dimensions. The reduced oven cavity volume would limit the size of large items that could be cooked in the oven. For this reason, this technology option was not analyzed. However, it should be noted that improved insulation, consisting of higher-density insulation with the baseline 2-inch thickness, was still analyzed for standard gas and electric ovens. This higher-density insulation is already used for self-clean gas and electric ovens.

Bi-radiant oven (electric only)

The 1996 TSD assumed that three major conditions would have to be met in order to consider the bi-radiant oven as a viable technology option. These included the use of (1) low-emissivity cavity lining materials; (2) electronic controls; and (3) highly-absorptive baking and roasting utensils. While electronic controls are currently in widespread use in electric ovens, cavity maintenance issues and the requirement for specialized cookware negatively impact consumer utility. In addition, there is currently no such product on the market and the last working prototype known to DOE was tested in the 1970s.

Halogen lamp oven (electric only)

DOE is not aware of any ovens that utilize halogen lamps alone as the heating element, and no data were found or submitted to demonstrate how efficiently halogen elements alone perform relative to conventional ovens. DOE believes that it would not be practicable to manufacture, install and service halogen lamps for use in consumer ovens on the scale necessary to serve the relevant market at the time of the standard's effective date.

No oven door window

GRI issued a topical report[1] that discussed this technology option in the previous rulemaking. GRI's experimental tests showed a small savings in annual energy usage (increase in efficiency) for both the standard and self-clean ovens by eliminating the door window. However, GRI reported there could actually be a net energy loss due to consumer practices, which would be a function of the number of times a consumer would open the door to inspect the food while cooking. With four door openings per test, a standard oven would realize a net energy savings of 34 thousand British thermal units per year (kBtu/yr). For a self-clean oven there is a net energy loss of 3 kBtu/yr. The report also stated there would be reduced consumer utility and the possibility of failure of delicate food items (*e.g.,* soufflés), as well as decreased safety without the window due to increased risk of burns from additional door openings while the oven is in use.

Reflective surfaces

As noted in the 1996 TSD, manufacturers stated that it has been very difficult to obtain satisfactory cooking performance with reflective surfaces. The reflective materials degrade after the first baking function and continue to degrade through the life of the product. This is especially true of self-clean ovens, as the self-clean process damages the reflective walls and negates any possible energy savings.[2]

GRI[3] performed tests on this technology option that measured a decrease in energy efficiency. The reflective surface interfered with the convective currents and the thermostat, thus fooling the thermostat into cycling. GRI reported that increased reflectance from the chrome-plated inner surface of the oven caused repeated thermostat cycling that “might have contributed to the higher energy consumption” which resulted in a 12.61 percent decrease in energy efficiency. Arthur D. Little Inc. (ADL)[4] also commented that the reflected radiation was different from the normal radiation emitted by the oven cavities in use at the time.

Based on these studies, it is uncertain whether, or how much, energy savings is realizable with this technology option. A smarter controller for the oven could potentially compensate for the thermostat problems. However, there is a general lack of sophistication in the technology in terms of maintaining clean, reflective surfaces over the lifetime of the product. For these reasons, this technology option was not analyzed.

4.2.2 Remaining Design Options

The following sections list the technology options for both electric and gas conventional ovens that were retained by DOE and subsequently designated as design options. Each of these technologies were evaluated further in the subsequent engineering analysis.

Table 4.2.1 Retained Design Options for Electric and Gas Ovens

1. Electronic spark ignition (gas only)
2. Forced convection
3. Improved insulation
4. Improved door seals (standard ovens only)
5. Oven separator (electric only)
6. Reduced conduction losses
7. Reduced vent rate
8. Low-standby-loss electronic controls
9. Optimized burner and cavity design (gas only)

REFERENCES

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[1] *Ibid.*

[2] *Ibid.*

[3] GRI. 1994. *Op. cit.*

[4] Arthur D. Little Inc. (ADL). 1994. *Electric Oven and Cooktop Data Analysis*. Prepared by ADL, Cambridge, MA, for Association of Home Appliance Manufacturers, Reference 47066, submitted as comment No. 001 to the NOPR, July 15, 1994.

CHAPTER 5. ENGINEERING ANALYSIS

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CHAPTER 5. ENGINEERING ANALYSIS

5.1 INTRODUCTION

After conducting the screening analysis, the U.S. Department of Energy (DOE) performed an engineering analysis based on the remaining design options. The engineering analysis consists of estimating the energy consumption and costs of conventional ovens at various levels of increased efficiency. This section provides an overview of the engineering analysis (section 5.1), discusses product classes (section 5.2), establishes baseline and incremental efficiency levels (section 5.3), explains the methodology used during data gathering (section 5.4) and discusses the analysis and results (section 5.5).

The primary inputs to the engineering analysis are baseline information from the market and technology assessment (chapter 3 of this notice of proposed rulemaking (NOPR) technical support document (TSD) and technology options from the screening analysis (chapter 4). Additional inputs were determined through teardown analysis and manufacturer interviews. The primary output of the engineering analysis is a set of cost-efficiency curves. In the subsequent markups analysis (chapter 6), DOE determined customer (*i.e.*, product purchaser) prices by applying distribution markups, sales tax and contractor markups. After applying these markups, the cost-efficiency curves serve as the input to the building energy-use and end-use load characterization (chapter 7), and the life-cycle cost (LCC) and payback period (PBP) analyses (chapter 8).

DOE typically structures its engineering analysis around one of three methodologies. These are: (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 (BOM) derived from teardowns of the product or equipment being analyzed. Deciding which methodology to use for the engineering analysis depends on the covered product, the design options under study, and any historical data that DOE can draw on.

DOE stated in a request for information (RFI) notice published on February 12, 2014 (the February 2014 RFI) that in order to create the cost-efficiency relationship, it anticipated having to structure its engineering analysis using a design-option approach, supplemented by reverse engineering (physical teardowns and testing of existing products in the market) to identify the incremental cost and efficiency improvement associated with each design option or design option combination. In addition, DOE stated that it intended to consider cost-efficiency data from the 2009 *Final Rule Technical Support Document: Residential Dishwashers, Dehumidifiers, and Cooking Products and Commercial Clothes Washers* (2009 TSD), which was released as part of the most recent standards rulemaking.[a] 79 FR 8337, 8347. DOE maintained this approach for this NOPR. In addition, DOE conducted interviews with manufacturers of conventional ovens to develop a deeper understanding of the various combinations of design options used to increase product efficiency, and their associated manufacturing costs.

5.2 PRODUCT CLASSES ANALYZED

DOE separated residential cooking products into several product classes based on the energy source (*i.e.*, gas or electric) and installation configuration. These distinctions yielded eight conventional oven product classes.

For **electric ovens**, as discussed in previous rulemakings, DOE determined that the type of oven-cleaning system is a utility feature that affects performance. DOE also determined for this rulemaking that built-in and slide-in ovens are equipped with an additional exhaust fan and vent assembly that is not present in freestanding products, and which consumes additional energy in fan-only mode every cooking cycle. A more detailed discussion of installation configurations is provided in chapter 3. DOE analyzed the following product classes for electric ovens:

- Freestanding standard oven with or without a catalytic line;
- Built-in/slide-in standard oven with or without a catalytic line
- Freestanding self-cleaning oven; and
- Built-in/slide-in self-cleaning oven.

For **gas ovens**, DOE analyzed the following product classes based upon the same reasoning as electric ovens:

- Freestanding standard oven with or without a catalytic line;
- Built-in/slide-in standard oven with or without a catalytic line
- Freestanding self-cleaning oven; and
- Built-in/slide-in self-cleaning oven.

In summary, DOE analyzed the product classes listed in Table 5.2.1 for the NOPR.

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[a] Available online at *http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0127-0097*

Table 5.2.1 Proposed Product Classes for Conventional Cooking Products

Product Class	Product Type	Sub-Category	Installation Type
1	Electric oven	Standard with or without a catalytic line	Freestanding
2			Built-in/Slide-in
3		Self-clean	Freestanding
4			Built-in/Slide-in
5	Gas oven	Standard with or without a catalytic line	Freestanding
6			Built-in/Slide-in
7		Self-clean	Freestanding
8			Built-in/Slide-in

5.3 EFFICIENCY LEVELS

5.3.1 Baseline Efficiency Levels

A baseline unit is a product that just meets current Federal energy conservation standards. DOE analyzed the baseline units for each product class in the engineering analysis, and the subsequent LCC and PBP analyses. To determine energy savings and changes in price, DOE compared more energy-efficient units to the baseline unit.

As part of the February 2014 RFI, DOE initially developed baseline efficiency levels by considering the current standards for conventional gas ovens and the baseline efficiency levels for conventional electric ovens from the previous standards rulemaking analysis. DOE developed tentative baseline efficiency levels for the February 2014 RFI considering the current test procedure in Appendix I based on the integrated annual energy consumption (IAEC) metric combining active mode (including fan-only mode), standby mode, and off mode energy use. The baseline efficiency levels proposed in the February 2014 RFI are presented in Table 5.3.1. DOE developed baseline efficiency levels for standby mode and off mode based on test data presented in the microwave oven test procedure SNOPR that published on May 16, 2012 (77 FR 28805, 28811)[b]. For fan-only mode, DOE developed baseline efficiency levels considering the additional annual energy consumption in fan-only mode based on test data presented in an SNOPR for the conventional cooking products test procedure published on May 25, 2012. The efficiency levels are based on an oven with a cavity volume of 3.9 cubic feet (ft^3). 77 FR 31444, 31448.

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[b] In the May 2012 microwave oven test procedure SNOPR, DOE considered test procedure amendments for measuring the standby mode and off mode energy consumption of combined cooking products and, as a result, presented standby power data for microwave ovens, conventional cooking tops, and conventional ovens.

Table 5.3.1 February 2014 RFI Conventional Oven Baseline Efficiency Levels

Product Class	2009 Standards Rulemaking		Proposed Integrated Annual Energy Consumption (IAEC)
	Energy Factor (EF)	Annual Energy Consumption[c]	
Electric Oven – Standard Oven with or without a Catalytic Line	0.1066	274.9 kWh	370.0 kWh
Electric Oven – Self-Clean Oven	0.1099	266.6 kWh	360.0 kWh
Gas Oven – Standard Oven with or without a Catalytic Line	0.0536	1656.7 kBtu	2076.5 kBtu
Gas Oven – Self-Clean Oven	0.0540	1644.4 kBtu	1965.0 kBtu

DOE developed baseline efficiency levels for this NOPR considering both data from the previous standards rulemaking and the measured energy use of units in the DOE test sample based on the test procedure in Appendix I discussed in section 5.5.2. DOE also requested energy use data as part of the manufacturer interviews. However, because manufacturers are not currently required to conduct testing according to the DOE test procedure, very little energy use information was available. As a result, the baseline efficiency levels for this NOPR differ from those presented in the February 2014 RFI. DOE compared the minimum cooking efficiency measured in its test sample to the minimum cooking efficiency levels assumed for the previous standards rulemaking analysis. Often, the lowest measured efficiency in DOE's test sample for this NOPR was lower than the values for the previous rulemaking.

To update the baseline efficiency levels for conventional ovens, first DOE relied on the EF versus cavity volume relationship derived in the 2009 TSD and derived a new relationship between IAEC and cavity volume. Using the slope from the previous rulemaking, DOE selected new intercepts corresponding to the ovens in its test sample with the lowest efficiency, so that no ovens were cut off by the baseline curve. DOE then set baseline standby energy consumption for conventional ovens equal to that of the oven or range with the highest standby energy consumption in DOE's test sample to maintain the full functionality of controls for consumer utility. While only DOE test data was available to validate the baseline equation for gas ovens, DOE compared the new baseline equation for electric ovens with data available in the Natural Resources Canada (NRCan) databases, which showed that DOE's assumptions for slopes and intercepts reasonably represented the market. A detailed discussion of DOE's derivation of the cavity volume relationship is provided in 5.1.2.

In addition to the product classes proposed in the February 2014 RFI, DOE is also proposing separate product classes for freestanding and built-in/slide-in ovens as discussed in

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[c] DOE notes that the previous conventional cooking products test procedure in Appendix I included the clock energy consumption. As a result, DOE subtracted the clock energy consumption before adding the standby and off mode energy consumption when considering integrated efficiency levels for this standards rulemaking.

section 5.2. DOE developed separate baseline efficiency levels for these product classes by adding the maximum fan-only mode annual energy consumption measured in the test sample, as presented in section 5.5.2, to the baseline efficiency intercepts discussed above.

The proposed baseline efficiency levels for this NOPR are presented in Table 5.3.2. After receiving manufacturer feedback and reviewing products currently on the market, DOE determined that a cavity volume of 3.9 ft^3 no longer represents the market average. Thus, efficiency levels are based on an oven with a cavity volume of 4.3 ft^3.

Table 5.3.2 Conventional Oven Baseline Efficiency Levels

Product Class	Sub Type	Proposed IAEC*
Electric Oven – Standard Oven with or without a Catalytic Line	Freestanding	294.5 kWh
	Built-in/Slide-in	301.5 kWh
Electric Oven – Self-Clean Oven	Freestanding	355.0 kWh
	Built-in/Slide-in	361.1 kWh
Gas Oven – Standard Oven with or without a Catalytic Line	Freestanding	2118.2 kBtu
	Built-in/Slide-in	2128.1 kBtu
Gas Oven – Self-Clean Oven	Freestanding	1883.8 kBtu
	Built-in/Slide-in	1893.7 kBtu

* Proposed IAEC baseline efficiency levels are normalized based on a 4.3 ft^3 volume oven.

5.3.2 Incremental Efficiency Levels

For each product class, DOE analyzed several efficiency levels and determined the incremental cost at each of these levels. For the February 2014 RFI, DOE tentatively proposed the incremental efficiency levels presented in Table 5.3.3 through Table 5.3.6. DOE developed these levels based primarily on the efficiency levels presented in the 2009 TSD, adjusted to account for the proposed and amended test procedures. DOE also considered efficiency levels for standby mode and off mode associated with changing conventional linear power supplies to switch-mode power supplies (SMPS) and the Commission of the European Communities Regulation 1275/2008 (hereinafter “Ecodesign regulation”), which requires products to have a maximum standby power of 1 W. 79 FR 8337, 8345-6 (Feb. 12, 2014). The efficiency levels proposed in the February 2014 RFI are based on an oven with a cavity volume of 3.9 ft^3.

Table 5.3.3 February 2014 RFI Gas Standard Oven Efficiency Levels

Level	Efficiency Level Source	Proposed IAEC (*kBtu*)
Baseline	2009 TSD (Electric Glo-bar Ignition)	2076.5
1	2009 TSD (Electric Glo-bar Ignition) + SMPS	1932.0
2	2009 TSD (Improved Insulation) + SMPS	1844.2
3	2009 TSD (2 + Electronic Spark Ignition) + SMPS	1717.7
4	2009 TSD (3 + Improved Door Seals) + SMPS	1702.6
5	2009 TSD (4 + Reduced Vent Rate) + SMPS	1695.4
6	2009 TSD (5 + Reduced Conduction Losses) + SMPS	1685.9
7	2009 TSD (6 + Forced Convection) + SMPS	1636.0
8	2009 TSD (7) + 1W Standby	1499.1

Table 5.3.4 February 2014 RFI Gas Self-Clean Oven Efficiency Levels

Level	Efficiency Level Source	Proposed IAEC (*kBtu*)
Baseline	2009 TSD (Baseline)	1965.0
1	2009 TSD (Baseline) + SMPS	1820.5
2	2009 TSD (Forced Convection) + SMPS	1596.9
3	2009 TSD (2) + Electronic Spark Ignition + SMPS	1482.3
4	2009 TSD (3 + Improved Door Seals) + SMPS	1472.0
5	2009 TSD (4 + Reduced Conduction Losses) + SMPS	1467.8
6	2009 TSD (5) + 1 W Standby	1330.9

Table 5.3.5 February 2014 RFI Electric Standard Oven Efficiency Levels

Level	Efficiency Level Source	Proposed IAEC (*kWh*)
Baseline	2009 TSD (Baseline)	370.0
1	2009 TSD (Baseline) + SMPS	327.7
2	2009 TSD (Reduced Vent Rate) + SMPS	316.1
3	2009 TSD (2 + Improved Insulation) + SMPS	304.8
4	2009 TSD (3 + Improved Door Seals) + SMPS	300.9
5	2009 TSD (4 + Reduced Conduction Losses) + SMPS	300.3
6	2009 TSD (5 + Forced Convection) + SMPS	295.2
7	2009 TSD (6) + 1 W Standby	255.0

Table 5.3.6 February 2014 RFI Electric Self-Clean Oven Efficiency Levels

Level	Efficiency Level Source	Proposed IAEC (*kWh*)
Baseline	2009 TSD (Baseline)	360.0
1	2009 TSD (Baseline) + SMPS	317.7
2	2009 TSD (Reduced Conduction Losses) + SMPS	317.0
3	2009 TSD (2 + Forced Convection) + SMPS	312.0
4	2009 TSD (3) + 1 W Standby	271.9

The baseline efficiency levels for this NOPR differ from those presented in the February 2014 RFI. For the NOPR, DOE developed incremental efficiency levels for each product class by first considering information from the 2009 TSD. DOE retained the relative percent increase in efficiency determined in the previous rulemaking for reduced vent rate, improved insulation and door seals, and reduced conduction losses for all oven product classes.

DOE updated the incremental efficiency levels in cases where DOE identified design options during testing and reverse engineering performed in support of this NOPR. DOE's testing of conventional gas ovens showed that energy use was correlated to oven burner and cavity design (*e.g.*, thermal mass of the cavity and racks) and can be significantly reduced when optimized. Section 5.5.2 discusses how thermal mass, and in particular oven cavity thickness, relates to oven energy consumption and cooking efficiency. DOE determined the incremental increase in efficiency associated with optimized burner and cavity design by comparing the lowest measured efficiency for a gas oven having thin cavity walls and a low thermal mass to the lowest measured efficiency for a gas oven with cavity walls greater than 0.039 inches (1 mm) and a high thermal mass.

DOE also added an efficiency level for electric ovens based on test data for a unit in its test sample equipped with an oven separator. The oven separator allows the user to reduce the cavity volume that is used for cooking so that the individual cavities are more appropriately sized to the load and so that different temperature settings can be used simultaneously. DOE first determined the efficiency of the oven when measured without the separator and then measured with the separator according to the proposed test method in the December 2014 TP SNOPR. Noting that the efficiency benefit provided by the oven separator is dependent on cavity volume, DOE then used the slope discussed in section 5.1.2 to derive a new intercept for the IAEC versus cavity volume relationship and to determine the relative percent increase in efficiency due to the oven separator.

To develop the efficiency levels for the electronic spark ignition design option, DOE compared two gas ovens of similar design but different ignition systems (*i.e.*, glo-bar versus electronic spark ignition). Based on DOE's testing, electronic spark ignition systems resulted in a relative increase in cooking efficiency ranging from 8 to 11 percent, depending on the product class. DOE notes that these testing based estimates account for any contribution of the glo-bar ignition system to heating of the test load. DOE performed a similar analysis to update the incremental efficiency increase resulting from the use of forced convection, comparing the convection and non-convection modes for ovens of similar construction. The resulting relative increase in cooking efficiency ranged from 3.5 to 6 percent, depending on the product class.

DOE reevaluated the efficiency levels associated with standby power improvements based on product testing and reverse engineering. To determine standby power levels, DOE measured the standby power of the ovens and ranges in its test sample. The results are presented in section 5.5.2. As discussed in section 5.3.1, DOE selected the baseline standby power levels for conventional ovens based on the highest measured standby mode power consumption in DOE's test sample. Based on DOE's reverse engineering analyses, the baseline products were equipped with linear power supplies. DOE determined the reduction in standby power associated with changing from a linear power supply to a SMPS using the highest measured standby power for each power supply design to maintain the full functionality of controls for consumer utility. DOE reevaluated the efficiency levels associated with standby power improvements based on design options identified during product testing and reverse engineering rather than considering an efficiency level specifically associated with the 1-W Ecodesign regulation standby requirement.

DOE's testing of freestanding, built-in, and slide-in installation configurations for conventional gas and electric ovens revealed that built-in and slide-in ovens consume energy in fan-only mode, whereas freestanding ovens do not. The energy consumption in fan-only mode for built-in and slide-in ovens ranges from 1 watt-hour (Wh) to 32 Wh per cycle and can extend from 4.5 to 69 minutes after the cooking cycle ends. The percentage of annual energy consumption represented by fan-only mode ranged from 0.1 to 0.5 percent for gas ovens and 0.2 to 2.4 percent for electric ovens. The variation in fan-only mode energy consumption depends on the controls and oven cavity design. DOE developed separate baseline IAEC values for each installation configuration. DOE notes that the relative decrease in IAEC for each incremental efficiency level remained constant across installation configuration since fan-only mode energy consumption is independent of the design options retained for this NOPR.

Table 5.3.7 through Table 5.3.10 show the incremental efficiency levels for each product class, including the source for the derivation of the efficiency level, whether it be the analysis in the 2009 TSD or the updates described above based on testing for the NOPR. The efficiency levels are normalized based on an oven with a cavity volume of 4.3 ft^3.

Table 5.3.7 Electric Standard Oven Efficiency Levels

Level	**Efficiency Level Source**	**Design Option**	**Proposed IAEC (*kWh*)**	
			Freestanding	**Built-in / Slide-in**
Baseline	NOPR Testing	Baseline	294.5	301.5
1	NOPR Testing	Baseline + SMPS	284.6	291.4
2	2009 TSD	1 + Reduced Vent Rate	271.7	278.2
3	2009 TSD	2 + Improved Insulation	259.2	265.4
4	2009 TSD	3 + Improved Door Seals	254.9	261.0
5	NOPR Testing	4 + Forced Convection	244.6	250.5
6	NOPR Testing	5 + Oven Separator	207.8	212.8
7	2009 TSD	6 + Reduced Conduction Losses	207.3	212.2

Table 5.3.8 Electric Self-Clean Oven Efficiency Levels

Level	**Efficiency Level Source**	**Design Option**	**Proposed IAEC (*kWh*)**	
			Freestanding	**Built-in / Slide-in**
Baseline	NOPR Testing	Baseline	355.0	361.1
1	NOPR Testing	Baseline + SMPS	345.1	351.0
2	NOPR Testing	1 + Forced Convection	327.2	332.7
3	NOPR Testing	2 + Oven Separator	278.9	283.7
4	2009 TSD	3 + Reduced Conduction Losses	278.1	282.9

Table 5.3.9 Gas Standard Oven Efficiency Levels

Level	Efficiency Level Source	Design Option	Proposed IAEC (*kBtu*)	
			Freestanding	Built-in / Slide-in
Baseline	2009 TSD	Baseline	2118.2	2128.1
1	NOPR Testing	Baseline + Optimized Burner/Cavity	1649.3	1657.0
2	NOPR Testing	1 + SMPS	1614.7	1622.2
3	NOPR Testing	2 + Electronic Spark Ignition	1490.7	1497.7
4	2009 TSD	3 + Improved Insulation	1414.8	1421.5
5	2009 TSD	4 + Improved Door Seals	1400.6	1407.2
6	NOPR Testing	5 + Forced Convection	1355.6	1362.0
7	2009 TSD	6 + Reduced Conduction Losses	1347.0	1353.3

Table 5.3.10 Gas Self-Clean Oven Efficiency Levels

Level	Efficiency Level Source	Design Option	Proposed IAEC (*kBtu*)	
			Freestanding	Built-in / Slide-in
Baseline	2009 TSD	Baseline	1883.8	1893.7
1	NOPR Testing	Baseline + SMPS	1848.2	1858.0
2	NOPR Testing	1 + Electronic Spark Ignition	1668.7	1677.5
3	NOPR Testing	2 + Forced Convection	1596.3	1604.7
4	2009 TSD	3 + Reduced Conduction Losses	1591.0	1599.4

5.4 METHODOLOGY OVERVIEW

DOE relied on multiple sources of information for this engineering analysis. These sources include a review of TSDs from previous rulemakings, manufacturer interviews, internal product testing, and product teardowns.

5.4.1 Review of Previous Technical Support Documents and Models

DOE reviewed previous rulemaking TSDs to assess their applicability to the current standard setting process for residential conventional ovens. These previous rulemaking TSDs served as a source for design options and energy consumption analysis, in addition to other sources. For conventional ovens, the previous rulemaking TSD was developed in support of a final rule for establishing energy conservation standards for residential dishwashers, dehumidifiers, cooking products, and commercial clothes washers published in 2009. 74 FR 16040 (April 8, 2009).

5.4.2 Manufacturer Interviews

DOE understands that there is variability among manufacturers in baseline units, design strategies, and cost structures. To better understand and explain these variances, DOE conducted manufacturer interviews. These confidential interviews provided a deeper understanding of the various combinations of technologies used to increase residential conventional oven efficiency, and their associated manufacturing costs. DOE conducted interviews in advance of this NOPR analysis. Sample questions from the NOPR phase interviews are contained in appendix 12-A of this NOPR TSD.

During the interviews, DOE also gathered information about the capital expenditures required to increase the efficiency of the baseline units to various efficiency levels (*i.e.*, conversion capital expenditures by efficiency or energy-use level). The interviews provided information about the size and the nature of the capital investments. DOE also requested information about the depreciation method used to expense the conversion capital. The manufacturer impact analysis in chapter 12 of the NOPR TSD includes a discussion of this information obtained during manufacturer interviews.

5.4.3 Product Testing

Because most manufacturers do not currently perform product testing according to the existing DOE test procedure, DOE conducted its own investigative testing using methods proposed in the December 2014 TP SNOPR to develop a better understanding of the design options and product features currently available on the market. The investigative testing also allowed DOE to characterize the distribution of product energy consumption in the marketplace.

5.4.4 Product Teardowns

Other than obtaining detailed manufacturing costs directly from a manufacturer, the most accurate method for determining the production cost of a product is to disassemble representative units piece-by-piece and estimate the material, labor, and overhead costs associated with each component using a process commonly called a physical teardown. A supplementary method, called a catalog teardown, uses published manufacturer catalogs and supplementary component data to estimate the major physical differences between a product that has been physically disassembled and another similar product. DOE only performed a physical teardown analysis on conventional ovens and conventional ranges. The teardown methodology is explained in the following sections.

5.4.4.1 Selection of Units

DOE generally adopts the following criteria for selecting units for teardown analysis:

- The selected products should span the full range of efficiency levels for each product class under consideration. Because manufacturers are not currently required to report product efficiency or energy use, DOE selected test units based on a review of design options listed in product literature;
- Within each product class, the selected products should, if possible, come from the same manufacturer and belong to the same product platform;

- The selected products should, if possible, come from manufacturers with large market shares in that product class, although the highest efficiency products are chosen irrespective of manufacturer; and
- The selected products should have non-efficiency-related features that are the same as, or similar to, features of other products in the same class and at the same efficiency level.

5.4.4.2 Generation of Bill of Materials

The end result of each teardown is a structured BOM, which describes each product part and its relationship to the other parts, in the estimated order of assembly. The BOMs describe each fabrication and assembly operation in detail, including the type of value—added equipment needed (*e.g.*, stamping presses, injection molding machines, spot-welders, etc.) and the estimated cycle times associated with each conversion step. The result is a thorough and explicit model of the production process.

Materials in the BOM are divided between raw materials that require conversion steps to be made ready for assembly, while purchased parts are typically delivered ready for installation. The classification into raw materials or purchased parts is based on DOE's previous industry experience, recent information in trade publications, and discussions with original equipment manufacturers (OEMs). For purchased parts, the purchase price is based on volume-variable price quotations and detailed discussions with suppliers.

For parts fabricated in-house, the prices of the underlying "raw" metals (*e.g.*, tube, sheet metal) are estimated on the basis of 5-year averages to smooth out spikes in demand. Other "raw" materials such as plastic resins, insulation materials, etc. are estimated on a current-market basis. The costs of raw materials are based on manufacturer interviews, quotes from suppliers, secondary research, and by subscriptions to publications including the American Metals Market[d] (AMM). Past price quotes are indexed using applicable Bureau of Labor Statistics producer price index tables as well as AMM monthly data.

5.4.4.3 Cost Structure of the Spreadsheet Models

The manufacturing cost assessment methodology used is a detailed, component-focused technique for rigorously calculating the manufacturing cost of a product (direct materials, direct labor and some overhead costs). Figure 5.4.1 shows the three major steps in generating the manufacturing cost.

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[d] For information on American Metals Market, please visit: www.amm.com.

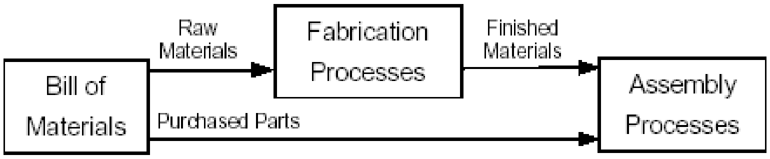

Figure 5.4.1 Manufacturing Cost Assessment Stages

The first step in the manufacturing cost assessment was the creation of a complete and structured BOM from the disassembly of the units selected for teardown. The units were dismantled, and each part was characterized according to weight, manufacturing processes used, dimensions, material, and quantity. The BOM incorporates all materials, components, and fasteners with estimates of raw material costs and purchased part costs. Assumptions on the sourcing of parts and in-house fabrication were based on industry experience, information in trade publications, and discussions with manufacturers. Interviews and plant visits were conducted with manufacturers to ensure accuracy on methodology and pricing.

Following the development of a detailed BOM, the major manufacturing processes were identified and developed for the spreadsheet model. Some of these processes are listed in Table 5.4.1.

Table 5.4.1 Major Manufacturing Processes

Fabrication	Finishing	Assembly/Joining	Quality Control
Fixturing Stamping/Pressing Brake Forming Cutting and Shearing Turret Punch Tube Forming	Washing Powder Coating Enameling De-burring Polishing	Adhesive Bonding Spot Welding Seam Welding Packaging	Inspecting & Testing

Fabrication process cycle times for each part made in-house were estimated and entered into the BOM. Based on estimated assembly and fabrication time requirements, the labor content of each appliance could be estimated. For this analysis, DOE estimated labor costs based on typical annual wages and benefits of industry employees.

Cycle requirements for fabrication steps were similarly aggregated by fabrication machine type while accounting for dedicated vs. non-dedicated machinery and/or change-over times (die swaps in a press, for example). 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: material, labor, and overhead.

Design options used in units subject to teardown are noted in the summary sheet of each cost model and are cost-estimated individually. Thus, various implementations of design options can be accommodated, ranging from assemblies that are entirely purchased to units that are made entirely from raw materials. Hybrid assemblies, consisting of purchased parts and parts made on site are thus also accommodated.

5.4.4.4 Cost Model and Definitions

The cost model is based on production activities and divides factory costs into the following categories:

- Materials: Purchased parts (*i.e.*, motors, valves, *etc*.), raw materials, (*i.e.*, cold rolled steel, copper tube, *etc*.), 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.

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 (out-sourced) 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.
- Supervisory labor: Labor associated with fabrication and assembly basis. Assigned on a span basis (x number of employees per supervisor) that depends on the industry.
- Indirect labor: Labor costs that scale with fabrication and assembly labor. These included the cost of technicians, manufacturing engineering support, stocking, *etc*. that are proportional to all other labor.
- Equipment depreciation: Money allocated to pay for initial equipment installation and replacement as the production equipment is amortized. All depreciation is assigned in a linear fashion and affected equipment life depends on the type of equipment.
- Tooling depreciation: Cost for initial tooling (including non-recurring engineering and debugging of the tools) and tooling replacement as it wears out or is rendered obsolete.
- 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 of unit cost.

5.4.4.5 Cost Model Assumptions

As discussed in the previous section, assumptions about manufacturer practices and cost structure played an important role in estimating the final product cost. 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. Site visits allowed DOE to confirm its cost model assumptions through direct observation of the manufacturing plant, as well as through manufacturer interviews, reviews of current Bureau of Labor Statistics data, etc.

5.5 ANALYSIS AND RESULTS

5.5.1 Manufacturer Interviews

DOE conducted interviews with residential conventional oven manufacturers to develop a better understanding of current product features and the technologies used to improve energy efficiency. The interviewed represent a wide range of U.S. market share and included both domestic and international companies that sell cooking products in the United States. During these interviews, DOE asked manufacturers questions about the following topics related to the engineering analysis:

- Product classes
- Design features of current baseline products
- Proposed incremental efficiency levels and design options
- Impacts on consumer utility
- Installation and repair costs as a function of efficiency

The discussion helped DOE understand what proposed design options have already been implemented and what additional design options DOE should consider.

The discussion below represents a consolidation of the manufacturer responses.

5.5.1.1 Product Classes

DOE asked manufacturers whether separate product classes were warranted for gas ovens with higher burner input rates, including products marketed as commercial-style. Manufacturers indicated that without an established test procedure, it was not possible to comment on whether commercial-style products warrant a separate product class. However, manufacturers generally agreed that the major difference between standard residential and commercial-style ovens and ranges was consumer-driven aesthetics and not performance.

5.5.1.2 Design Features of Current Baseline Products

DOE discussed the features of baseline products identified during the previous energy conservation standards rulemaking with manufacturers. Manufacturers generally stated that the baseline identified in the previous rulemaking may not be representative of products currently being sold on the market. Most manufacturers indicated that they do not currently test their conventional ovens according to the existing DOE test procedure and thus have limited or no data to help support a baseline estimate.

5.5.1.3 Proposed Incremental Efficiency Levels and Design Options

DOE asked manufacturers to comment on the incremental efficiency levels presented in the February 2014 RFI. In general, manufacturers were not able to provide feedback on the proposed incremental efficiency levels due to the lack of available data.

DOE also asked manufacturers to describe the changes associated with each active mode efficiency level relative to the baseline units in each product class. Manufacturers generally commented that there is little improvement available for insulation in most ovens. Given the consumer-based drive for ovens with larger cavity volumes, manufacturers claim to have already optimized insulation thickness and density to achieve the largest cavity size possible while still meeting exterior surface temperature safety requirements. Manufacturers stated there is little room for improvement in oven door seals beyond those already rated for use in self-clean ovens.

5.5.1.4 Oven Energy Consumption as a Function of Cavity Volume

DOE asked manufacturers how oven energy consumption may scale with cavity volume. Manufacturers stated that ovens with smaller cavities are generally more efficient but did not supply data to support this statement.

5.5.1.5 Impact on Consumer Utility

DOE asked manufacturers how the design option changes identified in the February 2014 RFI may impact consumer utility. Manufacturers indicated that if an energy conservation standard resulted in reduced burner input rates for ovens, pre-heat and overall cooking times may be affected. Manufacturers stated that pre-heat and faster cooking times are important consumer features.

5.5.2 Product Testing

DOE’s oven test procedure in Appendix I involves setting the oven controls to achieve an average internal cavity temperature that is 325° ± 5 °F higher than the room ambient air temperature and measuring the amount of energy required to raise the temperature of an aluminum block test load at room temperature by 234 °F above its initial temperature. The measured energy consumption includes the energy input during the time the load is being heated plus the energy consumed during fan-only mode. In the December 2014 TP SNOPR, DOE did not modify the active mode test method but proposed to incorporate methods for measuring conventional oven volume according to an AHAM procedure[e], to clarify that the existing oven test block must be used to test all ovens regardless of input rate, and to measure the energy consumption and efficiency of conventional ovens equipped with an oven separator. 79 FR 71894.

The annual primary energy consumption for cooking, E_{CO}, for electric ovens and for gas ovens, is defined as:

$E_{CO} = \frac{E_O \times K_e \times O_O}{W_1 \times C_p \times T_S}$ for electric ovens, where,

E_O = test energy consumption, as measured,
K_e = 3.412 Btu/Wh (3.6 kJ/Wh,) conversion factor of watt-hours to Btus,
O_O = 29.3 kWh (105,480 kJ) per year, annual useful cooking energy output of conventional electric oven,
W_1 = measured weight of test block in pounds (kg),
C_p = 0.23 Btu/lb-°F (0.96 kJ/kg ÷ °C), specific heat of test block,
T_S = 234 °F (130 °C), temperature rise of test block.

$E_{CO} = \frac{E_O \times O_O}{W_1 \times C_p \times T_S}$ for gas ovens, where,

E_O = test energy consumption, as measured
O_O = 88.8 kBtu (93,684 kJ) per year, annual useful cooking energy output of conventional gas oven,
and W_1, C_p and T_S are the same as defined above.

The DOE test procedure also includes a method for measuring the annual primary energy consumption for conventional oven self-cleaning operations, and the secondary energy consumption of a gas oven that uses electrical energy consumption for the ignition system and the display. The total integrated annual electrical energy consumption, IAEC, is defined as the sum of the annual energy consumption in each of these modes:

$IAEC = E_{CO} + E_{SO} + E_{SC} + E_{SS} + E_{OTLP} + (E_{OF} \times N_O)$ where,

E_{SO} = annual secondary (electrical) cooking energy consumption for gas ovens only,
E_{SC} = annual self-cleaning energy consumption,
E_{SS} = annual secondary (electrical) self-cleaning energy consumption,

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[e] The test standard published by the Association of Home Appliance Manufacturers titled, “Procedures for the Determination and Expression of the Volume of Household Microwave and Conventional Ovens,” Standard OV-1-2011

E_{OTLP} = annual standby mode energy consumption,
E_{OF} = fan-only mode energy consumption as measured in section 3.2.1.2 of this appendix,
N_O = representative number of annual conventional electric or gas oven cooking cycles per year, depending on the fuel type.

In support of this NOPR analysis, DOE selected a test sample which included units representing each product class. DOE then performed testing according to the proposed clarifications in the December 2014 TP SNOPR. DOE used this data to help determine appropriate product classes (as discussed in chapter 3 of this TSD) and efficiency levels, and to determine whether certain design changes resulted in reduced product energy consumption.

5.5.2.1 Product Selection

DOE conducted a market survey of conventional oven and range models and their associated features to identify the primary differentiators among commercially-available units. Because there are no performance-based energy conservation standards or energy reporting requirements for conventional ovens, DOE selected test units based on performance-related features and technologies advertised in product literature. These features included, among other things: 1) whether or not the product was marketed as commercial-style or professional-style; 2) oven fuel type; 3) oven cavity volume in ft^3; 4) the presence of a forced convection cooking function; and 5) oven installation configuration (*i.e.*, built-in/slide-in versus freestanding). DOE's test sample included 1 gas wall oven, 7 gas ranges, 5 electric wall ovens, and 2 electric ranges for a total of 15 conventional ovens covering all of the product classes considered in this NOPR. The key parameters for each of the test units are presented in Table 5.5.1 through Table 5.5.2.

Table 5.5.1 DOE Conventional Gas Oven Test Units

Test Unit #	Type	Installation Configuration	Burner Input Rate (*Btu/h*)	Cavity Volume (*ft^3*)	Ignition Type	Convection (Y/N)
1	Standard	Freestanding	18,000	4.8	Spark	N
2	Standard	Freestanding	18,000	4.8	Glo-bar	N
3	Self-Clean	Freestanding	18,000	5.0	Glo-bar	Y
4	Standard	Freestanding	16,500	4.4	Glo-bar	N
5	Self-Clean	Built-in	13,000	2.8	Glo-bar	N
6	Standard	Freestanding	28,000	5.3	Glo-bar	Y
7	Standard	Slide-in	27,000	4.4	Glo-bar	Y
8	Standard	Freestanding	30,000	5.4	Glo-bar	Y

Table 5.5.2 DOE Conventional Electric Oven Test Units

Test Unit #	Type	Installation Configuration	Heating Element Wattage (*W*)	Cavity Volume (*ft^3*)	Convection (Y/N)
1	Self-Clean	Freestanding	3,000	5.9*	Y
2	Standard	Freestanding	2,000	2.4	N
3	Self-Clean	Built-in	3,400	2.7	N
4	Standard	Built-in	2,600	4.3	N
5	Self-Clean	Built-in	2,600	4.3	N
6	Self-Clean	Built-in	2,600	4.3	Y
7	Self-Clean	Built-in	2,800	4.3**	N

* Test Unit 1 was equipped with an oven separator that allowed for splitting the single cavity into two separate smaller cavities with volumes of 2.7 ft^3 and 3.0 ft^3.

** Test Unit 7 was a double oven having two separate cavities with equal volumes. According to the DOE test procedure in Appendix I, the measured energy consumption for these cavities are averaged together.

Several units were selected from a single manufacturer that appeared to have similar construction, rated power, and volume, but differed in ancillary features such as whether or not the product was equipped with self-clean or forced convection. The range of input rates and cavity volumes were determined on the basis of manufacturer specifications. Products marketed as commercial-style or professional-style typically had oven burner input rates above 18,000 Btu/h.

5.5.2.2 Test Results and Derivation of Incremental Efficiency Levels

As discussed above, each test unit was evaluated according to the oven test procedure proposed in the December 2014 TP SNOPR. Results are presented below as cooking efficiency and/or IAEC where appropriate. IAEC includes active mode (including fan-only mode for conventional ovens), standby mode, and off mode energy use.

Table 5.5.3 presents the testing results for conventional gas ovens in DOE’s test sample. Because oven cooking efficiency and energy consumption depend on cavity volume, DOE normalized IAEC using the relationship between energy consumption and cavity volume discussed in section 5.1.2 for comparison.

Table 5.5.3 DOE Conventional Gas Oven Test Results

Test Unit #[**]	Oven Product Class	Cavity Volume (ft^3)	Oven Cooking Efficiency	Fan-Only Mode Energy Use Per Cycle (*kWh*)	IAEC (*kBtu/yr*)	Normalized IAEC[*] (*kBtu/yr*)
1	Gas Standard – Freestanding	4.8	6.6%	0.000	1341.4	1234.2
2	Gas Standard – Freestanding	4.8	6.0%	0.000	1503.7	1396.5
3	Gas Self-Clean - Freestanding	5.0	7.6%	0.000	1419.0	1269.0
4	Gas Standard – Freestanding	4.4	6.2%	0.000	1516.6	1495.2
5	Gas Self-Clean – Built-in/Slide-in	2.8	9.4%	0.001	1171.3	1492.9
6	Gas Standard – Freestanding	5.3	4.3%	0.000	2078.9	1864.5
7	Gas Standard – Built-in/Slide-in	4.4	5.2%	0.016	1938.0	1916.5
8	Gas Standard – Freestanding	5.4	3.9%	0.000	2315.1	2079.3

* Measured IAEC normalized to a fixed cavity volume of 4.3 ft^3.
** Units 6, 7, and 8 have oven burner input rates greater than 18,000 Btu/h and were marketed as commercial-style.

The normalized IAEC for conventional gas ovens ranged from 1148 to 1994 kBtu/year, with lower IAEC corresponding to less energy consumption. DOE separated freestanding ovens and built-in/slide-in ovens into different product classes, as noted in section 5.2, because these products consume additional energy required by exhausting air from the oven cavity to meet safety-related temperature requirements since the oven is enclosed in cabinetry.

As discussed in chapter 3, through testing, reverse engineering analyses, and discussions with manufacturers, DOE determined that the major differentiation between conventional gas ovens with lower burner input rates and those with higher input rates, including those marketed as commercial-style, was design and construction related to aesthetics rather than improved cooking performance. DOE also believes that the high thermal mass of products marketed as commercial-style could lead to a low oven cooking efficiency and possibly require higher oven input rates to compensate for the heat lost to heating the cavity. In order to quantify the impact on cooking efficiency and energy consumption, due to decreasing the mass of the oven cavity, DOE compared the cooking efficiency of the gas oven to the normalized cavity volume as shown in Figure 5.5.1. DOE normalized both the measured cooking efficiency and the mass of the cavity to a single volume of 4.3 ft^3. The mass of the cavity walls were scaled by cavity dimensions and the oven rack by length.

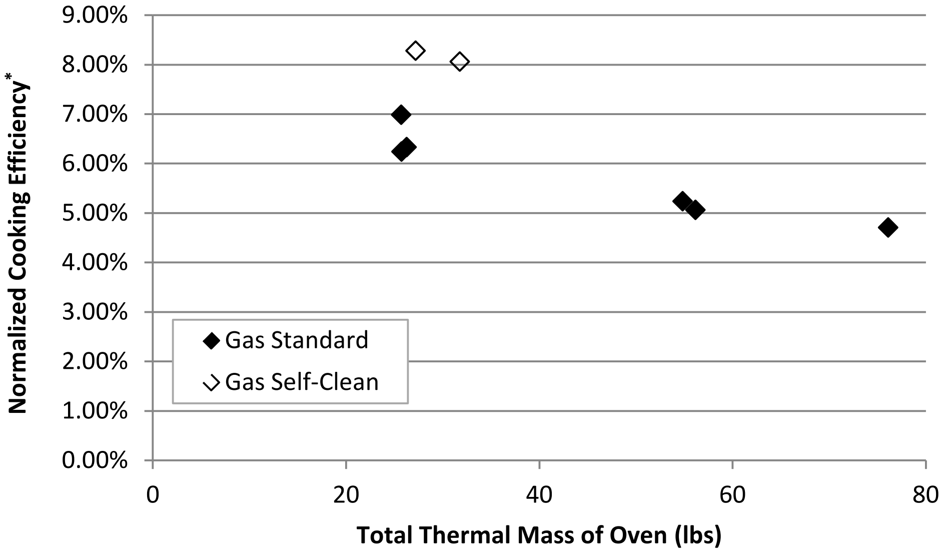

Figure 5.5.1 Conventional Gas Oven Energy Factor versus Thermal Mass[f]

Figure 5.5.1 shows that cooking efficiency decreases with increasing thermal mass for conventional gas ovens. DOE's reverse engineering also confirmed that thicker cavity walls and heavier racks were the primary differences contributing to the increased thermal mass of the ovens marketed as commercial-style. In review of the preparatory studies for the European Commission Ecodesign Requirements for ovens[g], DOE noted that "modern ovens" in the European Union (EU) comprise steel having a thickness of approximately 0.039 inches (1 mm) while older and less efficient ovens had cavity thicknesses greater than 0.039 inches. Results from DOE's reverse engineering analysis showed that the gas ovens included in DOE's test sample with the lowest efficiencies had cavity wall thicknesses greater than 0.039 inches and the heaviest racks. In contrast, the gas ovens with the highest efficiencies had cavity wall thicknesses of less than 0.039 inches, suggesting that thicker cavities, and thus larger mass, leads to lower cooking efficiency for gas ovens.

DOE updated its estimates from the previous rulemaking for the measured energy use of ovens with glo-bar ignition by measuring the disaggregated energy use for the ignition system during the cooking cycle. Table 5.5.4 contains the glo-bar power and per-cycle energy consumption measured in DOE's test sample.

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[f] Measured cooking efficiency normalized to a fixed cavity volume of 4.3 ft^3.

[g] Lot 22 – Domestic and commercial ovens (electric, gas, microwave), including when incorporated in cookers – Task 4: Technical analysis of existing products. August 2011. Available at: http://www.eceee.org/ecodesign/products/Lot22_23_kitchen/Lot22_Task4_Final.pdf

Table 5.5.4 Glo-bar Energy Consumption for Gas Ovens

Test Unit #	Source	Oven Product Class	Average Glo-bar Power (*W*)	Electrical Energy Consumption Per Cycle (*Wh*)
1*	Gas	Gas Standard – Freestanding	0	0
2	Gas	Gas Standard – Freestanding	403.6	173.9
3	Gas	Gas Self-Clean - Freestanding	403.7	186.5
4	Gas	Gas Standard – Freestanding	408.1	182.9
5	Gas	Gas Self-Clean – Built-in/Slide-in	312.8	135.9
6	Gas	Gas Standard – Freestanding	389.1	210.1
7	Gas	Gas Standard – Built-in/Slide-in	437.0	179.6
8	Gas	Gas Standard – Freestanding	413.3	217.3

* Unit 1 had a battery powered electronic spark ignition system.

Based on DOE's testing of units in its test sample, the average, measured glo-bar power ranged from 313 W to 437 W. Electric glo-bar ignition systems for units in DOE's test sample consumed between 0.136 kWh to 0.217 kWh per cycle, with an average of 0.184 kWh per cycle. DOE notes that the glo-bar energy consumption may vary depending on burner and cavity design (*e.g.*, burner input rating, cavity volume). DOE also notes that the glo-bar ignition system was not powered on throughout the entire cooking cycle and only consumed power when gas flow to the burner was on, turning off when the burner cycled off. Any contribution of the glo-bar ignition system to heating the load would be accounted for in testing according to the DOE test procedure in Appendix I. Conversely, the gas flow in the oven using a battery powered electronic spark ignition system remained on continuously. As discussed in section 5.3.2, DOE updated its efficiency level analysis by first comparing energy consumption of a gas oven with glo-bar ignition to electronic spark ignition.

Table 5.5.5 presents the testing results for conventional electric ovens in the test sample. As with gas ovens, DOE normalized IAEC using the energy consumption versus cavity volume relationship discussed in section 5.1.2 for comparison between units of differing cavity volume.

Table 5.5.5 DOE Conventional Electric Oven Test Results

Test Unit #	Oven Product Class	Cavity Volume (ft^3)	Oven Cooking Efficiency	Fan-Only Mode Energy Use Per Cycle (*kWh*)	IAEC (*kWh/yr*)	Normalized IAEC** (*kWh/yr*)
1	Electric Self-Clean – Freestanding	5.9*	13.1%	0.000	266.2	198.6
2	Electric Standard – Freestanding	2.4	14.4%	0.000	213.7	274.1
3	Electric Self-Clean – Built-in/Slide-in	2.7	22.5%	0.002	158.7	226.4
4	Electric Standard – Built-in/Slide-in	4.3	10.6%	0.032	287.8	287.8
5	Electric Self-Clean – Built-in/Slide-in	4.3	10.9%	0.032	308.8	308.8
6	Electric Self-Clean – Built-in/Slide-in	4.3	9.9%	0.031	341.8	341.8
7	Electric Self-Clean – Built-in/Slide-in	4.3	10.0%	0.030	370.0	370.0

* Test Unit 1 was equipped with an oven separator that allowed for splitting the single cavity into two separate smaller cavities with volumes of 2.7 ft^3 and 3.0 ft^3.

** Measured cooking efficiency normalized to a fixed cavity volume of 4.3 ft^3.

The normalized IAEC for conventional electric ovens ranged from 274 to 288 kWh/year for standard ovens and 199 to 370 kWh/year for self-clean ovens. For the same reasons as conventional gas ovens, DOE separated freestanding and built-in/slide-in ovens into different product classes.

As IAEC takes into account any standby power consumed by electronic controls in addition to any active mode energy consumption, DOE measured standby power for the ovens and ranges in DOE's test sample according to the test procedure specified in Appendix I. Table 5.5.6 and Table 5.5.7 list measured standby power values for both ovens and ranges. Those units in the test sample that did not consume energy in a standby or off mode are not listed.

Table 5.5.6 Standby Power of Ovens in the DOE Test Sample

Product Class	Standby Power (W)	Power Supply Type
Electric Self-Clean Built-in/Slide-in	1.72	Linear
Electric Standard Built-in/Slide-in	0.53	SMPS
Electric Self-Clean Built-in/Slide-in	0.66	SMPS
Electric Self-Clean Built-in/Slide-in	0.84	SMPS
Electric Self-Clean Built-in/Slide-in	1.61	SMPS
Gas Self-Clean Built-in/Slide-in	1.67	Linear

Table 5.5.7 Standby Power of Ranges in the DOE Test Sample

Product Class	Standby Power (W)	Power Supply Type
Electric Self-Clean Oven Built-in/Slide-in	1.19	SMPS
Electric Standard Oven Freestanding	1.23	Linear
Gas Self-Clean Oven Freestanding	1.61	Linear
Gas Standard Oven Freestanding	2.15	Linear
Gas Standard Oven Freestanding	0.79	Linear

As noted in section 5.3.1, DOE set baseline standby energy consumption for conventional ovens equal to that of the oven/range with the highest standby energy consumption in the test sample in order to maintain the full functionality of controls for consumer utility. Comparing results in Table 5.5.6 to Table 5.5.7, standby energy consumption was consistently higher for conventional ranges than for ovens that were not part of a range. Thus, DOE used standby measured for conventional ranges to establish the baseline.

5.5.3 Product Teardowns

After conducting the investigative testing described in the previous section, DOE conducted teardowns on all 15 of its test units. The test units spanned the range of product efficiencies and features available on the market from multiple manufacturers. DOE relied on the cooking product teardowns to supplement the information gained through manufacturer interviews and to investigate performance observed during testing. Specifically, the teardowns allowed DOE to identify design features for improving efficiency and to develop corresponding manufacturing costs for products at different efficiency levels.

5.5.3.1 Baseline Construction

Baseline Gas Ovens

The interior surface of the oven cavity for the gas ovens in DOE’s teardown sample had a porcelain enamel coating for durability and cleanability. Accessories such as an incandescent light to illuminate the food load without having to open the oven door and a temperature sensor for control of cooking processes were also located within the cavity. The metal pieces comprising the cavity walls were formed by stamping and had grooves to support oven racks. The back of the cavity was typically its own metal piece mechanically sealed to the top, bottom, and sides, which were composed of a single wrapped piece of sheet metal. Cavity construction did vary slightly by manufacturer. Baseline ovens were typically equipped with two to three oven racks made of enamel-coated steel rods.

The outside of the oven cavity was wrapped with insulation and DOE observed that the space between the cavity and the outer sheet metal enclosure was made as small as practically possible in order to maximize the cavity volume. Combustion products from the burner and gases released in the interior cavity during the cooking process are vented from the top of the cavity through a sheet metal air channel using natural convection. As discussed in previous sections, built-in/slide-in ovens had an added fan, motor, and vent assembly to provide cooling and venting for combustion byproducts. DOE also observed that some gas ovens in its test sample incorporated additional air channels between the exterior oven shell and the layer of insulation around the interior cavity to provide an added layer of insulation, keeping the outer sheet metal enclosure within a safe temperature range

The gas burners performing the bake function were situated at the bottom of the oven cavity. The bake element was shielded by a baffle to help distribute heat evenly but was also shielded by the cavity base which partially conceals the element to prevent damage from food spills. Broil burners were sometimes located at the top of the oven cavity but for many baseline products, a drawer was added below the main cavity so that the same bake burner could be employed for broiling. In baseline products, DOE observed that the bake burner was ignited with a glo-bar, or hot-surface igniter. A bi-metallic gas valve in electrical series with the igniter deformed as current in the circuit increases, allowing gas to flow as long as the hot surface igniter was energized by the burner controller.

All of the gas ovens examined had a door attached by two hinges at the bottom of the oven cavity opening. The oven door had an interior enamel-coated panel, a dual-pane glass window surrounded by insulation, and an exterior panel consisting typically consisting of ceramic glass or sheet metal. For standard ovens, baseline products had a silicone rubber gasket lining the perimeter of the cavity opening, but for self-clean ovens, even baseline products had a fiberglass door seal lined with a metallic mesh.

DOE observed that baseline gas ovens primarily had either electromechanical controls or electronic controls although the self-cleaning function required electronic control and a door locking mechanism for gas self-clean ovens. For gas ovens with electronic controls, the user interface and clock display were a push-button control panel with a Liquid Crystal Display (LCD) or Light-Emitting Diode (LED) display.

Baseline Electric Ovens

The baseline electric oven cavities examined by DOE were similar in construction to gas ovens. Accessories, insulation, and door seals were also made of the same materials. The primary difference in construction between gas and electric ovens observed by DOE was that the bake and broil heating elements were radiant elements made up of a composite metal rod. The bake elements, while still located at the bottom of the cavity were unshielded in the baseline products. Additionally, baseline electric ovens featured electronic controls incorporating a push-button control panel and either an LCD or LED display.

5.5.4 Conventional Oven Energy Use versus Volume

The conventional oven efficiency levels detailed in the previous sections are predicated upon baseline ovens with a cavity volume of 4.3 ft^3. Based on DOE's testing of conventional gas and electric ovens and discussions with manufacturers, IAEC scales with oven cavity volume due to the fact that larger ovens have higher thermal masses and larger volumes of air (including larger vent rates) than smaller ovens. Because the DOE test procedure for measuring IAEC uses a fixed test load size, larger ovens with higher thermal mass will have a higher measured IAEC. As a result, DOE considered available data to characterize the relationship between IAEC and oven cavity volume.

DOE determined the slope of the baseline curves by first reviewing data from the 2009 TSD, which presented a relationship between measured energy factor (EF) and cavity volume for each product class. DOE believes these slopes continue to be relevant based on DOE's testing described in the previous sections. Because DOE is proposing to use IAEC to establish incremental efficiency levels in this NOPR, DOE translated the EF determined using the 2009 TSD relationship to IAEC by assuming a baseline standby mode energy consumption. DOE plotted baseline IAEC versus cavity volume for each product class and compared it to the measured test data discussed in section 5.5.2 as shown in Figure 5.5.2 through Figure 5.5.5.

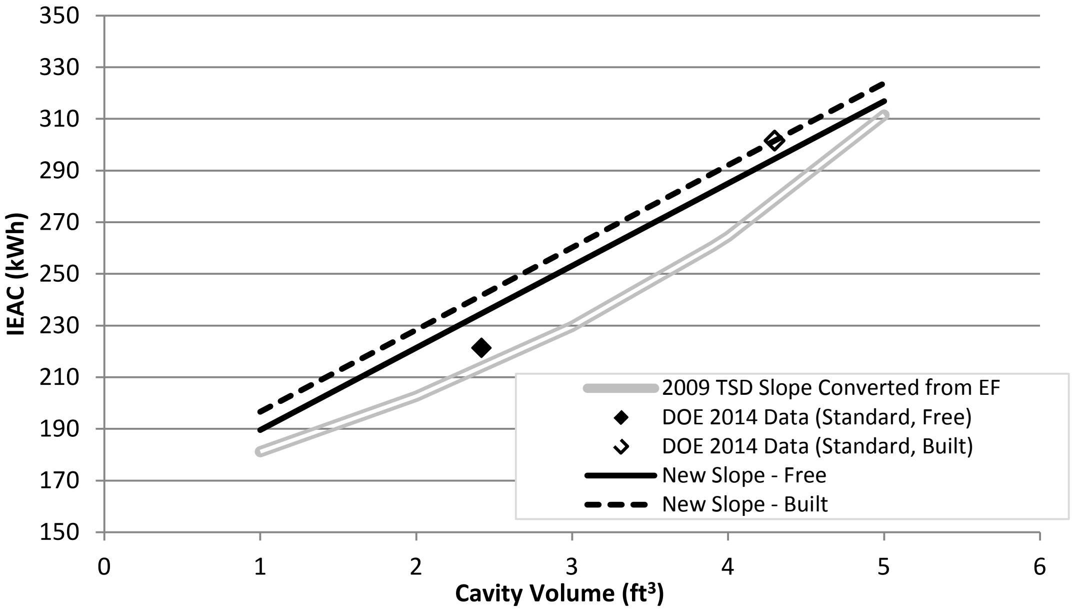

Figure 5.5.2 Electric Standard Oven Slope

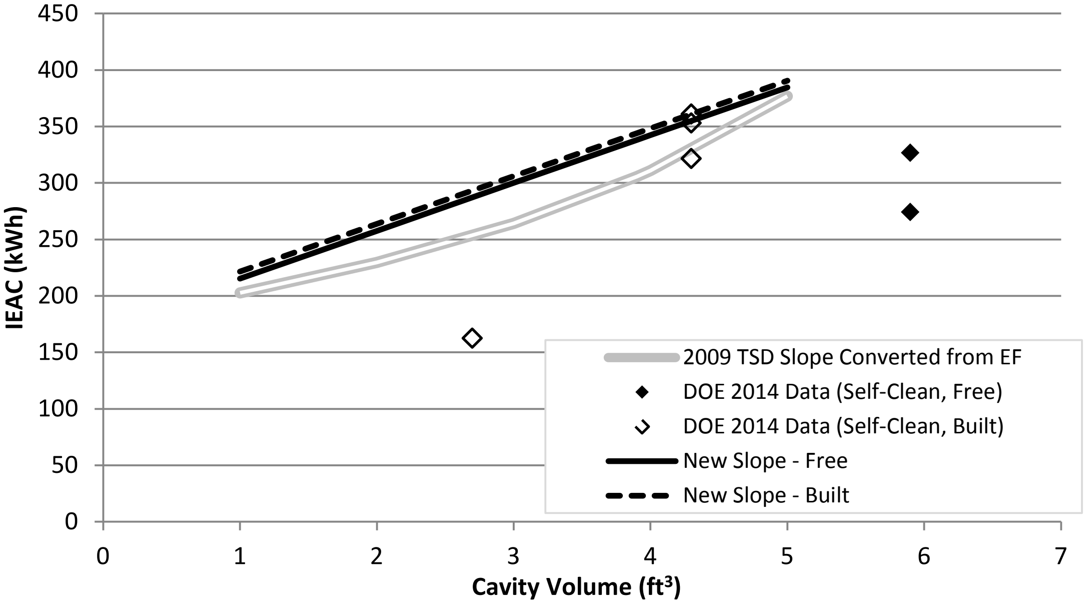

Figure 5.5.3 Electric Self-Clean Slope

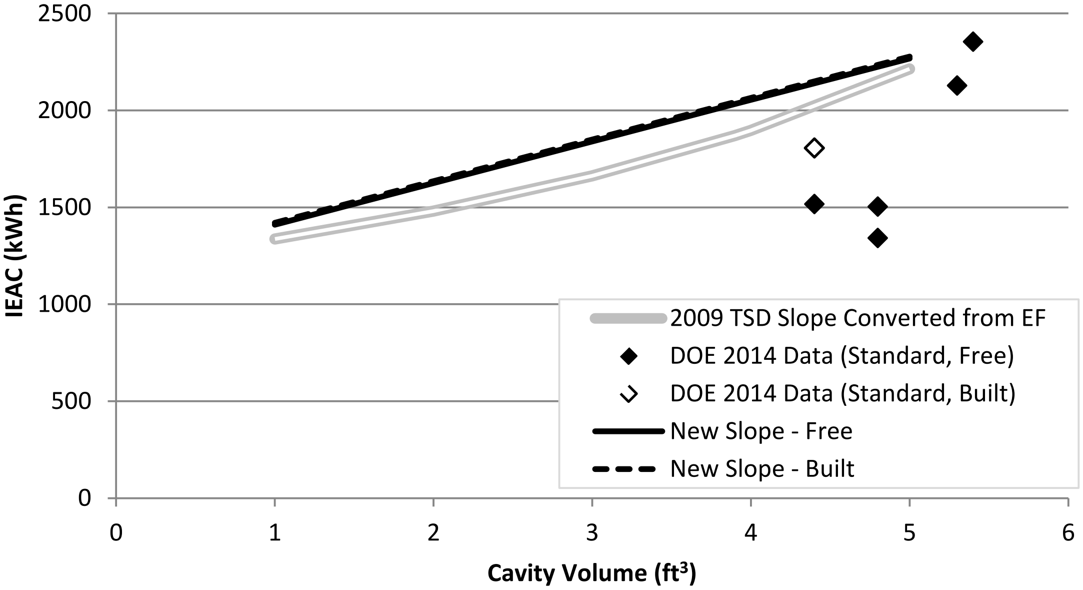

Figure 5.5.4 Gas Standard Oven Slope

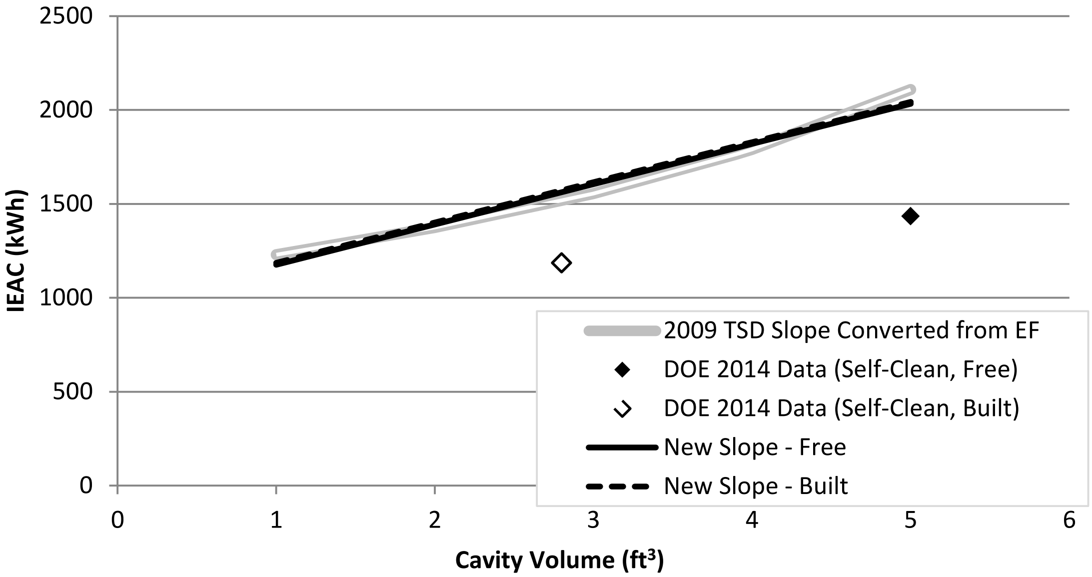

Figure 5.5.5 Gas Self-Clean Oven Slope

Although the relationship between IAEC and cavity volume derived using the 2009 slope was not linear, DOE notes that the Canadian and European Union energy conservation standards (as discussed in section 3.7 of chapter 3 of this NOPR TSD) also use a linear relationship between energy consumption and cavity volume. DOE performed a linear curve fit on the IAEC evaluated for discrete cavity volumes that were considered to represent the range of cavity volumes available on the market. The resulting IAEC versus cavity volume equations were used to establish the baseline slope for each product class. If necessary, the baseline intercepts were adjusted so that none of the ovens in the DOE test sample were cut off by the baseline curve. DOE also noted that baseline built-in/slide-in conventional ovens would consume more energy than freestanding ovens, so DOE offset the baseline intercepts for these product classes by adding an assumed value for fan-only energy mode energy consumption.

For electric ovens, DOE validated this approach using the data available in the NRCan product databases.[h] DOE notes that this data is based annual energy consumption measured using the same test procedure considered for the previous DOE standards rulemaking. DOE used these annual energy consumption values from the NRCan product database to estimate IAEC by subtracting clock energy and adding baseline standby energy consumption and fan-only mode energy consumption. Figure 5.5.6 compares the NRCan built-in oven data against the proposed DOE baseline equation discussed above.

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[h] Available at: http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.search-recherche&appliance=OVENS_E. The NRCan product databases do not include information for conventional gas ovens.

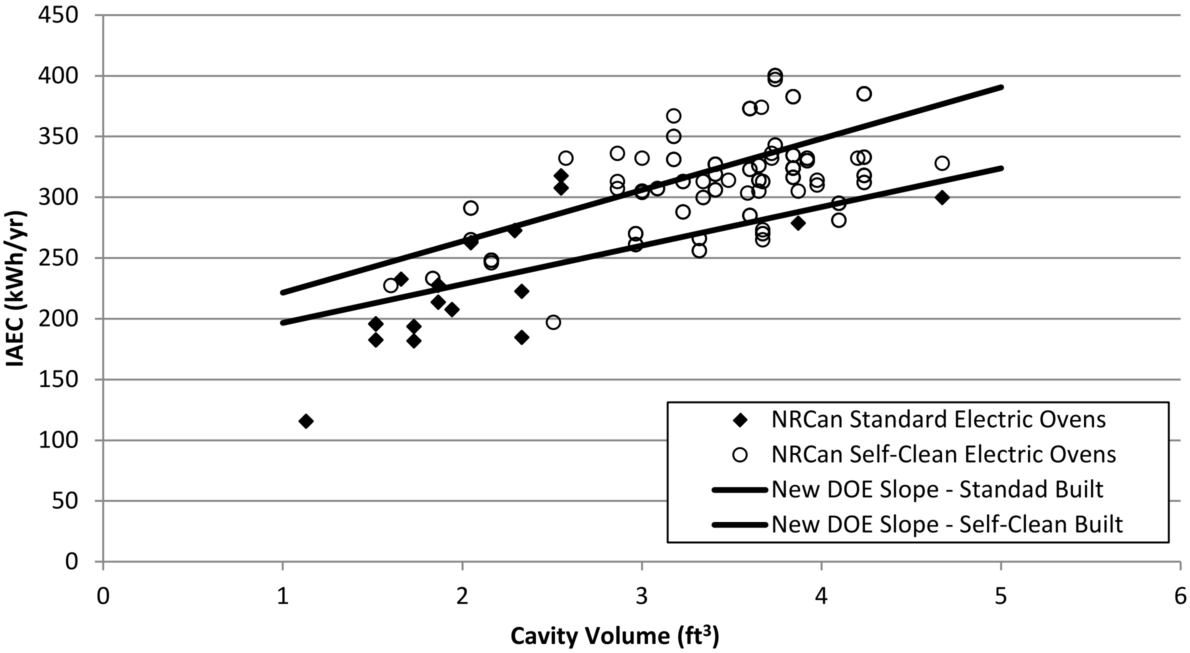

Figure 5.5.6 NRCan Electric Oven Data and New DOE Slope for Electric Ovens

Although some ovens in the NRCan database have IAEC values exceeding the DOE's proposed baseline, the majority of the products in both product classes meet the DOE's proposed baseline criteria. Values for the slopes and finalized intercepts for each conventional oven product class are presented in Table 5.5.8 and Table 5.5.9. The intercepts for each incremental efficiency level were then chosen so that the equations pass through the desired IAEC corresponding to a particular volume.

Table 5.5.8 Slopes and Intercepts of Electric Oven IAEC versus Cavity Volume Relationship

	Standard Electric Ovens		**Self-Clean Electric Ovens**	
	Slope = 31.8		**Slope = 42.3**	
Level	**Freestanding Intercepts**	**Built-in / Slide-in Intercepts**	**Freestanding Intercepts**	**Built-in / Slide-in Intercepts**
Baseline	157.74	164.78	173.12	179.18
1	147.82	154.62	163.24	169.13
2	134.98	141.47	145.28	150.86
3	122.45	128.64	97.05	101.81
4	118.20	124.29	96.24	100.98
5	107.91	113.75	-	-
6	71.10	76.07	-	-
7	70.54	75.49	-	-

Table 5.5.9 Slopes and Intercepts of Gas Oven IAEC versus Cavity Volume Relationship

Level	Standard Gas Ovens		Self-Clean Gas Ovens	
	Slope = 214.4		Slope = 214.4	
	Freestanding Intercepts	Built-in / Slide-in Intercepts	Freestanding Intercepts	Built-in / Slide-in Intercepts
Baseline	1196.3	1206.2	961.8	971.8
1	727.4	735.1	926.3	936.0
2	692.7	700.3	746.7	755.5
3	568.8	575.8	674.4	682.8
4	492.9	499.5	669.1	677.5
5	478.7	485.2	-	-
6	433.7	440.1	-	-
7	425.1	431.4	-	-

5.5.5 Cost Estimates

For the models in the NOPR analysis teardown sample, DOE developed manufacturer cost estimates based on the method outlined in section 5.4.4.

5.5.5.1 Baseline Cost Estimates

From the product teardowns discussed above, DOE developed the following baseline manufacturer product costs (MPCs) for each of the conventional cooking product, product classes. All costs presented are in 2013 dollars.

Table 5.5.10 Baseline Manufacture Product Costs for all Product Classes

Product Class	Product Type	Sub-Category	Installation Type	Baseline Manufacturer Product Cost (***2014$***)
1	Electric oven	Standard with or without a catalytic line	Freestanding	$265.22
2			Built-in/Slide-in	$280.76
3		Self-clean	Freestanding	$291.26
4			Built-in/Slide-in	$306.80
5	Gas oven	Standard with or without a catalytic line	Freestanding	$294.34
6			Built-in/Slide-in	$309.88
7		Self-clean	Freestanding	$362.98
8			Built-in/Slide-in	$378.52

5.5.5.2 Incremental Cost Estimates

Based on the analyses discussed above, DOE developed the cost-efficiency results for each product class shown in Table 5.5.11 through Table 5.5.14. Where available, DOE developed incremental MPCs based on manufacturing cost modeling of test units in its sample featuring the proposed design options. For design options that were not observed in DOE's sample of test units for this NOPR, DOE used the incremental MPCs developed as part of the 2009 TSD, then adjusted the values to reflect changes in the Bureau of Labor Statistics' Producer Price Index (PPI) for household cooking appliance manufacturing.[i] DOE notes that the estimated incremental MPCs would be equivalent for the freestanding and built-in/slide-in oven product classes.

Table 5.5.11 Electric Standard Oven Incremental Manufacturing Product Cost (2014$)

Level	Design Option	Cost Source	Cost
Baseline	-	-	-
1	Baseline + SMPS	Teardown Analysis	$0.82
2	1 + Reduced Vent Rate	2009 TSD	$2.76
3	2 + Improved Insulation	Teardown Analysis	$7.89
4	3 + Improved Door Seals	Teardown Analysis	$10.22
5	4 + Forced Convection	Teardown Analysis	$34.40
6	5 + Oven Separator	Teardown Analysis	$66.14
7	6 + Reduced Conduction Losses	2009 TSD	$70.36

Table 5.5.12 Electric Self-Clean Incremental Manufacturing Product Cost (2014$)

Level	Design Option	Cost Source	Cost
Baseline	-	-	-
1	Baseline + SMPS	Teardown Analysis	$0.82
2	1 + Forced Convection	Teardown Analysis	$25.00
3	2 + Oven Separator	Teardown Analysis	$56.74
4	3 + Reduced Conduction Losses	2009 TSD	$61.93

Table 5.5.13 Gas Standard Oven Incremental Manufacturing Product Cost (2014$)

Level	Design Option	Cost Source	Cost
Baseline	-	-	-
1	Baseline + Optimized Burner/Cavity	Teardown Analysis	$0.00
2	1 + SMPS	Teardown Analysis	$0.82
3	2 + Electronic Spark Ignition	Teardown Analysis	$7.31
4	3 + Improved Insulation	Teardown Analysis	$12.44
5	4 + Improved Door Seals	Teardown Analysis	$14.77
6	5 + Forced Convection	Teardown Analysis	$35.43
7	6 + Reduced Conduction Losses	2009 TSD	$39.74

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[i] Available at: http://www.bls.gov/ppi/.

Table 5.5.14 Gas Self-Clean Oven Incremental Manufacturing Product Cost (2014$)

Level	Design Option	Cost Source	Cost
Baseline	-	-	-
1	Baseline + SMPS	Teardown Analysis	$0.82
2	1 + Electronic Spark Ignition	Teardown Analysis	$7.31
3	2 + Forced Convection	Teardown Analysis	$27.96
4	3 + Reduced Conduction Losses	2009 TSD	$33.15

CHAPTER 6. MARKUPS FOR EQUIPMENT PRICE DETERMINATION

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CHAPTER 6. MARKUPS FOR EQUIPMENT PRICE DETERMINATION

6.1 INTRODUCTION

To carry out its economic analyses of potential new energy conservation standards for conventional cooking products, the U.S. Department of Energy (DOE) must determine the cost to the consumer of both baseline products (*i.e.*, products not subject to new energy conservation standards) and more efficient products. DOE applies two types of markups, depending on the type of product: (1) baseline markups on the direct business costs of products having baseline efficiency (baseline products) and (2) incremental markups on incremental product costs of higher-efficiency products. DOE estimated consumer prices for baseline products by applying a baseline markup to the manufacturer selling prices (MSP) estimated in the engineering analysis. For products having higher-than-baseline efficiency, DOE estimated consumer prices by applying appropriate markups to the incremental MSP estimated in the engineering analysis. DOE developed one set of markups for all conventional cooking products.

In the rulemaking for conventional cooking products, DOE is considering one product type: conventional ovens. DOE has identified eight product classes for conventional ovens.

6.1.1 Distribution Channels

The consumer equipment price depends on the distribution channel through which products move from manufacturers to purchasers. At each point in the distribution channel, companies mark up the price of the equipment to cover their business costs and profit margin.

DOE based the distribution channel on data from the Association of Home Appliance Manufacturers (AHAM).[1] AHAM estimates that 93 percent of conventional cooking products are sold through retail outlets. Because an overwhelming majority of products are sold through retail outlets, DOE assumed that all of the products are sold to retail outlets by manufacturers, and then purchased by consumers from retail outlets, as shown in Figure 6.1.1 .

Figure 6.1.1 Distribution Channel for Cooking Products

6.1.2 Markup Calculation Procedure

At each point in the distribution channel, companies mark up the price of the equipment to cover their business costs and profit margin. In financial statements, gross margin is the difference between the company revenue and the company cost of sales or cost of goods sold (*CGS*). Inputs for calculating the gross margin include all corporate costs — overhead costs (sales, general, and administration); research and development (R&D) and interest expenses; depreciation, and taxes—and profits. In order for sales of a product to contribute positively to company cash flow, the price of products must include a markup greater than the corporate gross margin. Individual products may command a lower or higher markup, depending on their perceived added value and the competition they face from similar products in the market. In developing markups for manufacturers and retailers, DOE obtained data about the revenue, *CGS*, and expenses of firms that produce and sell cooking products. DOE's approach categorizes the expenses into two categories: invariant costs, which are fixed labor and occupancy expenses that increase in proportion to the amount of labor required to produce or sell the product, and variant costs, which are variable operating costs that do not scale with labor and vary in proportion to *CGS*.

6.1.2.1 Approach for Manufacturer Markups

DOE applies manufacturer markups to transform a manufacturer's equipment cost into a manufacturer sales price (*MSP*). Using the *CGS* and gross margin, DOE calculated the manufacturer markup (MU_{MFG}) with the following equation:

$$\boldsymbol{MU_{MFG} = \frac{CGS_{MFG} + GM_{MFG}}{CGS_{MFG}}}$$

where:

MU_{MFG} = Manufacturer markup,
CGS_{MFG} = Manufacturer's cost of goods sold, and
GM_{MFG} = Manufacturer's gross margin.

6.1.2.2 Approach for Retailer Markups

DOE based the retailer markups for cooking products on financial data for electronics and appliance stores from the 2012 U.S. Census *Annual Retail Trade Survey* (ARTS), which is the most recent survey that includes industry-wide detailed operating expenses for that economic sector.[2] DOE organized the financial data into statements that break down cost components incurred by firms in the sector. DOE assumes that the income statements faithfully represent the various average costs incurred by firms selling home appliances. Although electronics and appliance stores handle multiple commodity lines, the data provide the best available indication of expenses incurred during the sale of cooking products.

The baseline markup transforms the manufacturer sales price of baseline products to the retailer sales price. DOE considers baseline models to be products sold under current market conditions (*i.e.*, without new energy conservation standards). DOE used the following equation to calculate an average baseline markup (MU_{BASE}) for retailers.

$$MU_{BASE} = \frac{CGS_{RTL} + GM_{RTL}}{CGS_{RTL}}$$

Where:

MU_{BASE} = retailer's baseline markup,
CGS_{RTL} = retailer's cost of goods sold (*CGS*), and
GM_{RTL} = retailer's gross margin (*GM*).

Incremental markups are coefficients that relate the change in the *MSP* of higher-efficiency models to the change in retailer sales price. DOE considers higher-efficiency models to be products sold under market conditions after implementation of new efficiency standards. The incremental markup reflects the retailer's increase in a product's *CGS* due to new or amended efficiency standards.

There is, unfortunately, a lack of empirical data regarding appliance retailer markup practices in response to a product's cost increase (due to increased efficiency or other factors). DOE understands that real-world markup practices vary depending on the market conditions that retailers face and on the magnitude of the change in *CGS*. Pricing in retail stores also may involve rules of thumb that are difficult to quantify and to incorporate into DOE's analysis.

Given the uncertainty about actual markup practices in appliance retailing, DOE's approach reflects the following key concepts:

1. Changes in the efficiency of products sold are not expected to increase economic profits. Thus, DOE calculates markups/gross margins to allow cost recovery for retail companies in the distribution channel (including changes in the cost of capital) without changes in company profits.
2. Efficiency improvements affect some distribution costs but not others. DOE estimates retail prices using markups that reflect the distribution costs expected to change with efficiency, but not the distribution costs that are not expected to change with efficiency.

The approach to incremental markups is described in more detail in Dale et al (2004).[3] To estimate incremental retailer markups, DOE divides retailers' operating expenses into two categories: (1) those that do not change when *CGS* increases because of amended efficiency standards ("invariant"), and (2) those that increase proportionately with *CGS* ("variant"). DOE defines invariant costs as including labor and occupancy expenses, because those costs likely will not increase as a result of a rise in *CGS*. All other expenses, as well as net profit, are assumed to vary in proportion to *CGS*. Although it is possible that some other expenses may not scale with *CGS*, DOE takes a conservative position that includes other expenses as variant costs. Note that under DOE's approach, a high fixed cost component yields a low incremental markup.

DOE used the following equation to calculate the incremental markup (MU_{INCR}) for retailers.

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

Where:

MU_{INCR} = retailer's incremental markup,
CGS_{RTL} = retailer's cost of goods sold, and
VC_{RTL} = retailer's variant costs.

In developing incremental markups, DOE treats profits as constant over time. Although retailers may be able to reap higher profits for a limited time, DOE's approach assumes that competition in the appliance retail market, combined with relatively inelastic demand (*i.e.*, the demand is not expected to decrease significantly in response to a relatively small increase in price), will exert downward pressure on retail margins.

To measure the degree of competition in appliance retailing, DOE estimated the four-firm concentration ratio (FFCR) of major appliance sales in three retail channels: electronics and appliance stores, building materials and supplies dealers, and general merchandise stores.
The FFCR represents the market share of the four largest firms in a given sector. Generally, an FFCR of less than 40 percent indicates that the sector is not concentrated; an FFCR of more than 70 percent indicates that a sector is highly concentrated.[4, 5]

The FFCR of appliance sales within each retail channel is estimated as the sector FFCR times the percent of total sales within each channel accounted for by major appliances. As shown in Table 6.1.1, appliance sales in electronics and appliance stores, household appliance stores, building materials and supplies dealers, and general merchandise stores have a FFCR less than the 40-percent threshold.[6] The electronics and appliance stores sector includes a subsector titled "household appliance stores." Because that subsector includes numerous stores, it has a FFCR of only 21.3 percent.

Table 6.1.1 Four-Firm Concentration Ratio for Major Appliance Sales in Three Retail Channels

Sector	FFCR (% of Sector Sales)	Percent of Sales Accounted for by Major Appliances (%)	FFCR (% of Major Appliance Sales)
Electronics and appliance stores	46.3	42.1	19.5
Subsector: household appliance stores	21.3	37.1	7.9
Building materials and supplies dealers	45.9	17.0	7.8
General merchandise stores	73.2	31.6	23.1

Source: U.S. Economic Census. *Establishment and Firm Size* (*Including Legal Form of Organization*). 2007.
*Note: It is assumed that major appliance sales are uniformly distributed within all firms in each sector.

6.1.2.3 Overall Markup

The overall markup is the product of the manufacturer and retailer markups, as well as sales taxes.

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

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

where:

EQP_{BASE} = Consumer equipment price for baseline models,
$COST_{MFG}$ = Manufacturer cost for baseline models,
MU_{MFG} = Manufacturer markup,
MU_{BASE} = Baseline retailer markup,
Tax_{SALES} = Sales tax, and
$MU_{OVERALL\_BASE}$ = Baseline overall markup (product of manufacturer markup, baseline retailer markup, and sales tax).

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

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

where:

EQP_{STD} =	Consumer equipment price for models meeting new efficiency standards,
EQP_{BASE} =	Consumer equipment price for baseline models,
$COST_{MFG}$ =	Manufacturer cost for baseline models,
$\Delta COST_{MFG}$ =	Change in manufacturer cost for higher-efficiency models,
MU_{MFG} =	Manufacturer markup,
MU_{INCR} =	Incremental retailer markup,
Tax_{SALES} =	Sales tax,
$MU_{OVERALL\_BASE}$ =	Baseline overall markup (product of manufacturer markup, baseline retailer markup, and sales tax), and
$MU_{OVERALL\_INCR}$ =	Incremental overall markup (product of manufacturer markup, incremental retailer markup, and sales tax).

6.2 MANUFACTURER MARKUPS

DOE developed an average manufacturer markup by examining the annual Securities and Exchange Commission (SEC) 10-K reports filed by two publicly-traded manufacturers primarily engaged in appliance manufacturing and whose combined product range includes conventional cooking products.[7] The two manufacturers represent over 40 percent of the market share for covered conventional cooking products. Because these companies are diversified, producing a range of different appliances, an industry average markup was assumed by DOE to be representative for the manufacture of each type of covered product. DOE evaluated markups for the years between 2007 and 2013, inclusive.

Table 6.2.1 lists the average corporate gross margin during the years from 2007 to 2013, and corresponding markups, for both of the manufacturers.

Table 6.2.1 Major Appliance Manufacturer Gross Margins and Markups

	Mfr A	Mfr B
Average Net Revenues (Million)	$18,494	$15,606
Corporate Gross Margin	15.0%	20.9%
Markup	1.18	1.26

Source: SEC 10-K reports (2007-20013)

The weighted average markup value based on the market share of these two major publicly traded conventional cooking product manufacturers is 1.20.

6.3 RETAILER MARKUP FOR CONVENTIONAL COOKING PRODUCTS

The 2012 ARTS data for electronics and appliance stores provide total sales data and detailed operating expenses.[8] To construct a complete data set for estimating markups, DOE needed to estimate *CGS* and *GM*. The most recent 2012 ARTS publishes a separate document containing historical sales and gross margin from 1993 to 2012 for household appliance stores. DOE combined the *GM* as a percent of sales reported for 2012 with the detailed operating expenses data from 2012 ARTS to construct a complete income statement for electronics and appliance stores. DOE used these data to estimate both baseline and incremental markups.

Table 6.3.1 shows the calculation of the baseline retailer markup, which is estimated to be 1.39.

Table 6.3.1 Data for Calculating Baseline Markup: Electronics and Appliance Stores

Business Item	Amount ($1,000,000)
Sales	102,998
Cost of goods sold (CGS)	73,946
Gross margin (GM)	29,052
Baseline markup = (CGS+GM)/CGS	1.39

Source: U.S. Census, *2012 Annual Retail Trade Survey*.

Table 6.3.2 shows the breakdown of operating expenses for electronics and appliance stores as reported in the 2012 ARTS. The incremental markup is estimated to be 1.13.

Table 6.3.2 Data for Calculating Incremental Markup: Electronics and Appliance Stores

Business Item	Amount ($1,000,000)
Sales	102,998
Cost of goods sold (CGS)	*73,946*
Gross margin (GM)	*29,052*
Labor & Occupancy Expenses (invariant)	
Annual payroll	11,371
Employer costs for fringe benefit	2,023
Contract labor costs, including temporary help	209
Purchased utilities, total	529
Cost of purchased repair and maintenance services	386
Cost of purchased professional and technical services	1,117
Purchased communication services	362
Lease and rental payments	3,166
Taxes and license fees (mostly income taxes)	451
Subtotal:	19,617
Other Operating Expenses & Profit (variant)	
Expensed equipment	75
Cost of purchased packaging and containers	47
Other materials and supplies not for resale	463
Cost of purchased transportation, shipping, and warehousing services	567
Cost of purchased advertising and promotional services	1,961
Cost of purchased software	122
Cost of data processing and other purchased computer services, except communications + commissions paid	280
Depreciation and amortization charges	1,564
Other operating expenses	2,113
Net profit before tax (operating profit)	*2,243*
Subtotal:	9,435
Incremental markup = (CGS + Total Other Operating Expenses and Profit)/CGS	**1.13**

Source: U.S. Census. *2012 Annual Retail Trade Survey*.

6.4 SALES TAXES

The sales tax comprises state and local taxes applied to the price a consumer pays for a product. The sales tax is a multiplicative factor that increases the consumer product price.

DOE derived state and local taxes from data provided by the Sales Tax Clearinghouse.[9] The data represent weighted averages that include county and city rates. DOE then derived population-weighted average tax values for each RECS region, as shown in Table 6.4.1.[10]

Table 6.4.1 Average Sales Tax Rates by Census Division and Large State

RECS Region	State(s)	U.S. Population in 2019 (projected)	2014 Tax Rate (%)
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	8,453,982	5.13
2	Massachusetts	6,855,546	6.25
3	New York	19,576,920	8.40
4	New Jersey	9,461,635	6.95
5	Pennsylvania	12,787,354	6.40
6	Illinois	13,236,720	8.05
7	Indiana, Ohio	18,271,066	6.87
8	Michigan	10,695,993	6.00
9	Wisconsin	6,004,954	5.45
10	Iowa, Minnesota, North Dakota, South Dakota	10,353,316	6.86
11	Kansas, Nebraska	4,693,244	7.13
12	Missouri	6,199,882	7.20
13	Virginia	8,917,395	5.60
14	Delaware, District of Columbia, Maryland, West	9,742,487	5.59
15	Georgia	10,843,753	7.10
16	North Carolina, South Carolina	15,531,866	7.00
17	Florida	23,406,525	6.65
18	Alabama, Kentucky, Mississippi	12,198,158	7.25
19	Tennessee	6,780,670	9.45
20	Arkansas, Louisiana, Oklahoma	11,515,069	8.67
21	Texas	28,634,896	7.95
22	Colorado	5,278,867	6.10
23	Idaho, Montana, Utah, Wyoming	6,285,110	5.29
24	Arizona	8,456,448	7.20
25	Nevada, New Mexico	5,536,624	7.31
26	California	42,206,743	8.45
27	Oregon, Washington, Alaska, Hawaii	13,879,323	5.30
Population-weighted average			**7.144**

6.5 SUMMARY OF MARKUPS

Table 6.5.1 summarizes the markups at each stage in the distribution channel and the overall baseline and incremental markups, as well as sales taxes.

Table 6.5.1 Summary of Markups

Markup	**Baseline**	**Incremental**
Manufacturer	1.20	
Retailer	1.39	1.13
Sales Tax	1.071	
Overall	1.79	1.45

REFERENCES

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1 Association of Home Appliance Manufacturers. *AHAM 2003 Fact Book*, 2003. Washington, DC. p. 25.

2 U.S. Census Bureau, *2012 Annual Retail Trade Survey, Electronics and Appliance Stores.* 2012: Washington, DC. http://www.census.gov/retail/index.html

3 Dale, L. et al, *An Analysis of Price Determination and Markups in the Air-Conditioning and Heating Equipment Industry*, January 2004.

4 University of Maryland University College: http://info.umuc.edu/mba/public/AMBA607/IndustryStructure.html.

5 Quick MBA: http://www.quickmba.com/econ/micro/indcon.shtml.

6 U.S. Economic Census. *Establishment and Firm Size* (*Including Legal Form of Organization*). 2007.

7 Security Exchange Commission, *SEC 10-K Reports*, Various dates, 2007-2013, Security Exchange Commission. http://www.sec.gov/

8 U.S. Census Bureau, *2012 Annual Retail Trade Survey, Electronics and Appliance Stores.* 2012: Washington, DC. http://www.census.gov/retail/index.html

9 Sales Tax Clearinghouse Inc., *State Sales Tax Rates Along with Combined Average City and County Rates*, 2014. (Last accessed July 18, 2014.) http://thestc.com/STrates.stm

10 U.S. Census Bureau, Population Division, *Table A1: Interim Projections of the Total Population for the United States and States: April 1, 2000 to July 1, 2030*. 2005.

CHAPTER 7. ENERGY USE ANALYSIS

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CHAPTER 7. ENERGY USE ANALYSIS

7.1 INTRODUCTION

To carry out the life-cycle cost (LCC) and payback period (PBP) calculations described in Chapter 8, DOE needed to determine the operating cost savings to consumers from more-efficient equipment. The LCC and PBP analysis requires data on annual energy use because, along with energy prices, DOE uses these data to establish the most significant component of consumer operating costs. (Maintenance and repair costs are the other contributors to operating cost.) This chapter describes how DOE determined the annual energy consumption of residential electric and gas ranges and how more-efficient equipment impacts annual energy consumption.

The annual energy consumption of electric and gas ranges has been in continual decline since the late 1970s. DOE's 2009 technical support document (TSD) identified several studies that estimated the annual energy consumption of electric and gas ranges.[1] The studies that covered the time period of 1977–2004 showed a steady decline in the annual energy consumption. More recent studies from the 2010 California Residential Appliance Saturation Study (CA RASS)[2] and the Florida Solar Energy Center (FSEC)[3] show that the decline has somewhat levelled off in the annual energy consumption.

7.2 AVERAGE ANNUAL ENERGY CONSUMPTION

Based on the research conducted for the 1996 TSD, DOE published revisions to its test procedure as a final rule in 1997 that included a reduction in the annual useful cooking energy output and a reduction in the number of self-cleaning oven cycles per year.[4] The annual useful cooking energy output relates the efficiency of the cooking appliance to the annual energy consumption.

The DOE test procedure implicitly assumes that any electrical energy consumption in a gas range is allocated to the oven rather than the cooking top.

For electric self-cleaning and non-self-cleaning ovens, the following DOE test procedure equation is used to determine the total annual energy consumption (E_{AO}):

$$\boldsymbol{E_{AO} = \frac{O_O}{R_O}}$$

where:

O_O = 29.3 kWh per year, annual useful cooking energy output, and
R_O = Oven energy factor.

For gas self-cleaning and non-self-cleaning ovens, the annual energy consumption is composed of gas energy (E_{AOG}) and electrical energy (E_{AOE}). The following DOE test procedure equation is used to determine the total annual energy consumption:

$$\boldsymbol{E_{AOG} + E_{AOE} \times K_e = \frac{O_O}{R_O}}$$

where:

O_O = 88.8 kBtu per year, annual useful cooking energy output,
R_O = Oven energy factor, and
K_e = 3,412 Btu/kWh, conversion factor for kWh to Btus.

Based on the baseline cooking energy efficiency established in the engineering analysis for conventional cooking products, the annual energy consumption of electric and gas ovens can be determined using the above DOE test procedure equations.

DOE identified two additional studies that confirmed the continued downward trend in electric and gas range energy use: (1) the 2010 CA RASS and (2) a 2010 study conducted by FSEC. The CA RASS reported an average electric range annual energy consumption of 265 kWh per year while the FSEC study reported an average electric range annual energy consumption of 310 kWh per year, both of which are lower than the consumption values derived from the DOE test procedure for a non-self-cleaning range (266 + 253 = 519 kWh) and a self-cleaning range (266 + 298 = 563 kWh). The CA RASS also reported an average gas range annual energy consumption of 34.1 therms (3410 kBtu) per year.

Using the data from the studies in the 2009 TSD, the CA RASS, and FSEC, Figure 7.2.1 and Figure 7.2.2 show how the annual energy consumption of electric ranges and gas ranges, respectively, have varied over time. The figures indicate whether the estimates came from metered studies or conditional demand analyses. The figures below demonstrate that the annual energy use of cooking products has continued to decline over time. As a result, DOE believes that an electric range annual energy consumption of 287.5 kWh per year (the average of the CA RASS and FSEC studies) is more representative of baseline annual energy use than that derived from the DOE test procedure.

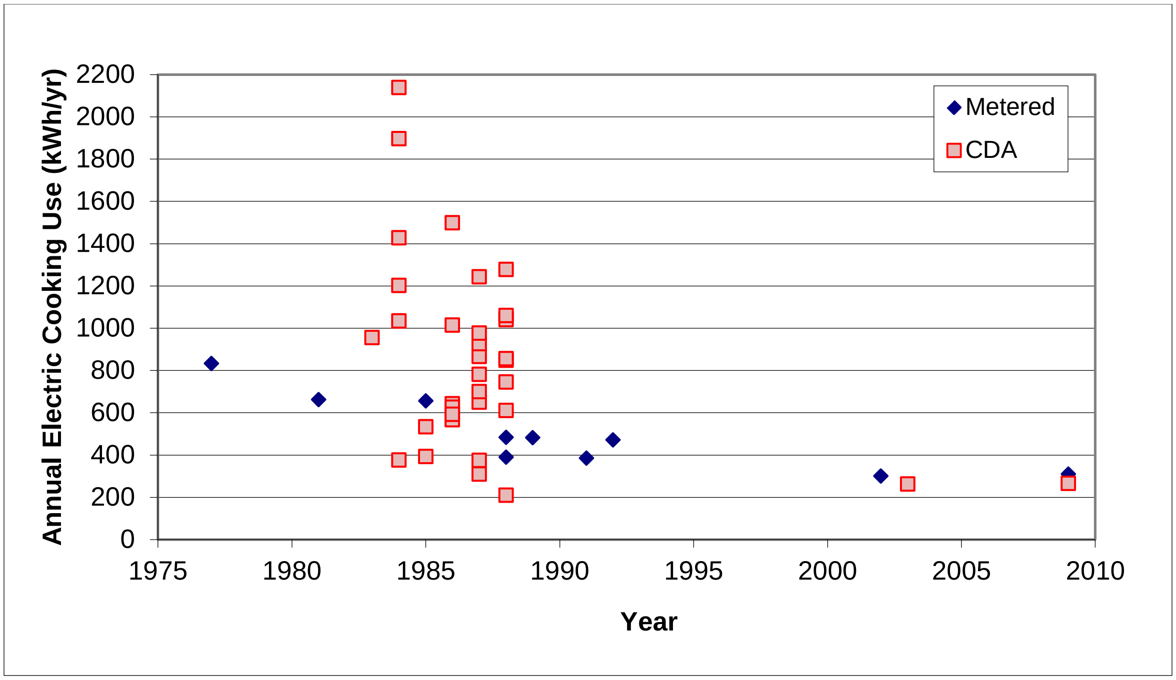

Figure 7.2.1 Historical Estimates of Annual Electric Range Energy Use

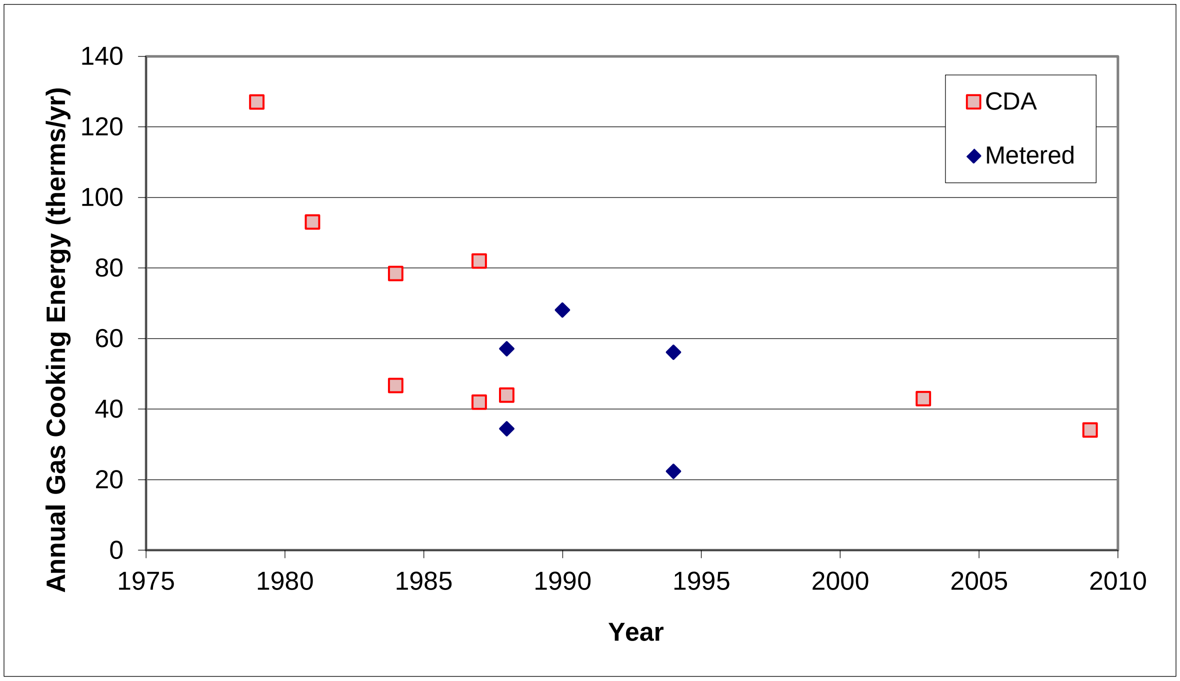

Figure 7.2.2 Historical Estimates of Annual Gas Range Energy Use

Table 7.2.1 shows the integrated annual energy consumption (IAEC), the new metric for efficiency of conventional cooking products, which are also based on DOE’s test procedure and associated annual energy consumption based on the CA RASS and FSEC studies. DOE considers the annual energy consumption values to be representative of electric and gas cooking energy usage circa the mid-1990s. Note that, because the annual useful cooking energy output values based on the updated annual energy use data are lower than those in the current DOE test procedure, the annual energy consumption for each oven are lower than the IAEC shown in Table 7.2.1.

Table 7.2.1 Annual Energy Consumption of Baseline Electric and Gas Ovens Based on DOE Test Procedure Energy Use Calculations

Product Type	**Baseline Efficiency Level (Proposed IAEC)****	**Annual Energy Consumption**
Electric Standard Ovens, Free-Standing	294.5 kWh	135.6 kWh
Electric Standard Ovens, Built-In/Slide-In	301.5 kWh	135.6.0kWh
Electric Self-Clean Ovens, Free-Standing	355.0 kWh	174.6 kWh
Electric Self-Clean Ovens, Built-In/Slide-In	361.1 kWh	175.3 kWh
Gas Standard Ovens, Free-Standing	2,118.2 kBtu	1,040.1 kBtu
Gas Standard Ovens, Built-In/Slide-In	2,128.1 kBtu	1,040.1 kBtu
Gas Self-Clean Ovens, Free-Standing	1,883.8 kBtu	1,126.3 kBtu
Gas Self-Clean Ovens, Built-In/Slide-In	1,893.7 kBtu	1,127.6 kBtu

** Proposed IAEC baseline efficiency levels are normalized based on a 4.3 ft3 volume for ovens

7.2.1 Annual Energy Consumption of Energy-Using Components

DOE performed several calculation steps to disaggregate the representative baseline average annual energy consumption value for an electric range (287.5 kWh per year) into appropriate energy use values for the various energy-using components of electric and gas ovens. The calculations are presented in Appendix 7A. Table 7.2.2 shows the results of these calculations for ovens. In the tables, DOE presents the energy use values for standard ovens and self-cleaning ovens with their disaggregated energy use components (i.e., cooking, ignition, self-cleaning, and standby) that correspond to the baseline efficiency levels (see Table 7.2.1).

Table 7.2.2 Component Annual Energy Use of Baseline Ovens

Energy Use Components	**Electric Standard Oven**		**Electric Self-Clean Oven**		**Gas Standard Oven**		**Gas Self-Clean Oven**	
	Free-standing	**Built-In/ Slide-In**	**Free-standing**	**Built-In/ Slide-In**	**Free-standing**	**Built-In/ Slide-In**	**Free-standing**	**Built-In/ Slide-In**
Cooking								
Efficiency	10.9%	10.6%	9.9%	9.7%	4.4%	4.3%	5.7%	5.7%
Electric (kWh/yr)	114.1	114.1	123.9	123.9				
Gas (kBtu/yr)					883.1	883.1	685.5	685.5
Self-Cleaning								
Electric (kWh/yr)			32.8	32.8			5.8	5.8
Gas (kBtu/yr)							217.8	217.8
Ignition								
Electric (kWh/yr)					43.5	43.5	43.5	43.5
Gas (kBtu/yr)								
Standby (kWh/yr)	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2
Total	135.6 kWh	135.6 kWh	174.6 kWh	175.3 kWh	1,040.1 kBtu	1,040.1 kBtu	1,126.3 kBtu	1,127.6 kBtu
Annual Useful Cooking Energy Output	12.4 *kWh*	12.4 *kWh*	12.4*kWh*	12.4 *kWh*	37.7 *kBtu*	37.7 *kBtu*	37.7 *kBtu*	37.7 *kBtu*
IAEC	294.5 kWh	301.5 kWh	355.0 kWh	361.1 kWh	2,118.2 kBtu	2,128.1 kBtu	1,883.8 kBtu	1,893.7 kBtu

7.2.2 Annual Energy Consumption by Efficiency Level

As discussed in Chapter 5, for the purposes of developing the cost-efficiency relationships of electric and gas range cooking products, DOE analyzed four efficiency levels for electric and gas self-clean ovens, and seven efficiency levels for electric and gas standard ovens, in addition to the baseline level. The following tables present the annual energy consumption of electric and gas range cooking products by efficiency level. DOE based the baseline annual energy consumption for each cooking product on the 'total' values shown in Table 7.2.2.

Table 7.2.3 and Table 7.2.4 show the electric standard oven IAEC as well as their corresponding annual energy consumption. The baseline annual energy consumption of 135.6 kWh is taken from Table 7.2.2 and consists of two components: cooking energy and standby energy. For efficiency levels 5, 6, and 7, it includes energy for forced convection through a convection fan. The convection fan has a test energy consumption of 1.07 kWh and 1.10 kWh per year for freestanding and built-in units, respectively. The standby is based on a power consumption of 2.2 Watts in the baseline, and 1.1 Watts for efficiency levels 1 through 7. DOE determined the annual cooking energy consumption for a more efficient level by taking the ratio of the cooking efficiencies of the more efficient and baseline levels and multiplying it by the baseline annual cooking energy consumption.

Table 7.2.3 Electric Standard Ovens - Freestanding: Annual Energy Consumption by Efficiency Level

Level	**IAEC** *(kWh)*	**Cooking Energy**	**Non-Cooking* Energy**	**Total**
		kWh/year	*kWh/year*	*kWh/year*
Baseline	294	116.3	19.3	135.6
1	285	116.2	9.6	125.8
2	272	110.7	9.6	120.4
3	259	105.4	9.6	115.1
4	255	103.7	9.6	113.3
5	245	98.8	10.8	109.6
6	208	83.3	10.8	94.1
7	207	83.0	10.8	93.9

*Includes Standby Energy

Table 7.2.4 Electric Standard Ovens – Built-in/Slide-in: Annual Energy Consumption by Efficiency Level

Level	**IAEC** *(kWh)*	**Cooking Energy**	**Non-Cooking* Energy**	**Total**
		kWh/year	*kWh/year*	*kWh/year*
Baseline	302	116.3	19.3	135.6
1	291	116.1	9.6	125.7
2	278	110.7	9.6	120.3
3	265	105.4	9.6	115.0
4	261	103.6	9.6	113.2
5	250	98.7	10.9	109.6
6	213	83.2	10.9	94.1
7	212	83.0	10.9	93.8

*Includes Standby and Forced Convection Energy

Table 7.2.5 and Table 7.2.6 show the electric self-clean oven IAEC and cooking efficiencies as well as their corresponding annual energy consumption. The baseline annual energy consumption values of 174.6 kWh and 175.3 are taken from Table 7.2.2 for freestanding and built-in models, respectively, and consist of three components: cooking energy, self-cleaning energy, and standby. For efficiency levels 2, 3, and 4, it includes energy for forced convection through a convection fan. The convection fan has a test energy consumption of 1.18 kWh and 1.21 kWh per year for freestanding and built-in units, respectively. The self-cleaning energy is based on data from DOE's test procedure, i.e., a consumption of 5.8 kWh per self-cleaning cycle for freestanding and built-in units. There are four self-cleaning cycles per year. The standby is based on a power consumption of 2.2 Watts in the baseline and 1.1 Watts for efficiency levels 1 through 4. DOE determined the annual cooking energy consumption for a more efficient level by taking the ratio of the cooking efficiencies of the more efficient and baseline levels and multiplying it by the baseline annual cooking energy consumption. DOE assumed that self-cleaning remains constant with increased efficiency.

Table 7.2.5 Electric Self-Clean Ovens - Freestanding: Annual Energy Consumption by Efficiency Level

Level	IAEC *(kWh)*	Cooking Energy	Non-Cooking* Energy	Total
		kWh/year	*kWh/year*	*kWh/year*
Baseline	355	118.4	56.2	174.6
1	345	118.3	46.6	164.9
2	327	110.7	47.9	158.6
3	279	91.5	47.9	139.5
4	278	91.2	47.9	139.1

*Includes Standby, Forced Convection and Self-Clean Energy

Table 7.2.6 Electric Self-Clean Ovens – Built-in/Slide-in: Annual Energy Consumption by Efficiency Level

Level	IAEC *(kWh)*	Cooking Energy	Non-Cooking* Energy	Total
		kWh/year	*kWh/year*	*kWh/year*
Baseline	361	118.4	56.8	175.3
1	351	118.3	47.2	165.5
2	333	110.6	48.6	159.2
3	284	91.5	48.6	140.1
4	283	91.2	48.6	139.8

*Includes Standby, Forced Convection and Self-Clean Energy

Table 7.2.7 and Table 7.2.8 show the gas standard oven IAEC along with their corresponding annual energy consumption. The baseline annual energy consumption of 1,040.1 kBtu is taken from Table 7.2.2 and consists of three components: cooking energy, ignition energy and standby. For efficiency levels 6 and 7, it includes energy for forced convection through a convection fan. The convection fan has a test energy consumption of 2.48 kWh and

2.49 kWh per year for freestanding and built-in units, respectively. The standby is based on a power consumption of 2.2 Watts in the baseline and 1.1 Watts for efficiency levels 1 through 7. DOE determined the annual cooking energy consumption for a more efficient level by taking the ratio of the IAEC of the more efficient and baseline levels and multiplying it by the baseline annual cooking energy consumption.

Table 7.2.7 Gas Standard Ovens - Freestanding: Annual Energy Consumption by Efficiency Level

Level	IAEC *kBtu/yr*	Cooking Energy	Non-Cooking* Energy	Total
		kBtu/yr	*kBtu/yr*	*kBtu/yr*
Baseline	2,118	831.3	208.8	1040.1
1	1,649	626.6	208.8	835.4
2	1,615	625.8	175.9	801.7
3	1,491	571.7	175.9	747.6
4	1,415	603.4	32.9	636.3
5	1,401	597.2	32.9	630.1
6	1,356	573.9	41.0	614.9
7	1,347	570.1	41.0	611.1

*Includes Standby, Forced Convection and Ignition Energy

Table 7.2.8 Gas Standard Ovens – Built-in/Slide-in: Annual Energy Consumption by Efficiency Level

Level	IAEC *kBtu/yr*	Cooking Energy	Non-Cooking* Energy	Total
		kBtu/yr	*kBtu/yr*	*kBtu/yr*
Baseline	2,128	831.3	208.8	1040.1
1	1,657	626.7	208.8	835.5
2	1,622	625.8	175.9	801.8
3	1,498	571.8	175.9	747.7
4	1,421	603.1	32.9	636.0
5	1,407	596.9	32.9	629.8
6	1,362	573.6	41.1	614.7
7	1,353	569.8	41.1	610.9

*Includes Standby, Forced Convection and Ignition Energy

Table 7.2.9 and Table 7.2.10 show the gas self-clean oven IAEC along with their corresponding annual energy consumption. The baseline annual energy consumption of 1,126.3 kBtu and 1,127.6 kBtu for free-standing and built-in ovens is taken from Table 7.2.2 and consists of four components: cooking energy, self-clean energy, ignition energy and standby. The baseline annual energy consumption assumes that the oven uses a globar or hot surface ignition device which, has a test energy consumption of 43.52 kWh per year. For efficiency levels 2, 3, and 4, it includes energy for forced convection through a convection fan. The convection fan has a test energy consumption of 2.21 kWh and 2.22 kWh per year for freestanding and built-in units, respectively. The self-cleaning energy is based on test data namely, gas consumption of 57.45 kBtu and electrical consumption of 1.53 kWh per self-cleaning cycle. There are four self-cleaning cycles per year. The standby is based on a power consumption of 2.2 Watts in the baseline and 1.1 Watts for efficiency levels 1 through 4. DOE determined the annual cooking energy consumption for a more efficient level by taking the ratio of the IAEC of the more efficient and baseline levels and multiplying it by the baseline annual cooking energy consumption. DOE assumed that the self-cleaning energy remain constant with increased efficiency.

Table 7.2.9 Gas Self-Clean Ovens - Freestanding: Annual Energy Consumption by Efficiency Level

Level	IAEC *kBtu/yr*	Cooking Energy	Non-Cooking* Energy	Total
		kBtu/yr	*kBtu/yr*	*kBtu/yr*
Baseline	1,884	660.8	465.5	1126.3
1	1,848	659.6	432.6	1092.2
2	1,669	645.1	283.4	928.5
3	1,596	607.9	291.0	898.9
4	1,591	605.4	291.0	896.4

*Includes Standby, Self-Clean, Forced Convection, and Ignition Energy

Table 7.2.10 Gas Self-Clean Ovens – Built-in/Slide-in: Annual Energy Consumption by Efficiency Level

Level	IAEC *kBtu/yr*	Cooking Energy	Non-Cooking* Energy	Total
		kBtu/yr	*kBtu/yr*	*kBtu/yr*
Baseline	1,894	660.8	466.8	1127.6
1	1,858	659.5	433.9	1093.4
2	1,677	644.7	284.7	929.4
3	1,605	607.5	292.3	899.9
4	1,599	605.0	292.3	897.4

*Includes Standby, Self-Clean, Forced Convection, and Ignition Energy

7.2.3 Variability of Annual Energy Consumption

DOE's Energy Information Administration (EIA) conducts a Residential Energy Consumption Survey (RECS) that collects energy-related data for occupied primary housing units in the U.S. The 2009 RECS collected data from 12,083 housing units representing almost 113.6 million households.[5] The RECS indicates which households in the survey use electric and gas ranges and ovens. With regard to electric cooking products, 7347 household records have standard ovens, and 5166 household records have self-cleaning ovens. With regard to gas cooking products, 3626 household records have standard ovens, and 1995 household records have self-cleaning ovens. The above totals represent ovens in households as either a stand-alone unit or as part of a range.

Although RECS does not provide the annual energy consumption of the cooking product for each household record, it does provide the frequency of cooking use. For each household using a conventional cooking product, RECS provides data on the frequency of use and number of meals cooked in the following bins: (1) less than once per week, (2) once per week, (3) a few times per week, (4) once per day, (5) two times per day, and (6) three or more times per day. Thus, DOE can utilize the frequency of use to define the variability of the annual energy consumption. Conducting the analysis in this manner captures the observed variability in annual energy consumption while maintaining the average annual energy consumption shown above in Table 7.2.1. To determine the variability of cooking product energy consumption, DOE first equated the weighted-average cooking frequency from RECS with the average energy use values reported in Table 7.2.1. Table 7.2.11presents the weighted-average cooking frequency values along with the corresponding annual energy use values from Table 7.2.1.

Table 7.2.11 Annual Energy Use of Baseline Ovens with corresponding RECS Cooking Frequency

	Ovens			
	Electric		**Gas**	
	Standard Freestanding/Built-In	**Self-Clean Freestanding/Built-In**	**Standard Freestanding/Built-In**	**Self-Clean Freestanding/Built-In**
Annual Energy Consumption	135.6/135.6 *kWh*	174.6/175.3 *kWh*	1040.1/1040.1 *kBtu*	1126.3/1127.6 *kBtu*
RECS average cooking frequency *(meals per day)*	0.72	0.69	0.68	0.68

DOE then varied the annual energy consumption for each RECS household based on its reported cooking frequency. DOE determined the annual cooking energy consumption for each RECS household with an oven based on the following equation:

$$\boldsymbol{E_{AO\_HH}} = \boldsymbol{Freq_{O\_HH}} \times \frac{\boldsymbol{E_{AO\_AVG}}}{\boldsymbol{Freq_{O\_AVG}}}$$

where:

E_{AO_HH} = Oven annual energy consumption for specific RECS household,
$Freq_{O\_HH}$ = Oven frequency for specific RECS household,
E_{AO_AVG} = Average oven annual energy consumption (from Table 7.2.15); 135.6 kWh for electric standard ovens; 174.5 kWh and 175.3 kWh for electric self-clean freestanding and built-in ovens respectively; 1040.1 kBtu for gas standard ovens; and 1126.3 kBtu and 1127.6 kBtu for gas self-clean freestanding and built-in ovens respectively, and
$Freq_{O\_AVG}$ = Average oven frequency (from Table 7.2.10); 0.72 meals/day for electric standard ovens; 0.69 meals/day for electric self-clean ovens; 0.68 meals/day for gas standard ovens; and 0.68 meals per day for gas self-clean ovens.

For all RECS households oven cooking frequency varies between zero and four meals per day. Figures 7.2.3 through 7.2.8 show the probability distributions of annual cooking energy consumption based on correlating the average cooking energy use to the cooking frequency data from RECS.

Figures 7.2.3 and 7.2.4 show the distribution of annual energy use for electric standard and self-cleaning ovens, respectively.

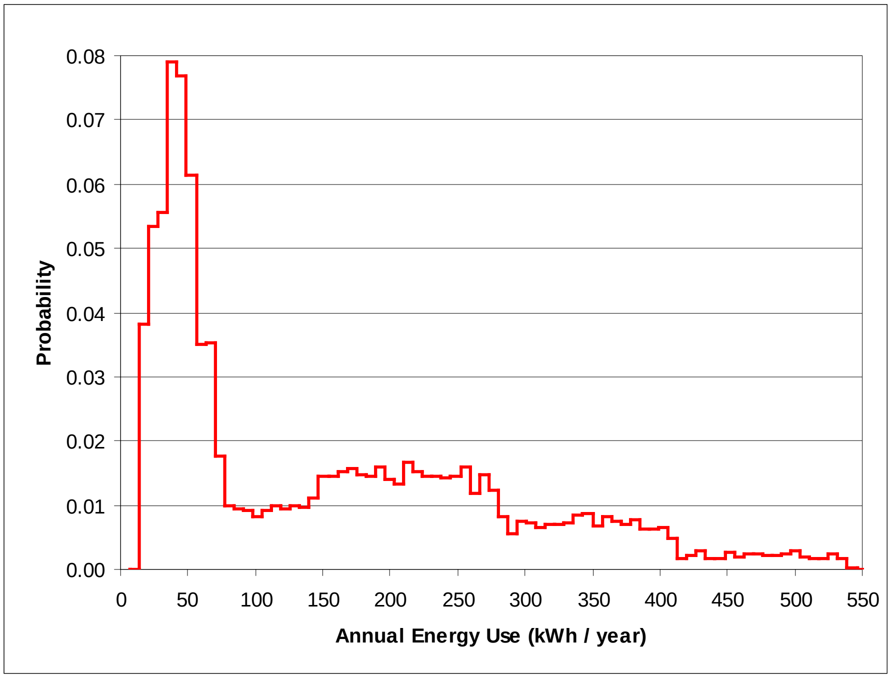

Figure 7.2.3 Distribution of Baseline Electric Standard Oven Annual Energy Use Based on 2009 RECS Cooking Frequency

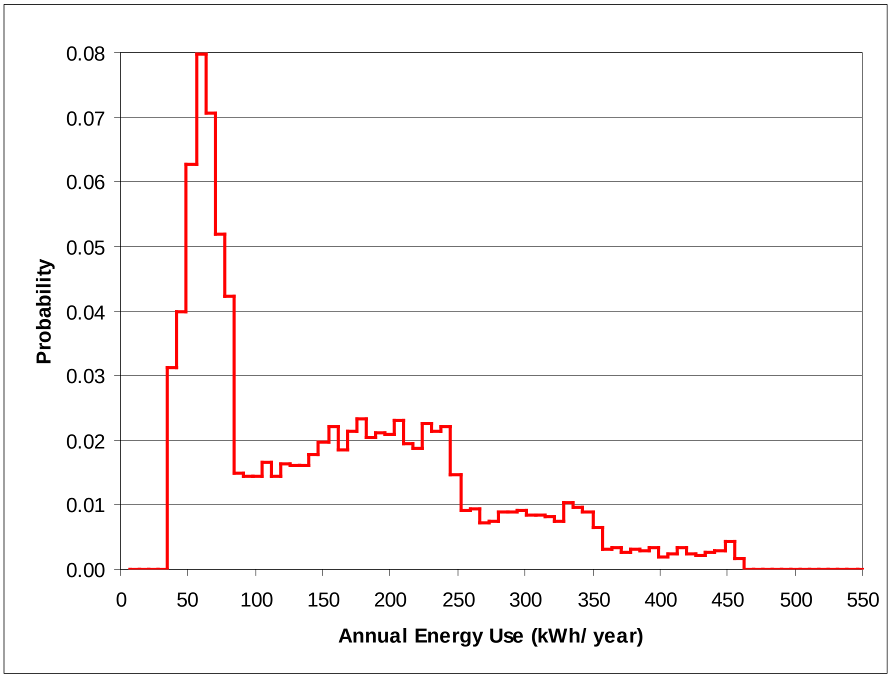

Figure 7.2.4 Distribution of Baseline Electric Self-Cleaning Oven Annual Energy Use Based on 2009 RECS Cooking Frequency

Figures 7.2.5 and 7.2.6 show the distribution of annual energy use for gas standard and self-cleaning ovens, respectively.

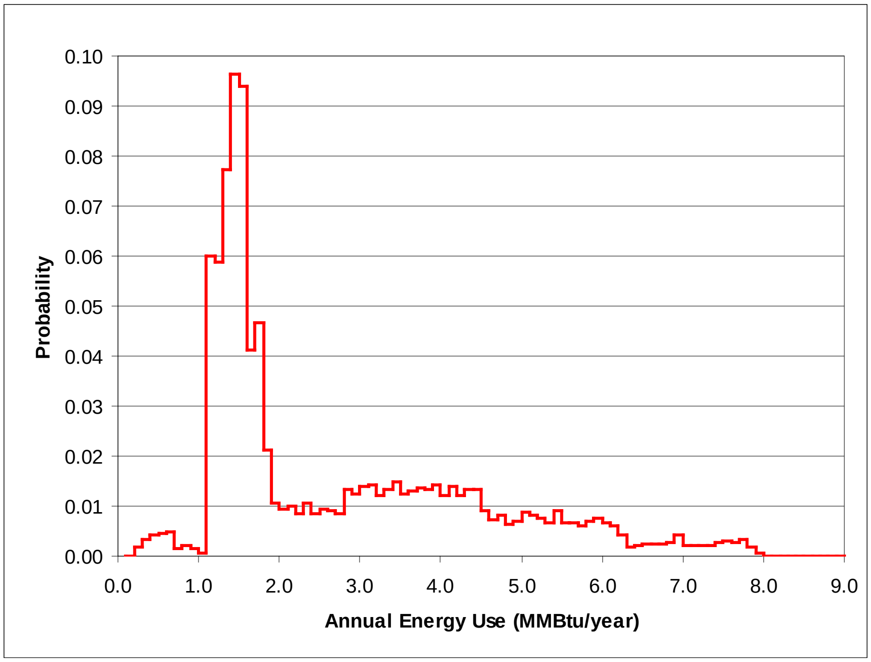

Figure 7.2.5 Distribution of Baseline Gas Standard Oven Annual Energy Use Based on 2009 RECS Cooking Frequency

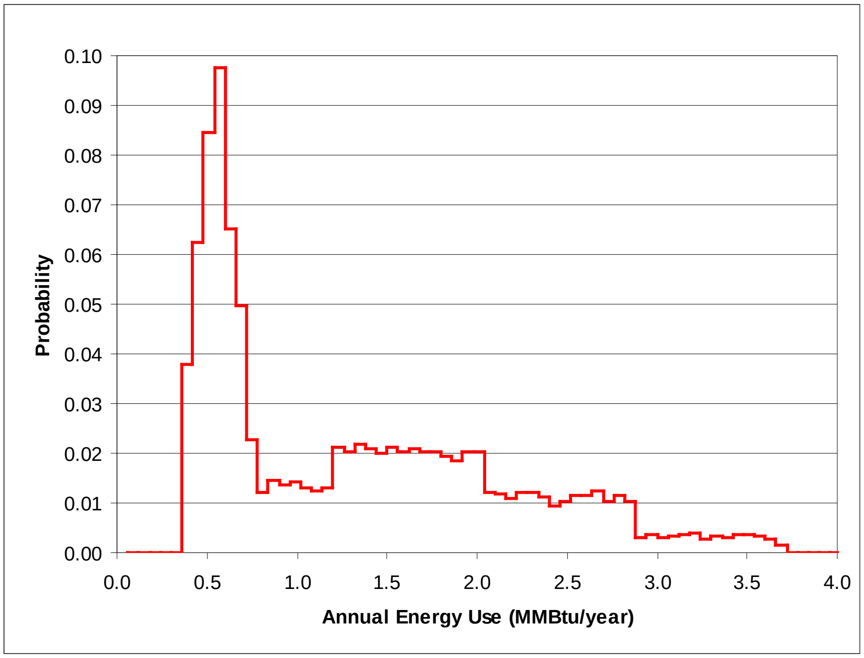

Figure 7.2.6 Distribution of Baseline Gas Self-Cleaning Oven Annual Energy Use Based on 2009 RECS Cooking Frequency

As will be described later in Chapter 8 on the LCC and PBP analysis, DOE used the RECS household samples with their associated baseline annual cooking energy consumption to conduct the LCC and PBP analysis.

REFERENCES

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1 U.S. Department of Energy-Office of Codes and Standards. *Technical Support Document for Consumer Products and Commercial and Industrial Equipment: Residential Dishwashers, Dehumidifiers, and Cooking Products, and Commercial Clothes Washers*, March 2009. <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/57#23standards>

2 California Energy Commission. 2009 *California Residential Appliance Saturation Study*, October 2010. Prepared for the California Energy Commission by KEMA, Inc. Contract No. 200-2010-004. < http://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-V2.PDF>

3 FSEC 2010. Updated Miscellaneous Electricity Loads and Appliance Energy Usage Profiles for Use in Home Energy Ratings, the Building America Benchmark and Related Calculations. Published as FSEC-CR-1837-10, Florida Solar Energy Center, Cocoa, FL. <http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1837-10-R01.pdf>

4 U.S. Federal Register. *Energy Conservation Program for Consumer Products: Test Procedure for Kitchen Ranges and Ovens, Cooking tops, Ovens, and Microwave Ovens, Final Rule*, October 3, 1997. 62 FR 51976.

5 U.S. Department of Energy-Energy Information Administration. *Residential Energy Consumption Survey, 2009 Public Use Data Files*, 2009. Washington, DC. <http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=microdata>

CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

8.1 INTRODUCTION

This chapter of the notice of public rulemaking (NOPR) technical support document (TSD) describes the Department of Energy (DOE)'s method for analyzing the economic impacts of new energy conservation standards on individual consumers. The effects of standards on individual consumers include a change in operating expense (usually decreased) and a change in purchase price (usually increased). This chapter describes three metrics DOE used in the consumer analysis to determine the effect of standards on individual consumers of conventional cooking products:

- **Life-cycle cost** (LCC) is the total consumer expense over the life of an appliance, including purchase price and operating costs (including energy expenditures). DOE discounts future operating costs to the time of purchase, and sums them over the lifetime of the product.
- **Payback period** (PBP) measures the amount of time it takes a consumer to recover the assumed higher purchase price of more energy-efficient equipment through lower operating costs.
- **Rebuttable payback period** is a special case of the PBP. Whereas LCC and PBP are estimated over a range of inputs that reflect field conditions, rebuttable payback period is based on laboratory conditions, specifically inputs to DOE's test procedure.

Inputs to the LCC and PBP are discussed in section 8.2 of this chapter. Results for the LCC and PBP are presented in section 8.3. The rebuttable PBP is discussed in section 8.4. Key variables and calculations are presented for each metric. DOE performed the calculations discussed herein using a series of Microsoft Excel® spreadsheets which are accessible on the Internet (http://www.eere.energy.gov/buildings/appliance_standards/). Details and instructions for using the spreadsheets are discussed in appendix 8A.

8.1.1 General Approach to Analysis

DOE uses the following equation to calculate life-cycle cost (LCC), the total consumer expense throughout the life of an appliance.

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

Eq. 8.1

Where:

LCC = life-cycle cost in dollars,
IC = total installed cost in dollars,

$\sum$ = sum over the appliance lifetime, from year 1 to year N,
N = lifetime of the appliance in years,
OC = operating cost in dollars,
r = discount rate, and
t = year for which operating cost is being determined.

Numerically, the payback period (PBP), defined above, is the ratio of the increase in purchase cost (i.e., from a less energy efficient design to a more efficient design) to the decrease in annual operating expenditures. This type of calculation results in what is termed a simple payback period, because it does not take into account changes in operating expenses over time or the time value of money. That is, the calculation is done at an effective discount rate of zero percent. The equation for PBP is:

$$PBP = \frac{\Delta IC}{\Delta OC}$$

Eq. 8.2

Where:

ΔIC = difference in total installed cost between the more energy efficient design and the baseline design, and
ΔOC = difference in annual operating expenses.

Payback periods are expressed in years. Payback periods greater than the life of the product indicate that the increased total installed cost is not recovered through reduced operating expenses.

Recognizing that several inputs to the determination of consumer LCC and PBP are either variable or uncertain, DOE conducted the LCC and PBP analysis by modeling both the uncertainty and variability of the inputs using Monte Carlo simulation and probability distributions. Appendix 8B provides a detailed explanation of Monte Carlo simulation and the use of probability distributions. DOE used Microsoft Excel spreadsheets combined with Crystal Ball (a commercially available add-in program) to develop LCC and PBP spreadsheet models that incorporate both Monte Carlo simulation and probability distributions.

In addition to using probability distributions to characterize several of the inputs to the analysis, DOE developed a sample of individual households that use electric and gas ovens. By developing household samples, DOE was able to calculate the LCC and PBP for each household to account for the variability in energy consumption and/or energy price associated with a range of households.

As described in chapter 7 (section 7.2.3) of this NOPR TSD, DOE used the Energy Information Administration's (EIA's) 2009 Residential Energy Consumption Survey (RECS 2009) to develop household samples for electric and gas ovens[1]. The EIA designed RECS 2009, which consists of 12,083 housing units, to be a national representation of 113.6 million households in the United States. Although RECS does not provide the annual energy consumption of the cooking product for each household record, it does provide the frequency of cooking use. Refer to chapter 7 of this NOPR TSD for details. DOE used RECS to establish the variability of annual cooking energy use and of energy prices. DOE assigned unique number of meals cooked to each household in the sample. The variability among households in annual oven use and/or energy pricing contributes to the range of LCCs and PBPs calculated for the baseline efficiency level and each increased efficiency level.

DOE displays the LCC results as distributions of impacts compared to baseline conditions. Results, which are presented in section 8.3, are based on 10,000 samples per Monte Carlo simulation run. To illustrate the implications of the analysis, DOE generated a frequency chart that depicts the variation in LCC for each efficiency level being considered.

8.1.2 Overview of Inputs to Analysis

DOE categorizes inputs to the LCC and PBP analysis as (1) inputs for establishing the purchase expense, otherwise known as the total installed cost, and (2) inputs for calculating operating costs. The primary inputs for establishing the total installed cost are listed below.

- *Baseline manufacturer cost*: The costs incurred by the manufacturer to produce products that meet current minimum efficiency standards.
- *Standard-level manufacturer cost increases*: The change in manufacturer costs associated with producing products that meet a given standard level.
- *Markups and sales tax*: The increases associated with converting the manufacturer cost to a consumer product cost.
- *Installation cost*: The cost to the consumer of installing the product. The installation cost represents all costs required to install the product other than the marked-up consumer product cost. The installation cost includes labor, overhead, and any miscellaneous materials and parts. Thus, the total installed cost equals the consumer product cost plus the installation cost.
- *Learning rate:* The cost reduction factor associated with economies of scale and technology learning.

The primary inputs for calculating operating costs are listed below.

- *Product energy consumption*: The on-site energy use associated with operating a product.
- *Product efficiency*: The product energy consumption associated with standard-level products (*i.e.*, products having efficiencies greater than those of baseline products).
- *Energy prices*: The prices consumers pay for energy (*e.g.*, electricity or natural gas).
- *Energy price trends*: DOE used the EIA's *Annual Energy Outlook 2014* (*AEO 2014*) to project energy prices[2].

- *Repair and maintenance costs*: Repair costs are associated with repairing or replacing components that have failed. Maintenance costs are associated with maintaining the operation of the product.
- *Lifetime*: The age at which the product is retired from service.
- *Discount rate*: The rate at which DOE discounts future expenditures to establish their present value.

The data inputs for calculating the PBP for each TSL are the total installed cost of the product to the consumer for each energy efficiency level and the annual (first-year) operating expenditures. The inputs to total installed cost are the product cost plus the installation cost. The inputs to operating costs are the first year energy cost, the annual repair cost, and the annual maintenance cost. The PBP uses the same inputs as the LCC analysis, except the PBP does not require energy price trends or discount rates. Because the PBP is what is termed a simple payback, the required energy price is only for the year in which a new energy efficiency standard takes effect. The energy price DOE uses in the PBP calculation is the price projected for that year. Discount rates are also not required for calculating the simple PBP.

Figure 8.1.1 depicts the relationships among inputs to the calculation of the LCC and PBP. In the figure, the yellow boxes indicate inputs, the green boxes indicate intermediate outputs, and the blue boxes indicate final outputs (the LCC and PBP).

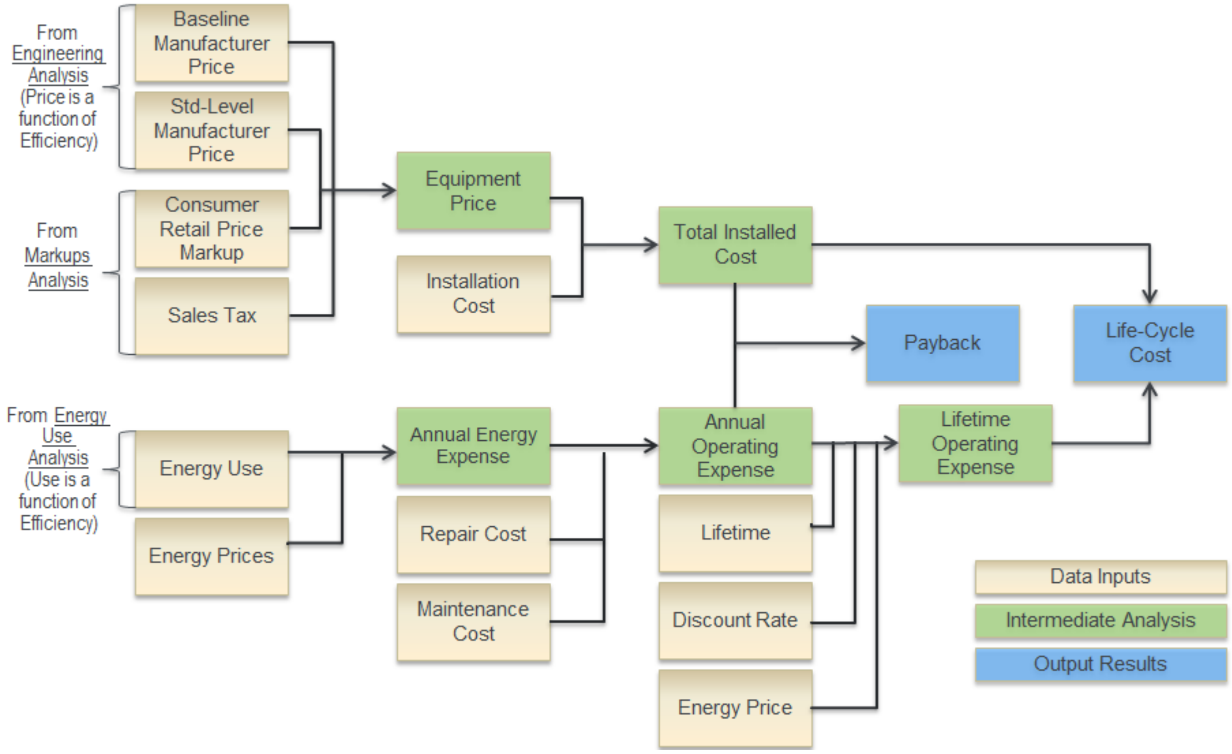

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

8.2 INPUTS TO LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

DOE gathered most of the data for performing the LCC and PBP analysis in 2014. DOE expresses dollar values in 2014$.

8.2.1 Inputs to Total Installed Cost

DOE uses the following equation to define the total installed cost.

$$IC = CPC + INST$$

Eq. 8.3

Where:

IC = total installed cost,
CPC = consumer product cost (i.e., consumer cost for the product only), and
INST = consumer cost to install the product.

The product cost depends on how the consumer purchases the product. As discussed in chapter 6 of this NOPR TSD, DOE defined markups and sales taxes for converting manufacturing costs into consumer product costs. Table 8.2.1summarizes the inputs for determining total installed cost.

Table 8.2.1 Inputs to Total Installed Cost

Baseline manufacturer cost
Standard-level manufacturer Cost
Markups throughout distribution chain
Sales tax (replacement applications)
Installation cost

The *baseline manufacturer cost* is the cost incurred by the manufacturer to produce products that meet current minimum efficiency standards. *Standard-level manufacturer cost increases* are the change in manufacturer cost associated with producing products that meet a new standard level. *Markups and sales tax* convert the manufacturer cost to a consumer product cost. The *installation cost* represents all costs required for the consumer to install the product, other than the marked-up consumer product cost. The installation cost includes labor, overhead, and any miscellaneous materials and parts.

DOE calculated the total installed cost for baseline products based on the following equation.

$$\begin{aligned} IC_{BASE} &= CPC_{BASE} + INST_{BASE} \\ &= COST_{MFG} \times MU_{OVERALL\_BASE} + INST_{BASE} \end{aligned}$$

Eq. 8.4

Where:

IC_{BASE} = total installed cost for baseline model,
CPC_{BASE} = consumer product cost for baseline model,
$INST_{BASE}$ = installation cost for baseline model,
$COST_{MFG}$ = manufacturer cost for baseline model, and
$MU_{OVERALL\_BASE}$ = overall baseline markup (product of manufacturer markup, baseline retailer or distributor markup, and sales tax).

DOE used the following equation to calculate the total installed cost for standard-level products.

$$\begin{aligned} IC_{STD} &= CPC_{STD} + INST_{STD} \\ &= \left(CPC_{BASE} + \Delta CPC_{STD}\right) + \left(INST_{BASE} + \Delta INST_{STD}\right) \\ &= \left(CPC_{BASE} + INST_{BASE}\right) + \left(\Delta CPC_{STD} + \Delta INST_{STD}\right) \\ &= IC_{BASE} + \left(\Delta COST_{MFG} \times MU_{OVERALL\_INCR} + \Delta INST_{STD}\right) \end{aligned}$$

Eq. 8.5

Where:

IC_{STD} = total installed cost for standard-level model,
CPC_{STD} = consumer product cost for standard-level model,
$INST_{STD}$ = installation cost for standard-level model,
CPC_{BASE} = consumer product cost for baseline model,
ΔCPC_{STD} = change in product cost for standard-level model,
$INST_{BASE}$ = baseline installation cost,
$\Delta INST_{STD}$ = change in installation cost for standard-level model,
IC_{BASE} = baseline total installed cost,
$\Delta COST_{MFG}$ = change in manufacturer cost for standard-level model, and
$MU_{OVERALL\_INCR}$ = overall incremental markup (product of manufacturer markup, incremental retailer or distributor markup, and sales tax).

The rest of this section provides information about each of the above input variables, which DOE used to calculate the total installed cost for conventional cooking products.

8.2.1.1 Forecasting Future Product Prices

Examination of historical price data for certain appliances and equipment that have been subject to energy conservation standards indicates that the assumption of constant real prices and costs may, in many cases, overestimate long-term trends in appliance and equipment prices. Economic literature and historical data suggest that the real costs of these products may in fact trend downward over time according to “learning” or “experience” curves. Desroches et al. (2013) summarizes the data and literature currently available that is relevant to price projections for selected appliances and equipment[3]. The extensive literature on the “learning” or “experience” curve phenomenon is typically based on observations in the manufacturing sector[a]. In the experience curve method, the real cost of production is related to the cumulative production or “experience” with a manufactured product. This experience is usually measured in terms of cumulative production. A common functional relationship used to model the evolution of production costs in this case is:

$$Y = a\,X^{-b}$$

Eq. 8.6

Where:

a = an initial price (or cost),
b = a positive constant known as the learning rate parameter,
X = cumulative production, and
Y = the price as a function of cumulative production.

Thus, as experience (production) accumulates, the cost of producing the next unit decreases. The percentage reduction in cost that occurs with each doubling of cumulative production is known as the learning rate (LR), given by:

$$\mathrm{LR} = 1 - 2^{-b}$$

Eq. 8.7

In typical learning curve formulations, the learning rate parameter is derived using two historical data series: cumulative production and price (or cost).

To derive the learning rate parameter for gas and electric ovens, DOE obtained historical Producer Price Index (PPI) data for “gas household ranges, ovens surface cooking units, and equipment” and “electric household ranges, ovens surface cooking units, and equipment” from the Bureau of Labor Statistics’ (BLS) spanning the time period 1982-2014 and 1970-2014, respectively[b]. These are the most representative price indices for these two product categories. Inflation-adjusted price indices were calculated by dividing the PPI series by the gross domestic product-chained price index for the same years. These inflation-adjusted price indices (shown in Figure 8.2.1and Figure 8.2.2) ware used in subsequent analysis steps.

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[a] In addition to Desroches (2013), see Weiss, M., Junginger, H.M., Patel, M.K., Blok, K., (2010a). A Review of Experience Curve Analyses for Energy Demand Technologies. Technological Forecasting & Social Change. 77:411-428.

[b] Product series ID: PCU3352213Y for gas household ranges, ovens, surface cooking units and equipment and PCU3352211Y for electric household ranges, ovens, surface cooking units and equipment. Available at: http://www.bls.gov/ppi/.

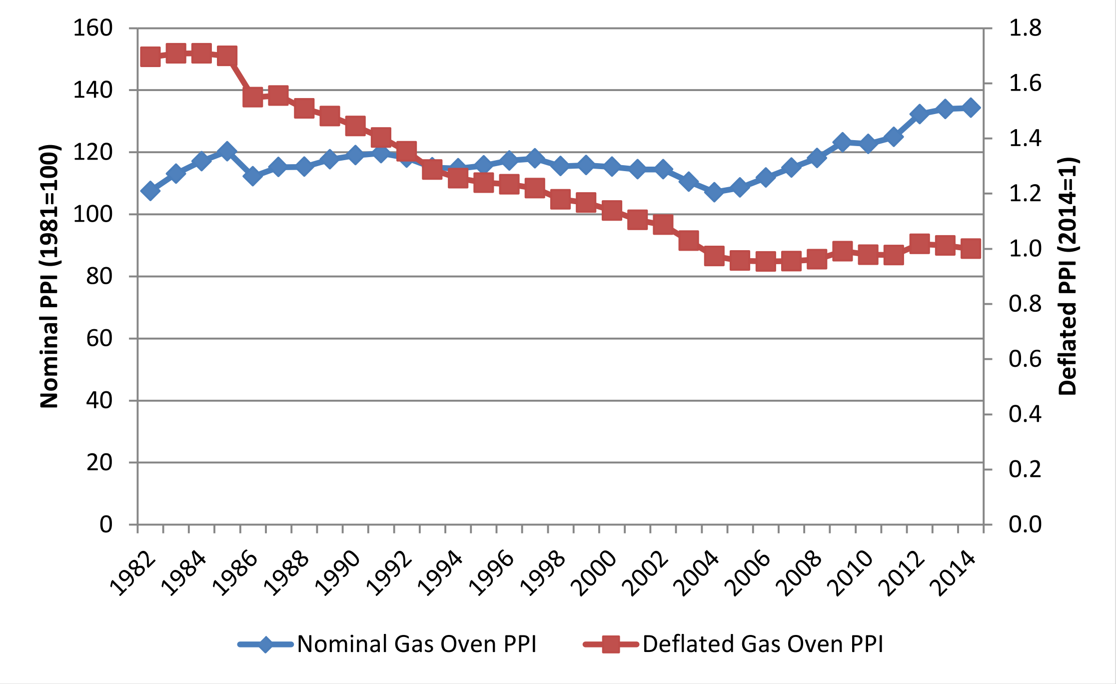

Figure 8.2.1 **Nominal and Deflated Gas Oven PPI from 1982 to 2014**

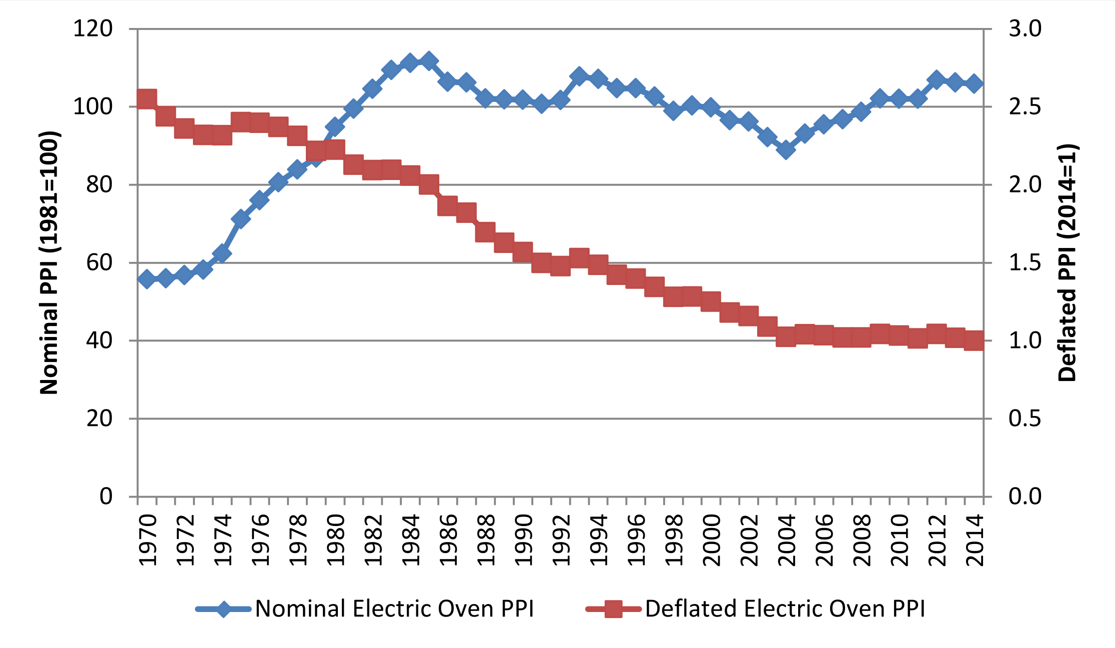

Figure 8.2.2 **Nominal and Deflated Electric Oven PPI from 1970 to 2014**

DOE assembled a time-series of annual shipments for 1970 to 2012 for both gas and electric ovens from Association of Household Appliance Manufacturers (AHAM) and Market

Research Magazine.[4] The annual shipments data were used to estimate cumulative shipments (production). Projected shipments after 2012 were obtained from the base case projections made for the NIA (see chapter 9 of this TSD). Figure 8.2.3 and Figure 8.2.4 show the shipments time series used in the analysis.

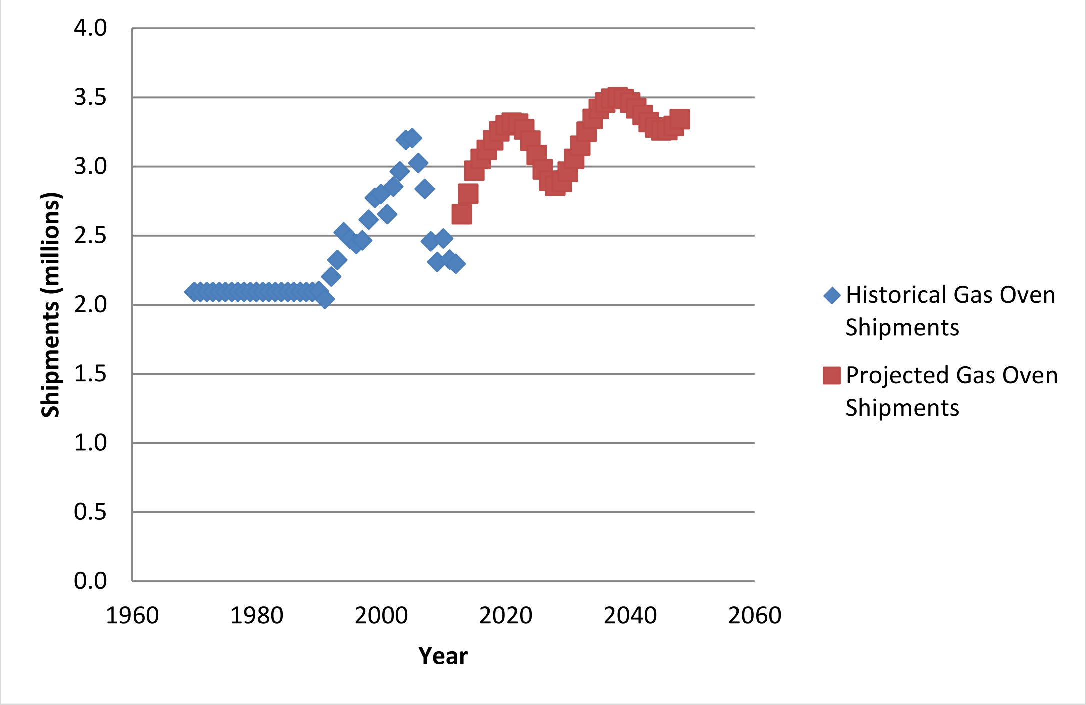

Figure 8.2.3 **Historical and Projected Shipments of Gas Ovens**

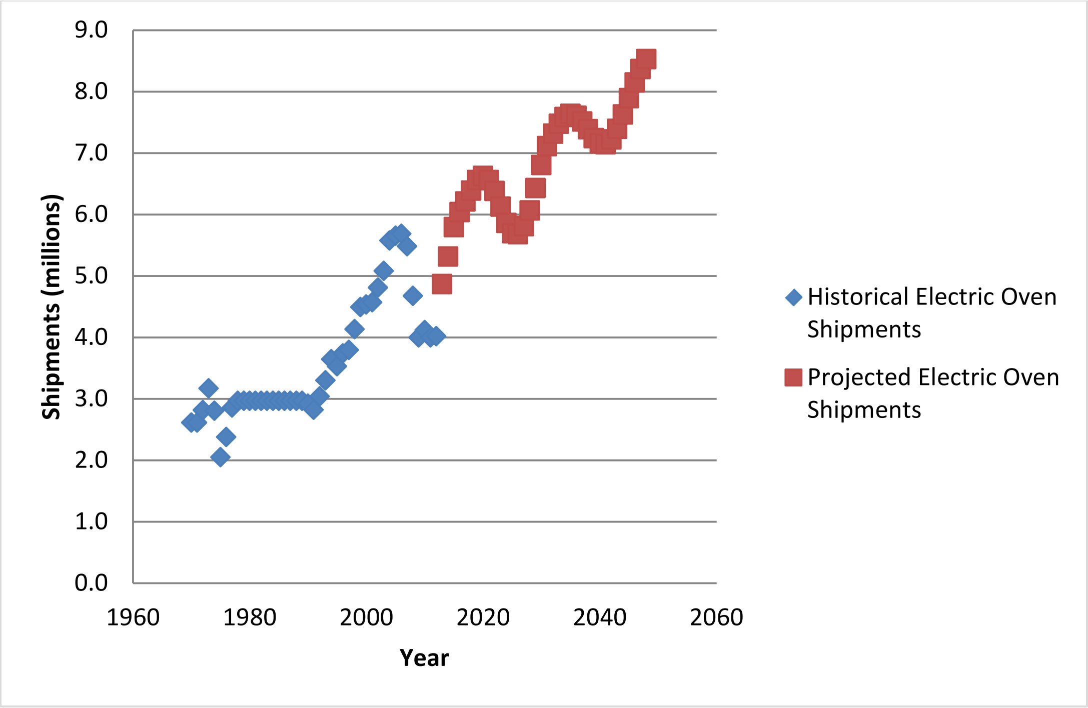

Figure 8.2.4 Historical and Projected Shipments of Electric Ovens

To estimate learning rate parameter, a least-squares power-law fit was performed on the deflated price index versus cumulative shipments. See Figure 8.2.5 and Figure 8.2.6.

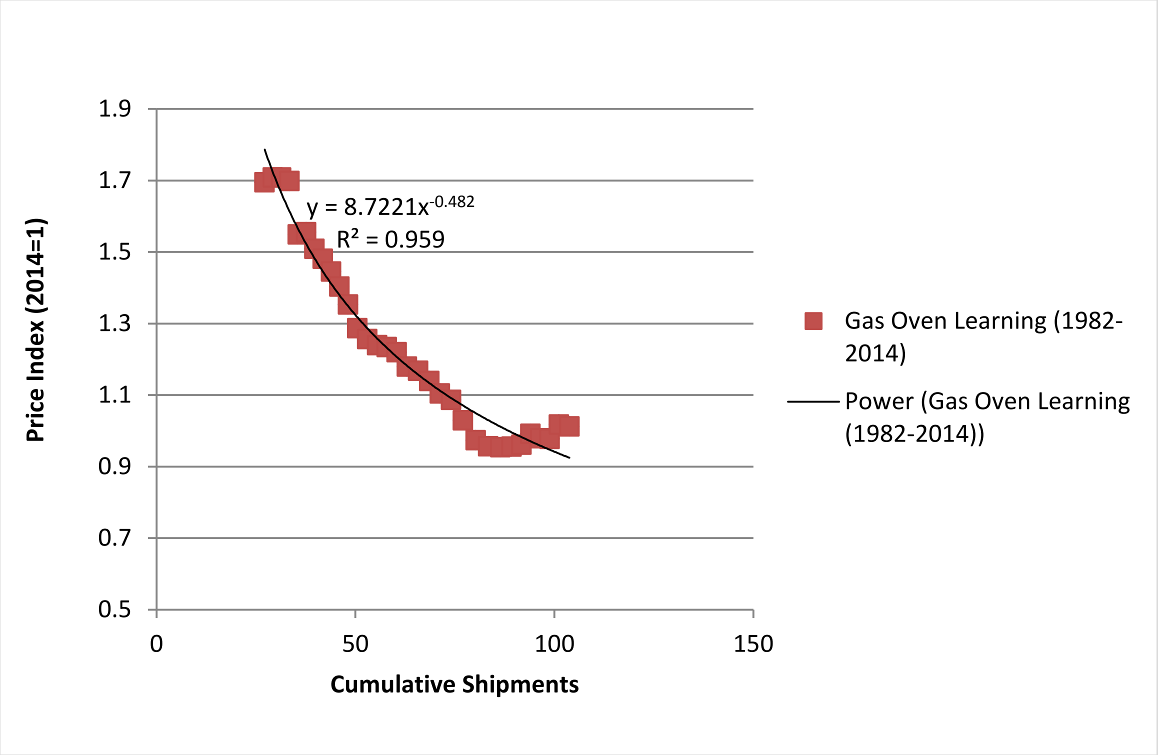

Figure 8.2.5 **Relative Price versus Cumulative Shipments of Gas Ovens from 1982 to 2014, with Power Law Fit**

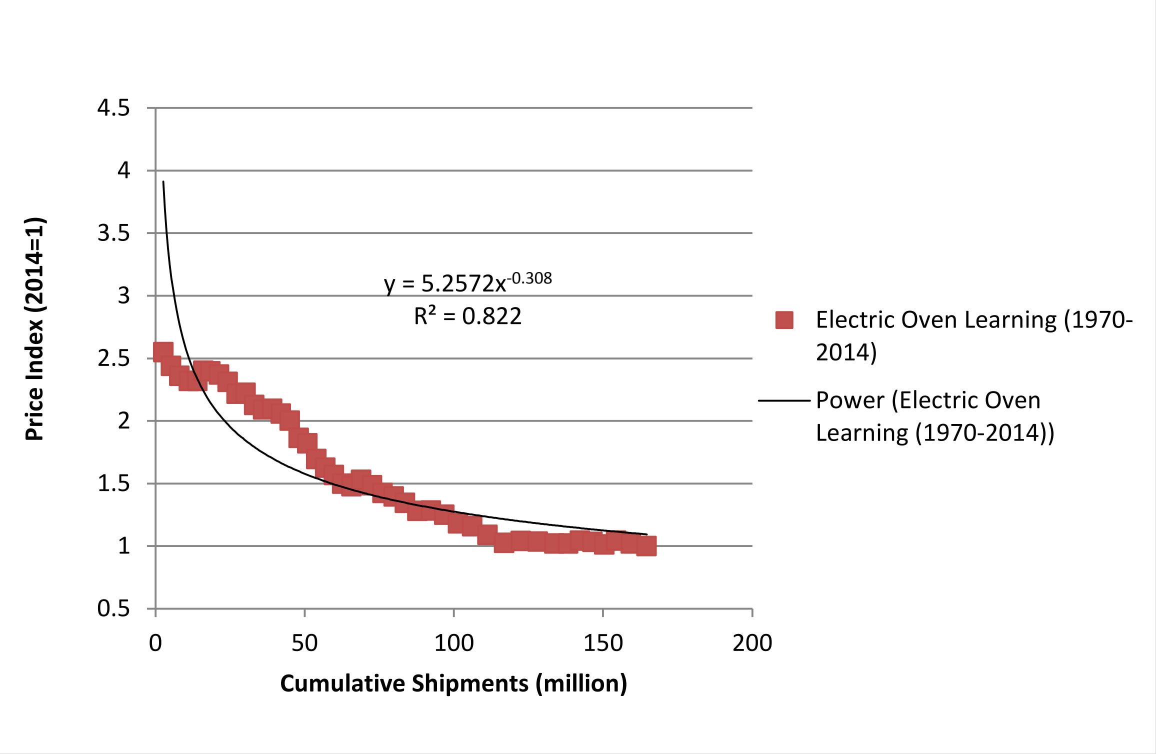

Figure 8.2.6 **Relative Price versus Cumulative Shipments of Electric Ovens from 1970 to 2014, with Power Law Fit**

The form of the fitting equation is:

$$P(X) = P_o X^{-b}, \tag{Eq. 8.8}$$

where, the two parameters, *b* (the learning rate parameter) and P_o (the price or cost of the first unit of production), are obtained by fitting the model to the data. DOE notes that the cumulative shipments on the right hand side of the equation can have a dependence on price, so there is an issue with simultaneity where the independent variable is not truly independent. DOE's use of a simple least squares fit is equivalent to an assumption of no significant first price elasticity effects in the cumulative shipments variable.

For gas ovens, the parameter values obtained are:

$P_o = 8.722^{+1.406}_{-1.211}$(95% confidence), and
b = 0.482±0.036 (95% confidence).

The estimated learning rate (defined as the fractional reduction in price expected from each doubling of cumulative production) is 28.4%±1.8% (95% confidence).

For electric ovens, the parameter values obtained are:

$P_o = 5.257^{+1.035}_{-0.865}$ (95% confidence), and
b = 0.308±0.044 (95% confidence).

The estimated learning rate (defined as the fractional reduction in price expected from each doubling of cumulative production) is 19.2%±2.5% (95% confidence).

DOE derived two price factor indices, with 2014 equal to 1, to project prices for gas and electric ovens in each future year in the analysis period. The index value in a given year is a function of the LR and the cumulative production forecast through that year. DOE applied the same value to project prices for both product categories at each considered efficiency level. The estimated price forecast index is shown in Figure 8.2.7.

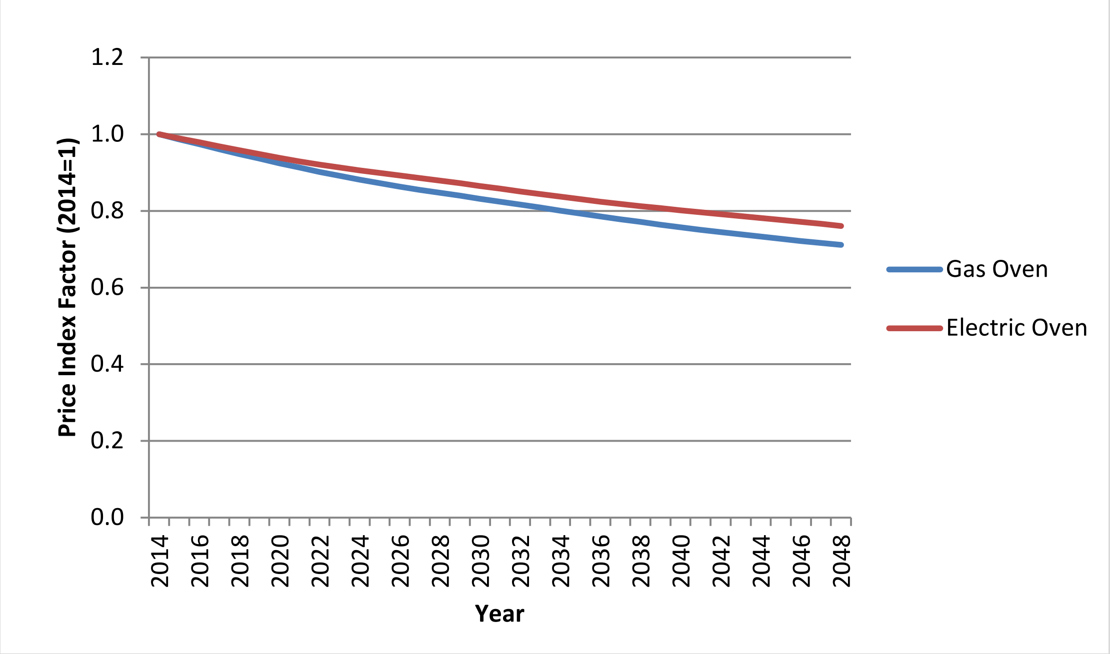

Figure 8.2.7 Price Forecast Indices for Gas Electric Cooktop and Ovens

8.2.1.2 Baseline Manufacturer Costs

DOE developed the baseline manufacturer costs for all eight product classes of conventional cooking products (described in chapter 5 of this NOPR TSD, Engineering Analysis). Also included in the table are the associated baseline integrated annual energy consumption values (IAEC).

Table 8.2.2 Baseline Manufacturer Costs

Product Class	Integrated Annual Energy Consumption (IAEC)		Baseline Manufacturer Cost (2014$)
	Gas (kBtu/year)	*Electricity (kWh/year)*	
Electric Standard Ovens, Freestanding	--	294.5	$265.22
Electric Standard Ovens, Built-In/Slide-In	--	301.5	$280.76
Electric Self-Clean Ovens, Freestanding	--	355.0	$291.26
Electric Self-Clean Ovens, Built-In/Slide-in	--	361.1	$306.80
Gas Standard Ovens, Freestanding	2,118.2	--	$294.34
Gas Standard Ovens, Built-In/Slide-In	2,128.1	--	$309.88
Gas Self-Clean Ovens, Freestanding	1,883.8	--	$362.98
Gas Self-Clean Ovens, Built-In/Slide-In	1,893.7	--	$378.52

8.2.1.3 Incremental Manufacturer Cost by Efficiency Level

DOE used a reverse-engineering analysis to develop manufacturer cost increases associated with increases in the efficiency of conventional cooking products. Refer to Chapter 5, Engineering Analysis, of this NOPR TSD for details. Table 8.2.3 through Table 8.2.10 present the incremental manufacturer costs at each efficiency level for all eight product classes of conventional cooking products. Also included in each of the tables are the associated integrated annual energy consumption (IAEC) values.

Table 8.2.3 Electric Standard Ovens, Freestanding: Incremental Manufacturer Cost by Efficiency Level

EL	IAEC	Manufacturer Cost Increase (2014$)
	kWh/year	
Baseline	294.5	--
1	284.6	$0.82
2	271.7	$2.76
3	259.2	$7.89
4	254.9	$10.22
5	244.6	$34.40
6	207.8	$66.14
7	207.3	$70.36

Table 8.2.4 Electric Standard Ovens, Built-In/Slide-In: Incremental Manufacturer Cost by Efficiency Level

EL	IAEC	Manufacturer Cost Increase (2014$)
	kWh/year	
Baseline	301.5	--
1	291.4	$0.82
2	278.2	$2.76
3	265.4	$7.89
4	261.0	$10.22
5	250.5	$34.40
6	212.8	$66.14
7	212.2	$70.36

Table 8.2.5 Electric Self-Clean Ovens, Freestanding: Incremental Manufacturer Cost by Efficiency Level

EL	IAEC	Manufacturer Cost Increase (2014$)
	kWh/year	
Baseline	355.0	--
1	345.1	$0.82
2	327.2	$25.00
3	278.9	$56.74
4	278.1	$61.93

Table 8.2.6 Electric Self-Clean Ovens, Built-In/Slide-In: Incremental Manufacturer Cost by Efficiency Level

EL	IAEC	Manufacturer Cost Increase (2014$)
	kWh/year	
Baseline	361.1	--
1	351.0	$0.82
2	332.7	$25.00
3	283.7	$56.74
4	282.9	$61.93

Table 8.2.7 Gas Standard Ovens, Freestanding: Incremental Manufacturer Cost by Efficiency Level

EL	IAEC	Manufacturer Cost Increase (2014$)
	kBtu/year	
Baseline	2118.2	--
1	1649.3	$0.00
2	1614.7	$0.82
3	1490.7	$7.31
4	1414.8	$12.44
5	1400.6	$14.77
6	1355.6	$35.43
7	1347.0	$39.74

Table 8.2.8 Gas Standard Oven, Built-In/Slide-In: Incremental Manufacturer Cost by Efficiency Level

EL	IAEC	Manufacturer Cost Increase (2014$)
	kBtu/year	
Baseline	2128.1	--
1	1657.0	$0.00
2	1622.2	$0.82
3	1497.7	$7.31
4	1421.5	$12.44
5	1407.2	$14.77
6	1362.0	$35.43
7	1353.3	$39.74

Table 8.2.9 Gas Self-Clean Ovens, Freestanding: Incremental Manufacturer Cost by Efficiency Level

EL	IAEC	Manufacturer Cost Increase (2014$)
	kBtu/year	
Baseline	1883.8	--
1	1848.2	$0.82
2	1668.7	$7.31
3	1596.3	$27.96
4	1591.0	$33.15

Table 8.2.10 Gas Self-Clean Ovens, Built-In/Slide-In: Incremental Manufacturer Cost Increases by Efficiency Level

EL	IAEC	Manufacturer Cost Increase (2014$)
	kBty/year	
Baseline	1893.7	--
1	1858.0	$0.82
2	1677.5	$7.31
3	1604.7	$27.96
4	1599.4	$33.15

8.2.1.4 Overall Markup

The overall markup is the value determined by multiplying the manufacturer and retailer markups and the sales tax together to arrive at a single markup value. Table 8.2.14 shows the overall baseline and incremental markups for conventional cooking products. Refer to chapter 6 of this NOPR TSD for details.

Table 8.2.11 Cooking Products: Overall Markup

Markup	Baseline	Incremental
Manufacturer	1.20	
Retailer	1.39	1.13
Sales Tax	1.071	
Overall	1.79	1.45

8.2.1.5 Installation Cost

DOE derived baseline installation costs for ovens from data in the *RS Means Mechanical Cost Data, 2013*.[5] The book estimates the labor required to install residential cooking range equipment. Table 8.2.12 summarizes the nationally representative costs associated with the installation of a 30-inch, free-standing cooking range as presented in *RS Means Mechanical Cost*

Data. DOE decided that the costs of installing a range are representative of the costs of installing an oven. Table 8.2.12 provides both bare costs (i.e., costs before overhead and profit (O&P)) and installation costs including O&P. *RS Means* provides minimum and maximum costs. DOE used the average of the minimum and maximum labor costs as its estimate of installation costs for ovens.

DOE used the cooking range installation cost data to estimate its installation costs for ovens. DOE determined that only gas ovens with electric or electronic ignition devices would incur added installation costs.

Table 8.2.12 Cooking Range (1 Oven): Baseline Installation Costs

	Bare Costs (2014$)			**Including Overhead & Profit (2014$)**		
Installation Type	**Material**	**Labor**	**Total**	**Total**	**Material***	**Labor****
Minimum	$435	$37	$472	$540	$479	$61
Maximum	$1,700	$92	$1,792	$2,025	$1,870	$155
					Average (2014$)	**$108.00**

* Material costs including O&P equal bare costs plus 10% profit.

** DOE derived labor costs including O&P by subtracting material with O&P from total with O&P.

Source: RS Means, *Mechanical Cost Data, 2013.*

8.2.1.6 Total Installed Cost

The total installed cost is the sum of the consumer product cost and installation cost. 8-18Table 8.2.13 through Table 8.2.20 present the total installed costs for each conventional cooking product class at each efficiency level examined.

Table 8.2.13 Electric Standard Ovens, Freestanding: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	**Equipment Price (2014$)**	**Installation Cost (2014$)**	**Total Installed Cost (2014$)**
Baseline	$448.71	$108.00	$556.71
1	$449.83	$108.00	$557.83
2	$452.50	$108.00	$560.50
3	$459.55	$108.00	$567.55
4	$462.76	$108.00	$570.76
5	$496.02	$108.00	$604.02
6	$539.67	$108.00	$647.67
7	$545.47	$108.00	$653.47

Table 8.2.14 Electric Standard Ovens, Built-In/Slide-In: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2014$)	Installation Cost (2014$)	Total Installed Cost (2014$)
Baseline	$475.00	$108.00	$583.00
1	$476.12	$108.00	$584.12
2	$478.79	$108.00	$586.79
3	$485.84	$108.00	$593.84
4	$489.05	$108.00	$597.05
5	$522.31	$108.00	$630.31
6	$565.96	$108.00	$673.96
7	$571.76	$108.00	$679.76

Table 8.2.15 Electric Self-Clean Ovens, Freestanding: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2014$)	Installation Cost (2014$)	Total Installed Cost (2014$)
Baseline	$492.48	$108.00	$600.48
1	$493.60	$108.00	$601.60
2	$526.85	$108.00	$634.85
3	$570.47	$108.00	$678.47
4	$577.61	$108.00	$685.61

Table 8.2.16 Electric Self-Clean Ovens, Built-In/Slide-In: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2014$)	Installation Cost (2014$)	Total Installed Cost (2014$)
Baseline	$518.75	$108.00	$626.75
1	$519.88	$108.00	$627.88
2	$553.12	$108.00	$661.12
3	$596.75	$108.00	$704.75
4	$603.88	$108.00	$711.88

Table 8.2.17 Gas Standard Ovens, Freestanding: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2014$)	Installation Cost (2014$)	Total Installed Cost (2014$)
Baseline	$493.77	$108.00	$601.77
1	$493.77	$108.00	$601.77
2	$494.89	$108.00	$602.89
3	$503.73	$108.00	$611.73
4	$510.73	$108.00	$618.73
5	$513.91	$108.00	$621.91
6	$542.08	$108.00	$650.08
7	$547.96	$108.00	$655.96

Table 8.2.18 Gas Standard Ovens, Built-In/Slide-In: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2014$)	Installation Cost (2014$)	Total Installed Cost (2014$)
Baseline	$519.84	$108.00	$627.84
1	$519.84	$108.00	$627.84
2	$520.95	$108.00	$628.95
3	$529.80	$108.00	$637.80
4	$536.80	$108.00	$644.80
5	$539.98	$108.00	$647.98
6	$568.15	$108.00	$676.15
7	$574.03	$108.00	$682.03

Table 8.2.19 Gas Self-Clean Ovens, Freestanding: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2014$)	Installation Cost (2014$)	Total Installed Cost (2014$)
Baseline	$608.40	$108.00	$716.40
1	$609.52	$108.00	$717.52
2	$618.36	$108.00	$726.36
3	$646.51	$108.00	$754.51
4	$653.58	$108.00	$761.58

Table 8.2.20 Gas Self-Clean Ovens, Built-In/Slide-In: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2014$)	Installation Cost (2014$)	Total Installed Cost (2014$)
Baseline	$634.45	$108.00	$742.45
1	$635.57	$108.00	$743.57
2	$644.41	$108.00	$752.41
3	$672.55	$108.00	$780.55
4	$679.62	$108.00	$787.62

8.2.2 Inputs to Operating Cost

DOE defines operating cost (OC) by the following equation:

$$OC = EC + RC + MC$$

Eq. 8.9

where:

EC = Energy expenditure associated with operating the equipment,
RC = Repair cost associated with component failure, and
MC = Service cost for maintaining equipment operation.

Table 8.2.21 shows the inputs for determining annual operating costs and their discounted values throughout the product lifetime.

Table 8.2.21 Inputs for Operating Cost

Annual energy consumption
Energy prices and price trends
Repair and maintenance Costs
Energy Price Trends
Product Lifetime
Discount Rate
Effective Date of Standard

The *annual energy consumption* is the site energy use associated with operating the product. Annual energy consumption varies with product efficiency. *Energy prices* are the prices paid by consumers for energy (e.g., electricity or natural gas). Multiplying the annual energy consumption by the energy price yields the annual energy cost. *Repair costs* are associated with repairing or replacing components that have failed. *Maintenance costs* are associated with maintaining the operation of the product. DOE used *energy price trends* to forecast energy prices into the future and, along with the product lifetime and discount rate, to establish the present value of lifetime energy costs.

DOE used the following equation to calculate the annual operating cost for baseline products.

$$\boldsymbol{OC_{BASE} = EC_{BASE} + RC_{BASE} + MC_{BASE} = AEC_{BASE} \times PRICE_{ENERGY} + RC_{BASE} + MC_{BASE}}$$

Eq. 8.10

where:

OC_{BASE} = Baseline operating cost,
EC_{BASE} = Energy expenditure associated with operating the baseline equipment,
RC_{BASE} = Repair cost associated with component failure for the baseline equipment,
MC_{BASE} = Service cost for maintaining baseline equipment operation,
AEC_{BASE} = Annual energy consumption for baseline equipment, and
$PRICE_{ENERGY}$ = Energy price.

DOE calculated the operating cost for standard-level products based on the following equation:

$$\boldsymbol{\begin{aligned} OC_{STD} &= EC_{STD} + RC_{STD} + MC_{STD} = AEC_{STD} \times PRICE_{ENERGY} + RC_{STD} + MC_{STD} \\ &= \left(AEC_{BASE} - \Delta AEC_{STD}\right) \times PRICE_{ENERGY} + \left(RC_{BASE} + \Delta RC_{STD}\right) + \left(MC_{BASE} + \Delta MC_{STD}\right) \end{aligned}}$$

Eq. 8.11

where:

OC_{STD} = Standard-level operating cost,
EC_{STD} = Energy expenditure associated with operating standard-level equipment,
RC_{STD} = Repair cost associated with component failure for standard-level equipment,
MC_{STD} = Service cost for maintaining standard-level equipment operation,
AEC_{STD} = Annual energy consumption for standard-level equipment,
$PRICE_{ENERGY}$ = Energy price,
ΔAEC_{STD} = Change in annual energy consumption caused by standard-level equipment,
ΔRC_{STD} = Change in repair cost caused by standard-level equipment, and
ΔMC_{STD} = Change in maintenance cost caused by standard-level equipment.

The remainder of this section provides information about each of the above input variables that DOE used to calculate the operating costs for all product classes for conventional cooking products.

8.2.2.1 Annual Energy Consumption

Chapter 7, Energy Use Analysis, details how DOE determined the annual energy consumption for baseline and standard-level products.

As described in section 7.2.3 of chapter 7 of this NOPR TSD, DOE developed a sample of individual households that use one of the product classes of conventional cooking products. By developing household samples, DOE was able to perform the LCC and PBP calculations for each household to account for the variability in both energy use and energy price associated with each household. DOE used EIA's 2009 RECS to develop the household samples and, in turn, to establish the variability in both annual energy consumption and energy pricing. Refer to chapter 7 to review the variability of annual energy consumption for conventional cooking products.

The tables presented in this section are based on the energy use analysis described in chapter 7. Keep in mind that the annual energy consumption values in the tables below are averages. DOE captured the variability in energy consumption when it conducted its LCC and PBP analysis.

Table 8.2.22 through Table 8.2.29 provide the annual energy consumption by efficiency level for all eight product classes of conventional cooking products.

Table 8.2.22 Electric Standard Ovens, Freestanding: Annual Energy Consumption by Efficiency Level

Efficiency Level	**IAEC***	**Cooking Energy**	**Non-Cooking Energy****	**Total**
	kWh/year	*kWh/year*	*kWh/year*	*kWh/year*
Baseline	294	116.3	19.3	135.6
1	285	116.2	9.6	125.8
2	272	110.7	9.6	120.4
3	259	105.4	9.6	115.1
4	255	103.7	9.6	113.3
5	245	98.8	10.8	109.6
6	208	83.3	10.8	94.1
7	207	83.0	10.8	93.9

*IAEC results based on DOE's engineering analysis

**Includes Standby, Self-Clean, Forced Convection, and Ignition Energy

Table 8.2.23 Electric Standard Ovens, Built-In/Slide-In: Annual Energy Consumption by Efficiency Level

Efficiency Level	IAEC*	Cooking Energy	Non-Cooking Energy**	Total
	kWh/year	*kWh/year*	*kWh/year*	*kWh/year*
Baseline	302	116.3	19.3	135.6
1	291	116.1	9.6	125.7
2	278	110.7	9.6	120.3
3	265	105.4	9.6	115.0
4	261	103.6	9.6	113.2
5	250	98.7	10.9	109.6
6	213	83.2	10.9	94.1
7	212	83.0	10.9	93.8

*IAEC results based on DOE's engineering analysis
**Includes Standby, Self-Clean, Forced Convection, and Ignition Energy

Table 8.2.24 Electric Self-Clean Ovens, Freestanding: Annual Energy Consumption by Efficiency Level

Efficiency Level	IAEC*	Cooking Energy	Non-Cooking Energy**	Total
	kWh/year	*kWh/year*	*kWh/year*	*kWh/year*
Baseline	355	118.4	56.2	174.6
1	345	118.3	46.6	164.9
2	327	110.7	47.9	158.6
3	279	91.5	47.9	139.5
4	278	91.2	47.9	139.1

*IAEC results based on DOE's engineering analysis
**Includes Standby, Self-Clean, Forced Convection, and Ignition Energy

Table 8.2.25 Electric Self-Clean Ovens, Built-In/Slide-In: Annual Energy Consumption by Consumption by Efficiency Level

Efficiency Level	IAEC*	Cooking Energy	Non-Cooking Energy**	Total
	kWh/year	*kWh/year*	*kWh/year*	*kWh/year*
Baseline	361	118.4	56.8	175.3
1	351	118.3	47.2	165.5
2	333	110.6	48.6	159.2
3	284	91.5	48.6	140.1
4	283	91.2	48.6	139.8

*IAEC results based on DOE's engineering analysis
**Includes Standby, Self-Clean, Forced Convection, and Ignition Energy

Table 8.2.26 Gas Standard Ovens, Freestanding: Annual Energy Consumption by Efficiency Level

Efficiency Level	IAEC*	Cooking Energy	Non-Cooking Energy**	Total
	kBtu/year	*kBtu/year*	*kBtu/year*	*kBtu/year*
Baseline	2,118	831.3	208.8	1040.1
1	1,649	626.6	208.8	835.4
2	1,615	625.8	175.9	801.7
3	1,491	571.7	175.9	747.6
4	1,415	603.4	32.9	636.3
5	1,401	597.2	32.9	630.1
6	1,356	573.9	41.0	614.9
7	1,347	570.1	41.0	611.1

*IAEC results based on DOE's engineering analysis

**Includes Standby, Self-Clean, Forced Convection, and Ignition Energy

Table 8.2.27 Gas Standard Ovens, Built-In/Slide-In: Annual Energy Consumption by Efficiency Level

Efficiency Level	IAEC*	Cooking Energy	Non-Cooking Energy**	Total
	kBtu/year	*kBtu/year*	*kBtu/year*	*kBtu/year*
Baseline	2,128	831.3	208.8	1040.1
1	1,657	626.7	208.8	835.5
2	1,622	625.8	175.9	801.8
3	1,498	571.8	175.9	747.7
4	1,421	603.1	32.9	636.0
5	1,407	596.9	32.9	629.8
6	1,362	573.6	41.1	614.7
7	1,353	569.8	41.1	610.9

*IAEC results based on DOE's engineering analysis

**Includes Standby, Self-Clean, Forced Convection, and Ignition Energy

Table 8.2.28 Gas Self-Clean Ovens, Freestanding: Annual Energy Consumption by Efficiency Level

Efficiency Level	IAEC*	Cooking Energy	Non-Cooking Energy**	Total
	kBtu/year	*kBtu/year*	*kBtu/year*	*kBtu/year*
Baseline	1,884	660.8	465.5	1126.3
1	1,848	659.6	432.6	1092.2
2	1,669	645.1	283.4	928.5
3	1,596	607.9	291.0	898.9
4	1,591	605.4	291.0	896.4

*IAEC results based on DOE's engineering analysis

**Includes Standby, Self-Clean, Forced Convection, and Ignition Energy

Table 8.2.29 Gas Self-Clean Ovens, Built-In/Slide-In: Annual Energy Consumption by Efficiency Level

Efficiency Level	IAEC*	Cooking Energy	Non-Cooking Energy**	Total
	kBtu/year	*kBtu/year*	*kBtu/year*	*kBtu/year*
Baseline	1,894	660.8	466.8	1127.6
1	1,858	659.5	433.9	1093.4
2	1,677	644.7	284.7	929.4
3	1,605	607.5	292.3	899.9
4	1,599	605.0	292.3	897.4

*IAEC results based on DOE's engineering analysis
**Includes Standby, Self-Clean, Forced Convection, and Ignition Energy

8.2.2.2 Energy Prices

DOE used probability distributions to characterize the regional variability in energy and water prices. DOE developed the probability associated with each regional energy and water price based on the population weight of each region. DOE's method for deriving energy and water prices is described here.

Residential Electricity Prices

DOE used data from EIA Form 861[6] to estimate electricity prices for residential consumers in each of the above geographic areas. Those data include, for every utility that serves final consumers, annual electricity sales in kilowatt-hours; revenues from electricity sales; and number of customers in the residential, commercial, and industrial sectors. DOE calculated prices for each of 27 geographic areas in accordance with *RECS 2009* geographic areas.

The calculation of average residential electricity price proceeded in two steps.

1. For each utility, DOE estimated an average residential price by dividing the residential revenues by residential sales.
2. DOE calculated a regional average price, weighting each utility that serves residences in a region by the number of residential consumers served in that region.

Table 8.2.30 shows the average prices for each geographic region.

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Table 8.2.30 Average Residential Electricity Prices in 2013

	Geographic Area	2014$/kWh
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$0.168
2	Massachusetts	$0.161
3	New York	$0.191
4	New Jersey	$0.159
5	Pennsylvania	$0.131
6	Illinois	$0.109
7	Indiana, Ohio	$0.119
8	Michigan	$0.149
9	Wisconsin	$0.138
10	Iowa, Minnesota, North Dakota, South Dakota	$0.115
11	Kansas, Nebraska	$0.113
12	Missouri	$0.108
13	Virginia	$0.111
14	Delaware, District of Columbia, Maryland, West Virginia	$0.127
15	Georgia	$0.116
16	North Carolina, South Carolina	$0.116
17	Florida	$0.115
18	Alabama, Kentucky, Mississippi	$0.108
19	Tennessee	$0.102
20	Arkansas, Louisiana, Oklahoma	$0.097
21	Texas	$0.116
22	Colorado	$0.121
23	Idaho, Montana, Utah, Wyoming	$0.103
24	Arizona	$0.118
25	Nevada, New Mexico	$0.121
26	California	$0.164
27	Alaska, Hawaii, Oregon, Washington	$0.129

Source: EIA From 861 for 2012.

Residential Natural Gas Prices

DOE obtained data for calculating regional prices of natural gas from the EIA publication, *Natural Gas Navigator*.[7] This publication presents monthly volumes of natural gas deliveries and average prices by state for residential, commercial, and industrial customers. The Department used the complete annual data for 2012 to calculate an average annual price for each geographic area.

The calculation of average prices proceeded in two steps.

1. For each state, DOE calculated the annual residential price of natural gas using a simple average of data.
2. DOE then calculated a regional price, weighting each state in a region by its number of households.[8]

The method used to calculate natural gas prices differs from that used to calculate electricity prices, because the EIA does not provide consumer- or utility-level data on gas consumption and prices. The prices in Table 8.2.31 are in dollars per million Btu ($/MMBtu).

Table 8.2.31 Average Residential Natural Gas Prices in 2013

	Geographic Area	2014$/MMBtu
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$15.54
2	Massachusetts	$14.19
3	New York	$14.57
4	New Jersey	$11.68
5	Pennsylvania	$14.05
6	Illinois	$10.54
7	Indiana, Ohio	$12.62
8	Michigan	$10.41
9	Wisconsin	$9.74
10	Iowa, Minnesota, North Dakota, South Dakota	$10.04
11	Kansas, Nebraska	$12.37
12	Missouri	$15.43
13	Virginia	$14.39
14	Delaware, District of Columbia, Maryland, West Virginia	$13.98
15	Georgia	$17.53
16	North Carolina, South Carolina	$16.15
17	Florida	$19.50
18	Alabama, Kentucky, Mississippi	$14.36
19	Tennessee	$12.13
20	Arkansas, Louisiana, Oklahoma	$13.30
21	Texas	$13.69
22	Colorado	$9.31
23	Idaho, Montana, Utah, Wyoming	$9.02
24	Arizona	$16.64
25	Nevada, New Mexico	$10.83
26	California	$10.18
27	Alaska, Hawaii, Oregon, Washington	$15.91

Source: EIA Natural Gas Navigator for 2012.

Marginal Electricity and Gas Prices

Residential electricity and natural gas prices were adjusted by applying seasonal marginal price factors to reflect a change in a consumer's bill associated with a change in energy consumed. They are appropriate for determining energy cost savings associated with possible changes to efficiency standards.

EIA provides historical monthly electricity and natural gas consumption and expenditures by state. This data was used to determine 10-year average marginal prices factors for the RECS 2009 geographical areas, which are then used to convert average monthly energy prices into marginal monthly energy prices. DOE interpreted the slope of the regression line (consumption vs. expenditures) for each state as the marginal energy price factor for that state. Because a cooking product operates all year around, DOE determined summer and winter marginal price factors.

EIA also provides RECS 2009 billing data that was 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.

Table 8.2.32 and Table 8.2.33 show the resulting electricity and natural gas marginal price factors for both residential and commercial sectors.

Table 8.2.32 Residential Marginal Electricity Price Factors using EIA 2003-2013 Data

Geographical Area	Summer	Winter
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.936	0.999
Massachusetts	0.948	1.040
New York	1.141	0.913
New Jersey	1.198	0.985
Pennsylvania	1.073	0.832
Illinois	0.956	0.710
Indiana, Ohio	1.015	0.748
Michigan	1.126	0.959
Wisconsin	1.017	0.889
Iowa, Minnesota, North Dakota, South Dakota	1.073	0.844
Kansas, Nebraska	1.165	0.744
Missouri	1.229	0.764
Virginia	1.085	0.835
Delaware, District of Columbia, Maryland, West Virginia	1.103	0.903
Georgia	1.176	0.845
North Carolina, South Carolina	0.975	0.832
Florida	1.016	0.945
Alabama, Kentucky, Mississippi	0.998	0.827
Tennessee	0.945	0.857
Arkansas, Louisiana, Oklahoma	1.031	0.750
Texas	1.036	0.906
Colorado	1.112	0.799
Idaho, Montana, Utah, Wyoming	1.115	0.942
Arizona	1.053	0.841
Nevada, New Mexico	1.048	0.878
California	1.204	1.119
Alaska, Hawaii, Oregon, Washington	0.930	0.940

Table 8.2.33 Residential Marginal Natural Gas Price Factors using EIA 2003-2013 Data

Geographical Area	Summer	Winter
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.811	0.928
Massachusetts	0.878	1.041
New York	0.733	0.885
New Jersey	0.832	0.983
Pennsylvania	0.708	0.929
Illinois	0.658	0.956
Indiana, Ohio	0.685	0.913
Michigan	0.776	0.971
Wisconsin	0.786	0.982
Iowa, Minnesota, North Dakota, South Dakota	0.707	0.967
Kansas, Nebraska	0.670	0.939
Missouri	0.570	0.807
Virginia	0.667	0.954
Delaware, District of Columbia, Maryland, West Virginia	0.700	0.934
Georgia	0.548	0.873
North Carolina, South Carolina	0.639	0.920
Florida	0.637	0.810
Alabama, Kentucky, Mississippi	0.722	0.873
Tennessee	0.726	0.929
Arkansas, Louisiana, Oklahoma	0.628	0.834
Texas	0.588	0.840
Colorado	0.679	0.895
Idaho, Montana, Utah, Wyoming	0.851	0.951
Arizona	0.637	0.848
Nevada, New Mexico	0.702	0.891
California	0.832	1.083
Alaska, Hawaii, Oregon, Washington	0.836	0.947

8.2.2.3 Energy Price Trends

DOE used EIA's price forecasts to estimate future trends in electricity and natural gas prices. To arrive at prices in future years, DOE multiplied the average prices listed in 8-27Table 8.2.30 and Table 8.2.31 by the forecast of annual average price changes based on the reference case in EIA's *AEO 2015*.[2] To estimate the trend after 2040, DOE followed the guidance EIA previously provided to the Federal Energy Management Program (FEMP), to use the average rate of change during 2030–2040.

DOE calculated LCC and PBP based on three separate projections from *AEO 2015*: reference, low economic growth, and high economic growth. These three cases reflect the uncertainty of economic growth in the forecast period. The high and low growth cases show the projected effects of alternative growth assumptions on energy markets. Figure 8.2.8 and Figure 8.2.9 show the residential electricity and natural gas price trends, respectively, based on the three *AEO 2015* projections.

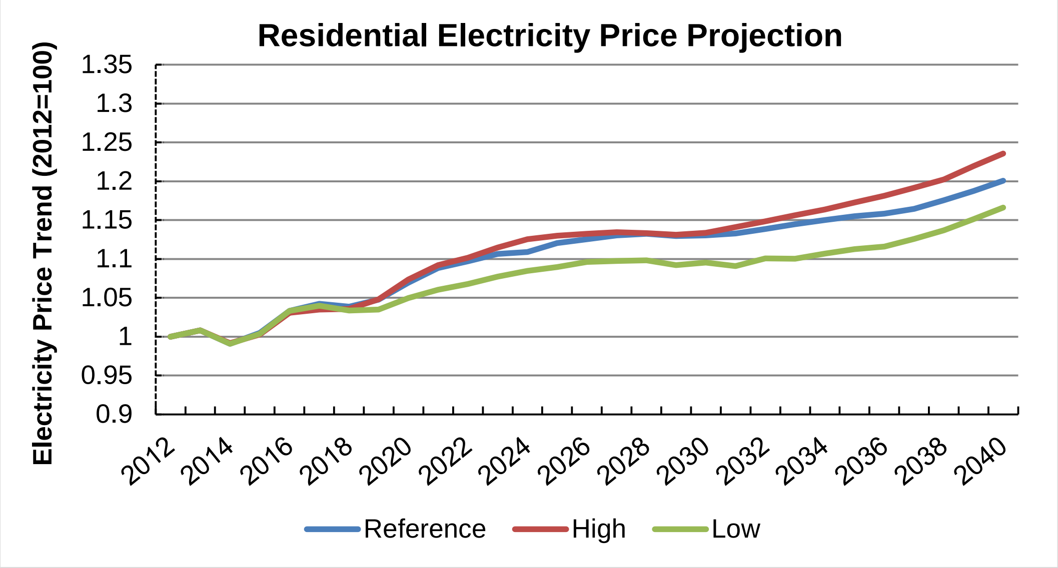

Figure 8.2.8 Electricity Price Trends

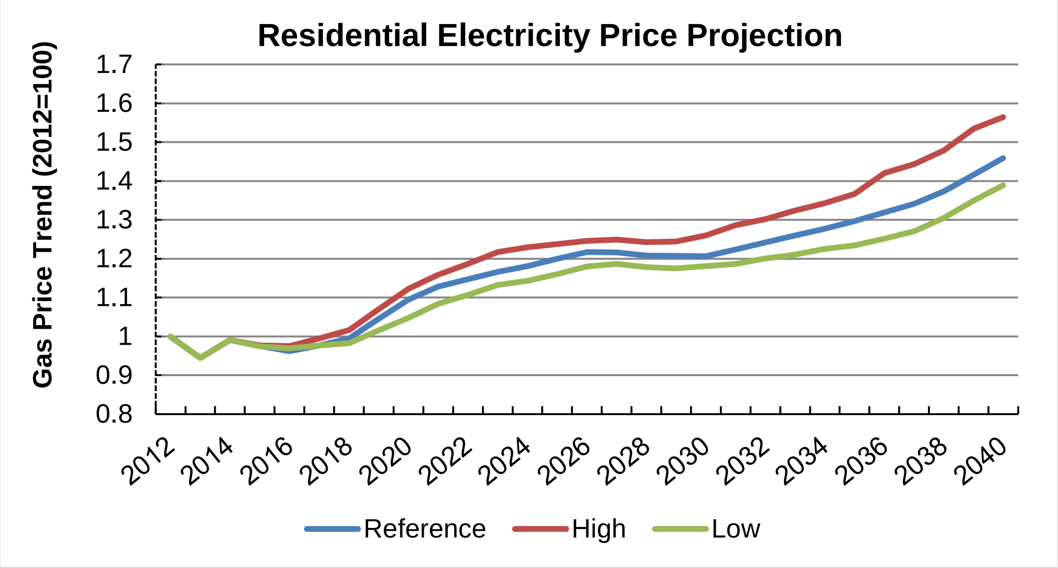

Figure 8.2.9 Natural Gas Price Trends

8.2.2.4 Repair and Maintenance Costs

For all electric cooking products, DOE did not include any changes in repair and maintenance costs for products more efficient than baseline products.

For gas ovens, DOE determined the repair and maintenance costs associated with different types of ignition systems. Following the approach adopted in the April 2009 Final Rule[9] for electric glo-bar/hot surface ignition systems, DOE estimated an average repair cost of $170 occurring every fifth year during the product's lifetime. For electronic spark ignition systems, DOE estimated an average repair cost of $206 occurring in the tenth year of the product's life. DOE determined the repair cost for the 2009 final rule by contacting six contractors, one each in Arizona, California, Colorado, Massachusetts, Minnesota, and Texas. Table 8.2.34 summarizes the findings from the discussions with the six contractors.

Table 8.2.34 Repair/Maintenance Findings for Gas Cooking Product Ignition Systems

Ignition System	Findings
Glo-bar/hot surface	• Fragile, typically last only 5 years. • Reasons for failure include burn out, cleaning sprays, jostling, and oxidation. • Average repair cost = $170
Electronic spark	• Definitely longer-lasting than Glo-bar igniters, but harder to gauge performance statistically. Modules can break after 5 years, while some last the lifetime of the appliance. Average 10 years. Electrodes rarely have problems. • Reasons for failure of spark module include power outage, pinched wire, and humidity issues. • Reasons for failure of spark electrode include physical abuse from pots and pans • Average repair cost = $206

Based on the contractors' input, DOE determined for electric glo-bar/hot surface ignition systems, the glo-bar requires replacement approximately every five years. In the case of electronic ignition systems, control modules tend to last 10 years. The electrodes/igniters can fail due to hard contact from pots or pans, although failures are rare. Based on the above findings, DOE included repair and maintenance costs for gas cooking product ignition systems (see Table 8.2.35).

Table 8.2.35 Repair/Maintenance Costs for Gas Cooking Product Ignition Systems

Ignition System	Repair/Maintenance Cost*	Occurrence
Glo-bar/hot surface**	\$170	Every 5th year of Cooking Product's Life
Electronic spark***	\$206	Every 10th year of Cooking Product's Life

* The costs indicate current day prices and are representative of 2014\$.
** Applicable to Baseline through efficiency level 3 for gas standard ovens and the baseline and efficiency level 1 for gas self-clean ovens.

*** Applicable to efficiency levels 4 through 7 for gas standard ovens and efficiency levels 2 through 4 for gas self-clean ovens.

8.2.2.5 Product Lifetime

For ovens, DOE considered the source from Appliance Magazine to estimate product lifetimes[10]. Table 8.2.25 shows the minimum, average, and maximum lifetime estimated for electric and gas cooking products, respectively.

Table 8.2.36 Conventional Cooking Products Lifetime Reference Values

Product	Minimum *years*	Average *years*	Maximum *years*
Electric	10.0	15.0	19.0
Gas	12.0	17.0	22.0

Source: Appliance Magazine, 2012.

To perform the LCC and PBP analysis, DOE had to develop survival functions for conventional cooking products. DOE estimated the percentage of appliances of a given age that would still be in operation in a given year. This survival function, which DOE assumes has the form of a cumulative Weibull distribution, provides an average and a median appliance lifetime.

The Weibull distribution is a probability distribution commonly used to measure failure rates.[c] Its form is similar to that of an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes through time. The cumulative Weibull distribution takes the form:

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

$$P(x) = 1 \text{ for } x \leq \theta.$$

Where:

$P(x)$ = probability that the appliance is still in use at age x;
x = age of appliance;

α = scale parameter, which would be the decay length in an exponential distribution;
β = shape parameter, which determines the way in which the failure rate changes through time; and
θ = delay parameter, which allows for a delay before any failures occur.

When *β* = 1, the failure rate is constant over time, giving the distribution the form of a cumulative exponential distribution. In the case of appliances, *β* commonly is greater than 1, reflecting an increasing failure rate as appliances age. Figure 8.2.10 and Figure 8.2.11 show the Weibull retirement and survival functions for electric and gas cooking products, respectively. The results of DOE's analysis are shown in Table 8.2.26.

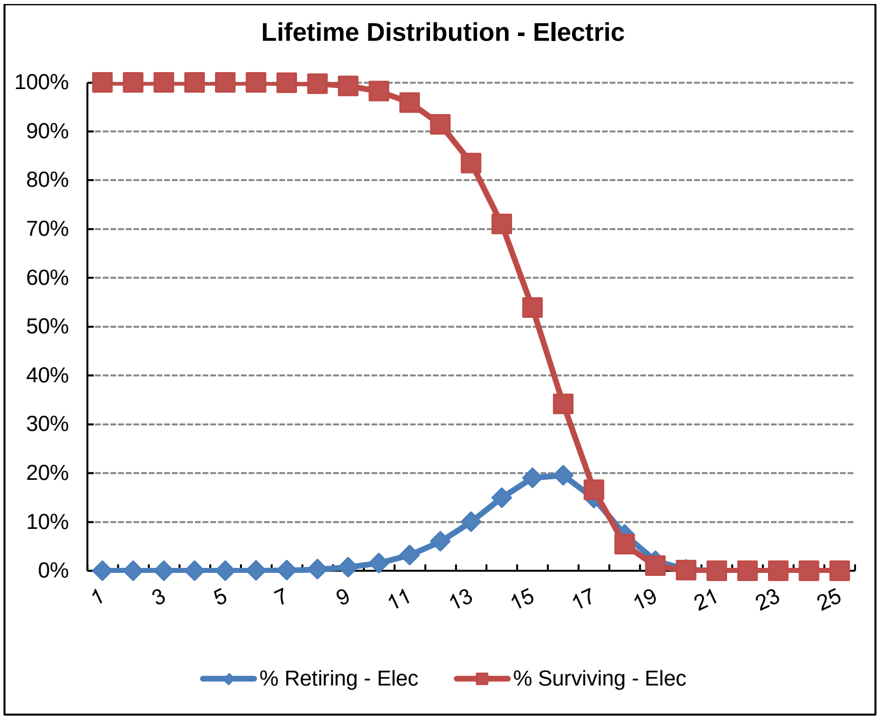

Figure 8.2.10 Weibull Function for Lifetime of Electric Cooking Products

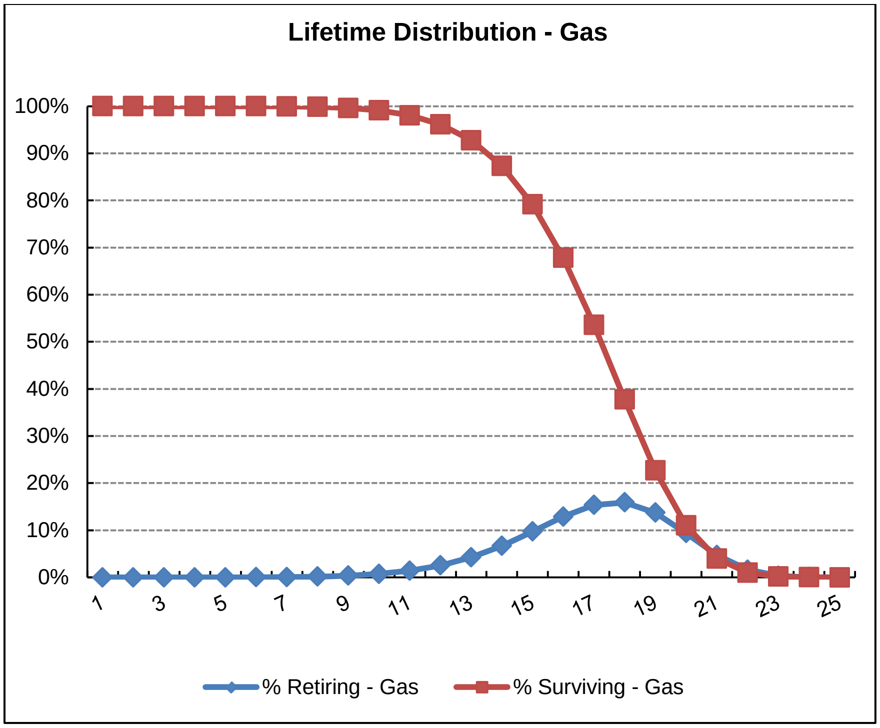

Figure 8.2.11 Weibull Function for Lifetime of Gas Cooking Products

Table 8.2.37 Lifetime Parameters

Product Fuel Type	**Average (Years)**	**Weibull Parameters**	
		Alpha (Scale)	**Beta (Shape)**
Electric	15.0	14.87	7.99
Gas	17.0	17.06	7.35

8.2.3 Discount Rate

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 Finances* (SCF)) 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 LCC and LCC 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 estimates separate discount rate distributions for six income groups, divided based on income percentile as reported in the Federal Reserve Board's SCF.[11] This disaggregation reflects the fact that low and high income consumers tend to have substantially different shares of debt and asset types and tend to face different rates on debts and assets. Summaries of shares and rates presented in this chapter are averages across the entire population.

Table 8.2.38 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 8.2.48). 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.[d] 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.

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[d] Note that 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 8.2.39 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 8.2.29). 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).[e] For example, a 6-percent nominal mortgage rate has an effective nominal rate of 4.5 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.

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

Table 8.2.40 Data Used to Calculate Real Effective Mortgage Rates

Year	Mortgage Interest Rates in Selected Years (%)			
	Average Nominal Interest Rate	Inflation Rate[12]	Applicable Marginal Tax Rate[13]	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 8.2.30 shows the household-weighted average effective real rates for different types of household debt. 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 2019.

Table 8.2.41 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,[14] savings bonds,[15] and bonds (AAA corporate bonds)[16] were collected from Federal Reserve Board time-series data. Rates on money market accounts came from Cost of Savings Index data.[17] 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.[18] 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 8.2.31. 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 2019. For each type, DOE developed a distribution of rates, as shown in appendix 8E.

Table 8.2.42 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 previously, 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. 8.12

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 previously.

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 8.2.32 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 8F presents the full probability distributions for each income group that DOE used in the LCC and PBP analysis.

Table 8.2.43 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

8.2.4 Compliance Date of Standard

The compliance date is the future date when manufacturers must comply with a new or amended standard. The compliance date of the potential energy conservation standards for conventional cooking products manufactured in, or imported into, the United States is April 1, 2019. DOE calculated the LCC for all consumers as if each would purchase a new product in 2019.

8.2.5 Product Energy Efficiency in the Base Case

To estimate the percentage of consumers who would be affected by a standard at any of the trial standard levels, DOE considered the projected distribution of efficiencies for products that consumers purchase under the base case (the case without new or amended energy conservation standards). DOE refers to this distribution of product efficiencies as the base-case efficiency distribution. Using the projected distribution of efficiencies for each product class, DOE randomly assigned a product efficiency to each sampled household. The energy efficiency distributions that DOE used in the LCC analysis are described below. For its determination of base case projected efficiencies, DOE implemented a consumer-choice model that assumes consumers are sensitive to first cost, i.e., equipment price, and calculates the market share for available efficiency options based on the first cost for conventional cooking products users.

The consumer-choice model uses a logit model to calculate the probability that a consumer will purchase product j based on the logistic curve probability function of the form:

$$P_j(z) = \frac{e^{z_j}}{\sum_{i=1}^{n} e^{z_i}}$$

Eq. 8.13

Where:

$P_j(z) =$ the probability a consumer will purchase product j among n possible options, and

$z =$ the 'logit', which is defined as follows

$$z_j = \beta_{FC} * FC_j$$

Eq. 8.14

Where:

$\beta_{FC} =$ consumer sensitivity to first cost,

$FC_j =$ first cost of product option j,

In Eq.10.2 , β_{FC} can be found by fitting an exponential function to the first cost distribution in the engineering analysis:

$$MS(FC) = Ne^{\beta_{FC}*FC}$$

Eq. 8.15

Where:

$N =$ Normalization factor,

$FC =$ First cost of a cooking product in 2014$,

$MS(FC) =$ Market share for a cooking product that costs FC, and

$\beta_{FC} =$ Consumer sensitivity to first cost.

The regression coefficients (β values) represent the consumer's sensitivity to first cost (β_{FC}). The coefficients are determined using historical shipments and equipment price data.

For the conventional cooking products, consumer sensitivities are user-specific based on users' housing type in the Residential Energy Consumption Survey (RECS) 2009.[19] Table 8.2.33 summarizes the market share between renters and home-owners by fuel type of cooking products that they use in RECS 2009. DOE assumed that landlords would have no economic incentive and renters would have no decision making power to purchase or replace an energy efficient cooking product, therefore, DOE assigned the percentage of renters found in the RECS 2009 to the baseline efficiency level. DOE then assumed that home-owners would have incentive to purchase or replace an energy efficient cooking product based on their sensitivity to the initial purchase costs. DOE used shipments data collected by the Market Research Magazine[20] and Producer Price Index (PPI) of household cooking appliance manufacturers[21] between the years 2002 – 2012 along with the manufactures costs data from the engineering analysis to analyze factors that influence consumer-purchasing decisions of cooking products.

By using the logit statistical model described by Eq. 8.6, DOE found the historical shipments data has a strong dependence on the first costs by product type. DOE then developed the best-fit to capture the relationship between historical shipments and price data. Table 8.2.33 shows the best-fit logit parameters calculated for conventional cooking products. DOE then used the parameters in Table 8.2.34 to derive efficiency distribution in a given year for home-owners. DOE combined the market share of renters with the efficiency distribution derived from the consumer-choice model for home-owners to project its base case efficiency distribution for the period between 2019 and 2048.

Table 8.2.44 Oven User Ownership by Fuel Type

Owners/Renters	Electric Ovens	Gas Ovens
Home owners	69.3%	66.1%
Renters	30.7%	33.9%

Source: RECS 2009.

Table 8.2.45 Best-fit Logit Parameters for Conventional Cooking Products

Product Class	N	β_{FC}
Electric Standard Ovens, Freestanding	36.71287	-0.00471
Electric Standard Ovens, Built-In/Slide-In	36.71287	-0.00471
Electric Self-Clean Ovens, Freestanding	39.981985	-0.004472
Electric Self-Clean Ovens, Built-In/Slide-In	39.981985	-0.004472
Gas Standard Ovens, Freestanding	8.4805448	-0.002612
Gas Standard Ovens, Built-In/Slide-In	8.4805448	-0.002612
Gas Self-Clean Ovens, Freestanding	8.4810489	-0.002141
Gas Self-Clean Ovens, Built-In/Slide-In	8.4810489	-0.002141

These efficiencies are then used to develop a trend for the average annual per-unit energy consumption. Table 8.2.35 and Table 8.2.36 show the base case efficiency distribution in 2019 for each product class.

Table 8.2.46 Base Case Market Share for Electric Ovens by Efficiency Level in 2019

EL	Electric Standard Ovens, Freestanding	Electric Standard Ovens, Built-In/Slide-In	Electric Self-Clean Ovens, Freestanding	Electric Self-Clean Ovens, Built-In/Slide-In
0	40.4%	40.4%	46.5%	46.5%
1	9.7%	9.7%	15.8%	15.8%
2	9.6%	9.6%	14.0%	14.0%
3	9.3%	9.3%	12.0%	12.0%
4	9.2%	9.2%	11.7%	11.7%
5	8.1%	8.1%	--	--
6	6.9%	6.9%	--	--
7	6.8%	6.8%	--	--

Table 8.2.47 Base Case Market Share for Gas Ovens by Efficiency Level in 2019

EL	Gas Standard Ovens, Freestanding	Gas Standard Ovens, Built-In/Slide-In	Gas Self-Clean Ovens, Freestanding	Gas Self-Clean Ovens, Built-In/Slide-In
0	42.5%	42.5%	47.5%	47.5%
1	8.6%	8.6%	13.6%	13.6%
2	8.6%	8.6%	13.4%	13.4%
3	8.4%	8.4%	12.8%	12.8%
4	8.3%	8.3%	12.6%	12.6%
5	8.2%	8.2%	--	-
6	7.8%	7.8%	--	-
7	7.7%	7.7%	--	-

8.3 RESULTS OF LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

This section presents the results of the LCC and PBP for conventional cooking products. As discussed in section 8.1.1, DOE's approach to the LCC analysis relied on developing samples of households that use each of the product classes. DOE also used probability distributions to characterize the uncertainty in many of the inputs to the analysis. DOE used a Monte Carlo simulation to perform the LCC calculations on the households in the sample. For each set of sample households that use the product in each product class, DOE calculated the average LCC and LCC savings and the median and average PBP for each of the efficiency levels. These standard levels are also referred to as trial standard levels (TSLs).

DOE calculated LCC savings and PBPs relative to the base-case products that it assigned to sample households. For some consumers DOE assigned a base-case product that is more efficient than some of the TSLs. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific TSL and the LCC of the baseline product. DOE calculated the average LCC savings and the median PBP values by excluding the households that are not impacted by a standard at a given efficiency level.

LCC and PBP calculations were performed 10,000 times on the sample of consumers established for each product class. Each LCC and PBP calculation was performed on a single household selected from the sample. A household was selected based on its weight (i.e., how representative it was of other households in the distribution). Each LCC and PBP calculation also sampled from the probability distributions that DOE developed to characterize many of the inputs to the analysis.

Using the Monte Carlo simulations for each TSL, DOE calculated the percent of consumers who experience a net LCC benefit, a net LCC cost, and no effect. DOE considered a consumer to receive no effect at a given standard level if DOE assigned it a baseline product having the same or higher efficiency than the standard level. The following sections present figures that illustrate the range of LCC and PBP effects among sample consumers.

8.3.1 Summary of Results

Table 8.3.1 through Table 8.3.16 show the LCC and simple PBP results by efficiency level for each oven product class. The average operating cost is the discounted sum.

Table 8.3.1 Average LCC and PBP Results by Efficiency Level for Electric Standard Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$557	$18	$206	$762	--
1	1	$558	$16	$191	$748	0.9
--	2	$560	$16	$182	$743	1.9
2	3	$568	$15	$174	$742	4.0
--	4	$571	$15	$171	$742	4.8
--	5	$604	$14	$166	$770	13.8
--	6	$648	$12	$142	$790	16.6
3	7	$653	$12	$142	$795	17.5

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

Table 8.3.2 Average LCC Savings Relative to the Base-Case Efficiency Distribution for Electric Standard Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	0	0%	---
1	1	0%	$13.96
--	2	3%	$16.82
2	3	12%	$15.18
--	4	22%	$12.66
--	5	65%	-$16.51
--	6	73%	-$34.87
3	7	82%	-$37.60

*The calculation does not include households with zero LCC savings (no impact)

Table 8.3.3 Average LCC and PBP Results by Efficiency Level for Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$583	$18	$206	$789	--
1	1	$584	$16	$190	$775	0.9
--	2	$587	$16	$182	$769	1.9
2	3	$594	$15	$174	$768	4.0
--	4	$597	$15	$171	$768	4.7
--	5	$630	$14	$166	$796	13.8
--	6	$674	$12	$142	$816	16.6
3	7	$680	$12	$142	$821	17.5

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

Table 8.3.4 Average LCC Savings Relative to the Base-Case Efficiency Distribution for Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	0	0%	---
1	1	0%	$14.11
--	2	3%	$16.92
2	3	12%	$15.25
--	4	22%	$12.72
--	5	65%	-$16.52
--	6	73%	-$34.92
3	7	82%	-$37.64

*The calculation does not include households with zero LCC savings (no impact)

Table 8.3.5 Average LCC and PBP Results by Efficiency Level for Electric Self-Clean Ovens, Free-Standing

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$600	$23	$266	$867	--
1,2	1	$602	$22	$251	$853	0.9
--	2	$635	$21	$241	$876	16.1
--	3	$678	$18	$212	$890	16.7
3	4	$686	$18	$211	$897	18.1

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

Table 8.3.6 Average LCC Savings Relative to the Base-Case Efficiency Distribution for Electric Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	0	0%	---
1,2	1	0%	$14.10
--	2	53%	-$12.85
--	3	62%	-$24.59
3	4	76%	-$27.79

*The calculation does not include households with zero LCC savings (no impact)

Table 8.3.7 Average LCC and PBP Results by Efficiency Level for Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$627	$23	$267	$894	--
1,2	1	$628	$22	$252	$880	0.9
--	2	$661	$21	$242	$903	16.0
--	3	$705	$18	$213	$918	16.7
3	4	$712	$18	$212	$924	18.1

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

Table 8.3.8 Average LCC Savings Relative to the Base-Case Efficiency Distribution for Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	Baseline	0%	---
1,2	1	0%	$14.20
--	2	53%	-$12.82
--	3	62%	-$24.60
3	4	76%	-$27.80

*The calculation does not include households with zero LCC savings (no impact)

Table 8.3.9 Average LCC and PBP Results by Efficiency Level for Gas Standard Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
1	Baseline	$602	$20	$600	$1,202	--
--	1	$602	$18	$572	$1,174	0.0
--	2	$603	$16	$553	$1,156	0.3
--	3	$612	$15	$545	$1,157	2.4
2	4	$619	$9	$277	$896	1.7
--	5	$622	$9	$276	$898	2.0
--	6	$650	$9	$278	$928	4.7
3	7	$656	$9	$277	$933	5.3

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

Table 8.3.10 Average LCC Savings Relative to the Base-Case Efficiency Distribution for Gas Standard Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
1	Baseline	0%	---
--	1	0%	$27.91
--	2	0%	$41.37
--	3	7%	$33.83
2	4	0%	$289.73
--	5	8%	$254.98
--	6	17%	$201.23
3	7	24%	$178.91

*The calculation does not include households with zero LCC savings (no impact)

Table 8.3.11 Average LCC and PBP Results by Efficiency Level for Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
1	Baseline	$628	$20	$600	$1,228	--
--	1	$628	$18	$572	$1,200	0.0
--	2	$629	$16	$553	$1,182	0.3
--	3	$638	$15	$545	$1,183	2.4
2	4	$645	$9	$277	$922	1.7
--	5	$648	$9	$276	$924	2.0
--	6	$676	$9	$278	$954	4.7
3	7	$682	$9	$277	$959	5.3

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

Table 8.3.12 Average LCC Savings Relative to the Base-Case Efficiency Distribution for Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
1	Baseline	0%	---
--	1	0%	$27.90
--	2	0%	$41.37
--	3	7%	$33.83
2	4	0%	$289.77
--	5	8%	$255.01
--	6	17%	$201.24
3	7	24%	$178.92

*The calculation does not include households with zero LCC savings (no impact)

Table 8.3.13 Average LCC and PBP Results by Efficiency Level for Gas Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$716	$22	$631	$1,347	--
1	1	$718	$20	$612	$1,329	0.8
2	2	$726	$13	$334	$1,060	1.2
--	3	$755	$13	$333	$1,087	4.6
3	4	$762	$13	$333	$1,094	5.4

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

Table 8.3.14 Average LCC Savings Relative to the Base-Case Efficiency Distribution for Gas Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	Baseline	0%	---
1	1	0%	$18.02
2	2	0%	$282.80
--	3	14%	$203.50
3	4	27%	$165.73

*The calculation does not include households with zero LCC savings (no impact)

Table 8.3.15 Average LCC and PBP Results by Efficiency Level for Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$742	$22	$631	$1,374	--
1	1	$744	$20	$612	$1,355	0.8
2	2	$752	$13	$334	$1,086	1.2
--	3	$781	$13	$333	$1,114	4.6
3	4	$788	$13	$333	$1,120	5.4

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

Table 8.3.16 Average LCC Savings Relative to the Base-Case Efficiency Distribution for Gas Self-Clean Ovens, Built-In/Slide-In

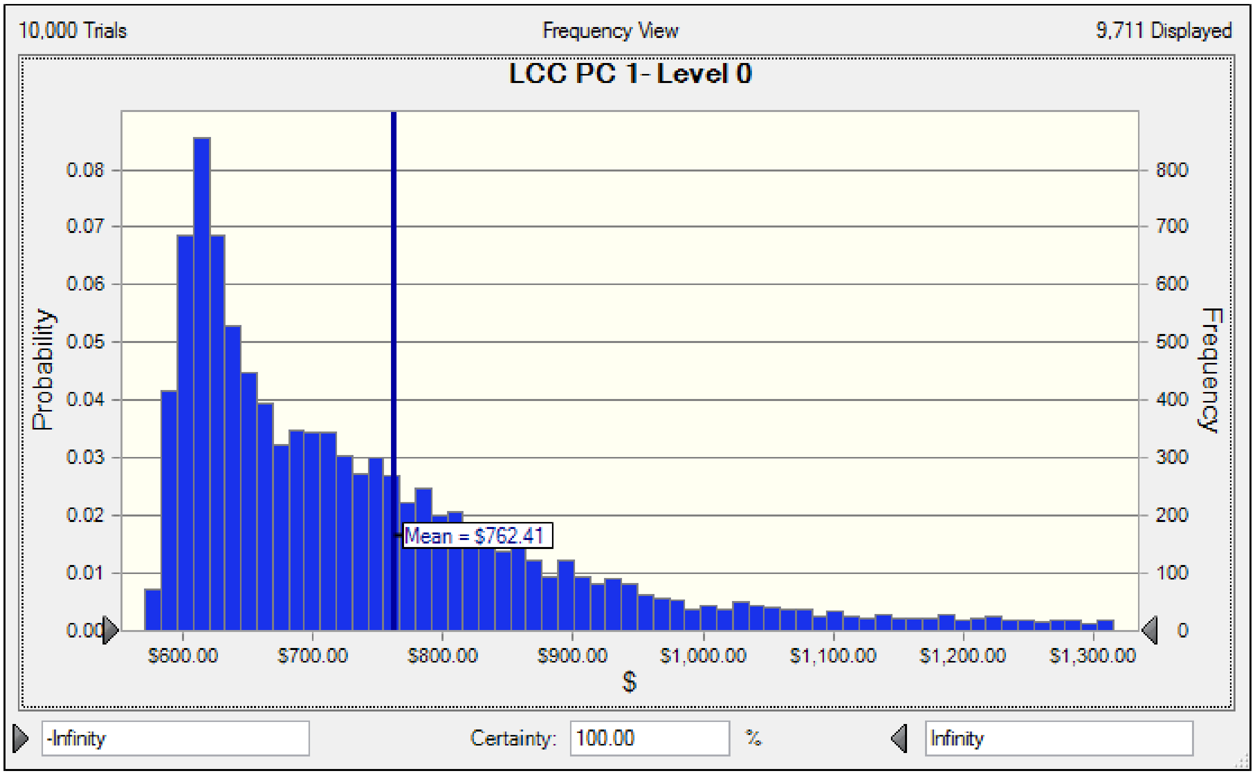
TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	Baseline	0%	---
1	1	0%	$18.03
2	2	0%	$282.85
--	3	14%	$203.51
3	4	27%	$165.75

*The calculation does not include households with zero LCC savings (no impact)

8.3.1.2 Distribution of Impacts

The figures in this section show the distribution of LCCs in the base case for each product class. The figures are presented as frequency charts that show the distribution of LCCs, and LCC impacts with their corresponding probability of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples.

Base-Case LCC Distributions. Figure 8.3.1 through Figure 8.3.8 show the base-case LCC distributions for each product class of conventional cooking products.

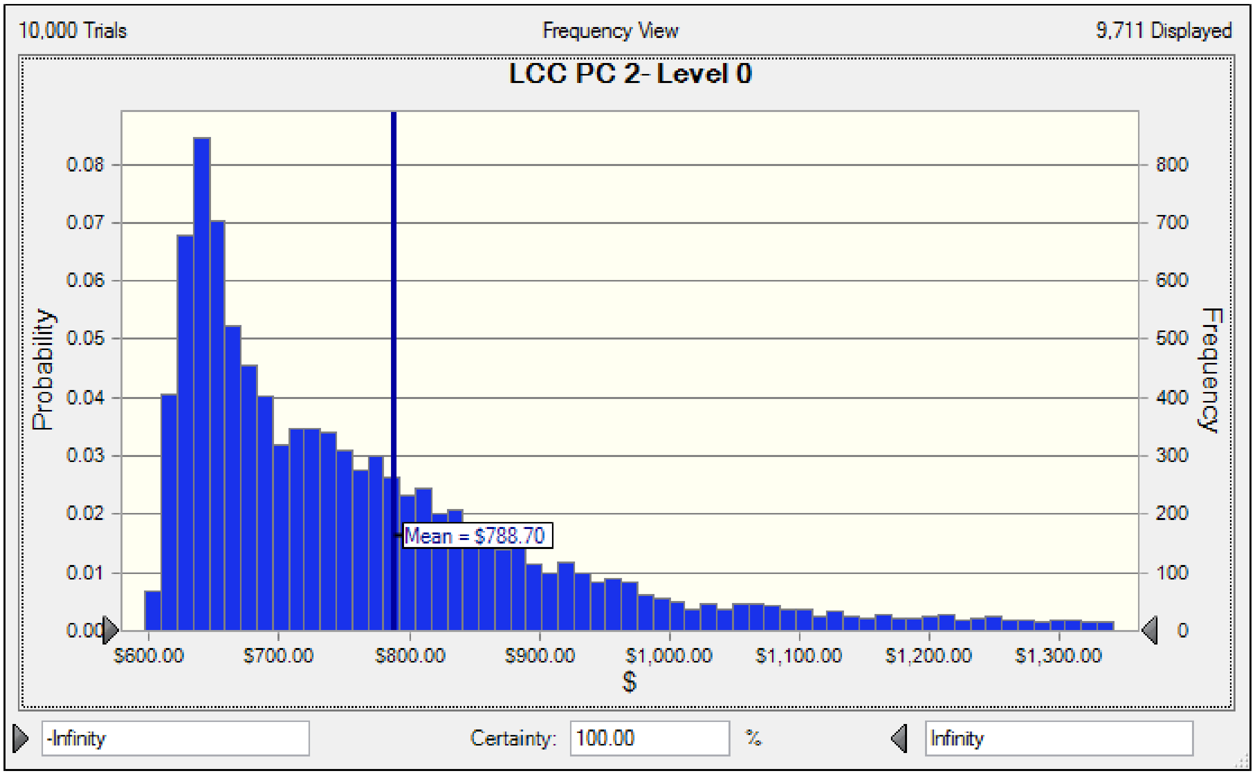


-Infinity

Certainty: 100.00 %

Infinity

Figure 8.3.1 Electric Standard Ovens, Freestanding: Base-Case LCC Distribution



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Certainty: 100.00 %

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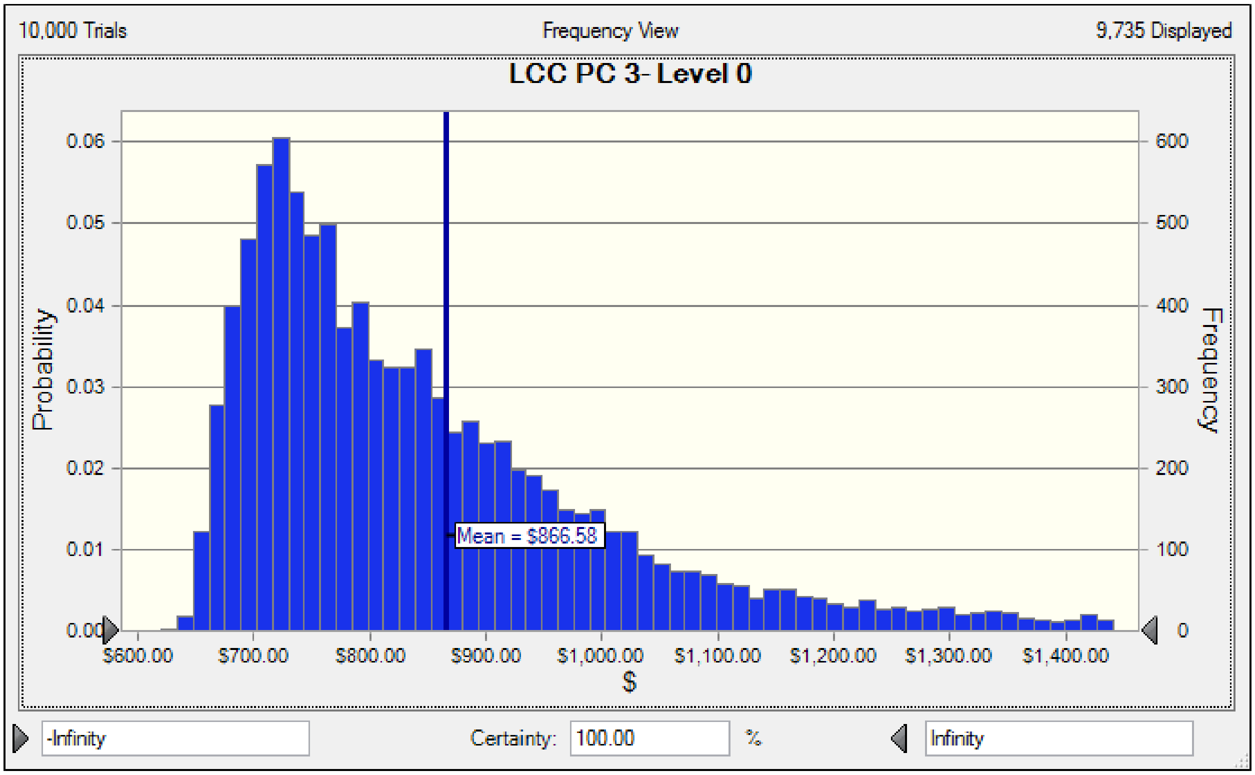
Figure 8.3.2 Electric Standard Ovens, Built-In/Slide-In: Base-Case LCC Distribution



10,000 Trials

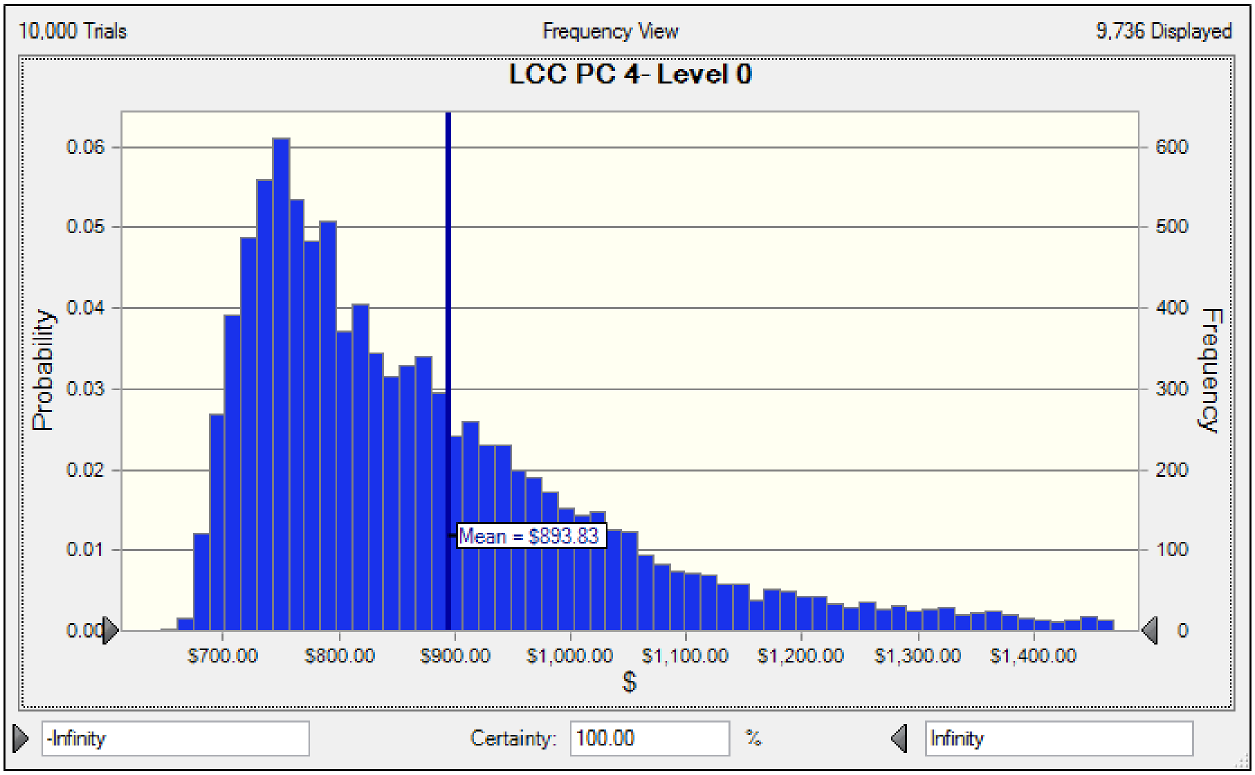
9,735 Displayed

-Infinity

Certainty: 100.00 %

Infinity

Figure 8.3.3 Electric Self-Clean Ovens, Freestanding: Base-Case LCC Distribution



10,000 Trials

9,736 Displayed

-Infinity

Certainty: 100.00 %

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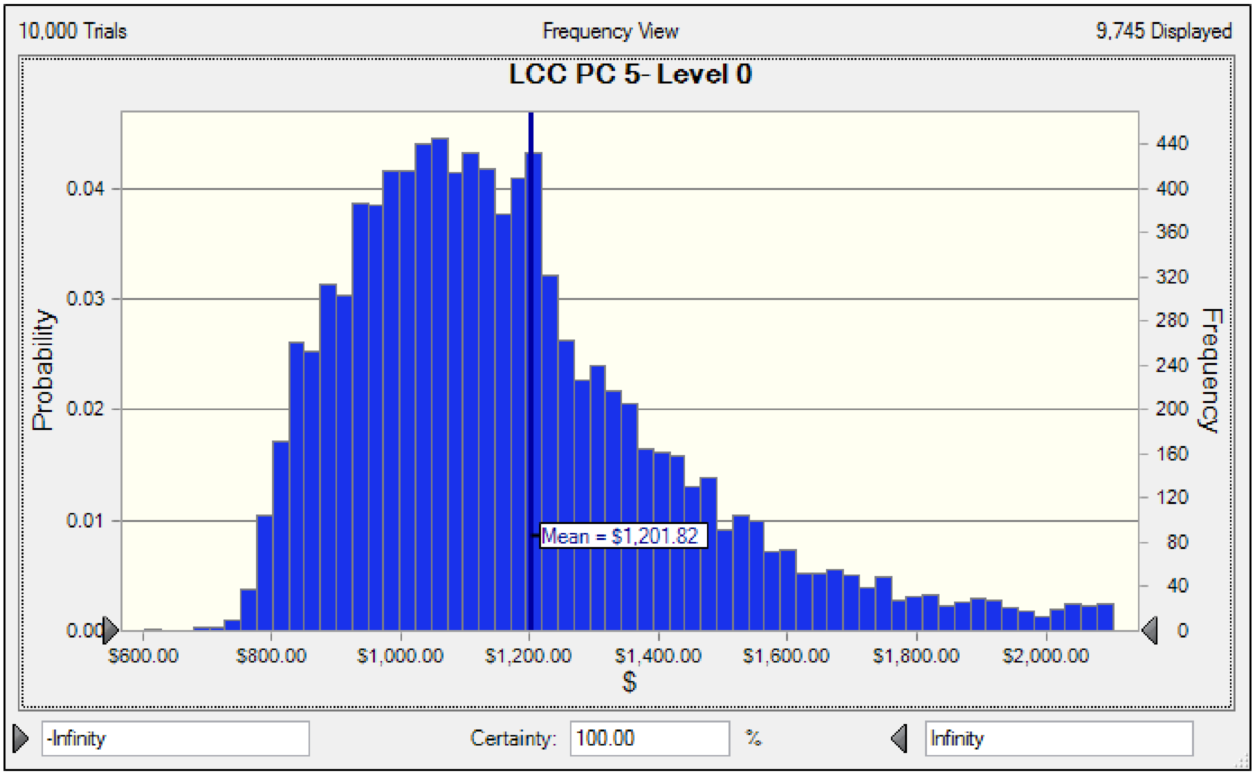
Figure 8.3.4 Electric Self-Clean Ovens, Built-In/Slide-In: Base-Case LCC Distribution



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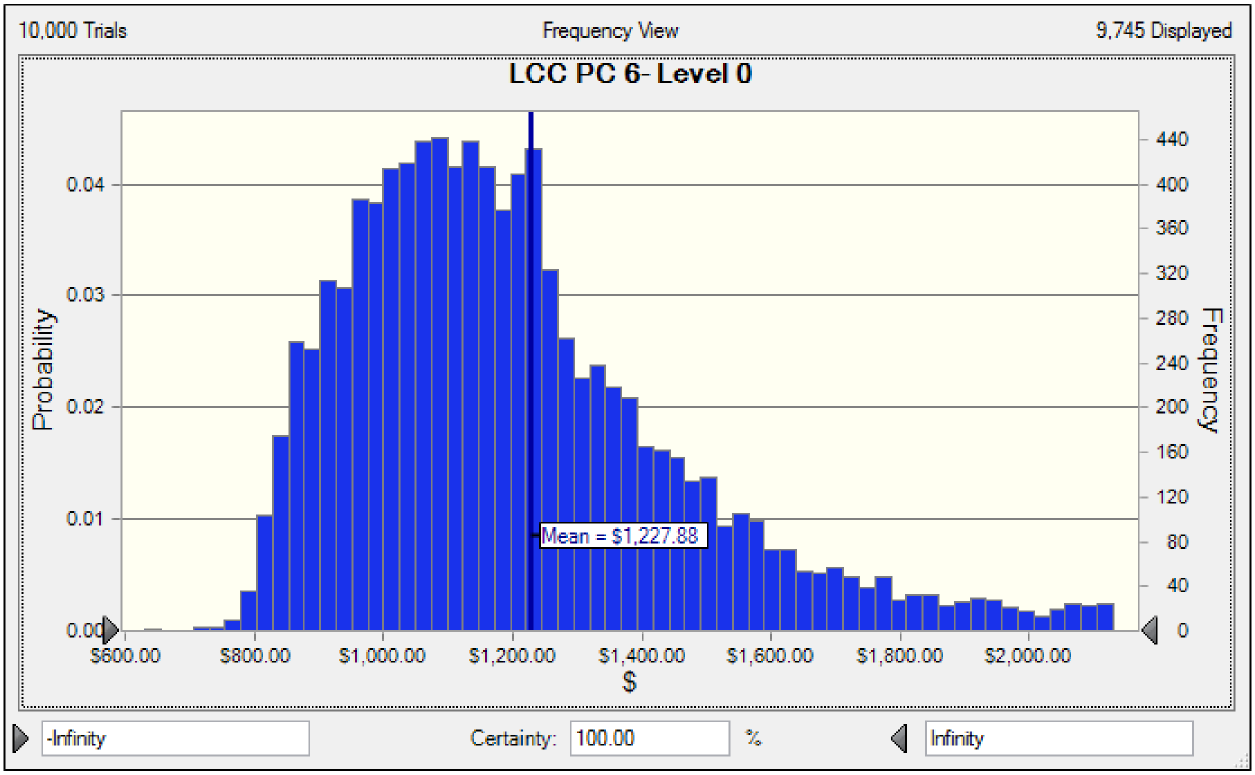
Certainty: 100.00 %

Infinity

Figure 8.3.5 Gas Standard Ovens, Freestanding: Base-Case LCC Distribution



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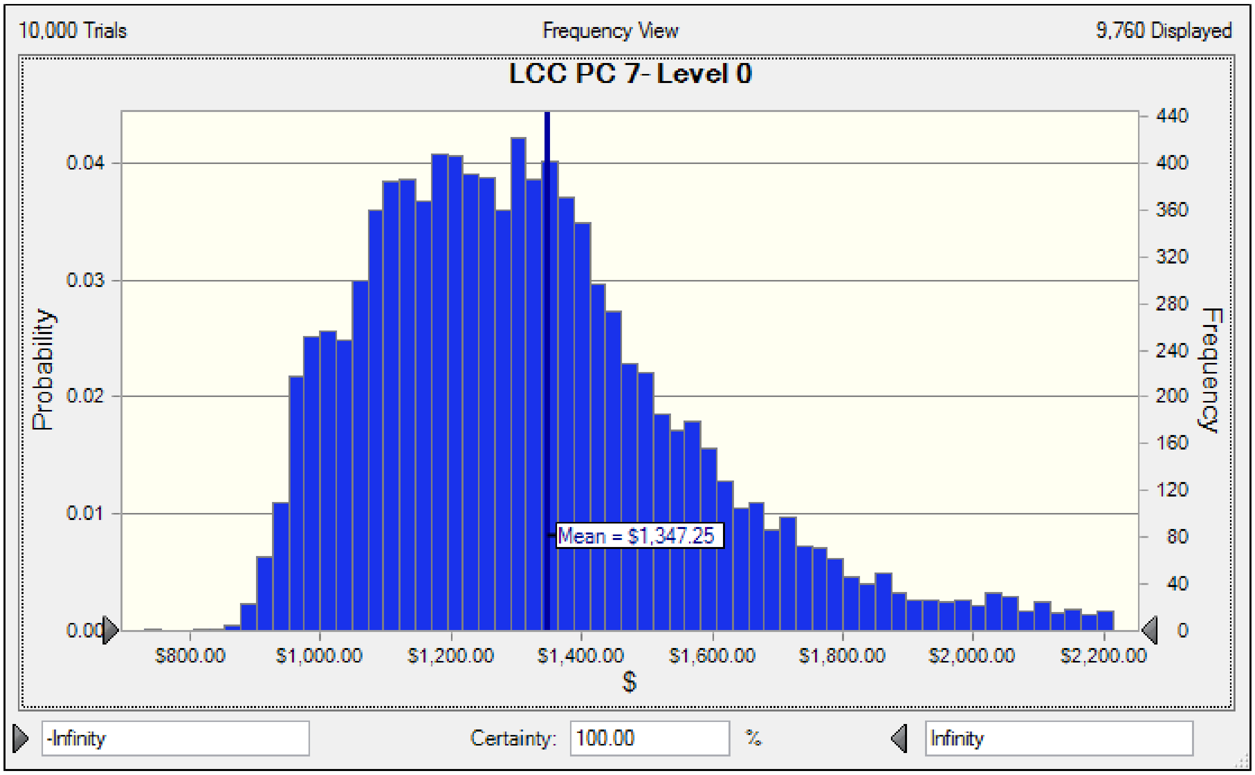
Certainty: 100.00 %

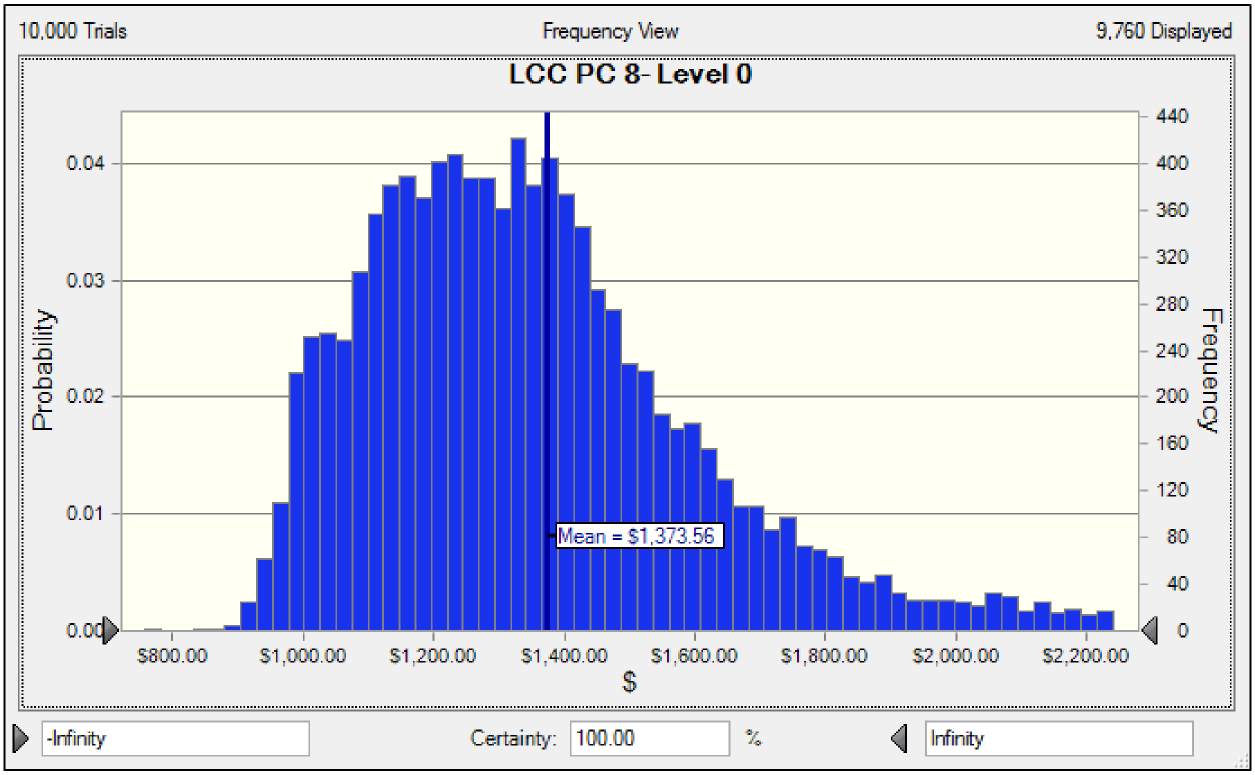
Infinity

Figure 8.3.6 Gas Standard Ovens, Built-In/Slide-In: Base-Case LCC Distribution



-Infinity Certainty: 100.00 % Infinity

Figure 8.3.7 Gas Self-Clean Ovens, Free-standing: Base-Case LCC Distribution

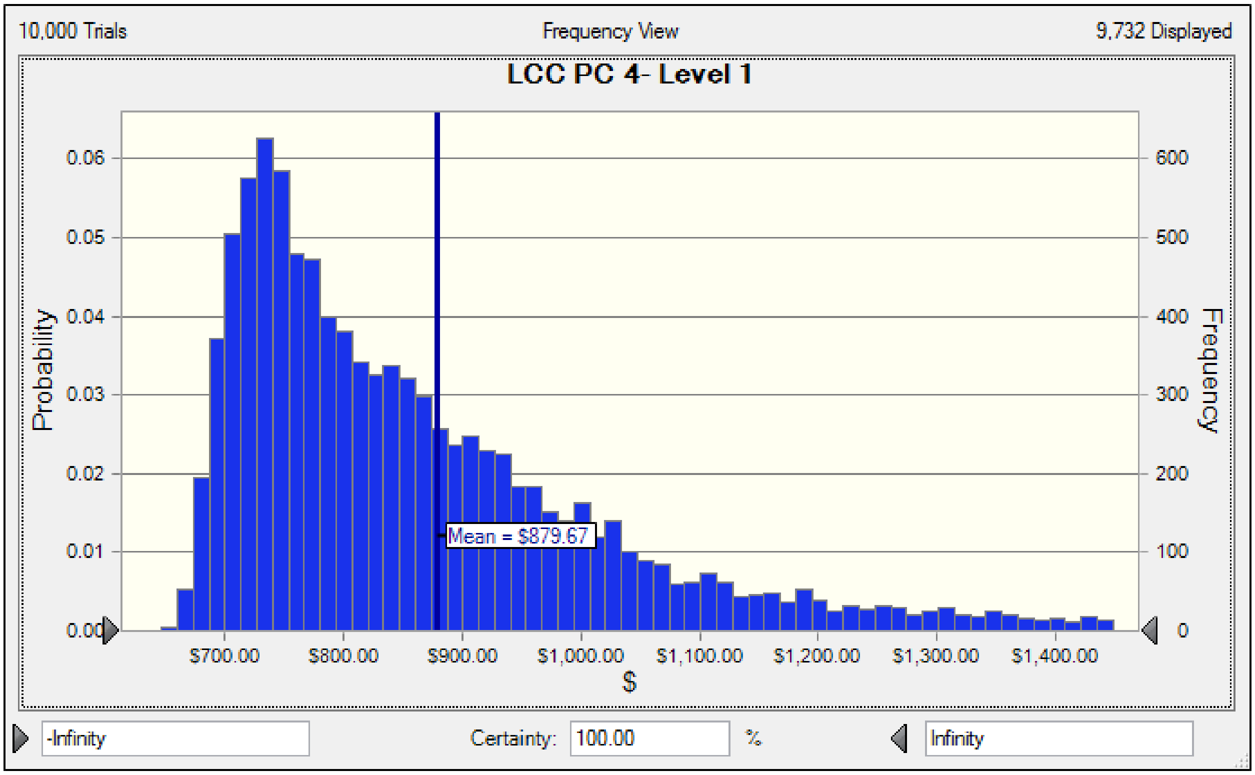


-Infinity Certainty: 100.00 % Infinity

Figure 8.3.8 Gas Self-Clean Ovens, Built-In/Slide-In: Base-Case LCC Distribution

Standard-Level Distributions of LCC Impacts

Figure 8.3.12 is an example of a frequency chart that shows the distribution of LCC differences for the case of Efficiency Level 1 for product class 4, Electric Self-Clean Ovens, Built-In/Slide-In . In the figure, a text box next to a vertical line at a given value on the x-axis shows the mean value of LCC (a savings of $879.7 in the example here). Refer to section 8.2.5 on the distribution of product efficiencies under the base case. DOE can generate a frequency chart like the one shown in Figure 8.3.9 for each efficiency level and product class.



10,000 Trials

Frequency View

9,732 Displayed

-Infinity

Certainty: 100.00 %

Infinity

Figure 8.3.9 Electric Self-Clean Ovens, Built-In/Slide-In: Distribution of LCC Impacts at EL1

8.3.1.3 Range of Impacts

Figure 8.3.10 through Figure 8.3.17 show the range of LCC savings for all efficiency levels considered for each conventional cooking product classes. For each efficiency 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 households have LCC savings in excess of that 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 each standard level.

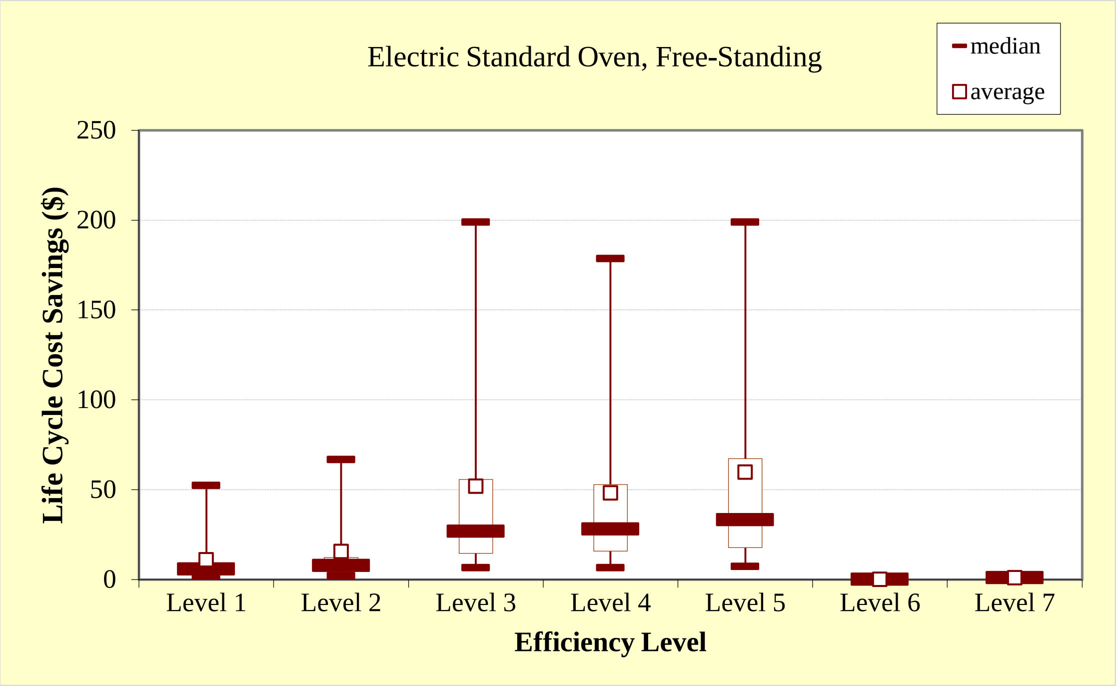


Figure 8.3.10 Electric Standard Ovens, Freestanding: Range of LCC Savings

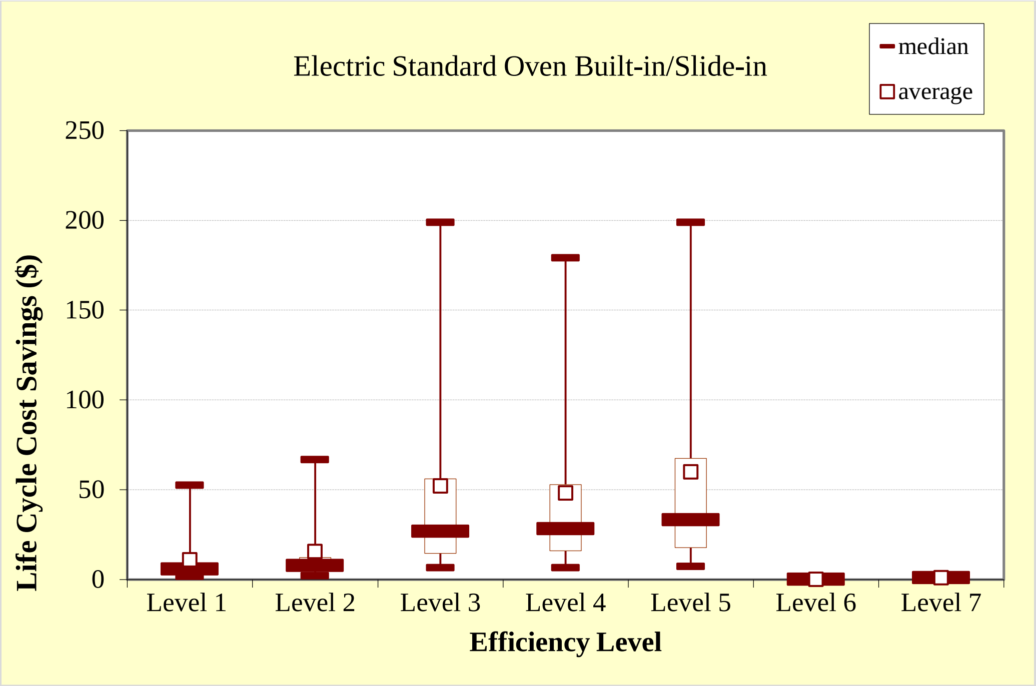


Figure 8.3.11 **Electric Standard Ovens, Built-In/Slide-In: Range of LCC Savings**

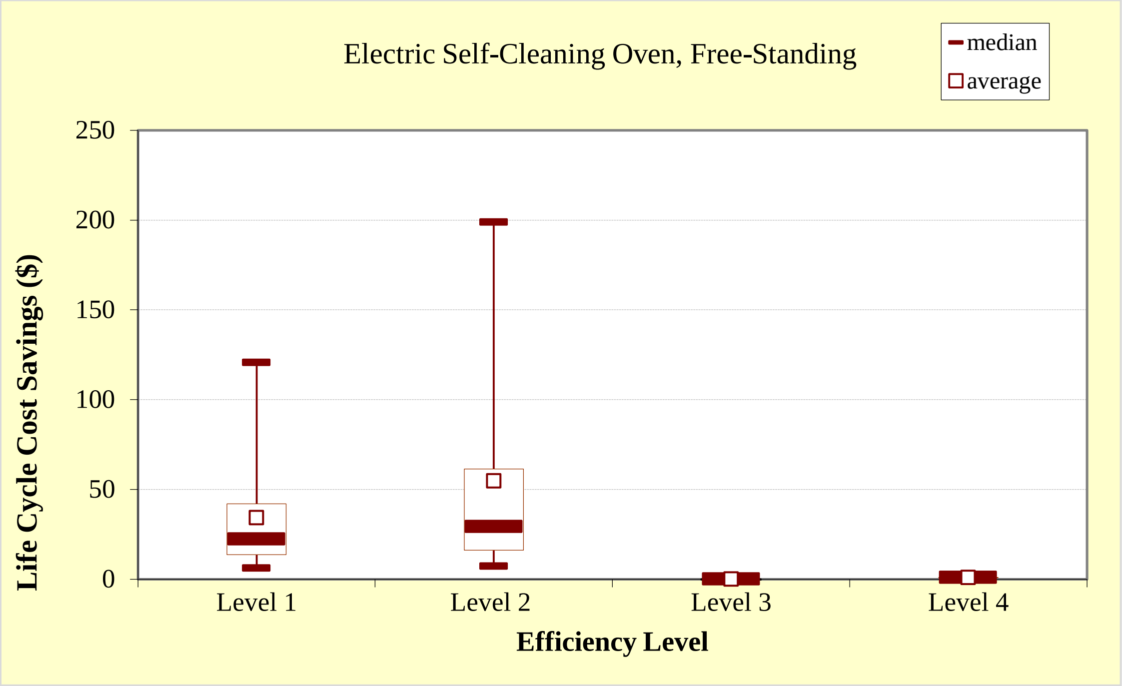


Figure 8.3.12 **Electric Self-Clean Ovens, Freestanding: Range of LCC Savings**

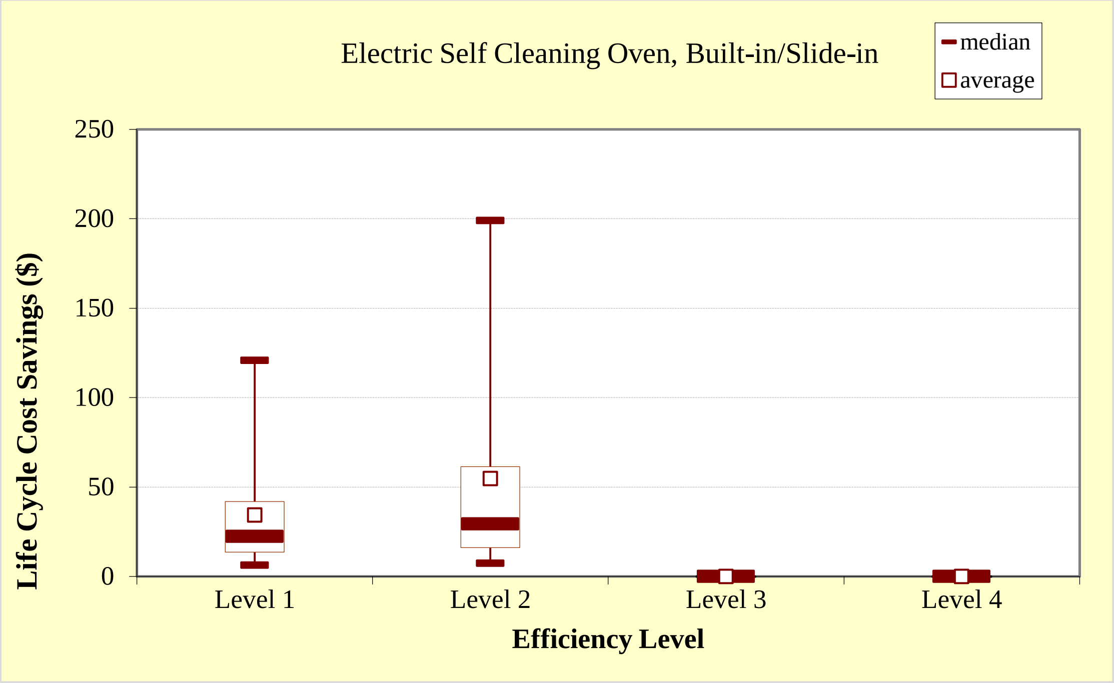


Figure 8.3.13 **Electric Self-Clean Ovens, Built-In/Slide-In: Range of LCC Savings**

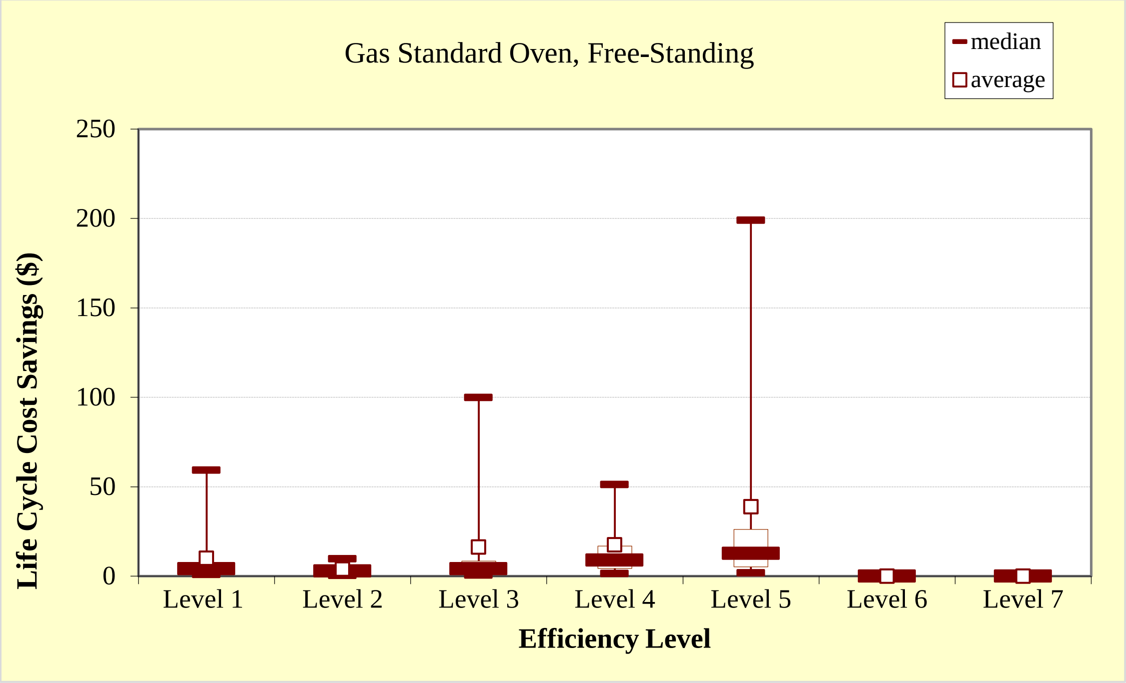


Figure 8.3.14 **Gas Standard Ovens, Freestanding: Range of LCC Savings**

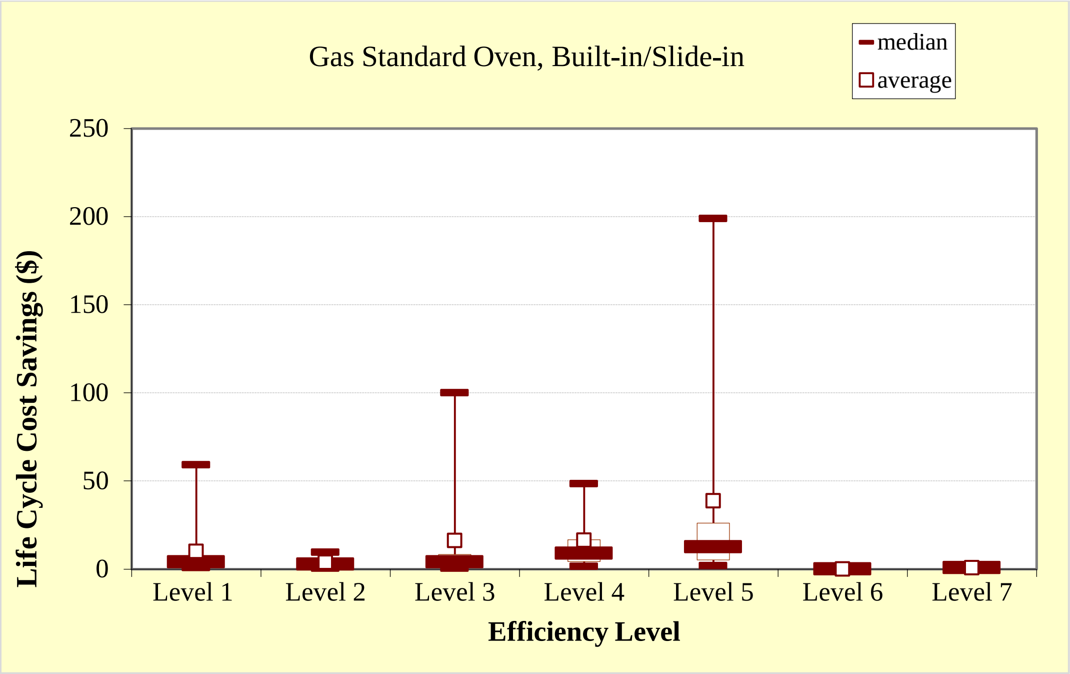


Figure 8.3.15 **Gas Standard Ovens, Built-In/Slide-In: Range of LCC Savings**

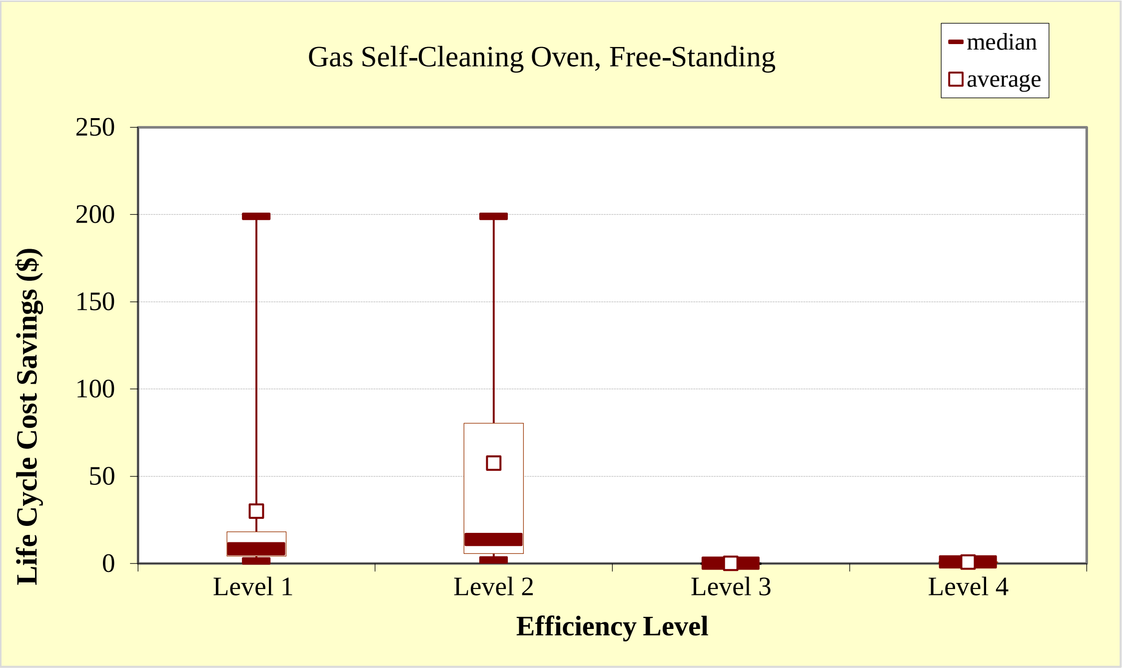


Figure 8.3.16 **Gas Self-Clean Ovens, Freestanding: Range of LCC Savings**

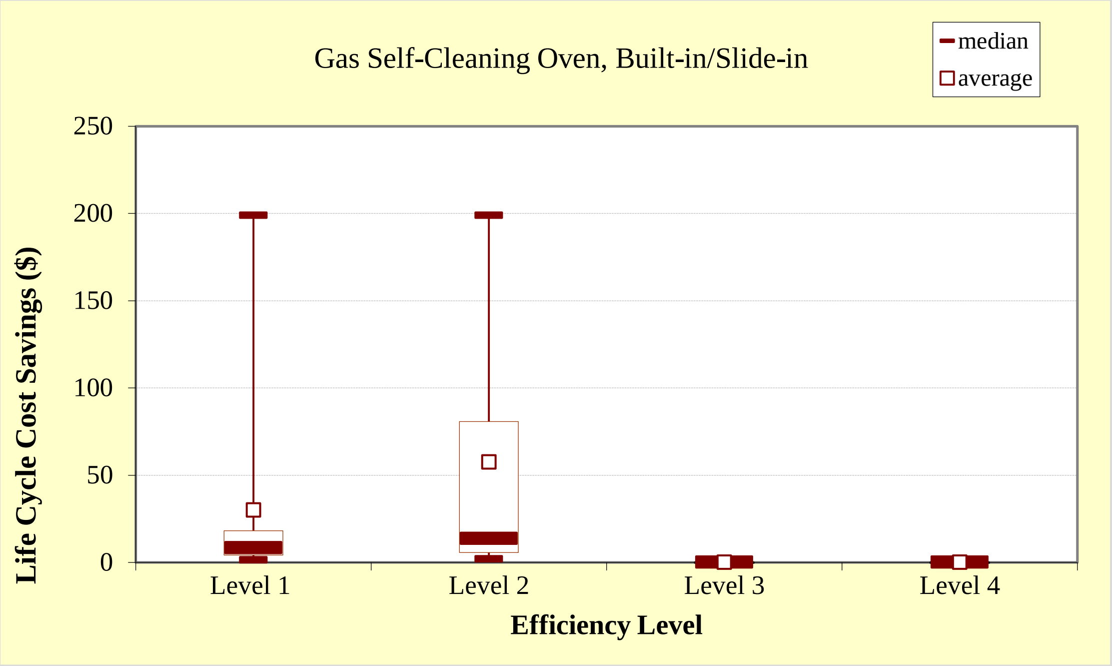


Figure 8.3.17 **Gas Self-Clean Ovens, Built-In/Slide-In: Range of LCC Savings**

8.4 REBUTTABLE PAYBACK PERIOD

DOE develops rebuttable PBPs to provide the legally established rebuttable presumption that an energy conservation 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 8.1.1. Unlike the analyses described in section 8.2.2, however, the rebuttable PBP is not based on household samples and probability distributions. The rebuttable PBP is based instead on discrete, single-point values. For example, whereas DOE uses a probability distribution of regional energy prices in the distributional PBP analysis, it uses only the national average energy price to determine the rebuttable PBP.

Other than the use of single-point values, the most notable difference between the distributional PBP and the rebuttable PBP is the latter’s reliance on the DOE test procedure to determine a product’s annual energy consumption. DOE based the annual energy consumption for the rebuttable PBP on the number of operating hours per year specified in DOE’s proposed test procedure for conventional cooking products. The following sections identify the differences, if any, between the annual energy consumptions determined by the distributional PBP and the rebuttable PBP for all product classes of conventional cooking products.

8.4.1 Inputs to the Rebuttable Payback Period Analysis

Because inputs for determining total installed cost for calculating the distributional PBP were based on single-point values, only the variability and/or uncertainty in the inputs for determining operating cost contributed to variability in the distributional 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 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 would take effect.
- An average discount rate or lifetime is not required in calculating the rebuttable PBP.
- The effective date of any new standard is assumed to be 2019.

8.4.2 Results of Rebuttable Payback Period Analysis

DOE calculated rebuttable PBPs for each efficiency level relative to the distribution of product efficiencies estimated for the baseline. In other words, DOE did not determine the rebuttable PBP relative to the base case energy efficiency, but relative to the distribution of product energy efficiencies for the baseline (*i.e.*, the case without new energy conservation standards). Table 8.4.1 and Table 8.4.2 present the rebuttable PBPs for each product class of conventional cooking products.

Table 8.4.1 Electric Ovens: Rebuttable Payback Periods

EL	Electric Standard, Freestanding	Electric Standard, Built-In/Slide-In	Electric Self-Clean, Freestanding	Electric Self-Clean, Built-In/Slide-In
	PBP *years*	**PBP** *years*	**PBP** *years*	**PBP** *years*
Baseline	--	--	--	--
1	0.87	0.85	0.87	0.86
2	1.27	1.24	9.41	9.25
3	2.34	2.29	7.82	7.69
4	2.71	2.65	8.44	8.30
5	7.24	7.07		
6	8.00	7.81	--	--
7	8.46	8.26	--	--

Table 8.4.2 Gas Ovens: Rebuttable Payback Periods

EL	Gas Standard, Freestanding	Gas Standard, Built-In/Slide-In	Gas Self-Clean	Gas Self-Clean
	PBP *years*	**PBP** *years*	**PBP** *years*	**PBP** *years*
Baseline	--	--	--	--
1	0.00	0.00	3.12	3.11
2	0.22	0.22	4.59	4.57
3	1.57	1.57	13.15	13.08
4	2.39	2.38	15.31	15.23
5	2.78	2.77	--	--
6	6.28	6.25	--	--
7	6.97	6.93	--	--

REFERENCES

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1 U.S. Energy Information Administration, *Residential Energy Consumption Survey 2009*, Washington, DC. <http://www.eia.gov/consumption/residential/data/2009/>

2 DOE–EIA. *Annual Energy Outlook 2014 with Projections to 2040*. 2014. Washington, D.C., DOE/EIA-0383(2014). <http://www.eia.gov/forecasts/aeo/pdf/0383%282014%29.pdf>

3 Desroches, Louis-Benoit, et al., "Incorporating Experience Curves in Appliance Standards Analysis", *Energy Policy* 52 (2013): 402-416.

4 UBM Canon, Market Research Magazine: Appliance Historical Statistical Review, 2014.

5 RS Means. *Mechanical Cost Data, 31st Annual Edition*, 2013. Kingston, MA.

6 U.S. Department of Energy–Energy Information Administration, Form EIA-861 for 2012, 2013. <http://www.eia.gov/electricity/data/eia861>

7 U.S. Department of Energy-Energy Information Administration, Natural Gas Prices, 2013. Washington, DC. <http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm>

8 U.S. Department of Commerce–Census Bureau, Population Estimates, Vintage 2012. <http://www.census.gov/popest/data/national/totals/2012/index.html>

9 U.S. Department of Energy 2009. *Energy Conservation Program: Energy Conservation Standards for Certain Consumer Products (Dishwashers, Dehumidifiers, Microwave Ovens, and Electric and Gas Kitchen Ranges and Ovens) and for Certain Commercial and Industrial Equipment (Commercial Clothes Washers); Final Rule*. 2013. <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/57#standards >

10 UBM Canon, Appliance Magazine, 2012.

11 The Federal Reserve Board, Survey of Consumer Finances 1989, 1992, 1995, 1998, 2001, 2004, 2007, 2010. <http://www.federalreserve.gov/pubs/oss/oss2/scfindex.html>

12 U.S. Department of Labor - Bureau of Labor Statistics, *Bureau of Labor Statistics Data, Prices & Living Conditions*, 2012. <http://data.bls.gov>

13 National Bureau of Economic Research, *U.S. Federal and State Average Marginal Income Tax Rates*, 2010. <http://users.nber.org/~taxsim/marginal-tax-rates/>

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14 The Federal Reserve Board, *Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: CDs (secondary market), Maturity: 6-month, Frequency: Annual, Description: Average rate on 6-month negotiable certificates of deposit (secondary market), quoted on an investment basis*, 2013. <www.federalreserve.gov/releases/H15/data.htm>

15 The Federal Reserve Board, *Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: State and local bonds, Maturity: 20-year, Frequency: Monthly, Description: Bond buyer go 20-bond municipal bond index*, 2013. <www.federalreserve.gov/releases/H15/data.htm>

16 The Federal Reserve Board, *Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: Corporate bonds/Moody's Seasoned AAA, Frequency: Annual, Description: Moody's yield on seasoned corporate bonds—all industries, AAA*, 2013. <www.federalreserve.gov/releases/H15/data.htm>

17 Mortgage-X - Mortgage Information Service, *Cost of Savings Index (COSI) Index History*, 2013. <http://mortgage-x.com/general/indexes/default.asp>

18 Damodaran Online Data Page, *The Data Page: Historical Returns on Stocks, Bonds and Bills - United States*, 2013. Damodaran. <http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/histretSP.html>

CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

Product shipments estimates are a necessary input to the national energy savings (NES) and net present value (NPV) calculations. Shipments are also a necessary input to the manufacturer impact analysis (MIA), which DOE conducts for its notices of proposed rulemaking (NOPRs). This chapter describes DOE's methodology for projecting annual shipments and presents results for cooking products.

DOE estimated shipments for oven products with a shipments model. DOE calibrated shipments model against historical shipments. For purposes of estimating the impacts of prospective trial standard levels (TSL) on product shipments, the shipments model accounts for the combined effects of changes in purchase price, annual operating cost on the consumer purchase decision.

The shipments model first considers specific market segments to estimate shipments by fuel category of oven products against historical shipments data. The results for which are then disaggregated to estimate shipments for each product class. DOE accounted for two market segments: (1) shipments due to new construction; (2) replacements of retired units from existing buildings.

The shipments models are Microsoft Excel spreadsheets that are accessible on the Internet (http://www.eere.energy.gov/buildings/appliance_standards/). Appendix 10A discusses how to access the shipments model spreadsheet contained in the NIA spreadsheets, and provides basic instructions for using them. The rest of this chapter explains the shipments models in more detail. Section 9.2 presents the shipments model methodology; section 9.3 describes the data inputs and the model calibration; section 9.4 discusses impacts on shipments from changes in equipment purchase price and operating cost; section 9.5 discusses the affected stock; and section 9.6 presents the results for different TSL scenarios.

9.2 SHIPMENTS MODEL METHODOLOGY

DOE first developed a national stock model for estimating annual shipments for the cooking products (i.e., cooking ranges and ovens) by its fuel category (i.e., electric and gas) considered for this standards rulemaking. The model considers market segmentation as a distinct input to the shipments forecast. As represented by the following equation, the two primary market segments are new installations and replacements.

$$Ship_p(j) = Rpl_p(j) + NI_p(j)$$

where:

$Ship_p(j)$ = total shipments of product p in year j,
$Rpl_p(j)$ = units of product p retired and replaced in year j, and
$NI_p(j)$ = number of new installations of product p in year j.

As the product-specific sections below discuss, DOE also considered a third market segment for the products to calibrate its shipments models to historical shipments data.

In principle, each market segment and each product class responds differently to both the base case demographic and economic trends and to the implementation of standards. Furthermore, retirements, early replacements, and efficiency trends[a] are dynamic and can vary among product classes. Rather than simply extrapolating a current shipments trend, the base case shipments analysis (i.e., the case without new standards) uses driver input variables, such as construction projections and product lifetime distributions, to project sales in each market segment. Thus, DOE's shipments models assume that construction, i.e., new housing units, drives new installations. In each year, the product shipments from the new construction market segment are equal to the number of new housing units built times the purchase rate, which is determined by the product class market share and the market saturation of the product under consideration.

DOE's shipments models take an accounting approach, tracking market shares of each product class, the vintage of units in the existing stock, and expected construction trends. The models estimate shipments due to replacements using sales in previous years and assumptions about the lifetime of the equipment. Therefore, estimated sales due to replacements in a given year are equal to the total stock of the appliance minus the sum of the appliances sold in previous years that still remain in the stock. DOE determined the useful service life of each appliance to estimate how long the appliance is likely to remain in stock. The following equation represents how DOE estimated replacement shipments.

$$Rpl_p(j) = Stock_p(j-1) - \sum_{age=0}^{ageMax} \sum_{j=N}^{j-1} Ship_j \times prob_{Rtr}(age)$$

where:

$Stock_p(j-1)$ = total stock of in-service appliances in year $j-1$,
$prob_{Rtr}(age)$ = probability that an appliance of a particular *age* will be retired, and
N = start year for when the model begins its stock accounting (start year is specific to each product based on available historical shipments data).

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[a] Efficiency trends affect shipments only in the standards case. A change in the efficiency distribution of the stock results in a change in the purchase price and operating cost and, therefore, produces a purchase price and operating cost impact on the shipments. This is discussed later in the chapter in section 9.4.

Stock accounting takes product shipments, a retirement function, and initial in-service product stock as inputs and provides an estimate of the age distribution of in-service product stocks for all years. The age distribution of in-service product stocks is a key input to both the NES and NPV calculations—the operating costs for any year depend on the age distribution of the stock. The dependence of operating cost on the equipment age distribution occurs under a TSL that produces increasing efficiency over time, where older, less efficient units may have higher operating costs, while younger, more-efficient units will have lower operating costs.

DOE calculated total in-service stock of equipment by integrating historical shipments data starting from a specific year. The start year depended on the historical data available for the product. As units are added to the in-service stock, some of the older ones retire and exit the stock. To estimate future shipments, DOE developed a series of equations that define the dynamics and accounting of in-service stocks. For new units, the equation is:

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

where:

Stock(j, age) = the population of in-service units of a particular age,
j = year for which the in-service stock is being estimated, and
Ship (j) = number of units purchased in year *j*.

The above equation states that the number of one-year-old units is simply equal to the number of new units purchased the previous year. The slightly more complicated equations (e.g., the following equation) are those that describe the accounting of the existing in-service stock of units:

$$Stock(j+1, age+1) = Stock(j, age) \times \left[1 - prob_{Rtr}(age)\right]$$

In the above equation, as the year is incremented from *j* to *j+1*, the age is also incremented from *age* to *age+1*. With time, a fraction of the in-service stock is removed, and that fraction is determined by a retirement probability function, $prob_{Rtr}(age)$, which is described in section 9.3. Because the products considered in this rulemaking are common appliances that have been used by U.S. consumers for a long time, replacements typically constitute the majority of shipments. Most replacements are made when equipment wears out and fails.

9.3 DATA INPUTS AND MODEL CALIBRATION

As discussed above, shipments are driven primarily by two market segments: new construction and replacements.

DOE estimated new construction shipments using two inputs: new housing projections and market saturation data. New housing includes newly constructed single- and multi-family units, referred to as "new housing completions," and mobile home placements. For new housing completions and mobile home placements, DOE used actual data through 2013 and adopted the projections from the DOE Energy Information Administration (EIA)'s *Annual Energy Outlook 2015* for the period of 2014–2040.[1] To determine new construction shipments for each fuel category product (i.e., electric and gas), DOE used estimations of its historical market saturations, combined with projections of housing starts.

DOE estimated replacements using product retirement functions that it developed from product lifetimes. DOE based the retirement function on a Weibull probability distribution for the product lifetime. The shipments models assume that no units are retired below a minimum product lifetime and all units are retired before exceeding a maximum product lifetime. The models determine the probability of retirement at a certain age for all products using the following equations:

$$prob_{Rtr}(age) = 0 \qquad \text{for } age < AgeMin$$

$$prob_{Rtr}(age) = \frac{1}{AgeMax - AgeMin} \qquad \text{for } AgeMin \le age \le AgeMax$$

$$prob_{Rtr}(age) = 1 \qquad \text{for } age > AgeMax$$

where:

$prob_{Rtr}(age)$ = probability of retirement at the age of the product,
$AgeMin$ = minimum retirement age, and
$AgeMax$ = maximum retirement age.

DOE used historical shipments of electric and gas cooking products as the basis for calibrating its shipments models. For both products, because new construction shipments and replacements were not accurately account for all product shipments, DOE developed another market segment to calibrate its shipments models. This additional market segment represented a small share of total shipments.

The sections below explain in detail each of the data inputs, including the third market segment that DOE developed to calibrate its shipments model for each fuel category cooking product.

9.3.1 Historical Shipments

DOE designed its shipments model for cooking tops and ovens by dividing these products into two general fuel categories: electric and gas. Both the electric and gas categories comprised the following product configurations: freestanding, built-in cooking tops, and built-in/slide-in ovens. DOE developed two shipments models: one model estimated the electric cooking product shipments while the other model estimated gas cooking product shipments.

After DOE estimated shipments for each fuel type, it then disaggregated the shipments into product types—eight product types for electric cooking products and five product types for gas cooking products. Since each product class consists of two or more product types, DOE then aggregated shipments for each product type into their appropriate product classes.

Table 9.3.1 shows the product types and product classes under each general fuel category (i.e., electric and gas cooking products). For electric cooking products there are eight product types and six product classes; for gas cooking products there are five product types and five product classes. Because ranges are comprised of cooking top and oven product classes, DOE needed to disaggregate range shipments into the appropriate cooking top and oven product classes to obtain the total shipments for each product class.

Table 9.3.1 Cooking Products: Product Categories, Product Types, and Product Classes

Product Categories	Electric								Gas				
Product Types (PT): 8 electric, 5 gas	Freestanding				Built-In Cooking Tops		Built-In/Slide-In Oven		Freestanding		Built-In Cooking Tops	Built-In/Slide-In Oven	
	PT 1. Coil-Std	PT 2. Coil-SC	PT 3. Smth-Std	PT 4. Smth-SC	PT 5. Coil	PT 6. Smooth	PT 7. Std	PT 8. SC	PT 9. Gas-Std	PT 10. Gas-SC	PT 11. Gas	PT 12. Std	PT 13. SC
Product Classes (PC): 4 electric, 4 gas	PC1: Electric Standard Oven with or without a Catalytic Line – Freestanding = Product Type 1, 3 PC2: Electric Standard Oven with or without a Catalytic Line – Built-In/Slide-In = Product Type 7 PC3: Electric Self-clean Oven – Freestanding = Product Type 2, 4 PC4: Electric Self-clean Oven – Built-In/Slide-In = Product Type 8												
	PC5: Gas Standard Oven with or without a Catalytic Line – Freestanding = Product Type 9 PC6: Gas Standard Oven with or without a Catalytic Line – Built-In/Slide-In = Product Type 12 PC7: Gas Self-clean Oven – Freestanding = Product Type 10 PC8: Gas Self-clean Oven – Built-In/Slide-In = Product Type 13												

Std = standard; SC = self-clean; Smth = smooth

Table 9.3.2 shows the historical shipments data of electric and gas cooking products. DOE relied on two data sources to establish historical shipments data: (1) data from Market Research Magazine provided for the period 2006 – 2012[2], and (2) data from DOE's 2006 technical support document (TSD) on cooking products covering the period 1970–2005[3].

Table 9.3.2 Historical Shipments: Electric and Gas Cooking Products (Unit: million)

Year	Electric	Gas	Year	Electric	Gas	Year	Electric	Gas
1970	3.00	2.33	1985	3.41	2.33	2000	5.03	3.18
1971	3.00	2.33	1986	3.41	2.33	2001	5.07	3.04
1972	3.23	2.33	1987	3.41	2.33	2002	5.34	3.27
1973	3.64	2.33	1988	3.41	2.33	2003	5.62	3.42
1974	3.22	2.33	1989	3.41	2.33	2004	6.14	3.72
1975	2.36	2.33	1990	3.35	2.35	2005	6.20	3.76
1976	2.73	2.33	1991	3.21	2.30	2006	6.23	3.59

Year	Electric	Gas	Year	Electric	Gas	Year	Electric	Gas
1977	3.28	2.33	1992	3.45	2.49	2007	5.99	3.33
1978	3.41	2.33	1993	3.73	2.63	2008	5.11	2.84
1979	3.41	2.33	1994	4.05	2.84	2009	4.33	2.60
1980	3.41	2.33	1995	3.92	2.72	2010	4.45	2.79
1981	3.41	2.33	1996	4.16	2.71	2011	4.32	2.62
1982	3.41	2.33	1997	4.24	2.74	2012	4.32	2.60
1983	3.41	2.33	1998	4.64	2.95			
1984	3.41	2.33	1999	4.98	3.14			

Source: 2006 – 2012: Market Research Magazine; 1970 – 2005: DOE's 2006 rulemaking for cooking products.

DOE used the three sources to establish historical market shares for each product type under each fuel type: (1) data collected from the web-sites of AJ Madison, Home Depot, Lowes in 2013, and (2) data from Market Research Magazine provided for the period 2006 – 2012[2], and (3) data from DOE's 2006 TSD on cooking products covering the period 1970–2005[3]. Because the historical shipments data is reported by range, oven, and surface cooking top, which did not provide detailed shipments information of range types, i.e. freestanding and built-in/slide-in ranges proposed by this rulemaking, therefore, DOE used web collected product model information to estimate the market share between the freestanding and built-in/slide-in ranges. Table 9.3.3 shows the market share between freestanding and built-in/slide-in ranges by fuel type. This information enables DOE to reallocate historical shipments data based on the newly proposed product classes. Table 9.3.4 presents the re-grouped market shares of the eight product types that comprise total electric cooking product shipments. Table 9.3.5 shows the re-grouped historical market shares of the five product types that comprise total gas cooking product shipments. For any given year, the sum of the product type market shares equals 100 percent under each fuel type.

Table 9.3.3 Market Share of Freestanding and Built-in/Slide-In Ranges by Fuel Type

Range Type	**Electric Ranges**		**Gas Ranges**	
	Number of Models	**% of Total**	**Number of Models**	**% of Total**
Freestanding	533	94.2%	110	91.7%
Slide-In	33	5.8%	10	8.3%
Total	566	100.0%	120	100.0%

Source: AJ Madison, Home Depot, and Lowes.

Table 9.3.4 Electric Cooking Products: Historical Shipment Market Shares by Product Type

Year	Percent of Total Shipments					
	Freestanding Ranges		Built-In Cooking Tops		Built-In/Slide-In Ovens	
	Standard	Self-Clean	Coil	Smooth	Standard	Self-Clean
1970–1989	32.80%	31.80%	4.10%	9.00%	7.10%	15.20%
1990	28.70%	36.20%	4.00%	8.80%	8.20%	14.10%
1991	32.10%	34.60%	3.80%	8.30%	4.50%	16.80%
1992	32.70%	33.80%	3.70%	8.30%	4.70%	16.80%
1993	32.80%	34.60%	3.60%	7.90%	4.20%	17.00%
1994	28.70%	40.20%	3.10%	6.90%	6.80%	14.20%
1995	30.90%	39.50%	3.10%	6.80%	3.90%	15.70%
1996	28.40%	42.50%	3.10%	6.90%	3.90%	15.30%
1997	26.50%	44.10%	3.30%	7.20%	3.60%	15.30%
1998	25.40%	45.30%	3.40%	7.50%	3.30%	15.20%
1999	24.70%	46.90%	3.10%	6.80%	3.00%	15.60%
2000	23.70%	48.00%	3.10%	6.80%	2.70%	15.70%
2001	22.60%	48.80%	3.10%	6.80%	2.50%	16.20%
2002	21.60%	49.60%	3.10%	6.80%	2.30%	16.70%
2003	17.80%	53.30%	3.30%	6.40%	2.30%	17.00%
2004	17.90%	52.70%	2.80%	6.50%	2.00%	18.10%
2005	19.60%	51.60%	2.60%	6.20%	1.90%	18.20%
2006	19.50%	51.20%	2.60%	6.20%	1.90%	18.60%
2007	20.00%	52.60%	2.50%	6.00%	1.80%	17.20%
2008	20.20%	53.10%	2.50%	6.00%	1.70%	16.50%
2009	20.60%	54.30%	2.30%	5.50%	1.60%	15.70%
2010	20.40%	53.90%	2.20%	5.30%	1.70%	16.50%
2012	20.60%	54.20%	2.20%	5.20%	1.70%	16.20%

Table 9.3.5 Gas Cooking Products: Historical Shipment Market Shares by Product Type

Year	Percent of Total Shipments				
	Freestanding Ovens		Built-In Cooking Tops	Built-In/Slide-In Ovens	
	Standard	Self-Clean		Standard	Self-Clean
1970–1989	57.9%	20.1%	10.1%	10.3%	1.5%
1990	57.9%	19.7%	10.9%	9.5%	2.0%
1991	56.5%	21.1%	11.4%	9.0%	2.0%
1992	56.0%	21.7%	11.7%	8.9%	1.7%
1993	53.4%	24.4%	11.8%	7.7%	2.6%

Year	Percent of Total Shipments				
	Freestanding Ovens		Built-In Cooking Tops	Built-In/Slide-In Ovens	
	Standard	Self-Clean		Standard	Self-Clean
1994	55.5%	23.1%	11.2%	8.5%	1.7%
1995	53.3%	27.4%	8.8%	7.8%	2.6%
1996	51.2%	28.8%	10.0%	8.0%	2.0%
1997	49.0%	30.9%	10.2%	7.4%	2.5%
1998	46.3%	32.7%	11.4%	7.1%	2.5%
1999	44.0%	34.8%	11.7%	7.0%	2.5%
2000	41.9%	36.9%	11.9%	6.9%	2.5%
2001	39.5%	38.4%	12.6%	6.9%	2.5%
2002	37.9%	40.2%	12.7%	6.7%	2.5%
2003	37.0%	40.6%	13.3%	6.0%	3.0%
2004	34.1%	42.9%	14.2%	6.6%	2.2%
2005	33.8%	42.7%	14.9%	6.4%	2.3%
2006	33.5%	42.2%	15.7%	6.3%	2.2%
2007	33.8%	42.6%	14.9%	6.4%	2.3%
2008	34.3%	43.3%	13.6%	6.4%	2.3%
2009	35.3%	44.6%	11.2%	6.6%	2.3%
2010	35.3%	44.6%	11.2%	6.5%	2.3%
2012	35.3%	44.5%	11.4%	6.5%	2.3%

Source: 2006 – 2012: Normalized based on 2005 market share.

DOE then calibrated historical market share data as shown in Table 9.3.4 and Table 9.3.5 to estimate market share projections of each product type for the period 2013 – 2048. Table 9.3.6 and Table 9.3.7 present the projected market share for electric and gas cooking products, respectively.

Table 9.3.6 Electric Cooking Products: Projected Shipment Market Shares by Product Type

Year	Percent of Total Shipments					
	Freestanding Ranges		Built-In Cooking Tops		Built-In/Slide-In Ovens	
	Standard	Self-Clean	Coil	Smooth	Standard	Self-Clean
2005	19.60%	51.60%	2.60%	6.20%	1.90%	18.20%
2006	19.50%	51.20%	2.60%	6.20%	1.90%	18.60%
2007	20.00%	52.60%	2.50%	6.00%	1.80%	17.20%
2008	20.20%	53.10%	2.50%	6.00%	1.70%	16.50%
2009	20.60%	54.30%	2.30%	5.50%	1.60%	15.70%
2010	20.40%	53.90%	2.20%	5.30%	1.70%	16.50%
2012	20.60%	54.20%	2.20%	5.20%	1.70%	16.20%

Year	Percent of Total Shipments					
	Freestanding Ranges		Built-In Cooking Tops		Built-In/Slide-In Ovens	
	Standard	Self-Clean	Coil	Smooth	Standard	Self-Clean
2013	20.60%	54.20%	2.10%	4.90%	1.70%	16.50%
2014	20.60%	54.20%	2.10%	5.10%	1.30%	16.70%
2015	20.60%	54.10%	2.10%	5.00%	1.20%	16.90%
2016	20.60%	54.10%	2.10%	4.90%	1.20%	17.20%
2017	20.50%	54.10%	2.00%	4.80%	1.10%	17.40%
2018	20.50%	54.20%	2.00%	4.70%	1.00%	17.70%
2019	20.50%	54.10%	1.90%	4.60%	1.00%	17.90%
2020	20.50%	54.10%	1.90%	4.50%	0.90%	18.10%
2021	20.50%	54.30%	1.80%	4.40%	0.90%	18.10%
2022	20.60%	54.60%	1.80%	4.30%	0.80%	18.00%
2023	20.50%	54.80%	1.70%	4.20%	0.80%	18.00%
2024	20.60%	55.00%	1.70%	4.10%	0.70%	17.90%
2025	20.60%	55.20%	1.70%	4.00%	0.70%	17.80%
2026	20.60%	55.40%	1.60%	3.90%	0.60%	17.80%
2027	20.70%	55.70%	1.60%	3.80%	0.60%	17.70%
2028	20.70%	55.80%	1.60%	3.70%	0.60%	17.60%
2029	20.80%	56.10%	1.50%	3.60%	0.50%	17.50%
2030	20.70%	56.30%	1.50%	3.60%	0.50%	17.40%
2031	20.70%	56.60%	1.50%	3.50%	0.50%	17.30%
2032	20.80%	56.70%	1.40%	3.40%	0.40%	17.20%
2033	20.80%	56.90%	1.40%	3.30%	0.40%	17.10%
2034	20.90%	57.20%	1.40%	3.20%	0.40%	17.00%
2035	20.90%	57.40%	1.30%	3.20%	0.40%	16.80%
2036	20.90%	57.70%	1.30%	3.10%	0.40%	16.70%
2037	20.90%	57.80%	1.30%	3.00%	0.30%	16.60%
2038	20.90%	58.10%	1.20%	3.00%	0.30%	16.50%
2039	21.00%	58.30%	1.20%	2.90%	0.30%	16.30%
2040	21.00%	58.50%	1.20%	2.80%	0.30%	16.20%
2041	21.10%	58.70%	1.20%	2.80%	0.30%	16.10%
2042	21.10%	59.20%	1.10%	2.60%	0.20%	15.80%
2043	21.10%	59.40%	1.10%	2.60%	0.20%	15.60%
2044	21.10%	59.70%	1.10%	2.50%	0.20%	15.50%
2045	21.20%	59.80%	1.00%	2.50%	0.20%	15.30%
2046	21.20%	60.00%	1.00%	2.40%	0.20%	15.20%
2047	21.20%	60.30%	1.00%	2.40%	0.20%	15.00%
2048	21.20%	60.50%	1.00%	2.30%	0.20%	14.80%

Table 9.3.7 Gas Cooking Products: Projected Shipment Market Shares by Product Type

Year	Percent of Total Shipments				
	Freestanding Ovens		Built-In Cooking Tops	Built-In/Slide-In Ovens	
	Standard	Self-Clean		Standard	Self-Clean
2005	33.8%	42.7%	14.9%	6.4%	2.3%
2006	33.5%	42.2%	15.7%	6.3%	2.2%
2007	33.8%	42.6%	14.9%	6.4%	2.3%
2008	34.3%	43.3%	13.6%	6.4%	2.3%
2009	35.3%	44.6%	11.2%	6.6%	2.3%
2010	35.3%	44.6%	11.2%	6.5%	2.3%
2012	35.3%	44.5%	11.4%	6.5%	2.3%
2013	35.3%	44.6%	11.6%	6.3%	2.2%
2014	34.5%	45.3%	11.7%	6.1%	2.5%
2015	34.5%	45.2%	11.8%	6.0%	2.5%
2016	34.5%	45.2%	11.9%	6.0%	2.5%
2017	34.5%	45.2%	11.9%	5.9%	2.5%
2018	34.5%	45.1%	12.0%	5.9%	2.5%
2019	32.2%	47.4%	12.1%	5.8%	2.5%
2020	31.9%	47.7%	12.2%	5.8%	2.5%
2021	31.5%	48.0%	12.2%	5.7%	2.5%
2022	31.2%	48.2%	12.3%	5.7%	2.5%
2023	30.9%	48.5%	12.4%	5.6%	2.5%
2024	30.6%	48.8%	12.5%	5.6%	2.5%
2025	30.3%	49.0%	12.5%	5.6%	2.5%
2026	30.1%	49.2%	12.6%	5.5%	2.6%
2027	29.8%	49.5%	12.7%	5.5%	2.6%
2028	29.5%	49.7%	12.8%	5.5%	2.6%
2029	29.3%	49.9%	12.9%	5.4%	2.6%
2030	29.0%	50.1%	12.9%	5.4%	2.6%
2031	28.8%	50.3%	13.0%	5.4%	2.6%
2032	28.5%	50.5%	13.1%	5.3%	2.6%
2033	28.3%	50.6%	13.2%	5.3%	2.6%
2034	27.8%	51.0%	13.3%	5.2%	2.6%
2035	27.6%	51.1%	13.4%	5.2%	2.6%
2036	27.4%	51.3%	13.5%	5.2%	2.6%
2037	27.2%	51.5%	13.6%	5.2%	2.6%
2038	27.0%	51.6%	13.7%	5.1%	2.6%
2039	26.8%	51.7%	13.8%	5.1%	2.6%
2040	26.6%	51.9%	13.9%	5.1%	2.6%
2041	26.4%	52.0%	13.9%	5.0%	2.6%
2042	26.2%	52.1%	14.0%	5.0%	2.6%
2043	26.0%	52.3%	14.1%	5.0%	2.6%

Year	Percent of Total Shipments				
	Freestanding Ovens		Built-In Cooking Tops	Built-In/Slide-In Ovens	
	Standard	Self-Clean		Standard	Self-Clean
2044	25.8%	52.4%	14.2%	5.0%	2.6%
2045	25.6%	52.5%	14.3%	4.9%	2.6%
2046	25.5%	52.6%	14.4%	4.9%	2.7%
2047	25.3%	52.7%	14.5%	4.9%	2.7%
2048	25.1%	52.8%	14.6%	4.9%	2.7%

9.3.2 Markets and Model Calibration

For each general fuel category of cooking products, i.e., electric and gas, the market is primarily comprised of the following: replacement units for equipment that has been retired from service and units for new housing. In addition to normal replacements, DOE's shipments model for each general category also assumed that a certain fraction of the stock would be not be replaced due to demolition of old housing units. Total electric cooking product shipments are represented by the following equation:

$$Ship_{ELEC}(j) = Rpl_{ELEC}(j) + NI_{ELEC}(j) + NR_{ELEC}(j)$$

where:

$Ship_{ELEC}(j)$ = total shipments of electric cooking products in year *j*,
$Rpl_{ELEC}(j)$ = replacement shipments in year *j*,
$NI_{ELEC}(j)$ = shipments to new households in year *j*, and
$NR_{ELEC}(j)$= non replaced shipments in year *j* due to building demolition.

Total gas cooking product shipments are represented by the same basic equation:

$$Ship_{GAS}(j) = Rpl_{GAS}(j) + NI_{GAS}(j) + NR_{GAS}(j)$$

where:

$Ship_{GAS}(j)$ = total shipments of gas cooking products in year *j*,
$Rpl_{GAS}(j)$ = replacement shipments in year *j*,
$NI_{GAS}(j)$ = shipments to new households in year *j*, and
$NR_{GAS}(j)$= non replaced shipments in year *j* due to building demolition.

The sections below discuss in further detail all three of these markets for each general cooking product category (i.e., cooking tops and ovens).

New Construction. To estimate shipments to new construction, DOE used projections of housing starts coupled with cooking product saturation data. In other words, to project the shipments for new construction for any given year, DOE multiplied the housing projections by the estimated saturation of cooking products for new housing units.

Figure 9.3.1 presents historical new housing starts based on the U.S. Census data for the period 1970 – 2013[4]. New housing is comprised of single- and multi-family units and mobile home placements. Figure 9.3.2 presents the projected new housing starts based on EIA's *AEO2015* for the period 2014–2040[1]. The *AEO* typically provides three scenarios of housing starts: the Reference case, the High Economic Growth case, and the Low Economic Growth case. To estimate housing starts for the period 2041−2048, DOE froze housing starts at the level in the year 2040 for all three economic projections. All three housing starts projections are presented in Figure 9.3.2 through Figure 9.3.4. DOE used the projections from the Reference case as its default to estimate its shipments to new construction.

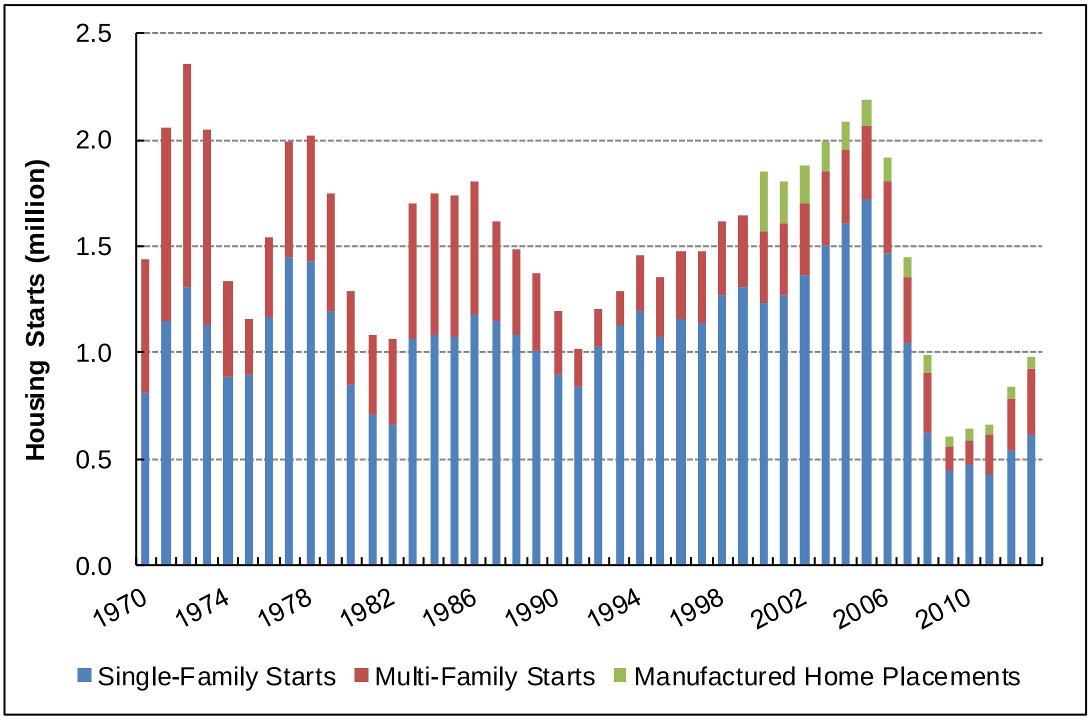

Figure 9.3.1 Historical Housing Starts by Housing Type (1970 – 2013)

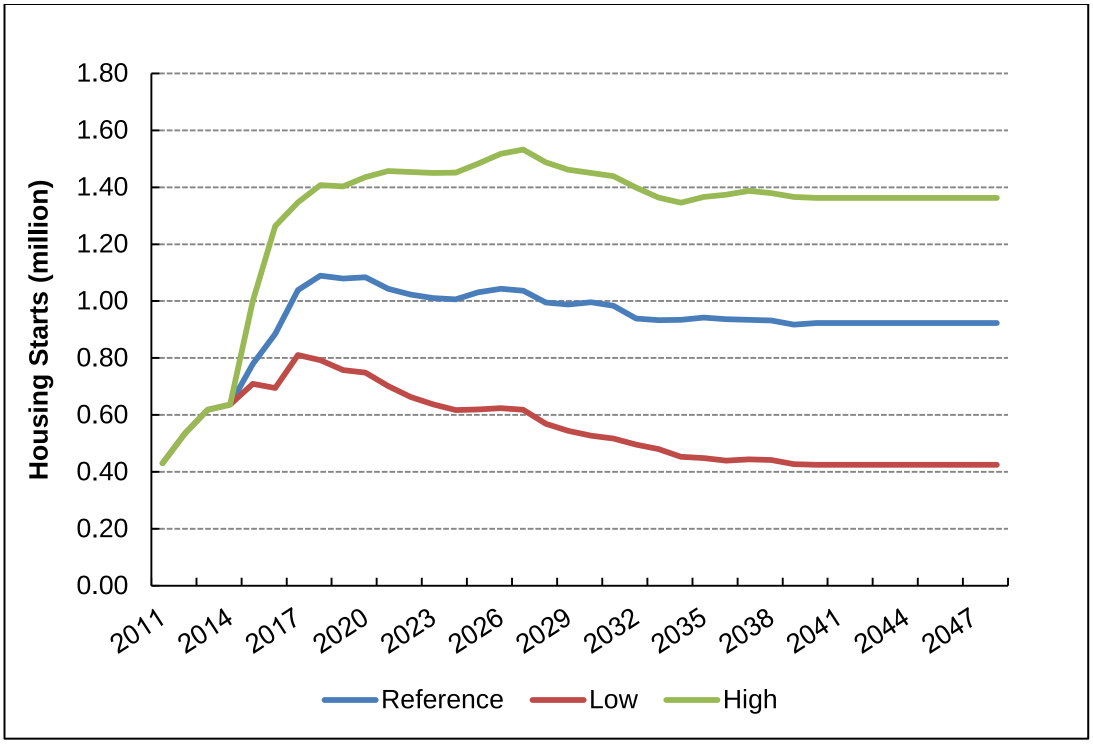

Figure 9.3.2 **Projected Single-Family Starts (2011 – 2048)**

Figure 9.3.3 **Projected Multi-Family Starts (2011 – 2048)**

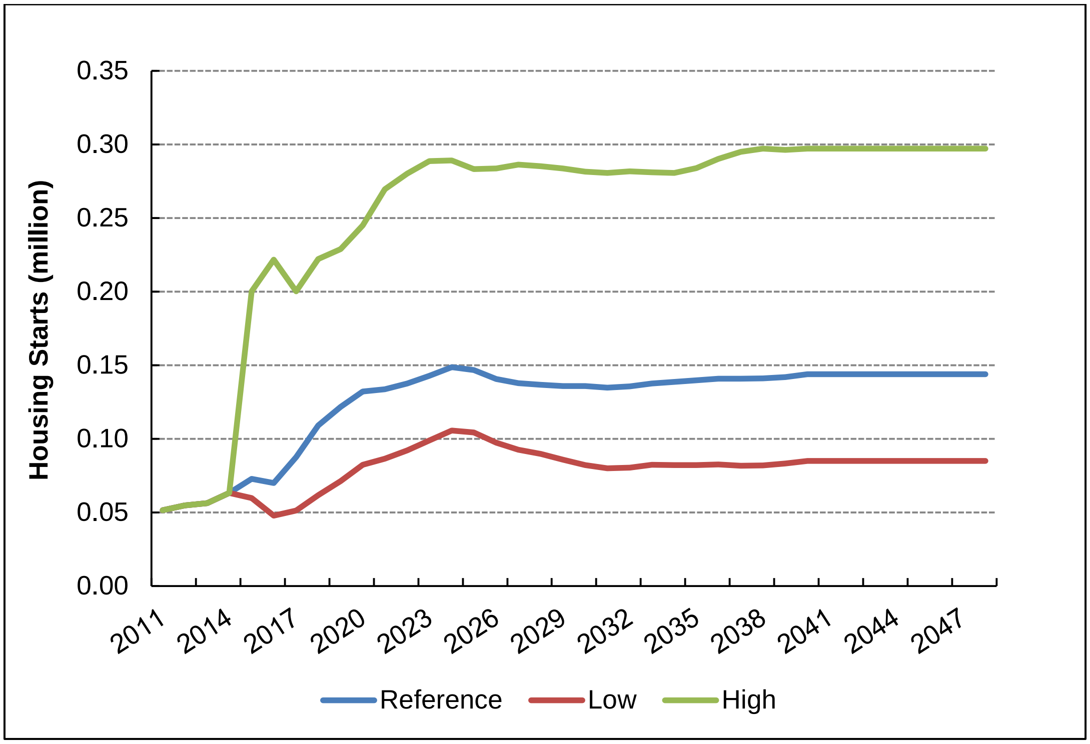

Figure 9.3.4 Projected Manufactured Home Placements (2011 – 2048)

To project saturation of cooking products in new housing starts, DOE reviewed data that provided by the Residential Energy Consumption Survey (RECS) 1997, 2001, 2005 and 2009[5]. DOE decided to only use the saturations for the year 2009 to estimate the shipments to new construction for future years, because the survey contains the largest households sample and its questions regarding saturation of cooking products are more accurately designed than previous versions. Because DOE conducted its shipments analysis by first projecting overall cooking product shipments by fuel category and then disaggregating the total shipments into product type using the historical market share data in Table 9.3.4 and Table 9.3.5, it used the overall saturation of electric and gas cooking products to estimate shipments to new construction, respectively. Table 9.3.8 summaries the saturation rates in new housing units in RECS 2009. To estimate saturation rates for the period 2010−2048, DOE froze saturation rates at the level in the year 2009.

Table 9.3.8 Saturation Rates of Cooking Products in New Housing Units in 2009

Electric Cooking Products			Gas Cooking Products		
Single-Family	**Multi-Family**	**Mobile-Home**	**Single-Family**	**Multi-Family**	**Mobile-Home**
81.6%	74.6%	88.7%	35.9%	27.6%	8.8%

Source: RECS2009.

Replacements. DOE determined shipments to the replacement market using an accounting method that tracks the total stock of units by vintage. DOE estimated stocks of electric and gas cooking products by vintage and by integrating historical shipments starting from the year 1970. Over time, some of the units will be retired and removed from the stock, thus triggering the shipment of a new unit. Because of the relationship between retirements and total stock, there is a strong correlation between past and future shipments, independent of efficiency standards.

Depending on the vintage, a certain percentage of each type of unit will fail and need to be replaced. To determine when an electric cooking product fails, DOE used a product survival function based on a Weibull lifetime distribution with an average value of 15 years. For gas cooking products, DOE used a product survival function based on the same Weibull lifetime distribution with an average value of 17 years. For a more complete discussion of cooking product lifetimes, refer back to section 8.2.3 of chapter 8. Figure 9.3.5 shows the survival functions that DOE used to estimate replacement shipments.

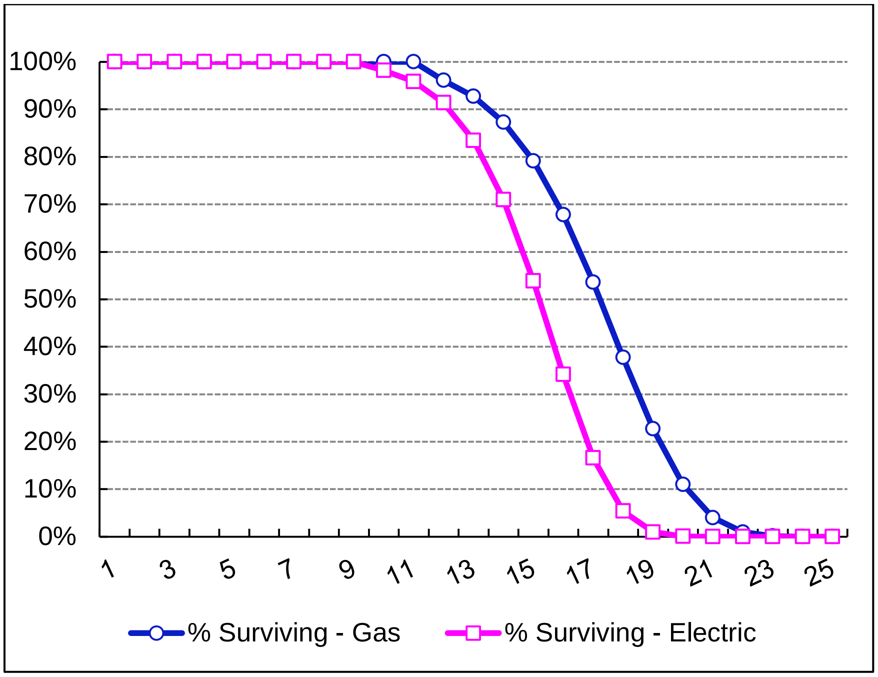

Figure 9.3.5 Electric and Gas Cooking Products: Surviving Functions

Model Calibration—Non-Replacement. To calibrate estimated shipments with the historical data, DOE introduced into the model a non-replacement market function. DOE assumed that some of the retiring cooking products would not be replaced in this category due to building demolition occur at the rate of 2.8 percent for electric cooking products and 4.1 percent for gas cooking products. DOE multiplied the not-replaced rates with the annual retiring electric and gas cooking products, respectively. DOE then excluded not-replaced units from the annual retiring units to estimate actual replacement of cooking products per annum for the period 2013–2048.

9.3.3 Base Case Shipments

Figure 9.3.6 and Figure 9.3.7 show the projected shipments of electric and gas oven products, respectively, in the base case (i.e., the case without new energy efficiency standards) and the historical shipments DOE used to calibrate the projection.

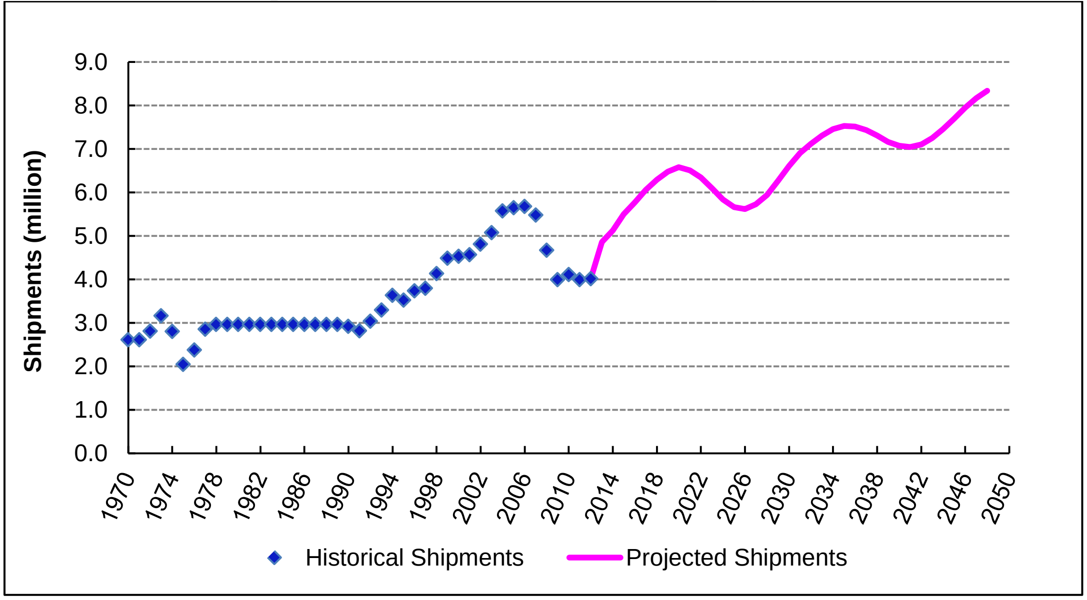

Figure 9.3.6 Electric Oven Products: Historical and Base Case Shipments Projection

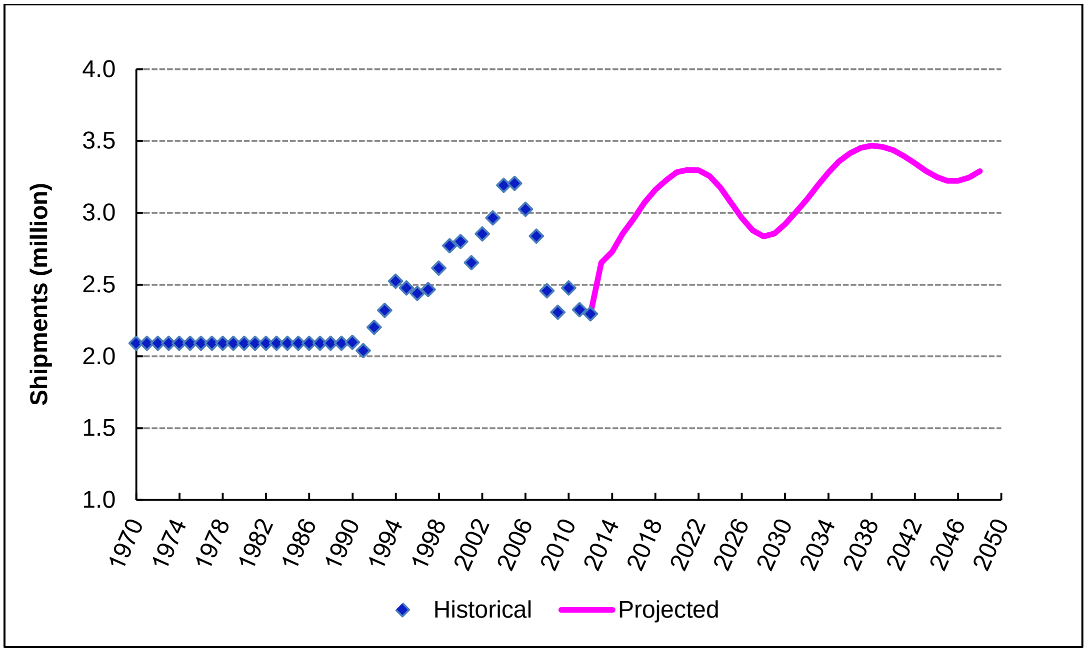

Figure 9.3.7 Gas Oven Products: Historical and Base Case Shipments Projection

Figure 9.3.8 presents total projected base case electric and gas oven product shipments over the analysis period (2019-2048). Note that electric oven shipments comprised 67 – 72 percent of total oven shipments during the analysis period.

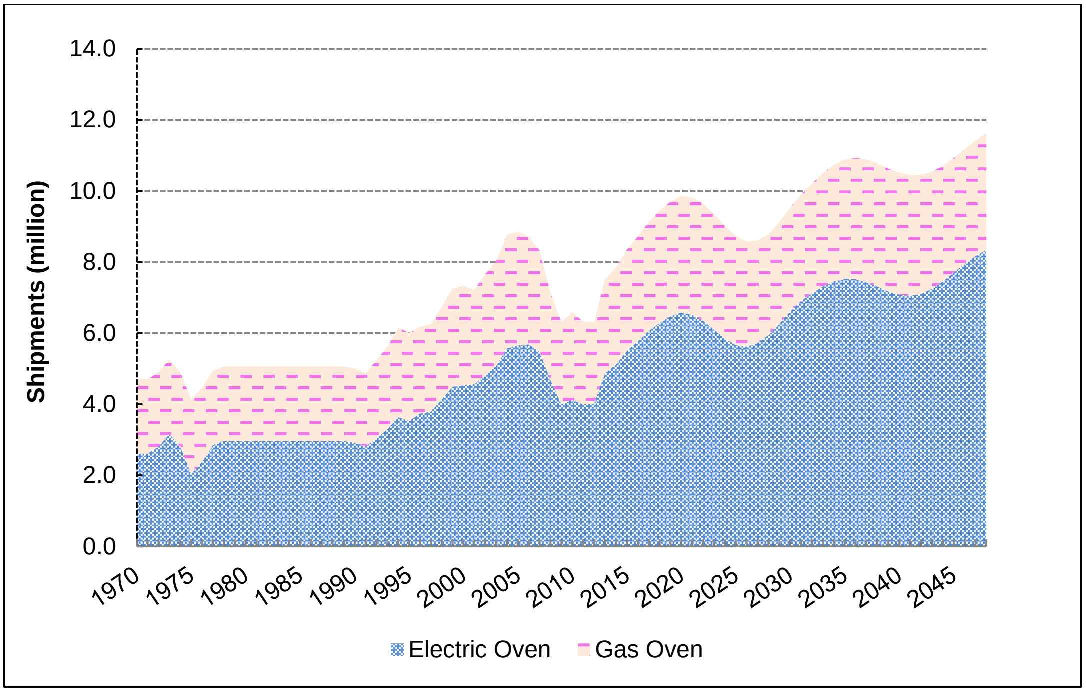

Figure 9.3.8 Electric Oven Products: Disaggregated Base Case Shipments Projection

9.4 EFFECT OF INCREASED PURCHASE PRICE ON SHIPMENTS

Economic theory suggests that, all else being equal, an increase in the price of a good leads to a decrease in demand for it. Because DOE projects that appliance standards often result in an increase in the price of the product, DOE conducts a literature review and an analysis of appliance price and efficiency data to estimate the effects on product shipments from increases in product price. DOE also considers the decreases in operating costs from higher energy efficiency and changes over time in household income.

In the case of oven products, the combined market of electric and gas oven products is completely saturated as indicated by the historical RECS data. Because of the nature of the end-use, every household is likely to be fitted with some type of oven product. A potential increase in purchase price could impact replacements in two ways – a unit due for replacement would either get replaced by the consumer immediately or the consumer would delay replacement by opting for repairing, before the eventual replacement. DOE did not get sufficient data to accurately characterize the replace versus repair decision. DOE therefore assumed that consumer price elasticity for oven products is zero. In other words, overall shipments for oven products would not be affected by any standards. However, since DOE uses a consumer choice model for estimating the efficiency distribution of the shipments, the impact of a price increase is captured in the shipments model through the consumers' choice of efficiency level while making a new purchase of the appliance.

9.5 AFFECTED STOCK

The affected stock is the in-service stock of the appliance or product that is affected by a TSL. In addition to the projection of product shipments under both the base case and the standards case, the affected stock (which represents the difference in the appliance stock for the base case and the standards case) is a key output of DOE's Shipments Models. The affected stock quantifies the impact that new product shipments have on the appliance stock due to a TSL. Therefore, the affected stock consists of those in-service units that are purchased in or after the year the standard has taken effect, as described by the following equation:

$$Aff\ Stock_p(j) = Ship_p(j) + \sum_{age=1}^{j-Std\_yr} Stock_p(age)$$

where:

$Aff\ Stock_p(j)$ = affected stock of units of product *p* of all vintages that are operational in year *j*,
$Ship_p(j)$ = shipments of product *p* in year *j*,
$Stock_p(j)$ = stock of units of product *p* of all vintages that are operational in year *j*,
age = age of the units (years), and
Std_yr = effective date of the standard.

As noted in the above equation, to calculate the affected stock, DOE must define the effective date of the standard. For the NES and NPV results presented in chapter 10, DOE assumed that new energy efficiency standards will become effective in the year 2019. Thus, all appliances purchased starting on the first day of the year 2019 are affected by the standard level.

9.6 RESULTS

The following section discusses the shipments projections for the various TSLs that DOE considered for each of the products. The TSLs are identified and described in chapter 10.

Because the combined market of electric and gas cooking products is completely saturated, DOE assumed that all electric and gas oven product TSLs would neither impact standards case shipments nor cause shifts in electric and gas oven product market shares. Thus, DOE's shipments model for electric and gas cooking products does not incorporate the use of *relative price* elasticities. As a result, projected shipments for all cooking product TSLs are equal to the base case shipments projection. Refer back to Figure 9.3.6 and Figure 9.3.7 to review the base case shipments projections for electric and gas oven products, respectively.

REFERENCES

1 U.S. Department of Energy-Energy Information Administration. *Annual Energy Outlook 2015*, April, 2015. Washington, DC. <http://www.eia.gov/forecasts/aeo/>.

2 UBM Canon, Market Research Magazine: Appliance Historical Statistical Review, 2014.

3 U.S. Department of Energy-Energy Efficiency and Renewable Energy Office. *Energy Conservation Standards for Electric and Gas Ranges and Ovens and Microwave Ovens, Dehumidifiers, and Commercial Clothes Washers*, 2006, EERE-2006-STD-0127, Washington, DC.

4 U.S. Census Bureau, Historical Data: New Privately Owned Housing Units Started, 1959 – 2013. <http://www.census.gov/construction/nrc/historical_data/>.

5 U.S. Department of Energy-Energy Information Administration. *Residential Energy Consumption Survey, 1997, 2001, 2005, and 2009*. Washington, DC. <http://www.eia.gov/consumption/residential/data/2009/>.

CHAPTER 10. NATIONAL IMPACT ANALYSIS

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

This chapter describes the method the U.S. Department of Energy (DOE) used to estimate the national impacts of each trial standard level (TSL) considered for oven products and presents the results of its calculations. For each TSL, DOE evaluated the following impacts: (1) national energy savings (NES) attributable to each potential standard level; (2) monetary value of the lifetime energy savings to consumers of oven products; (3) increased total installed costs; and (4) the net present value (NPV) of the difference between the value of the operating cost savings and the increased total installed costs.

The calculations and results are presented in a Microsoft Excel spreadsheet model, which is accessible through the Department's website[1]. The spreadsheet model, termed the national impact analysis (NIA) model, calculates energy savings and NPV for the nation. Details and instructions for using the NIA model are provided in appendix 10A.

The NIA calculation started with the shipments model, described in chapter 9, that DOE used to project future purchases of oven products. Chapter 9 includes an analysis of consumers' sensitivities to total installed cost, operating expense, and other factors that may lead to a change in total shipments relative to the base case under a proposed standard. DOE used the annual shipments projection to produce an accounting of annual NES, annual national energy cost savings, and annual national incremental non-energy costs resulting from purchasing, installing and operating the covered equipment. The NIA analysis accounts for costs and energy use over the lifetime of each unit shipped during the analysis period 2019 - 2048. The national-level results presented for each year of the analysis period, and as cumulative totals.

To calculate the annual NES, DOE estimated the lifetime site, primary and full-fuel-cycle (FFC) energy consumption at the unit level for each year in the analysis period. DOE defined these quantities as follows:

- Site energy consumption is the physical quantity of fossil fuels or electricity consumed at the site where the end-use service is provided. The site energy consumption is used to calculate the energy cost input to the NPV calculation.
- Primary energy consumption is defined by converting the site fuel use from physical units, for example cubic feet for natural gas, or kWh for electricity, to common energy units (million Btu or MMBtu). This step used the conversion factors listed in appendix 10B. For electricity the conversion factor is a marginal heat rate that incorporate losses in generation, transmission and distribution, and depends on the sector, end use and year. For this rule DOE used the values for residential end-use.
- The full-fuel-cycle (FFC) energy use is equal to the primary energy use plus the energy consumed "upstream" of the site in the extraction, processing and distribution of fuels. The FFC energy use was calculated by applying a fuel-specific FFC energy multiplier to the primary energy use. These multipliers are presented in appendix 10B.

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[1] U.S. Department of Energy, http://www.eere.energy.gov/buildings/appliance_standards/.

If a product uses multiple fuels[2], the energy use calculation estimated consumption for each fuel type separately. The unit's lifetime primary and FFC energy consumptions were then scaled up to the national level based on the annual shipments projection and according to two scenarios: the *base case* scenario, with no changes in the existing energy efficiency standards; and (b) the *standards case* scenario, where energy efficiency standards are set at the energy efficiency level corresponding to one of the trial standard levels (TSLs).

DOE followed a similar procedure to calculate the annual national energy cost savings and the annual national incremental installation, maintenance and other non-energy costs. For each unit shipped during the analysis period, and for each year of its lifetime, DOE estimated both the energy and the non-energy costs based on the unit's efficiency and any appropriate price trends. The unit-level estimates were then scaled up to the national level based on the annual shipments projection for the base case and the trial standard levels. DOE calculated the difference between the aggregated national energy cost savings and national incremental non-energy costs to obtain the NPV of each equipment class. DOE applied a weight to each equipment class based on its market share to sum these values to define the total NPV.

The two models used in the NIA—the NES model and the NPV model—are described more fully in subsequent sections. The descriptions include overviews of how DOE performed each model's calculations and summaries of the major inputs. After the technical model descriptions, this chapter presents the results of the NIA calculations.

10.2 TRIAL STANDARD LEVELS

DOE analyzed the benefits and burdens of three trial standard levels (TSLs) for oven products. The proposed criteria for grouping efficiency levels into TSLs to apply to each equipment class are outlined below, and the resulting efficiency level groupings by TSL are shown in Table 10.2.1 and Table 10.2.2.

1. TSL 3 was chosen to correspond to the max-tech efficiency level for each product class.
2. TSL 2 comprises efficiency levels that offer the maximum NPV.
3. TSL 1 was configured with standby levels with maximum NES.

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[2] For example, a furnace may use both natural gas for heating and auxiliary electricity.

Table 10.2.1 Trial Standard Levels for Electric Ovens

TSL	Electric Standard Ovens, Freestanding		Electric Standard Ovens, Built-In/Slide-In		Electric Self-Clean Ovens, Freestanding		Electric Self-Clean Ovens, Built-In/Slide-In	
	EL	IAEC (kWh/yr)	EL	IAEC (kWh/yr)	EL	IAEC (kWh/yr)	EL	IAEC (kWh/yr)
1	1	284.6	1	291.4	1	345.1	1	351.0
2	3	259.2	3	265.4	1	345.1	1	351.0
3	7	207.3	7	212.2	4	278.1	4	282.9

Table 10.2.2 Trial Standard Levels for Gas Ovens

TSL	Gas Standard Ovens, Freestanding		Gas Standard Ovens, Built-In/Slide-In		Gas Self-Clean Ovens, Freestanding		Gas Self-Clean Ovens, Built-In/Slide-In	
	EL	IAEC (kBtu/yr)	EL	IAEC (kBtu/yr)	EL	IAEC (kBtu/yr)	EL	IAEC (kBtu/yr)
1	Baseline	2,118.2	Baseline	2,128.1	1	1,848.2	1	1,858.0
2	4	1,414.8	4	1,421.5	2	1,668.7	2	1,677.5
3	7	1,347.0	7	1,353.3	4	1,591.0	4	1,599.4

10.3 PROJECTED EFFICIENCY TRENDS

10.3.1 Base Case

A key component of the NIA is the energy efficiency projected over time for the base case (without new standards) and for each of the standards cases.

For its determination of base case projected efficiencies, DOE implemented a consumer-choice model that assumes consumers are sensitive to first cost, i.e., equipment price, and calculates the market share for available efficiency options based on the first cost for oven products users.

The consumer-choice model uses a logit model to calculate the probability that a consumer will purchase product j based on the logistic curve probability function of the form:

$$P_j(z) = \frac{e^{z_j}}{\sum_{i=1}^{n} e^{z_i}}$$

Eq. 10.1

Where:

$P_j(z) =$ the probability a consumer will purchase product j among n possible options, and

$z =$ the ‘logit’, which is defined as follows

$$z_j = \beta_{FC} * FC_j$$

Eq. 10.2

Where:

β_{FC} = consumer sensitivity to first cost,
FC_j = first cost of product option j,

In Eq.10.2 , β_{FC} can be determined by fitting an exponential function to the first cost distribution in the engineering analysis:

$$MS(FC) = Ne^{\beta_{FC}*FC}$$

Eq. 10.3

Where:

N = Normalization factor,
FC = First cost of a oven product in 2014$,
$MS(FC)$ = Market share for a oven product that costs FC, and
β_{FC} = Consumer sensitivity to first cost.

The regression coefficients (β values) represent the consumer's sensitivity to first cost (β_{FC}). The coefficients are determined using historical shipments and equipment price data.

For oven products, consumer sensitivities are user-specific based on users' housing type in the Residential Energy Consumption Survey (RECS) 2009[1]. Table 10.3.1 summarizes the market share between renters and home-owners by fuel type of oven products that they use in RECS 2009. DOE assumed that landlords would have no economic incentive and renters would have no decision making to purchase or replace an energy efficient oven product, therefore, DOE assigned the percentage of renters found in the RECS 2009 to the baseline efficiency level. DOE then assumed home-owners would have incentive to purchase or replace an energy efficient oven product based on their sensitivity to the initial purchase costs. DOE used shipments data collected by the Market Research Magazine[2] and Producer Price Index (PPI) of household cooking appliance manufacturers[3] between the years 2002 – 2012 along with the manufactures costs data from the engineering analysis to analyze factors that influence consumer-purchasing decisions of oven products. By using the logit statistical model described by Eq. 10.3, DOE found that historical shipments data has a strong dependence on the first costs by product type. DOE then developed the best-fit to capture the relationship between historical shipments and price data. Table 10.3.2 shows the best-fit logit parameters calculated for oven products. DOE then used the parameters in Table 10.3.2 to derive efficiency distribution in a given year for home-owners. DOE combined the market share of renters with the efficiency distribution derived from the consumer-choice model for home-owners to project its base case efficiency distribution for the period between 2019 and 2048.

Table 10.3.1 Oven User Ownership by Fuel Type

Owners/Renters	Electric Ovens	Gas Ovens
Home owners	69.3%	66.1%
Renters	30.7%	33.9%

Source: RECS 2009.

Table 10.3.2 Best-fit Logit Parameters for Oven Products

Product Class	N	β_{FC}
Electric Standard Ovens, Freestanding	36.71287	-0.00471
Electric Standard Ovens, Built-In/Slide-In	36.71287	-0.00471
Electric Self-Clean Ovens, Freestanding	39.981985	-0.004472
Electric Self-Clean Ovens, Built-In/Slide-In	39.981985	-0.004472
Gas Standard Ovens, Freestanding	8.4805448	-0.002612
Gas Standard Ovens, Built-In/Slide-In	8.4805448	-0.002612
Gas Self-Clean Ovens, Freestanding	8.4810489	-0.002141
Gas Self-Clean Ovens, Built-In/Slide-In	8.4810489	-0.002141

10.3.2 Standards Case

For its determination of standards case projected efficiencies, DOE assumed a “roll-up” scenario to establish the efficiency distribution under different TSLs. Product efficiencies in the base case that do not meet the standard under consideration would “roll up” to meet the new standard level. All efficiency shares in the base case that were above the standard under consideration would not be affected.

These assumptions are used to determine the average per-unit energy consumption

$$UEC(L,F,v)= UEC(L,F,v)*eff(v,y0)$$

Where:

UEC = average annual per-unit site energy consumption
L = trial standard level
F = fuel type
v = vintage (year of purchase)
y_0 = compliance year 2019
eff = population-average efficiency trend relative to 2019

10.4 NATIONAL ENERGY SAVINGS

DOE calculates annual national energy savings (NES) and cumulative NES throughout the projected period, which extends from 2019 to 2048. Positive values of NES represent energy savings, meaning national energy consumption under the proposed standards is lower than in the base case.

10.4.1 Definition

The NES calculation begins with the calculation of the projected annual site energy consumption (*ASEC*) over the analysis period. DOE calculated the *ASEC* in the base case (without new standards) and for each trial standard level (TSL). The trial standard level is labelled L, with $L=0$ corresponding to the base case.

DOE calculated the *ASEC* by multiplying the number or stock of a given product by its unit energy consumption (*UEC*). For each equipment class, both the stock and the UEC are calculated as a function of the TSL, the analysis year and the vintage (year of purchase of the equipment). The derivation of the stock model is described in chapter 9. For each equipment class, the calculation of the national *AEC* is represented by the following equation:

$$ASEC(L,F,y) = \sum_{v} S(L,F,y,v) * UEC(L,F,v)$$

Where:

$ASEC$ = annual site energy consumption
L = trial standard level
F = fuel type
y = analysis year
v = vintage (year of purchase)
S = stock of product (millions of units)
UEC = annual energy consumption per unit

10.4.2 Shipments and Product Stock

DOE projected shipments of each product class under the base case and each standards case. Several factors affect projected shipments, including purchase cost, operating cost, and household income. As noted previously, the increased cost of more-efficient products causes some consumers to forego buying the products. Consequently, shipments projected under the standards cases are lower than under the base case. However, in the case of oven products, DOE determined that there would not be decrease in overall shipments due to an increase in cost of more-efficient products. The method DOE used to calculate and generate the shipments projections for each considered product class is described in detail in chapter 9, Shipments Analysis.

The product stock in a given year is the number of products shipped from earlier years that survive in that year. DOE assumes that products have an increasing probability of retiring as they age. The probability of survival as a function of years since the date of purchase constitutes the survival function. Chapter 9 provides additional details on the survival function that DOE used.

10.4.3 Annual Energy Consumption per Unit

DOE developed annual per-unit energy consumption as a function of product energy efficiency for each product class (see chapter 7, Energy Use Analysis, and chapter 8, Life-Cycle Cost and Payback Period Analysis). For the NES calculation DOE used a national average value for each equipment class exported from the LCC (chapter 8) to define the UEC in the starting year of the analysis period, $y_0 = 2019$. For subsequent years, DOE applied the efficiency trend discussed in section 10.3.

10.4.4 National Annual Energy Consumption

DOE used two steps to convert the annual site energy consumption numbers to an NES value. First, the site energy numbers are converted to common units, using the conversion factors presented in appendix 10B, and the energy consumption is summed over fuel type. This converts the site energy *ASEC* to primary energy *APEC*:

$$APEC(L,y) = \sum_F ASEC(L,F,y) * h(F,y).$$

In this equation $h(F,y)$ is the conversion factor for fuel type F in year y. For electricity the conversion factor is a marginal heat rate that incorporates losses in generation, transmission and distribution, and depends on the sector, end use and year. For this rule, DOE used the values for residential end-use.

DOE then defined the NES as the difference between the APEC in the base case ($L=0$) and in the standards case:

$$NES(L,y) = APEC(L=0,y) - APEC(L,y).$$

DOE presented results of the NES calculation as a cumulative sum over the analysis period. This period is defined as 30 years from the start date of the standard (2019-2048). DOE included in its NES estimate the lifetime energy savings for units shipped in the final year of the analysis period; hence the stock model is continued to 2072 in order to account for these savings. This calculation is represented by the equation

$$NES_{cum}(L) = \sum_y NES(L,y)$$

10.4.5 Primary Energy Conversion Factors

DOE calculates primary energy savings as the total site consumption across all fuel types converted to common units (MMBtu). For fossil fuels such as natural gas, fuel oil or propane, the conversion factor is a constant equal to the low-heating value for the fuel (listed in appendix 10B). Because the fossil fuel conversion factors are constant over time, DOE may perform this conversion inside the LCC, reporting fossil fuel consumption in energy units rather than physical units. For electricity use, the conversion from site kWh to power plant primary MMBtu uses a marginal heat rate factor that accounts for losses associated with the generation, transmission, and distribution of electricity. DOE derived these marginal factors using data published with the Energy Information Administration (EIA's) Annual Energy Outlook 2014 (AEO2014), following the methodology outlined in appendix 15A.[4] The factors depend on the sector and end-use, and also vary with time due to changes in the mix of fuels used for electric power generation. Figure 10.4.1 shows the site-to-power plant factors from 2019 to the end of the AEO analysis period (2040). For years after 2040 DOE held the factors constant and equal to their 2040 values.

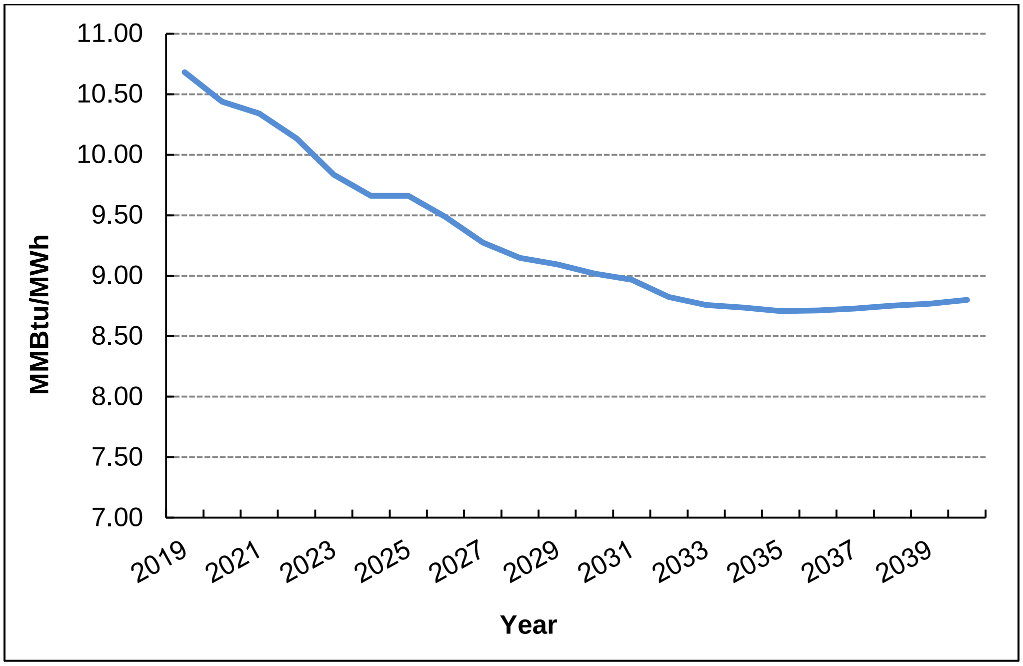

Figure 10.4.1 Site-to-Power Plant Energy Use Factor for Oven Products

10.4.6 Full-Fuel-Cycle Energy Factors

The full-fuel-cycle (FFC) energy use is equal to the primary energy use plus the energy consumed "upstream" of the site in the extraction, processing and distribution of fuels. The FFC energy use was calculated by applying a fuel-specific FFC energy multiplier to the primary energy use. DOE developed FFC multipliers using the data and projections generated by the National Energy Modeling System (NEMS) used for *AEO2014*. 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 multiplier for electricity represents the energy needed to produce and deliver the fuels that are consumed in electricity generation. The multipliers are dimensionless numbers that express the upstream energy use as a percentage of the primary energy use.

Because the FFC energy multipliers depend on the fuel type, the FFC energy is calculated starting with the annual site energy numbers *ASEC*. The equation is:

$$FFC(L,y) = \sum_F ASEC(L,F,y) * h(F,y) * \mu(F,y).$$

Where:

$ASEC$ = annual site energy consumption
L = trial standard level
F = fuel type

y = analysis year
h = energy unit conversion factor
μ = full fuel cycle multiplier
FFC = annual full fuel cycle energy consumption

If a product uses only one fuel, then the FFC energy is equal to the primary energy *APEC* multiplied by the FFC multiplier μ. For products that use multiple fuels, the relationship between the primary energy use and the FFC energy is less straight-forward.

As with the NES, DOE calculated cumulative, national level energy savings in the full-fuel-cycle metric by calculating the difference relative to the base case and summing over the analysis period:

$$NES\text{-}FFC(L,y) = FFC(L=0,y) - FFC(L,y),$$

$$NES\text{-}FFC_{cum}(L) = \sum_y NES\text{-}FFC(L,y)$$

10.5 NET PRESENT VALUE

DOE defined the net present value (*NPV*) as the net consumer benefit associated with each trial standard level. The net consumer benefit is defined as the sum of the change in operating cost relative to the base case and the change in the total installed cost relative to the base case. Typically the change in operating cost is positive (a savings to consumers), while the change in total installed cost is negative (a cost to consumers). The costs and savings are calculated in each year of the analysis period for all the equipment shipped in that year, discounted, and summed to provide a net present value.

10.5.1 Definition

The NPV is equal to the sum of two present-value estimates:

$$NPV = PV_{OCS} + PV_{TIC}$$

Where:

PV_{OCS} = present value of the reduction in operating cost relative to the base case
PV_{TIC} = present value of the increase in total installed cost relative to the base case

DOE determined the *PV-OCS* and *PVC* according to the following expressions:

$$PV_{OCS}(L) = \sum_y (OC(L=0,y) - OC(L,y))* DF(y)$$

$$PV_{TIC}(L) = \sum_y (TIC(L=0,y) - TIC(L,y))* DF(y)$$

Where:

OC = operating cost of the stock in year y
L = trial standard level, with $L=0$ corresponding to the base case
y = analysis year
DF = discount factor
TIC = total installed cost of the shipments in year y

DOE calculated the energy-related component of the operating cost based on the site energy use (described in section 10.4.4), the energy price and the energy price trend over the analysis period. The operating cost also includes routine repair and maintenance costs. The operating costs are incurred over the full lifetime of the unit, so the operating cost calculation uses the equipment stock. DOE calculated the total installed cost by multiplying the number of shipments times in each year by the sum of the equipment price and installation cost. These costs are incurred only in the year of purchase, so the TIC calculation uses the shipments only. If the maintenance, repair or installation costs do not depend on the trial standard level, they can be left out of the calculation. Each of these calculation steps are discussed in more detail in the following sections. As with the NES, the analysis period starts in the compliance year of the standard 2019 and concludes thirty years later in 2048. Operating costs are calculated until the units shipped in 2048 retire (2072).

10.5.2 Total Installed Cost

DOE described the total per-unit installed cost for each product class as a function of product efficiency or TSL in chapter 8. For the NPV calculation, DOE used the population average total installed cost exported from the LCC in the start year 2019 for the base and standards cases for each product class included in the model. In calculating the TIC, DOE used the shipments exported from the shipments model, which depend on the trial standard level.

DOE investigated the possibility that equipment prices, measured in constant dollars, might change over the analysis period. Incorporating the equipment price trend $\beta(y)$, the equation for TIC is

$$TIC(L,y) = Ship(L,y)*UIC(L,y_0)* b(y, y_0),$$

Where
$Ship$ = total shipments in year y as calculated in the shipments model
y_0 = compliance year 2019
L = trial standard level, with $L=0$ corresponding to the base case
UIC = average per-unit total installed cost 2019 exported from the LCC
b = equipment price trend relative to year 2019

DOE determined that the equipment price trend followed the equation below.

$$Y = a X^{-b}$$

Where:

a = an initial price (or cost),
b = a positive constant known as the learning rate parameter,
X = cumulative production, and
Y = the price as a function of cumulative production.

Thus, as experience (production) accumulates, the cost of producing the next unit decreases. The percentage reduction in cost that occurs with each doubling of cumulative production is known as the learning rate (LR), given by:

$$\mathrm{LR} = 1 - 2^{-b}$$

In typical learning curve formulations, the learning rate parameter is derived using two historical data series: cumulative production and price (or cost).

10.5.3 Annual Operating Cost

The per-unit annual operating cost includes costs for energy, repair, and maintenance. DOE determined the per-unit annual energy cost based on the annual site energy consumption (*ASEC)* discussed in section 10.4.3. The *ASEC* incorporates both changes in shipments and changes in equipment efficiency at each TSL. For each fuel type, DOE used the energy price in the start year, and energy price trend, that were used in the life-cycle cost analysis (chapter 8). The price trends are taken from the EIA's *AEO2015* reference case scenario.

DOE described the total per-unit repair and maintenance costs for each product class as a function of product efficiency in the LCC analysis in chapter 8. The NPV calculation is based on the population average repair and maintenance costs exported from the LCC, for each TSL. These costs are assumed to remain constant in real terms over the analysis period.

The equation for the operating cost in year y and TSL L is:

$$OC(L,y) = \sum_F ASEC(L,F,y)*e(F,y_0)*a(F,y,y_0)$$

Where

$ASEC$ = annual site energy consumption
L = trial standard level, with $L=0$ corresponding to the base case
F = fuel type
y_0 = compliance year 2019
e = energy price in 2013 exported from the LCC
L = trial standard level, with $L=0$ corresponding to the base case
a = energy price trend relative to year 2013

10.5.4 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:

$$DF(y) = (1+r)^{-(y-y_P)}$$

Where:
r = discount rate,
y = analysis year
y_P = year relative to which the present value is being determined.

Although DOE used consumer discount rates to determine the life-cycle cost of oven products (chapter 8), it used national discount rates to calculate national NPV. 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.[5] DOE defined the present year as 2014.

10.6 RESULTS

10.6.1 National Energy Savings

This section provides the national energy savings that DOE calculated for each of the TSLs analyzed for oven products. 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 such as is generated by the life-cycle cost and payback period analysis. Table 10.6.1 shows FFC energy savings for oven products by product class.

Table 10.6.1 Estimates of Cumulative Full-Fuel Cycle NES (quads)

Product Class	TSL1	TSL2	TSL3
Electric Standard Oven, Freestanding	0.024	0.060	0.168
Electric Standard Oven, Built-In/Slide-In	0.000	0.001	0.003
Electric Self-Clean Oven, Freestanding	0.074	0.074	0.389
Electric Self-Clean Oven, Built-In/Slide-In	0.022	0.022	0.113
Gas Standard Oven, Freestanding	0.000	0.216	0.223
Gas Standard Oven, Built-In/Slide-In	0.000	0.041	0.042
Gas Self-Clean Oven, Freestanding	0.040	0.281	0.297
Gas Self-Clean Oven, Built-In/Slide-In	0.002	0.014	0.015
All	**0.163**	**0.709**	**1.251**

10.6.2 Net Present Value of Consumer Benefit

This section provides results of calculating the NPV for each trial standard level considered for oven products. Results were calculated for the nation as a whole. Results, which are cumulative, are shown as the discounted dollar value of the net savings. 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 such as produced by the life-cycle cost and payback period analyses.

Table 10.6.2 and Table 10.6.3 list the results for cumulative NPV for oven products for 3-percent and seven-percent discount rates, respectively. A negative NPV indicates that the costs of a standard at a given efficiency level exceed the savings.

Table 10.6.2 Cumulative NPV Results based on Three-Percent Discount Rates (billion 2014$)

Product Class	TSL1	TSL2	TSL3
Electric Standard Oven, Freestanding	0.170	0.306	-0.581
Electric Standard Oven, Built-In/Slide-In	0.004	0.007	-0.016
Electric Self-Clean Oven, Freestanding	0.516	0.516	-1.052
Electric Self-Clean Oven, Built-In/Slide-In	0.153	0.153	-0.324
Gas Standard Oven, Freestanding	0.000	3.588	3.056
Gas Standard Oven, Built-In/Slide-In	0.000	0.670	0.571
Gas Self-Clean Oven, Freestanding	0.280	5.459	4.700
Gas Self-Clean Oven, Built-In/Slide-In	0.014	0.281	0.241
All	**1.137**	**10.980**	**6.597**

Table 10.6.3 Cumulative NPV Results based on Seven-Percent Discount Rates (billion 2014$)

Product Class	TSL1	TSL2	TSL3
Electric Standard Oven, Freestanding	0.072	0.113	-0.494
Electric Standard Oven, Built-In/Slide-In	0.002	0.003	-0.014
Electric Self-Clean Oven, Freestanding	0.211	0.211	-0.974
Electric Self-Clean Oven, Built-In/Slide-In	0.065	0.065	-0.303
Gas Standard Oven, Freestanding	0.000	1.547	1.233
Gas Standard Oven, Built-In/Slide-In	0.000	0.287	0.229
Gas Self-Clean Oven, Freestanding	0.115	2.302	1.861
Gas Self-Clean Oven, Built-In/Slide-In	0.006	0.119	0.096
All	**0.470**	**4.646**	**1.634**

REFERENCES

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1 U.S. Energy Information Administration, *Residential Energy Consumption Survey 2009*, Washington, DC.
<http://www.eia.gov/consumption/residential/data/2009/>

2 UBM Canon, Market Research Magazine: *Appliance Historical Statistical Review*, 2014.

3 U.S. Bureau of Labor Statistics, *Producer Price Index Industry Data: Household cooking appliance manufacturing*, 2014.

4 Energy Information Administration, Annual Energy Outlook 2014 with Projections to 2040, 2014. Washington, DC.
< http://www.eia.gov/forecasts/aeo/>

5 U.S. Office of Management and Budget (OMB), *Circular A-4: Regulatory Analysis*, 2003. (Posted September 17, 2003) (Last accessed April, 2013.)
<http://www.whitehouse.gov/sites/default/files/omb/assets/regulatory_matters_pdf/a-4.pdf>

CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

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CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

11.1 INTRODUCTION

Chapter 8 of this TSD describes the life-cycle cost (LCC) and payback period (PBP) analysis that examines energy savings and cost impacts of energy conservation standards on the U.S. population. In analyzing the potential impact of new or amended standards on consumers, the U.S. Department of Energy (DOE) further evaluates the impacts on identifiable groups of consumers (subgroups) that may be disproportionately affected by a national standard level. The consumer subgroup analysis evaluates effects by analyzing the LCC and PBPs for subgroups of residential consumers. For cooking products, DOE identified two consumer subgroups that warranted further study: (1) senior-only households and (2) low income households.

DOE determined the impact on consumer subgroups for conventional cooking products using the LCC spreadsheet model, which enables DOE to analyze the LCC for any subgroup by sampling only the data that apply to that subgroup. (Chapter 8 explains in detail the inputs to the model used in determining LCC and PBPs.) As described in section 11.3, the energy use and energy price characteristics of the two subgroups (senior-only and low-income) differ from those for the general population.

This chapter describes the identification of the two subgroups and gives the results of the LCC and PBP analyses for those subgroups.

11.2 IDENTIFIED SUBGROUPS

The following two sections describe how DOE defined the two consumer subgroups identified for further examination.

11.2.1 Senior-Only Households

Senior-only households comprise occupants who are all at least 65 years of age. Based on DOE's Energy Information Administration's Residential Energy Consumption Survey of 2009 (RECS), senior-only households represent 17 percent of the U.S. households.[1]

11.2.2 Low-Income Households

As defined in the RECS survey, low-income household residents are living at or below the poverty line. The poverty line varies with household size, age of head of household, and family income. The RECS survey classifies 15 percent of the country's households as low-income.

11.3 INPUTS TO THE CONSUMER SUBGROUP ANALYSIS

Table 11.3.1 through Table 11.3.8 summarize the weighted-average annual energy use for the households analyzed in the consumer subgroup analysis. These values are compared against the weighted-average values for the national sample.

Table 11.3.1 Electric Standard Ovens, Freestanding: Weighted-Average Annual Energy Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kWh/year)		
Baseline	135.56	113.36	164.37
1	125.81	103.63	154.59
2	120.38	99.24	147.82
3	115.09	94.95	141.21
4	113.29	93.50	138.97
5	109.64	90.55	134.42
6	94.09	77.97	115.02
7	93.85	77.77	114.72

Table 11.3.2 Electric Standard Ovens, Built-In/Slide-In: Weighted-Average Annual Energy Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kWh/year)		
Baseline	135.56	113.36	164.37
1	125.71	103.55	154.47
2	120.29	99.17	147.71
3	115.01	94.89	141.12
4	113.22	93.44	138.88
5	109.61	90.52	134.37
6	94.08	77.96	115.00
7	93.84	77.76	114.70

Table 11.3.3 Electric Self-Clean Ovens, Freestanding: Weighted-Average Annual Energy Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kWh/year)		
Baseline	174.63	157.71	208.03
1	164.89	147.99	198.27
2	158.57	142.57	190.16
3	139.45	126.19	165.65
4	139.13	125.91	165.24

Table 11.3.4 Electric Self-Clean Ovens, Built-In/Slide-In: Weighted-Average Annual Energy Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kWh/year)		
Baseline	175.26	158.34	208.66
1	165.46	148.57	198.81
2	159.17	143.17	190.75
3	140.07	126.81	166.27
4	139.75	126.53	165.86

Table 11.3.5 Gas Standard Ovens, Freestanding: Weighted-Average Annual Energy Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kBtu/year)		
Baseline	1040.1	934.3	1288.9
1	835.4	751.8	1031.9
2	801.7	718.2	998.1
3	747.6	670.0	930.1
4	636.3	570.7	790.4
5	630.1	565.2	782.6
6	614.9	551.7	763.5
7	611.1	548.3	758.8

Table 11.3.6 Gas Standard Ovens, Built-In/Slide-In: Weighted-Average Annual Energy Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kBtu/year)		
Baseline	1040.1	934.3	1288.9
1	835.5	751.9	1032.1
2	801.8	718.2	998.1
3	747.7	670.0	930.2
4	636.0	570.5	790.1
5	629.8	565.0	782.3
6	614.7	551.5	763.3
7	610.9	548.1	758.6

Table 11.3.7 Gas Self-Clean Ovens, Freestanding: Weighted-Average Annual Electricity Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kBtu/year)		
Baseline	1126.3	1069.8	1307.2
1	1092.2	1035.8	1272.8
2	928.5	883.6	1072.6
3	898.9	856.0	1036.4
4	896.4	853.7	1033.3

Table 11.3.8 Gas Self-Clean Ovens, Built-In/Slide-In: Weighted-Average Annual Electricity Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kBtu/year)		
Baseline	1127.6	1071.2	1308.6
1	1093.4	1037.0	1274.1
2	929.4	884.5	1073.4
3	899.9	857.0	1037.2
4	897.4	854.7	1034.2

11.4 RESULTS

Table 11.4.1 through Table 11.4.32 summarize the LCC and PBP results from DOE's subgroup analysis. The results describe the financial effects of potential standards on senior-only and low-income households. The tables present the average installed price; average lifetime operating cost (discounted); average life-cycle cost; average life-cycle cost savings; percentage of each subgroup who are burdened with net costs, realize net savings, or are not affected; and the simple payback period.

Table 11.4.1 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for Electric Standard Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$557	$15	$172	$729	--
1	1	$558	$14	$157	$715	0.9
--	2	$561	$13	$150	$711	2.0
2	3	$568	$12	$144	$711	4.4
--	4	$571	$12	$142	$712	5.3
--	5	$604	$12	$137	$741	15.7
--	6	$648	$10	$118	$766	19.5
3	7	$654	$10	$118	$771	20.6

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

Table 11.4.2 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Electric Standard Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	0	0%	---
1	1	0%	$14.00
--	2	4%	$15.21
2	3	15%	$12.28
--	4	25%	$9.63
--	5	69%	-$20.30
--	6	76%	-$42.92
3	7	84%	-$45.09

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.3 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$583	$15	$172	$755	--
1	1	$584	$14	$157	$741	0.9
--	2	$587	$13	$150	$737	2.0
2	3	$594	$12	$144	$738	4.4
--	4	$597	$12	$141	$739	5.3
--	5	$630	$12	$137	$767	15.6
--	6	$674	$10	$118	$792	19.5
3	7	$680	$10	$118	$798	20.6

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

Table 11.4.4 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	0	0%	---
1	1	0%	$14.11
--	2	4%	$15.30
2	3	15%	$12.34
--	4	25%	$9.68
--	5	69%	-$20.30
--	6	76%	-$42.96
3	7	84%	-$45.13

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.5 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for Electric Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$601	$21	$240	$840	--
1,2	1	$602	$19	$225	$826	0.9
--	2	$635	$19	$216	$851	17.0
--	3	$679	$16	$191	$870	18.8
3	4	$686	$16	$191	$877	20.3

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

Table 11.4.6 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Electric Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2013$
--	0	0%	---
1,2	1	0%	$14.19
--	2	54%	-$14.29
--	3	65%	-$30.37
3	4	79%	-$32.84

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.7 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$627	$21	$241	$868	--
1,2	1	$628	$19	$225	$854	0.9
--	2	$661	$19	$217	$879	17.0
--	3	$705	$17	$192	$897	18.7
3	4	$712	$17	$192	$904	20.3

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

Table 11.4.8 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	Baseline	0%	---
1,2	1	0%	$14.27
--	2	54%	-$14.27
--	3	65%	-$30.38
3	4	79%	-$32.84

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.9 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for Gas Standard Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
1	Baseline	$602	$18	$580	$1,182	--
--	1	$602	$16	$555	$1,157	0.0
--	2	$603	$15	$535	$1,138	0.3
--	3	$612	$14	$528	$1,140	2.6
2	4	$619	$8	$266	$885	1.8
--	5	$622	$8	$265	$888	2.1
--	6	$650	$9	$267	$917	5.1
3	7	$656	$9	$266	$923	5.7

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

Table 11.4.10 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Gas Standard Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
1	Baseline	0%	---
--	1	0%	$25.06
--	2	0%	$39.30
--	3	7%	$31.38
2	4	0%	$282.03
--	5	8%	$248.06
--	6	17%	$194.95
3	7	24%	$173.10

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.11 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
1	Baseline	$628	$18	$580	$1,208	--
--	1	$628	$16	$555	$1,183	0.0
--	2	$629	$15	$535	$1,164	0.3
--	3	$638	$14	$528	$1,167	2.6
2	4	$645	$8	$266	$911	1.8
--	5	$648	$8	$265	$914	2.1
--	6	$677	$9	$267	$943	5.1
3	7	$682	$9	$266	$949	5.7

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

Table 11.4.12 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
1	Baseline	0%	---
--	1	0%	$25.04
--	2	0%	$39.30
--	3	7%	$31.37
2	4	0%	$282.07
--	5	8%	$248.09
--	6	17%	$194.95
3	7	24%	$173.11

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.13 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for Gas Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$716	$21	$616	$1,333	--
1	1	$717	$19	$597	$1,314	0.7
2	2	$726	$13	$324	$1,050	1.3
--	3	$754	$13	$324	$1,078	4.8
3	4	$762	$13	$323	$1,085	5.7

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

Table 11.4.14 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Gas Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	Baseline	0%	---
1	1	0%	$18.39
2	2	0%	$278.34
--	3	14%	$199.67
3	4	27%	$162.47

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.15 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$742	$21	$617	$1,359	--
1	1	$744	$19	$597	$1,341	0.7
2	2	$752	$13	$324	$1,077	1.3
--	3	$780	$13	$324	$1,104	4.8
3	4	$788	$13	$324	$1,111	5.7

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

Table 11.4.16 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings
		Net Cost	2014$
--	Baseline	0%	---
1	1	0%	$18.40
2	2	0%	$278.39
--	3	14%	$199.69
3	4	27%	$162.48

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.17 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Electric Standard Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$557	$21	$246	$803	--
1	1	$558	$20	$231	$790	0.9
--	2	$561	$19	$221	$782	1.8
2	3	$568	$18	$211	$779	3.6
--	4	$571	$18	$208	$779	4.2
--	5	$604	$17	$201	$805	12.1
--	6	$648	$15	$172	$820	14.1
3	7	$654	$15	$171	$825	14.9

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

Table 11.4.18 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Electric Standard Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	0	0%	---
1	1	0%	$13.88
--	2	3%	$18.71
2	3	11%	$18.70
--	4	20%	$16.36
--	5	61%	-$12.01
--	6	68%	-$25.37
3	7	76%	-$28.75

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.19 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$583	$21	$246	$830	--
1	1	$585	$20	$231	$816	0.9
--	2	$587	$19	$221	$808	1.7
2	3	$594	$18	$211	$805	3.6
--	4	$597	$18	$208	$805	4.2
--	5	$631	$17	$201	$832	12.1
--	6	$674	$15	$172	$846	14.1
3	7	$680	$15	$171	$852	14.9

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

Table 11.4.20 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	0	0%	---
1	1	0%	$14.06
--	2	3%	$18.83
2	3	11%	$18.79
--	4	19%	$16.43
--	5	61%	-$12.01
--	6	68%	-$25.42
3	7	76%	-$28.80

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.21 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Electric Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$601	$27	$313	$914	--
1,2	1	$602	$26	$298	$900	0.9
--	2	$635	$25	$286	$921	14.6
--	3	$679	$21	$249	$928	14.1
3	4	$686	$21	$248	$934	15.2

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

Table 11.4.22 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Electric Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2013$
--	0	0%	---
1,2	1	0%	$13.98
--	2	50%	-$10.46
--	3	56%	-$14.51
3	4	71%	-$18.98

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.23 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$627	$27	$314	$941	--
1,2	1	$628	$26	$299	$927	0.9
--	2	$661	$25	$287	$948	14.6
--	3	$705	$21	$250	$955	14.1
3	4	$712	$21	$249	$961	15.2

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

Table 11.4.24 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	Baseline	0%	---
1,2	1	0%	$14.11
--	2	50%	-$10.43
--	3	56%	-$14.52
3	4	71%	-$18.99

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.25 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Gas Standard Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
1	Baseline	$602	$24	$658	$1,260	--
--	1	$602	$21	$623	$1,225	0.0
--	2	$603	$20	$604	$1,207	0.3
--	3	$612	$19	$594	$1,207	2.1
2	4	$619	$12	$307	$927	1.4
--	5	$622	$11	$306	$929	1.6
--	6	$651	$12	$308	$959	3.9
3	7	$657	$12	$307	$964	4.4

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

Table 11.4.26 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Gas Standard Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
1	Baseline	0%	---
--	1	0%	$35.21
--	2	0%	$47.28
--	3	6%	$40.92
2	4	0%	$314.79
--	5	8%	$277.45
--	6	17%	$221.22
3	7	24%	$197.33

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.27 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
1	Baseline	$628	$24	$658	$1,286	--
--	1	$628	$21	$623	$1,251	0.0
--	2	$630	$20	$604	$1,233	0.3
--	3	$638	$19	$594	$1,233	2.1
2	4	$645	$12	$307	$953	1.4
--	5	$649	$11	$306	$955	1.6
--	6	$677	$12	$308	$985	3.9
3	7	$683	$12	$307	$990	4.4

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

Table 11.4.28 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
1	Baseline	0%	---
--	1	0%	$35.19
--	2	0%	$47.27
--	3	6%	$40.91
2	4	0%	$314.84
--	5	8%	$277.49
--	6	17%	$221.22
3	7	24%	$197.34

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.29 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Gas Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$718	$25	$674	$1,392	--
1	1	$719	$24	$656	$1,375	0.8
2	2	$728	$15	$361	$1,088	1.0
--	3	$756	$15	$360	$1,116	4.0
3	4	$763	$15	$360	$1,122	4.7

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

Table 11.4.30 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Gas Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	Baseline	0%	---
1	1	0%	$17.28
2	2	0%	$298.61
--	3	14%	$216.56
3	4	27%	$176.87

*The calculation does not include households with zero LCC savings (no impact).

Table 11.4.31 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2014$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$744	$25	$675	$1,418	--
1	1	$745	$24	$656	$1,401	0.8
2	2	$754	$15	$361	$1,115	1.0
--	3	$782	$15	$360	$1,142	4.0
3	4	$789	$15	$360	$1,149	4.7

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

Table 11.4.32 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*
		Net Cost	2014$
--	Baseline	0%	---
1	1	0%	$17.30
2	2	0%	$298.68
--	3	14%	$216.59
3	4	27%	$176.89

*The calculation does not include households with zero LCC savings (no impact).

The low-income and senior-only consumer subgroups show the same trend in average LCC differences and consumer impacts (i.e., percentage of consumers significantly or insignificantly impacted) as the overall sample. For all cooking products, the average LCC costs, savings and payback periods for low-income and senior-only households mirror the savings for the general population.

REFERENCES

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1 U.S. Department of Energy–Energy Information Administration. *Residential Energy Consumption Survey, 2009 Public Use Data Files*. 2013. Washington, D.C. (Last accessed March 25, 2013.) <http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=characteristics>

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. 6312(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 new and amended energy conservation standards on manufacturers of residential conventional ovens, and assessed the impact of such standards 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 the products 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 new and amended energy conservation standards for each product by comparing changes in INPV between a base case 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 an industry characterization for the residential conventional oven industry, including data on market share, sales volumes and trends, pricing, employment, and financial structure. In Phase II, "Industry Cash Flow," DOE created a GRIM for residential conventional ovens, as well as an interview guide, to gather information on the potential impacts new and amended energy conservation standards would have on residential conventional oven manufacturers. DOE presented the MIA results for residential conventional ovens based on a set of considered TSLs. These TSLs are described in section 12.4.5.

In Phase III, "Manufacturer Interviews," DOE interviewed manufacturers that account for more than 85 percent of residential conventional oven sales. Interviewees included large and small manufacturers with various market shares and market focuses, providing a representative cross-section of the industry. During interviews, DOE discussed financial topics specific to each manufacturer and obtained each manufacturer's view of the residential conventional oven industry. The interviews provided DOE with valuable information for evaluating the impacts of new and amended energy conservation standards on manufacturer cash flows, investment requirements, and production employment.

12.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the residential conventional oven industry that built upon the market and technology assessment prepared for this rulemaking, see chapter 3 of this notice of proposed rulemaking (NOPR) technical support document (TSD). Before initiating the detailed impact studies, DOE collected information on the present and past structure and market characteristics of the industry. This information included market share data, unit shipments, manufacturer markups, and cost structures for various manufacturers. The industry profile includes: (1) further detail on the overall market and product characteristics; (2) estimated manufacturer market shares; (3) financial parameters such as net plant, property, and equipment (PPE); selling, general and administrative (SG&A) expenses; cost of goods sold, etc.; and (4) trends in the number of firms, specific residential appliance markets, and general product characteristics. The industry profile included a top-down cost analysis of residential conventional oven manufacturers that DOE used to derive preliminary financial inputs for the GRIM (*e.g.*, revenues, depreciation, SG&A, and research and development [R&D] expenses).

DOE also used public information to further calibrate its initial characterization of the residential conventional oven industry, including Securities and Exchange Commission (SEC) 10–K reports,[1] Standard & Poor's (S&P) stock reports,[2] and corporate annual reports. DOE supplemented this public information with data released by privately held companies.

12.2.2 Phase II: Industry Cash-Flow Analysis and Interview Guide

Phase II focused on the financial impacts of new and amended energy conservation standards on residential conventional oven manufacturers. New or more stringent energy conservation standards can affect manufacturers' cash flows 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 residential conventional ovens. In performing these analyses, DOE used the financial values derived during Phase I and the shipment scenarios used in the national impact analysis (NIA). In Phase II, DOE performed this preliminary industry cash-flow analysis and prepared written guides for manufacturer interviews.

12.2.2.1 Industry Cash-Flow Analysis

The GRIM uses several factors to determine a series of annual cash flows from the announcement year of new and amended energy conservation standards until several years after the standards' compliance date. These factors include annual expected revenues, costs of goods sold, SG&A, taxes, and capital expenditures related to the new and amended standards. Inputs for the GRIM include manufacturer production costs (MPCs) and shipment forecasts developed in other analyses. DOE derived the MPCs from the engineering analysis through purchasing and tearing down products. DOE then estimated typical manufacturer markups for residential conventional ovens from public financial reports and interviews with manufacturers to derive MSPs for all covered residential conventional ovens. In addition to the base case scenario, DOE developed alternative markup scenarios for the standards case scenarios for the GRIM based on discussions with manufacturers. DOE's shipments analysis, presented in chapter 9 of this NOPR TSD, provided the basis for the shipment projections 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 are compared to base case projections for the industry. The financial impact of new and amended energy conservation standards is the difference between the discounted annual cash flows in the base case and in the standards case at each TSL.

12.2.2.2 Interview Guides

During Phase III of the MIA, DOE interviewed manufacturers to gather information on the effects of new and amended energy conservation standards on revenues and finances, direct employment, capital assets, and industry competitiveness. Before the interviews, DOE distributed interview guides for the residential conventional oven industry. The interview guide provided a starting point to identify relevant issues and help identify the impacts of new and amended energy conservation standards on individual manufacturers or subgroups of manufacturers in their industry. Most of the information DOE received from these meetings is protected by non-disclosure agreements and resides with DOE's contractors. Before each telephone interview or site visit, DOE provided company representatives with an interview guide that included the topics for which DOE sought input. The MIA interview topics included (1) engineering, (2) key issues, (3) company overview and organizational characteristics, (4) markups and profitability, (5) shipment projections, (6) industry average financial parameters, (7) conversion costs, (8) cumulative regulatory burden, (9) direct employment impacts, (10) manufacturing capacity / exports / foreign competition / outsourcing, (11) industry consolidation, and (12) impacts on small businesses. This interview guide is presented in appendix 12A.

12.2.3 Phase III: Manufacturer Interviews

Using average cost and financial assumptions to develop an industry cash-flow model is not adequate for assessing differential impacts among a potential subgroup of manufacturers. Small manufacturers, niche players, or manufacturers exhibiting a cost structure that differs largely from the industry average could be more negatively impacted. During interviews, DOE identified one potential manufacturer subgroup (small manufacturers) that could be disproportionately impacted by new and amended energy conservation standards. As a result, DOE will analyze small business manufacturers as a subgroup.

12.2.3.1 Manufacturing Interviews

The information gathered in Phase I and the cash-flow analysis performed in Phase II are supplemented with information gathered from manufacturer interviews in Phase III. The interview process provides an opportunity for interested parties to express their views on important issues privately, allowing confidential or sensitive information to be considered in the rulemaking process.

DOE used these interviews to tailor the GRIM to reflect unique financial characteristics of residential conventional oven manufacturers. DOE contacted companies from its database of manufacturers and interviewed small and large companies, subsidiaries and independent firms, and public and private corporations to provide an accurate representation of the industry. Interviews were scheduled well in advance to provide every opportunity for key individuals to be available for comment. Although a written response to the questionnaire was acceptable, DOE sought interactive interviews, which helped clarify responses and identify additional issues. The resulting information provides valuable inputs to the GRIM developed for the residential conventional oven industry.

12.2.3.2 Revised Industry Cash-Flow Analysis

In Phase II of the MIA, DOE provided manufacturers with preliminary GRIM input financial figures for review and evaluation. During the interviews, DOE requested for comment on the values it selected for the parameters. DOE revised its industry cash-flow models based on this feedback. Section 12.4.3 provides more information on how DOE calculated the parameters.

12.2.3.3 Small Business Subgroup

As part of Phase III, DOE investigated whether small businesses should be analyzed as a subgroup. DOE used the Small Business Administration (SBA) small business size standards published on July 14, 2014, as amended, and the North American Industry Classification System (NAICS) code, presented in Table 12.2.1, to determine whether any small entities would be affected by this rulemaking.[a] For the industry 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.

Table 12.2.1 SBA and NAICS Classifications of Small Businesses Potentially Affected by This Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Household Cooking Appliance Manufacturing	N/A	750	335221

DOE used the Association of Home Appliance Manufacturers (AHAM)[3] member directory, SBA's database, information from the previous rulemaking adopting standards for residential conventional ovens, individual company websites, and market research tools (*e.g.*, Hoover's reports) to create a list of companies that potentially sell residential conventional ovens covered by this rulemaking. Additionally, DOE asked interested parties and industry representatives if they were aware of other small businesses in the residential conventional oven industry. DOE contacted select companies on its list, as necessary, to determine whether they met the SBA's definition of a residential conventional oven small business. DOE screened out companies that did not offer products covered by this rulemaking, did not meet the definition of a "small business," or are foreign owned and operated.

During its research, DOE identified seven companies that sell residential conventional ovens covered by this rulemaking and qualify as a small business per the SBA employment threshold for this industry. DOE contacted the residential conventional oven small businesses to solicit feedback on the potential impacts of new and amended energy conservation standards. One of the residential conventional oven small businesses consented to be interviewed during the

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[a] The size standards are available on the SBA's website at http://www.sba.gov/content/table-small-business-size-standards

MIA interviews. In addition to posing the standard MIA interview questions, DOE solicited data from manufacturers on differential impacts that these small businesses might experience from new and amended energy conservation standards. Because DOE was not able to certify that the proposed rulemaking for residential conventional ovens would not have a significant economic impact on a substantial number of small entities, DOE has analyzed small businesses as a subgroup as part of this rulemaking. The results of this subgroup analysis are presented in section 12.6.

12.2.3.4 Manufacturing Capacity Impact

One significant outcome of new and amended energy conservation standards could be the obsolescence of existing manufacturing assets, including tooling and investment. The manufacturer interview guide has a series of questions to help identify impacts of new and amended standards on manufacturing capacity. These include questions regarding capacity utilization and plant location decisions in the United States and North America (with and without new and amended 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 for any one-time changes to existing 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 12.4.8; DOE's discussion of the capacity impacts can be found in section 12.7.2.

12.2.3.5 Employment Impact

The impact of new and amended energy conservation standards on employment is an important consideration in the rulemaking process. To assess how domestic direct employment patterns might be affected, the interviews explored current employment trends in the residential conventional oven industry. The interviews also solicited manufacturers' views on changes in employment patterns that may result from new and amended standards. The employment impacts section of the interview guide focused on current employment levels associated with manufacturers at each production facility, expected future employment levels with and without new and amended energy conservation standards, and differences in workforce skills and issues related to retraining employees. The employment impacts are reported in section 12.7.1.

12.2.3.6 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects on manufacturers due to new and amended energy conservation standards and other regulatory actions affecting the same products. DOE analyzed the impact on manufacturers of multiple, product-specific regulatory actions. Based on its own research and discussions with manufacturers, DOE identified regulations relevant to residential conventional oven manufacturers, such as state regulations and other Federal regulations that impact other products made by the same manufacturers. Discussion of the cumulative regulatory burden can be found in section 12.7.3.

12.3 MANUFACTURER IMPACT ANALYSIS KEY ISSUES

Each MIA interview begins 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 believe DOE should explore and discuss further during the interview.

The following sections describe the most significant issues identified by manufacturers. These summaries are provided in aggregate to protect manufacturer confidentiality.

12.3.1 Premium Products Tend to be Less Efficient

Manufacturers stated that their premium products are usually less efficient than their baseline products. For example, ovens typically have bigger cavities with hidden heat sources under the floor of the cavity. This makes the heat source less direct, therefore decreasing the efficiency. On the other hand, baseline ovens tend to use direct heating sources which are more efficient. Manufacturers warned DOE that focusing only on the efficiency of residential conventional ovens could cause some manufacturers to redesign their products in a way that reduces consumer satisfaction as consumers tend to value premium features.

12.3.2 Product Utility

Manufacturers stated that energy efficiency is not one of the most important aspects that consumers value when purchasing residential conventional ovens. Manufacturers state that there are several other factors, such as performance and durability, which consumers value more when purchasing residential conventional ovens. Forcing manufacturers to improve the efficiency of their products could lead to some manufacturers removing premium features that consumers desire from their products, reducing overall consumer utility.

12.3.3 Testing and Certification Burdens

Several manufacturers expressed concern about the testing and recertification costs associated with new and amended energy conservation standards for residential conventional ovens. Because testing and certification costs are incurred on a per model basis, if a large number of models are required to be redesigned to meet new and amended standards, manufacturers would be forced to spend a significant amount of money testing and certifying products that were redesigned due to new and amended standards. Manufacturers stated that these testing and certification costs associated with residential conventional ovens could significantly strain their limited resources if these costs were all incurred in the three year time frame from the publication of a final rule to the implementation of the standards.

12.4 GRIM INPUTS AND ASSUMPTIONS

The GRIM serves as the main tool for assessing the impacts on industry due to new and amended energy conservation standards. DOE relies on several sources to obtain inputs for the GRIM. Data and assumptions from these sources are then fed into the accounting model that calculates the industry cash flow both with and without new and amended energy conservation standards.

12.4.1 Overview of the GRIM

The basic structure of the GRIM, illustrated in Figure 12.4.1, is an annual cash-flow analysis that uses manufacturer prices, manufacturing costs, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM spreadsheet uses a number of inputs to arrive at a series of annual cash flows, beginning with the base year of the analysis, 2015, and continuing to 2048. The model calculates the INPV by summing the stream of annual discounted cash flows during this period and adding a discounted terminal value.[4]

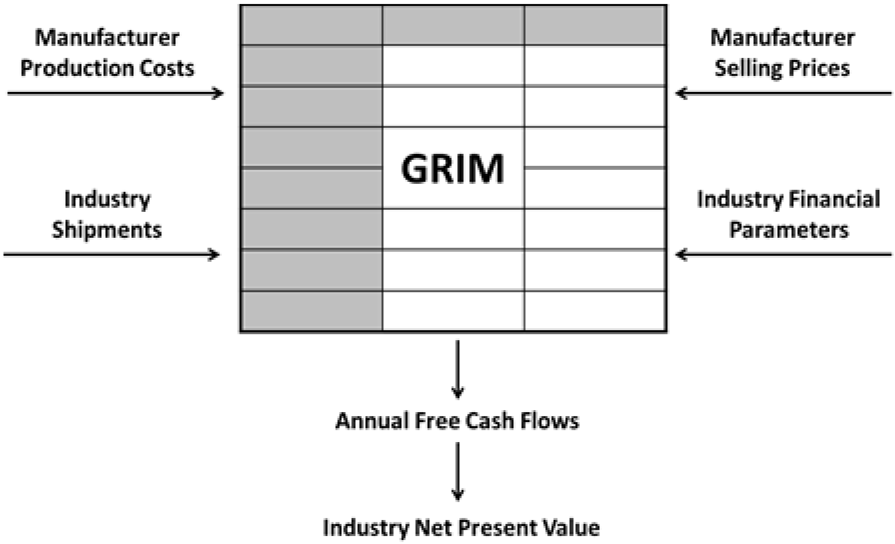

Figure 12.4.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the base case and the standard-case scenario induced by new and amended energy conservation standards. The difference in INPV between the base case and the standard case(s) represents the estimated financial impact of the new and amended energy conservation standards on manufacturers. Appendix 12B provides more technical details and user information for the GRIM.

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 the manufacturer interviews.

12.4.2.1 Corporate Annual Reports

Corporate annual reports to the SEC (SEC 10-Ks) provided many of the initial financial inputs to the GRIM. These reports exist for publicly held companies and are freely available to the general public. DOE developed initial financial inputs to the GRIM by examining the annual SEC 10-K reports filed by publicly traded manufacturers that produce residential conventional ovens, among other products. Since these companies do not provide detailed information about their individual product lines, DOE used financial information at the parent company level as its initial estimates of the financial parameters in the GRIM. These figures were later revised using feedback from interviews to be representative of residential conventional oven manufacturing. DOE used corporate annual reports to derive the following initial inputs to the GRIM:

- Tax rate

- Working capital
- SG&A
- R&D
- Depreciation
- Capital expenditures
- Net PPE

12.4.2.2 Standard and Poor Credit Ratings

S&P provides independent credit ratings, research, and financial information. DOE relied on S&P reports to determine the industry's average cost of debt when calculating the cost of capital.

12.4.2.3 Shipment Model

The GRIM used shipment projections derived from DOE's shipments model in the NIA. In the base case shipment analysis, DOE developed shipment projections based on historical data and an analysis of key market drivers for each product class. In the standards case, DOE modeled a roll-up scenario. The roll-up scenario represents the case in which all shipments in the base case that do not meet the new and amended standards shift up in efficiency to meet the new or amended standard level but do not exceed the new or amended standards. Also, no shipments that meet or exceed the new and amended standards have an increase in efficiency due to the new and amended standards. Chapter 9 of this NOPR TSD describes the methodology and analytical model DOE used to forecast shipments.

12.4.2.4 Engineering Analysis

The engineering analysis establishes the relationship between end-user price and the efficiency level for all residential conventional ovens covered in this rulemaking. DOE based its engineering analysis on commercially available residential conventional ovens that met the design options identified in the technology assessment and screening analysis (chapters 3 and 4 of this NOPR TSD). DOE's engineering approach consisted of the following steps: 1) identifying representative product classes to analyze, 2) selecting baseline residential conventional ovens, 3) identifying more efficient substitutes for the baseline residential conventional ovens, and 4) developing efficiency levels for the product classes. DOE developed MPCs for each product class at each EL analyzed. DOE purchased a number of units for each product class, then tested and tore down those units to create a unique bill of materials for the purchased units. Using the bill of materials for each residential conventional oven, DOE was able to create an aggregated MPC based on the material costs from the bill of materials, the labor costs based on an average labor rate and the labor hours necessary to manufacture the residential conventional oven analyzed, and the overhead costs, including depreciation, based on a markup applied to the material and labor costs based on the materials used. These MPCs are then used as inputs to the life-cycle cost (LCC) analysis and NIA after applying the appropriate manufacturer markup and distribution chain markup to each product. See chapter 5 of this NOPR TSD for a complete discussion of the engineering analysis.

12.4.2.5 Manufacturer Interviews

During the course of the MIA, DOE conducted interviews with a representative cross-section of manufacturers. DOE also interviewed manufacturers that account for a significant portion of sales in every product class. During these discussions, DOE obtained information to determine and verify GRIM input assumptions in the industry. 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, certification, and marketing);
- product cost structure, or the portion of the MPCs related to materials, labor, overhead, and depreciation costs;
- possible profitability impacts;
- impacts on small businesses; and
- cost-efficiency curves calculated in the engineering analysis.

12.4.3 Financial Parameters

Table 12.4.1 provides financial parameters for two public companies engaged in manufacturing and selling residential conventional ovens. The values listed are averages over a seven-year period (2007 to 2013).

Table 12.4.1 GRIM Financial Parameters Based on 2007–2013 Weighted Company Financial Data

Parameter	**Weighted Average**	**Manufacturers**	
		A	**B**
Tax Rate ***% of taxable income***	19.5	15.3	28.3
Working Capital ***% of revenues***	4.5	3.2	7.1
SG&A ***% of revenues***	11.2	9.2	15.5
R&D ***% of revenues***	2.4	2.8	1.7
Depreciation ***% of revenues***	3.0	3.0	3.0
Capital Expenditures ***% of revenues***	3.3	3.0	3.8
Net PPE ***% of revenues***	16.2	16.7	15.0

During interviews, residential conventional oven manufacturers were asked to comment on these financial parameters derived from SEC-10Ks and listed in Table 12.4.1. Where applicable, DOE adjusted the parameters in the GRIM using this manufacturer feedback to reflect the current residential conventional oven industry. Table 12.4.2 presents the revised parameters used for residential conventional oven manufacturers for this NOPR.

Table 12.4.2 GRIM Revised Residential Conventional Oven Industry Financial Parameters

Parameter	Weighted Average
Tax Rate *% of taxable income*	30.0
Working Capital *% of revenues*	4.5
SG&A *% of revenues*	11.2
R&D *% of revenues*	2.4
Depreciation *% of revenues*	3.0
Capital Expenditures *% of revenues*	3.3
Net PPE *% of revenues*	16.2

12.4.4 Corporate Discount Rate

DOE used the weighted average cost of capital (WACC) as the discount rate to calculate the INPV. A company's assets are financed by a combination of debt and equity. The WACC is the total cost of debt and equity weighted by their respective proportions in the capital structure of the industry. DOE estimated the WACC for the residential conventional oven industry based on representative companies, using the following formula:

WACC = After-Tax Cost of Debt x (Debt Ratio) + Cost of Equity x (Equity Ratio)
Equation 12.1

The cost of equity is the rate of return that equity investors (including, potentially, the company) expect to earn on a company's stock. These expectations are reflected in the market price of the company's stock. The capital asset pricing model (CAPM) provides one widely used means to estimate the cost of equity. According to the CAPM, the cost of equity (expected return) is:

Cost of Equity = Riskless Rate of Return + β x Risk Premium
Equation 12.2

Where:

Riskless rate of return = the rate of return on a "safe" benchmark investment, typically considered the short-term Treasury Bill (T-Bill) yield,
Risk premium = the difference between the expected return on stocks and the riskless rate, and
Beta (β) = the correlation between the movement in the price of the stock and that of the broader market. In this case, Beta equals one if the stock is perfectly correlated with the S&P 500 market index. A Beta lower than one means the stock is less volatile than the market index.

DOE determined that the industry average cost of equity for the residential conventional oven industry is 15.5 percent.

Table 12.4.3 Cost of Equity Calculation

Parameter	Industry-Weighted Average	Manufacturers	
		A	B
(1) Average Beta	1.70	1.70	1.71
(2) Yield on 10-Year T-Bill (1928-2013) %	5.2	-	-
(3) Market Risk Premium (1928-2013) %	6.1	-	-
Cost of Equity (2)+[(1)*(3)] %	15.5	-	-
Equity/Total Capital %	66.8	72.7	54.5

Bond ratings are a tool to measure default risk and arrive at a cost of debt. Each bond rating is associated with a particular spread. One way of estimating a company's cost of debt is to treat it as a spread (usually expressed in basis points) over the risk-free rate. DOE used this method to calculate the cost of debt for both manufacturers by using S&P ratings and adding the relevant spread to the risk-free rate.

In practice, investors use a variety of different maturity Treasury bonds to estimate the risk-free rate. DOE used the 10-year Treasury bond return because it captures long-term inflation expectations and is less volatile than short-term rates. The risk-free rate is estimated to be approximately 5.2 percent, which is the average 10-year Treasury bond return between 1928 and 2013.

For the cost of debt, S&P's Credit Services provided the average spread of corporate bonds for both the public manufacturers. DOE added the industry-weighted average spread to the average T-Bill rate. Since proceeds from debt issuance are tax deductible, DOE adjusted the gross cost of debt by the industry average tax rate to determine the net cost of debt for the industry. Table 12.4.4 presents the derivation of the cost of debt and the capital structure of the industry (*i.e.,* the debt ratio [debt/total capital]).

Table 12.4.4 Cost of Debt Calculation

Parameter	Industry-Weighted Average	Manufacturer	
		A	B
S&P Bond Rating	-	BBB	BBB
(1) Yield on 10-Year T-Bill (1928-2013) %	5.2	-	-
(2) Gross Cost of Debt %	6.8	6.8	6.8
(3) Tax Rate %	19.5	15.3	28.3
Net Cost of Debt (2) x (1-(3)) %	5.4	5.8	4.9
Debt/Total Capital %	33.2	27.3	45.5

Using public information for both these companies, the initial estimate for the residential conventional oven industry WACC was approximately 12.2 percent. Subtracting an inflation rate of 3.1 percent between 1928 and 2013, the inflation-adjusted WACC, which was the initial estimate of the discount rate used in the straw-man GRIM, was 9.1 percent. DOE asked for feedback on the 9.1 percent discount rate during manufacturer interviews. Most manufacturers agreed the 9.1 discount rate was appropriate to use for the residential conventional oven industry.

12.4.5 Trial Standard Levels

DOE developed TSLs for residential conventional ovens consistent with the engineering analysis. DOE analyzed 11 product classes for residential conventional ovens. Table 12.4.5 shows the efficiency levels at each TSL for the residential conventional ovens analyzed by DOE.

Table 12.4.5 Trial Standard Levels for Residential Conventional Ovens

Product Class	Product Class Description	TSL 1	TSL 2	TSL 3
1	Electric Standard Ovens, Free-Standing	EL 1	EL 3	EL 7
2	Electric Standard Ovens, Built-in/Slide-in	EL 1	EL 3	EL 7
3	Electric Self-Clean Ovens, Free-Standing	EL 1	EL 1	EL 4
4	Electric Self-Clean Ovens, Built-in/Slide-in	EL 1	EL 1	EL 4
5	Gas Standard Ovens, Free-Standing	Baseline	EL 4	EL 7
6	Gas Standard Ovens, Built-in/Slide-in	Baseline	EL 4	EL 7
7	Gas Self-Clean Ovens, Free-Standing	EL 1	EL 2	EL 4
8	Gas Self-Clean Ovens, Built-in/Slide-in	EL 1	EL 2	EL 4

TSL 1 sets the efficiency level at baseline for two product classes (gas standard ovens, free-standing; and gas standard ovens, built-in/slide-in), and EL 1 for six product classes (electric standard ovens, free-standing; electric standard ovens, built-in/slide-in; electric self-clean ovens, free-standing; electric self-clean ovens, built-in/slide-in; gas self-clean ovens, free-standing; and gas self-clean ovens, built-in/slide-in).

TSL 2 sets the efficiency level at EL 1 for two product classes (electric self-clean ovens, free-standing; and electric self-clean ovens, built-in/slide-in), EL 2 for two product classes (gas self-clean ovens, free-standing; and gas self-clean ovens, built-in/slide-in), EL 3 for two product classes (electric standard ovens, free-standing and electric standard ovens, built-in/slide-in); and EL 4 for two product classes (gas standard ovens, free-standing and gas standard ovens, built-in/slide-in).

TSL 3 sets the efficiency level at max tech for all product classes. This corresponds to EL 4 for four product classes (electric self-clean ovens, free-standing; electric self-clean ovens, built-in/slide-in; gas self-clean ovens, free-standing; and gas self-clean ovens, built-in/slide-in); and EL 7 for four product classes (electric standard ovens, free-standing; electric standard ovens, built-in/slide-in; gas standard ovens, free-standing; and gas standard ovens, built-in/slide-in.

12.4.6 NIA Shipment Forecast

The GRIM estimate manufacturer revenues based on the total unit-shipment forecasts and the distribution of those shipments by efficiency level. Changes in the efficiency distribution at each standards level are a key driver of manufacturer finances. For this analysis, the GRIM used the NIA's annual shipment forecasts from 2015 to 2048, the end of the analysis period. In the base case shipment analysis, DOE develops shipment projections based on historical data and an analysis of key market drivers for each product class. In the standards case, DOE modeled a roll-up shipment scenario. The roll-up scenario represents the case in which all shipments that in the base case do not meet the analyzed standard level, will increase in efficiency to now meet the analyzed standard level but do not exceed that standard level. Also, no shipments that meet or exceed the analyzed standard level increase in efficiency due to potential standards. The assumptions and methodology that drive the shipments analysis are described in chapter 9 of this NOPR TSD.

12.4.7 Production Costs

During the engineering analysis, DOE developed the MPC for all product classes at each EL analyzed. DOE purchased a number of units for each product class, then tested and tore down those units to create a unique bill of materials for the purchased units. Using the bill of materials for each residential conventional oven, DOE was able to create an aggregated MPC based on the material costs from the bill of materials, the labor costs based on an average labor rate and the labor hours necessary to manufacture the residential conventional oven analyzed, and the overhead costs, including depreciation, based on a markup applied to the material and labor costs based on the materials used.

Table 12.4.6 through Table 12.4.13 show the average production cost estimates for residential conventional ovens used in the GRIM for each product class at each efficiency level.

Table 12.4.6 Manufacturer Production Cost Breakdown (2014$) for Electric Standard Ovens, Free-Standing

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$192.29	$29.17	$9.55	$34.21	$265.22	1.20	$318.27
EL 1	$192.88	$29.26	$9.58	$34.32	$266.04	1.20	$319.25
EL 2	$194.29	$29.48	$9.65	$34.57	$267.98	1.20	$321.58
EL 3	$198.01	$30.04	$9.83	$35.23	$273.11	1.20	$327.73
EL 4	$199.70	$30.30	$9.92	$35.53	$275.44	1.20	$330.53
EL 5	$217.23	$32.96	$10.79	$38.65	$299.63	1.20	$359.55
EL 6	$240.24	$36.45	$11.93	$42.75	$331.37	1.20	$397.64
EL 7	$243.30	$36.91	$12.08	$43.29	$335.58	1.20	$402.70

Table 12.4.7 Manufacturer Production Cost Breakdown (2014$) for Electric Standard Ovens, Built-in/Slide-in

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$203.55	$30.88	$10.11	$36.22	$280.76	1.20	$336.92
EL 1	$204.15	$30.97	$10.14	$36.32	$281.58	1.20	$337.90
EL 2	$205.55	$31.19	$10.21	$36.57	$283.52	1.20	$340.22
EL 3	$209.27	$31.75	$10.39	$37.24	$288.65	1.20	$346.38
EL 4	$210.96	$32.01	$10.48	$37.54	$290.98	1.20	$349.18
EL 5	$228.50	$34.67	$11.35	$40.66	$315.17	1.20	$378.20
EL 6	$251.51	$38.16	$12.49	$44.75	$346.91	1.20	$416.29
EL 7	$254.56	$38.62	$12.64	$45.29	$351.12	1.20	$421.34

Table 12.4.8 Manufacturer Production Cost Breakdown (2014$) for Electric Self-Clean Ovens, Free-Standing

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$211.17	$32.04	$10.49	$37.57	$291.26	1.20	$349.52
EL 1	$211.76	$32.13	$10.51	$37.68	$292.08	1.20	$350.50
EL 2	$229.29	$34.79	$11.39	$40.80	$316.27	1.20	$379.52
EL 3	$252.31	$38.28	$12.53	$44.89	$348.01	1.20	$417.61
EL 4	$256.07	$38.85	$12.72	$45.56	$353.20	1.20	$423.83

Table 12.4.9 Manufacturer Production Cost Breakdown (2014$) for Electric Self-Clean Ovens, Built-in/Slide-in

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$222.43	$33.75	$11.04	$39.58	$306.80	1.20	$368.16
EL 1	$223.03	$33.84	$11.07	$39.68	$307.62	1.20	$369.15
EL 2	$240.56	$36.50	$11.95	$42.80	$331.81	1.20	$398.17
EL 3	$263.57	$39.99	$13.09	$46.90	$363.55	1.20	$436.26
EL 4	$267.33	$40.56	$13.27	$47.57	$368.74	1.20	$442.48

Table 12.4.10 Manufacturer Production Cost Breakdown (2014$) for Gas Standard Ovens, Free-Standing

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$213.40	$32.38	$10.60	$37.97	$294.34	1.20	$353.21
EL 1	$213.40	$32.38	$10.60	$37.97	$294.34	1.20	$353.21
EL 2	$213.99	$32.47	$10.63	$38.08	$295.16	1.20	$354.20
EL 3	$218.70	$33.18	$10.86	$38.91	$301.65	1.20	$361.98
EL 4	$222.42	$33.75	$11.04	$39.58	$306.78	1.20	$368.14
EL 5	$224.11	$34.00	$11.13	$39.88	$309.11	1.20	$370.94
EL 6	$239.08	$36.27	$11.87	$42.54	$329.77	1.20	$395.72
EL 7	$242.21	$36.75	$12.03	$43.10	$334.08	1.20	$400.90

Table 12.4.11 Manufacturer Production Cost Breakdown (2014$) for Gas Standard Ovens, Built-in/Slide-in

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$224.67	$34.09	$11.16	$39.98	$309.88	1.20	$371.86
EL 1	$224.67	$34.09	$11.16	$39.98	$309.88	1.20	$371.86
EL 2	$225.26	$34.18	$11.19	$40.08	$310.70	1.20	$372.85
EL 3	$229.96	$34.89	$11.42	$40.92	$317.19	1.20	$380.63
EL 4	$233.68	$35.46	$11.60	$41.58	$322.32	1.20	$386.79
EL 5	$235.37	$35.71	$11.69	$41.88	$324.65	1.20	$389.58
EL 6	$250.35	$37.98	$12.43	$44.55	$345.31	1.20	$414.37
EL 7	$253.47	$38.46	$12.59	$45.10	$349.62	1.20	$419.54

Table 12.4.12 Manufacturer Production Cost Breakdown (2014$) for Gas Self-Clean Ovens, Free-Standing

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$263.16	$39.93	$13.07	$46.82	$362.98	1.20	$435.58
EL 1	$263.76	$40.02	$13.10	$46.93	$363.80	1.20	$436.56
EL 2	$268.46	$40.73	$13.33	$47.77	$370.29	1.20	$444.35
EL 3	$283.44	$43.00	$14.07	$50.43	$390.95	1.20	$469.13
EL 4	$287.20	$43.57	$14.26	$51.10	$396.13	1.20	$475.36

Table 12.4.13 Manufacturer Production Cost Breakdown (2014$) for Gas Self-Clean Ovens, Built-in/Slide-in

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$274.43	$41.64	$13.63	$48.83	$378.52	1.20	$454.23
EL 1	$275.02	$41.73	$13.66	$48.94	$379.34	1.20	$455.21
EL 2	$279.73	$42.44	$13.89	$49.77	$385.83	1.20	$462.99
EL 3	$294.70	$44.71	$14.63	$52.44	$406.49	1.20	$487.78
EL 4	$298.46	$45.28	$14.82	$53.11	$411.67	1.20	$494.01

12.4.8 Capital and Product Conversion Costs

DOE expects new and amended energy conservation standards for residential conventional ovens to cause manufacturers to incur conversion costs to bring their production facilities and product designs into compliance with the new and amended standards. For the MIA, DOE classified these conversion costs into two major groups: (1) capital conversion costs, and (2) product conversion costs. Capital conversion costs are investments in property, plant, and equipment necessary to adapt or change existing production facilities such that new product designs can be fabricated and assembled. Product conversion costs are investments in research, development, testing, marketing, certification, and other non-capitalized costs necessary to make product designs comply with new and amended standards.

Using feedback from manufacturer interviews, DOE conducted a top-down analysis to calculate the capital and product conversion costs for residential conventional oven manufacturers. DOE asked manufacturers during interviews to estimate the total capital and product conversion costs they would need to incur to be able to produce each residential conventional oven at specific ELs. DOE then summed these values provided by manufacturers to arrive at total top-down industry conversion cost for residential conventional ovens.

DOE's estimates of the capital and product conversion costs for all residential conventional ovens can be found in Table 12.4.14 and Table 12.4.15.

Table 12.4.14 Capital Conversion Costs for all Residential Conventional Ovens by TSL

Product Class	**Product Class Description**	**TSL 1** ***(2014$ millions)***	**TSL 2** ***(2014$ millions)***	**TSL 3** ***(2014$ millions)***
1 & 2	Electric Standard Ovens	$3.0	$15.0	$168.0
3 & 4	Electric Self-Clean Ovens	$3.0	$3.0	$153.0
5 & 6	Gas Standard Ovens	-	$18.0	$111.0
7 & 8	Gas Self-Clean Ovens	$3.0	$6.0	$96.0
	Total	**$9.0**	**$42.0**	**$528.0**

Table 12.4.15 Product Conversion Costs for all Residential Conventional Ovens by TSL

Product Class	**Product Class Description**	**TSL 1** ***(2014$ millions)***	**TSL 2** ***(2014$ millions)***	**TSL 3** ***(2014$ millions)***
1	Electric Standard Ovens, Free-Standing	$1.4	$12.2	$112.2
2	Electric Standard Ovens, Built-in/Slide-in	$0.1	$0.6	$5.1
3	Electric Self-Clean Ovens, Free-Standing	$1.5	$1.5	$83.2
4	Electric Self-Clean Ovens, Built-in/Slide-in	$0.5	$0.5	$27.9
5	Gas Standard Ovens, Free-Standing	-	$34.9	$106.2
6	Gas Standard Ovens, Built-in/Slide-in	-	$6.3	$19.2
7	Gas Self-Clean Ovens, Free-Standing	$0.8	$11.3	$45.4
8	Gas Self-Clean Ovens, Built-in/Slide-in	$0.0	$0.6	$2.4
	Total	**$4.3**	**$67.9**	**$401.5**

12.4.9 Markup Scenarios

In the base case, DOE used the same baseline markup of 1.20 for all residential conventional ovens. In the standards case, DOE used two markup scenarios to represent the uncertainty about the impacts of new and amended energy conservation standards on prices and profitability following the implementation of new and amended energy conservation standards: (1) a preservation of gross margin markup scenario, and (2) a preservation of operating profit markup scenario. These scenarios lead to different markup values, which when applied to the inputted MPCs, result in varying revenue and cash-flow impacts.

12.4.9.1 Preservation of Gross Margin Markup Scenario

Under the preservation of gross margin markup scenario DOE applied a single uniform markup across all product classes and efficiency levels. As production costs increase with efficiency, this scenario implies that the absolute dollar markup will increase as well. Based on publicly available financial information for manufacturers of residential conventional ovens and comments from manufacturer interviews, DOE assumed the non-production cost markup—which includes SG&A expenses; R&D expenses; interest; and profit—to be 1.20 for all residential conventional ovens. Because this markup scenario assumes that manufacturers would be able to maintain their gross margin percentage as production costs increase in response to new and amended standards, it represents the upper bound to industry profitability under new and amended standards.

12.4.9.2 Preservation of Operating Profit Markup Scenario

DOE implemented the preservation of operating profit markup scenario because manufacturers stated that in the standards case, they do not expect to be able to mark up the full cost of production given the highly competitive market. The preservation of operating profit markup scenario assumes that manufacturers are able to maintain only the base case total operating profit in absolute dollars in the standards case, despite higher production costs and investment. The base case total operating profit is derived from marking up the cost of goods sold for each product by a flat percentage (the preservation of operating profit markup discussed in the previous section) to cover standard SG&A expenses, R&D expenses, interest, and profit. DOE adjusted the manufacturer markups in the GRIM at each TSL to yield approximately the same earnings before interest and taxes in the standards cases in the year after the compliance date of the new and amended standards as in the base case. DOE altered the markups only for the minimally compliant products in this scenario, with margin impacts not occurring for products that already exceed the new and amended standards. The preservation of operating profit markup scenario represents the lower bound of industry profitability following new and amended standards. Under this scenario, manufacturers are not able to earn additional operating profit on higher production costs and the investments required to comply with new and amended standards, like they are in the preservation of gross margin markup scenario. However, manufacturers are able to maintain the same operating profit in absolute dollars in the standards cases as they would have earned in the base case.

For residential conventional ovens, Table 12.4.16 through Table 12.4.23 lists the product classes DOE analyzed with the corresponding preservation of operating profit markups at each analyzed EL.

Table 12.4.16 Preservation of Operating Profit Markups for Electric Standard Ovens, Free-Standing

EL	Markups by Selected EL							
	Baseline	**EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**	**EL 6**	**EL 7**
Baseline	1.200							
EL 1	1.200	1.200						
EL 2	1.200	1.200	1.200					
EL 3	1.200	1.200	1.200	1.199				
EL 4	1.200	1.200	1.200	1.200	1.200			
EL 5	1.200	1.200	1.200	1.200	1.200	1.200		
EL 6	1.200	1.200	1.200	1.200	1.200	1.200	1.200	
EL 7	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.193

Table 12.4.17 Preservation of Operating Profit Markups for Electric Standard Ovens, Built-in/Slide-in

EL	Markups by Selected EL							
	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Baseline	1.200							
EL 1	1.200	1.200						
EL 2	1.200	1.200	1.200					
EL 3	1.200	1.200	1.200	1.199				
EL 4	1.200	1.200	1.200	1.200	1.200			
EL 5	1.200	1.200	1.200	1.200	1.200	1.200		
EL 6	1.200	1.200	1.200	1.200	1.200	1.200	1.200	
EL 7	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.193

Table 12.4.18 Preservation of Operating Profit Markups for Electric Self-Clean Ovens, Free-Standing

EL	Markups by Selected EL				
	Baseline	EL 1	EL 2	EL 3	EL 4
Baseline	1.200				
EL 1	1.200	1.200			
EL 2	1.200	1.200	1.200		
EL 3	1.200	1.200	1.200	1.200	
EL 4	1.200	1.200	1.200	1.200	1.195

Table 12.4.19 Preservation of Operating Profit Markups for Electric Self-Clean Ovens, Built-in/Slide-in

EL	Markups by Selected EL				
	Baseline	EL 1	EL 2	EL 3	EL 4
Baseline	1.200				
EL 1	1.200	1.200			
EL 2	1.200	1.200	1.200		
EL 3	1.200	1.200	1.200	1.200	
EL 4	1.200	1.200	1.200	1.200	1.195

Table 12.4.20 Preservation of Operating Profit Markups for Gas Standard Ovens, Free-Standing

EL	Markups by Selected EL							
	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Baseline	1.200							
EL 1	1.200	1.200						
EL 2	1.200	1.200	1.200					
EL 3	1.200	1.200	1.200	1.200				
EL 4	1.200	1.200	1.200	1.200	1.199			
EL 5	1.200	1.200	1.200	1.200	1.200	1.200		
EL 6	1.200	1.200	1.200	1.200	1.200	1.200	1.200	
EL 7	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.196

Table 12.4.21 Preservation of Operating Profit Markups for Gas Standard Ovens, Built-in/Slide-in

EL	Markups by Selected EL							
	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Baseline	1.200							
EL 1	1.200	1.200						
EL 2	1.200	1.200	1.200					
EL 3	1.200	1.200	1.200	1.200				
EL 4	1.200	1.200	1.200	1.200	1.199			
EL 5	1.200	1.200	1.200	1.200	1.200	1.200		
EL 6	1.200	1.200	1.200	1.200	1.200	1.200	1.200	
EL 7	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.196

Table 12.4.22 Preservation of Operating Profit Markups for Gas Self-Clean Ovens, Free-Standing

EL	Markups by Selected EL				
	Baseline	EL 1	EL 2	EL 3	EL 4
Baseline	1.200				
EL 1	1.200	1.200			
EL 2	1.200	1.200	1.199		
EL 3	1.200	1.200	1.200	1.200	
EL 4	1.200	1.200	1.200	1.200	1.197

Table 12.4.23 Preservation of Operating Profit Markups for Gas Self-Clean Ovens, Built-in/Slide-in

EL	Markups by Selected EL				
	Baseline	EL 1	EL 2	EL 3	EL 4
Baseline	1.200				
EL 1	1.200	1.200			
EL 2	1.200	1.200	1.199		
EL 3	1.200	1.200	1.200	1.200	
EL 4	1.200	1.200	1.200	1.200	1.197

12.5 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, the GRIM estimates the financial impact on the residential conventional oven industry. The following sections detail additional inputs and assumptions for residential conventional ovens. 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 Impacts on Industry Net Present Value

The INPV measures the residential conventional oven industry value and is used in the MIA to compare the economic impacts of different TSLs in the standards cases. The INPV is different from DOE’s net present value, which is applied to the U.S. economy. The INPV is the sum of all net cash flows discounted at the industry’s cost of capital, or discount rate. The residential conventional ovens GRIM estimates cash flows from 2016 to 2048. This timeframe models both the short-term impacts on the industry from the announcement of the standard until the compliance date (2016 until an estimated compliance date of 2019) and a long-term assessment over the 30-year analysis period used in the NIA (2019 – 2048).

In the MIA, DOE compares the INPV of the base case (no new or amended energy conservation standards) to that of each TSL in the standards cases. The difference between the base case and a standards case INPV is an estimate of the economic impacts that implementing that particular TSL would have on the industry. For the residential conventional oven industry, DOE examined the two markup scenarios previously described, the preservation of gross margin markup scenario and the preservation of operating profit markup scenario.

Table 12.5.1 and Table 12.5.2 provide the INPV estimates for the two markup scenarios for the residential conventional oven industry.

Table 12.5.1 Changes in Industry Net Present Value for Residential Conventional Ovens – Preservation of Gross Margin Markup Scenario

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	(2014$ millions)	783.5	762.8	702.6	140.6
Change in INPV	(2014$ millions)	-	(20.7)	(80.9)	(642.9)
	(%)	-	(2.6)	(10.3)	(82.0)

Table 12.5.2 Changes in Industry Net Present Value for Residential Conventional Ovens – Preservation of Operating Profit Markup Scenario

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	(2014$ millions)	783.5	762.1	697.1	56.0
Change in INPV	(2014$ millions)	-	(21.4)	(86.4)	(727.5)
	(%)	-	(2.7)	(11.0)	(92.9)

12.5.2 Impacts on Annual Cash Flow

While INPV is useful for evaluating the long-term effects of new and amended 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. To get an idea of the behavior of annual free cash flows, Figure 12.5.1 and Figure 12.5.2 present the annual free cash flows from 2015 through 2028 for the base case and different TSLs in the standards case.

Annual cash flows are discounted to the base year, 2015. Between 2016 and the 2019 compliance date of the new and amended energy conservation standards, cash flows are driven by the level of conversion costs and the proportion of these investments spent every year. After the standard's announcement date (*i.e.*, the publication date of the final rule), industry cash flows begin to decline as companies use their financial resources to prepare for the new and amended energy conservation standards. The more stringent the new and amended energy conservation standards, the greater the impact on industry cash flows in the years leading up to the compliance date, as product conversion costs lower cash inflows from operations and capital conversion costs increase cash outflows for capital expenditures.

Free cash flow in the year the new and amended energy conservation standards take effect is driven by two competing factors. In addition to capital and product conversion costs, new and amended energy conservation standards could create stranded assets (*i.e.*, tooling and equipment that would have enjoyed longer use if the energy conservation standards 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 new and amended energy conservation standards. 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 an increase in working capital that reduces cash flow from operations. A large increase in working capital is needed due to more costly production components and materials, higher inventories of 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 standards takes effect.

In the years following the compliance date of the standards, the impact on cash flow depends on the operating revenue. In the preservation of gross margin markup scenario, the manufacture markup is held constant to yield the same gross margin percentage in the standards case at each TSL as in the base case in the year after the standards take effect. The implicit assumption is that manufacturers can freely pass on and mark up higher cost units. The result under this scenario is that operating cash flow increases (in absolute terms) as revenue increases. At the highest TSL where MPCs dramatically increase, this scenario drives large increases in operating cash flow relative to the base case. The larger the production cost increase, the more likely it is that the increase in operating cash flow after the standards take effect will outweigh the initial conversion costs.

Under the preservation of operating profit scenario, cash flow decreases at each TSL in the standards case compared to the base case because the absolute dollar amount of the gross margin does not change despite an increase in sales and cost of goods sold. Therefore, the gross margin percentage is reduced.

Figure 12.5.1 and Figure 12.5.2 present the annual free cash flows for the residential conventional oven industry.

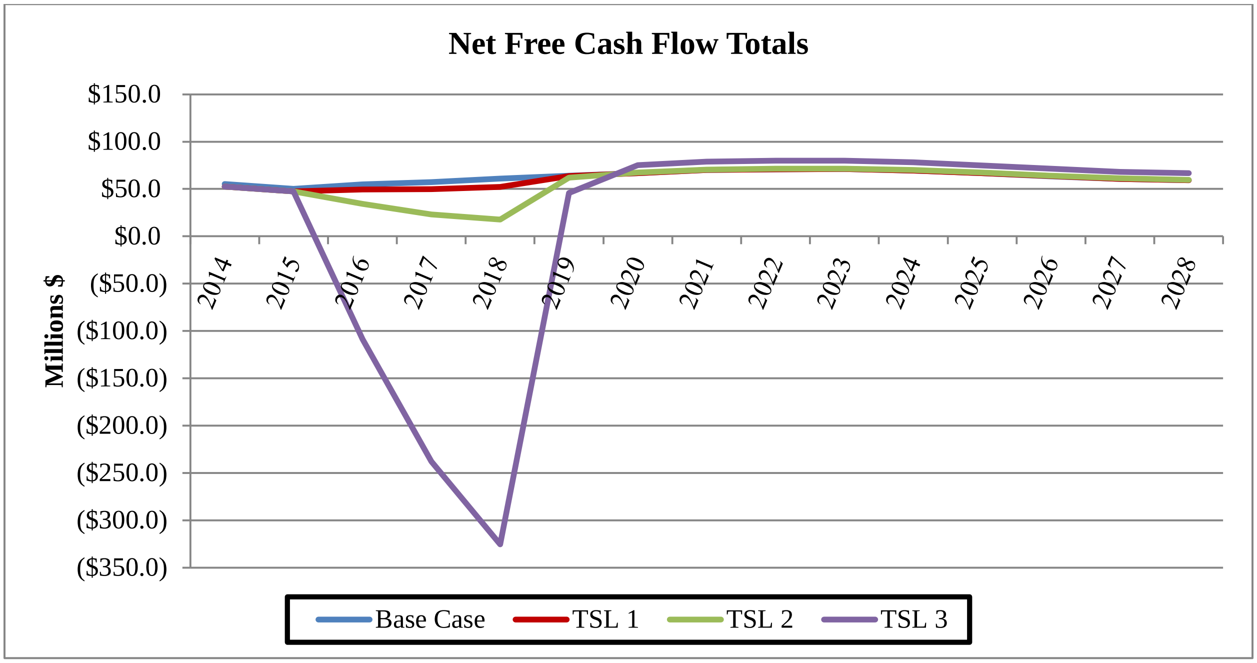

Figure 12.5.1 Annual Industry Free Cash Flows for Residential Conventional Ovens – Preservation of Gross Margin Markup Scenario

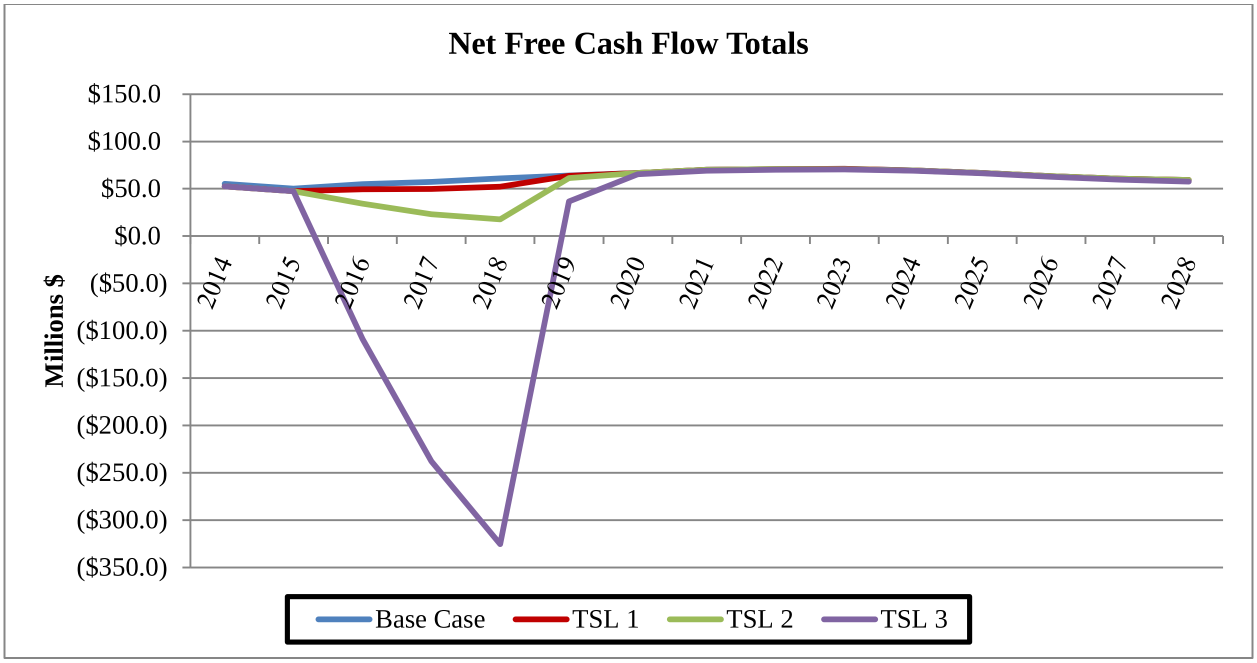

Figure 12.5.2 Annual Industry Free Cash Flows for Residential Conventional Ovens – Preservation of Operating Profit Markup Scenario

12.6 IMPACTS ON MANUFACTURER SUBGROUPS

As described in Section 12.2.3, DOE identified one subgroup of residential conventional oven manufacturers: small businesses. The results of this subgroup analysis are described in the following section.

12.6.1 Impacts on Small Business Manufacturers

12.6.1.1 Description and Estimated Number of Small Entities Regulated

DOE conducted a more focused inquiry on the companies that could be small businesses of residential conventional ovens covered by this rulemaking. To estimate the number of companies that could be small business manufacturers of residential conventional ovens covered by this rulemaking, DOE conducted a market survey using publicly available information. DOE's research involved industry trade association membership directories (including AHAM), information from previous rulemakings, individual company websites, SBA's database, and market research tools (*e.g.*, Hoover's reports). DOE also asked stakeholders and industry representatives if they were aware of any small manufacturers during manufacturer interviews and DOE public meetings. DOE used information from these sources to create a list of companies that potentially manufacture or sell residential conventional ovens and would be impacted by this rulemaking. As necessary, DOE contacted companies to determine whether they met the SBA's definition of a small business manufacturer of residential conventional ovens. DOE screened out companies that do not offer products covered by this rulemaking, do not meet the definition of a "small business," or are completely foreign owned and operated.

DOE identified 19 companies that sell residential conventional ovens that would be affected by this proposal. Of these 19 companies, DOE identified seven as small businesses. DOE contacted identified businesses to invite them to take part in a manufacturer impact analysis interview. Of the businesses contacted, DOE was able to reach and discuss potential standards with one small business. DOE also obtained information about small businesses and potential impacts on small businesses while interviewing large manufacturers.

Three major manufacturers supply approximately 85 percent of the market for residential conventional ovens. DOE estimates that the remaining 15 percent of the market is served by a combination of small businesses and large businesses. None of the three major manufacturers of residential conventional ovens affected by this rulemaking is a small business.

12.6.1.2 Comparison Between Large and Small Entities

In general, small manufacturers differ from large manufacturers in several ways that affect the extent to which a manufacturer may be impacted by proposed standards. Characteristics of small manufacturers typically include: lower production volumes, fewer engineering resources, and less access to capital. Lower production volumes in particular may place small manufacturers at a competitive disadvantage relative to large manufacturers as they convert products and facilities to comply with new and amended standards. When producing at lower volumes, a small manufacturer’s conversion costs must be spread over fewer units than a larger competitor’s. Therefore, unless a small manufacturer can differentiate its products in order to earn a price premium, the small manufacturer may experience a disproportionate cost penalty as it spreads one-time conversion costs over fewer unit sales. Additionally, when producing at lower volumes, small manufacturers may lack the purchasing power of their larger competitors and may therefore face higher costs when sourcing components for more efficient products. Disadvantages tied to lower production volumes may be further exacerbated by the fact that small manufacturers often have more limited engineering resources than their larger competitors, thereby complicating the redesign effort required to comply with new and amended standards. Finally, small manufacturers often have less access to capital, which may be needed to cover the conversion costs associated with new and amended standards. Combined, these factors may entail a disproportionate burden on small manufacturers.

At TSL 1 DOE estimates capital conversion costs of $0.3 million and product conversion costs of $0.6 million for an average small manufacturer. For an average large manufacturer, DOE estimates capital conversion costs of $1.1 million and product conversion costs of $0.5 million.

At TSL 2, the level proposed here, DOE estimates capital conversion costs of $1.3 million and product conversion costs of $3.1 million for an average small manufacturer. For an average large manufacturer, DOE estimates capital conversion costs of $2.7 million and product conversion costs of $3.3 million. Table 12.6.1 presents the estimated conversion costs as a percentage of annual revenue for an average small manufacturer relative to an average large manufacturer.

Table 12.6.1 Conversion Costs Facing an Average Small Manufacturer versus an Average Large Manufacturer of Residential Conventional Ovens

	Capital Conversion Costs as a Percentage of Annual Revenue	Product Conversion Costs as a Percentage of Annual Revenue	Total Conversion Costs as a Percentage of Annual Revenue
Average Small Manufacturer	2%	5%	7%
Average Large Manufacturer	1%	1%	1%

As the results indicate, new and amended energy conservation standards could potentially impact small businesses disproportionately. Although estimated conversion costs at TSL 2 are higher for an average large manufacturer than an average small manufacturer, the relative impacts of conversion costs on large manufacturers will likely be offset by higher annual revenues. This is consistent with the dynamic previously described, whereby large manufacturers tend to have larger production and sales volumes over which to spread costs and may also enjoy a competitive advantage due to their size and ability to access capital that may not be available to small manufacturers. Since the proposed standards could cause competitive concerns for small manufacturers, DOE cannot certify that the proposed standards would not have a significant impact on a substantial number of small businesses.

12.7 OTHER IMPACTS

12.7.1 Employment

DOE quantitatively assessed the impacts of new and amended energy conservation standards on direct employment. DOE used the GRIM to estimate the domestic labor expenditures and number of domestic production workers in the base case and at each TSL from 2019 to 2048. 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 involved with the manufacture of the residential conventional ovens are a function of the labor intensity of the products, the sales volume, and an assumption that wages remain fixed in real terms over time.

In the GRIM, DOE used the labor content of each product and the manufacturing production costs to estimate the annual labor expenditures in the industry. DOE used Census data and interviews with manufacturers to estimate the portion of the total labor expenditures that is attributable to domestic labor.

The production worker estimates in this section cover only workers up to the line-supervisor level directly involved in fabricating and assembling a product within a manufacturing facility. Workers performing services that are closely associated with production operations, such as material handing with a forklift, are also included as production labor. DOE's estimates account for production workers who manufacture only the specific products covered in this rulemaking. For example, a worker on a microwave oven production line would not be included with the estimate of the number of residential conventional oven workers.

The employment impacts shown in Table 12.7.1 represent the potential production employment that could result following new and amended energy conservation standards. The upper bound of the results estimates the maximum change in the number of production workers that could occur after compliance with new and amended energy conservation standards, when assuming that manufacturers continue to produce the same scope of covered products in the same production facilities. It also assumes that domestic production does not shift to lower labor-cost countries. Because there is a real risk of manufacturers evaluating sourcing decisions in response to new and amended energy conservation standards, the lower bound of the employment results includes the estimated total number of U.S. production workers in the industry who could lose their jobs if some or all existing production were moved outside of the United States. While the results present a range of employment impacts following 2019, the following sections also include qualitative discussions of the likelihood of negative employment impacts at the various TSLs. Finally, the employment impacts shown are independent of the employment impacts from the broader U.S. economy, documented in chapter 16 of this NOPR TSD.

Using 2011 ASM data and interviews with manufacturers, DOE estimates that approximately 60 percent of the residential conventional ovens sold in the United States are manufactured domestically. With this assumption, DOE estimates that in the absence of new and amended energy conservation standards, there would be approximately 6,564 domestic production workers involved in manufacturing residential conventional ovens in 2019. Table 12.7.1 shows the range of impacts of the analyzed new and amended energy conservation standards on U.S. production workers in the residential conventional oven industry.

Table 12.7.1 Potential Changes in the Total Number of All Domestic Residential Conventional Ovens Production Workers in 2019

	Base Case	**Trial Standard Level**		
		1	**2**	**3**
Total Number of Domestic Production Workers in 2019 (without changes in production locations)	6,564	6,571	6,622	7,397
Potential Changes in Domestic Production Workers in 2019*	-	0 - 7	(1,641) - 58	(3,282) – 833

* DOE presents a range of potential employment impacts. Numbers in parentheses indicate negative numbers.

At the upper end of the range, all examined TSLs show a slight increase in the number of domestic employment for residential conventional ovens. DOE believes that manufacturers would increase production hiring due to the increase in the labor associated with adding the required components to make residential conventional ovens more efficient. However, as previously stated, this assumes that in addition to hiring more production employees, all existing domestic production would remain in the United States and not shift to lower labor-cost countries.

DOE does not expect any significant changes in domestic employment at TSL 1 because standards would only affect standby mode power consumption at this TSL. Most manufacturers stated that this TSL would not require significant design changes and therefore would not have a significant impact on domestic employment decisions.

At TSLs 2 and 3, all product classes would require higher efficiency standards and therefore most manufacturers would be required to make modifications to their existing production lines. However, manufacturers stated that due to the larger size of most residential conventional ovens, very few units are shipped from far distances such as Asia or Europe. The vast majority of residential conventional ovens are currently made in North America. Some manufacturers stated that even significant changes to production line would not cause them to shift their production to lower labor-cost countries, as several manufacturers either only produce residential conventional ovens domestically or have recently made significant investments to continue to produce residential conventional ovens domestically. DOE estimates that at most 25 percent of the domestic labor for residential conventional ovens could move to other countries in response to the standards proposed at TSL 2. However, DOE believes this to be a high upper bound estimate as most manufacturers would not significantly alter their production locations at the efficiency levels prescribed at TSL 2.

At TSL 3, manufacturers could alter production locations in response to standards since all product classes would be required to meet max tech. DOE estimated that at most 50 percent of the domestic labor for residential conventional ovens could move to other countries in response to the standards prescribed at TSL 3.

12.7.2 Production Capacity

Residential conventional oven manufacturers stated that they did not anticipate any capacity constraints for the efficiency levels analyzed for either electric or gas residential conventional ovens.

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 industry as a whole. Assessing the impact of a single regulation may overlook the cumulative regulatory burden faced by manufacturers. For this cumulative regulatory burden analysis, DOE examines other significant product-specific regulations that could affect residential conventional oven manufacturers that will take effect three years before or three years after the effective date of the new and amended energy conservation standards for residential conventional ovens. DOE also describes additional state, Federal, and international regulations with which residential conventional oven manufacturers must comply.

Companies that produce a wide range of regulated products may be faced with more capital and product conversion costs than their competitors. Additional regulations can prompt those companies to exit the market or reduce their product offerings, potentially reducing overall competition. Companies that could be affected by this rulemaking also typically manufacture microwave ovens, residential clothes washers, residential clothes dryers, residential refrigerators and freezers, miscellaneous residential refrigeration equipment, and dishwashers, which are also either subject or potentially subject to other DOE energy conservation standards. Small businesses in particular may experience greater regulatory impacts due to lower sales volumes over which they must amortize the costs of meeting new and amended standards. DOE considers a proposed standard not to be economically justified if it contributes to an unacceptable level of cumulative regulatory burden.

12.7.3.1 DOE Regulations for Other Products Produced by Residential Conventional Oven Manufacturers

In addition to the proposed new and amended energy conservation standards on residential conventional ovens, several other existing and pending DOE energy conservation standards may apply to other products produced by residential conventional oven manufacturers. DOE acknowledges that each regulation can impact a manufacturer's financial operations. Multiple regulations affecting the same manufacturer can quickly strain manufacturers' profit and possibly cause them to exit particular markets. Table 12.7.2 lists the other DOE energy conservation standards that could also affect residential conventional oven manufacturers in the three years leading up to and after the estimated compliance date of new and amended energy conservation standards for residential conventional ovens.

Table 12.7.2 Other DOE Regulations Potentially Affecting Residential Conventional Oven Manufacturers

Regulation	Approximate Compliance Date	Number of Impacted Companies from the Market and Technology Assessment (MTA) (See Chapter 3)	Estimated Industry Total Conversion Expenses
Residential Clothes Washers	2015 & 2018	9	$418.5 million (2010$)[b]
Commercial Distribution Transformers	2016	1	$61.0 million (2011$)[c]
Microwave Ovens	2016	5	$43.1 million (2011$)[d]
Electric Motors	2016	1	$84.6 million (2013$)[e]
Metal Halide Lamp Fixtures	2017	1	$3.0 million (2012$)[f]

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[b] Estimated industry conversion expenses were published in the TSD for the May 2012 residential clothes washers direct final rule. 77 FR 32308 The TSD for the 2012 residential clothes washers direct final rule can be found at http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0019-0047

[c] Estimated industry conversion expenses were published in the TSD for the April 2013 distribution transformers final rule. 78 FR 23336 The TSD for the 2013 distribution transformers final rule can be found at http://www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0048-0760

[d] Estimated industry conversion expenses were published in the TSD for the June 2013 microwave ovens final rule. 78 FR 36316 The TSD for the 2013 microwave ovens final rule can be found at http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0048-0021

[e] Estimated industry conversion expenses were published in the TSD for the May 2014 electric motors final rule. 79 FR 30933 The TSD for 2014 electric motors final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/42

[f] Estimated industry conversion expenses were published in the TSD for the February 2014 metal halide lamp fixtures final rule. 79 FR 7745 The TSD for the 2014 metal halide lamp fixtures final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/16

Regulation	Approximate Compliance Date	Number of Impacted Companies from the Market and Technology Assessment (MTA) (See Chapter 3)	Estimated Industry Total Conversion Expenses
General Service Fluorescent Lamps and Incandescent Reflector Lamps	2018	1	$26.6 million (2012$)[g]
HID Lamps	2018*	1	N/A††
Commercial Clothes Washers Update	2018*	3	N/A††
Packaged Terminal Air Conditioners and Heat Pumps (ASHRAE)	2019*	1	N/A††
Commercial Compressors	2019*	1	N/A††
Miscellaneous Residential Refrigeration	2019*	1	N/A††
Single Packaged Vertical Units	2020*	1	N/A††
Candelabra Base Incandescent Lamps and Intermediate Base Incandescent Lamps	N/A[β]	1	N/A††
Other Incandescent Reflector Lamps	N/A[β]	1	N/A††

*The dates listed are an approximation. The exact dates are pending final DOE action.

† For minimum performance requirements prescribed by the Energy Independence and Security Act of 2007 (EISA 2007), DOE did not estimate total industry conversion costs because an MIA was not completed as part of a rulemaking. Pub. L. 110-140. EISA 2007 made numerous amendments to the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 U.S.C. 6291–6309), which established an energy conservation program for major household appliances and industrial and commercial equipment.

†† For energy conservation standards for rulemakings awaiting DOE final action, DOE does not have a finalized estimated total industry conversion cost.

[β] These rulemakings are placed on hold due to the Consolidated Appropriations Act, 2012 (Public Law 112-74).

12.8 CONCLUSION

The following section summarizes the impacts for the scenarios DOE believes are most likely to capture the range of impacts on residential conventional oven manufacturers as a result of new and amended energy conservation standards. DOE also notes that while these scenarios bound the range of most plausible impacts on manufacturers, there potentially could be circumstances that cause manufacturers to experience impacts outside of this range.

TSL 1 sets the efficiency level at baseline for two product classes (gas standard ovens, free-standing; and gas standard ovens, built-in/slide-in), and EL 1 for six product classes (electric standard ovens, free-standing; electric standard ovens, built-in/slide-in; electric self-clean ovens,

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[g] Estimated industry conversion expenses were published in the TSD for the January 2015 general service fluorescent lamp and incandescent reflector lamp final rule. XX FR XXXX the TSD for the 2015 general service fluorescent lamp and incandescent reflector lamp can be found at XX

free-standing; electric self-clean ovens, built-in/slide-in; gas self-clean ovens, free-standing; and gas self-clean ovens, built-in/slide-in). At TSL 1, DOE estimates impacts on INPV range from -$21.4 million to -$20.7 million, or a change in INPV of -2.7 percent to -2.6 percent. At TSL 1, industry free cash flow (operating cash flow minus capital expenditures) is estimated to decrease to $52.1 million, or a drop of 14.3 percent, compared to the base-case value of $60.8 million in 2018, the year leading up to new and amended energy conservation standards.

Percentage impacts on INPV are slightly negative at TSL 1. DOE does not anticipate that manufacturers would lose a significant portion of their INPV at this TSL. DOE projects that in the expected year of compliance (2019), 100 percent of gas standard oven, free-standing shipments; and gas standard oven, built-in/slide-in shipments would meet or exceed the efficiency levels required at TSL 1. Meanwhile in 2019, 60 percent of electric standard oven, free-standing shipments; 60 percent of electric standard oven, built-in/slide-in shipments; 53 percent of electric self-clean oven, free-standing shipments; 53 electric self-clean oven, built-in/slide-in shipments; 52 percent of gas self-clean oven, free-standing shipments; and 52 percent of gas self-clean oven, built-in/slide-in shipments would meet the efficiency levels at TSL 1.

DOE expects conversion costs to be small at TSL 1 because the design changes prescribed at this TSL only affect standby mode power consumption and do not apply to active mode power consumption. DOE expects residential conventional oven manufacturers to incur $4.3 million in product conversion costs for product redesigns that will convert residential conventional ovens from using linear power supply to switch mode power supply to reduce standby power consumption. DOE expects $9.0 million in capital conversion costs for manufacturers to upgrade production lines and retool equipment associated with achieving this reduction in standby power.

At TSL 1, under the preservation of gross margin markup scenario, the shipment-weighted average MPC increases very slightly by approximately 0.1 percent relative to the base-case MPC. This extremely slight price increase is outweighed by the $13.3 million in conversion costs estimated at TSL 1, resulting in slightly negative INPV impacts at TSL 1 under the preservation of gross margin markup scenario.

Under the preservation of operating profit markup scenario, manufacturers earn the same nominal operating profit as would be earned in the base case, but manufacturers do not earn additional profit from their investments. The very slight increase in the shipment weighted-average MPC is again outweighed by a slightly lower average manufacturer markup (slightly smaller than the 1.20 manufacturer markup used in the base case) and $13.3 million in conversion costs, resulting in slightly negative impacts at TSL 1.

TSL 2 sets the efficiency level at EL 1 for two product classes (electric self-clean ovens, free-standing; and electric self-clean ovens, built-in/slide-in), EL 2 for two product classes (gas self-clean ovens, free-standing; and gas self-clean ovens, built-in/slide-in), EL 3 for two product classes (electric standard ovens, free-standing and electric standard ovens, built-in/slide-in); and EL 4 for two product classes (gas standard ovens, free-standing and gas standard ovens, built-in/slide-in). At TSL 2, DOE estimates impacts on INPV to range from -$86.4 million to -$80.9 million, or a change in INPV of -11.0 percent to -10.3 percent. At this standard level, industry free cash flow is estimated to decrease to $17.6, or a drop of 71.0 percent, compared to the base-case value of $60.8 million in 2018.

Percentage impacts on INPV are moderately negative at TSL 2. While the $109.9 million in industry conversion costs represent a significant investment for manufacturers, DOE does not anticipate that manufacturers would lose a significant portion of their INPV at this TSL since the base case INPV for manufacturers is slightly less than $800 million. DOE projects that in 2019, 40 percent of electric standard oven, free-standing shipments; 40 percent of electric standard oven, built-in/slide-in shipments; 53 percent of electric self-clean oven, free-standing shipments; 53 percent of electric self-clean oven, built-in/slide-in shipments; 32 percent of gas standard oven, free-standing shipments; 32 percent of gas standard oven, built-in/slide-in shipments; 39 percent of gas self-clean oven, free-standing shipments; and 39 percent of gas self-clean oven, built-in/slide-in shipments would meet or exceed the efficiency levels at TSL 2.

While DOE expects conversion costs to be a large investment at TSL 2, the much larger base case INPV reduces the overall INPV impact on a percentage basis at TSL 2. DOE expects that product conversion costs will significantly rise from $4.3 million at TSL 1 to $67.9 million at TSL 2 for extensive product redesigns and testing. Capital conversion costs will also significantly increase from $9.0 million at TSL 1 to $42.0 million at TSL 2 to upgrade production equipment to accommodate for added or redesigned features in each product class. The large conversion costs at TSL 2 are driven by reduce vent rate and improve insulation in the electric oven product classes, and conversion from glo-bar to electronic spark ignition systems in the gas oven product classes.

At TSL 2, under the preservation of gross margin markup scenario, the shipment weighted-average MPC only slightly increases by 0.9 percent, relative to the base-case MPC. In this scenario, INPV impacts are moderately negative because manufacturers incur sizable conversion costs ($109.9 million) and are not able to recover much of those conversion costs through the slight increase in the shipment weighted-average MPC at TSL 2.

Under the preservation of operating profit markup scenario, the 0.9 percent shipment weighted-average MPC increase is outweighed by a slightly lower average manufacturer markup (slightly smaller than the 1.20 manufacturer markup used in the base case) and $109.9 million in conversion costs, resulting in moderately negative INPV impacts at TSL 2.

TSL 3 sets the efficiency level at max tech for all product classes. At TSL 3, DOE estimates impacts on INPV to range from -$727.5 million to -$642.9 million, or a change in INPV of -92.9 percent to -82.0 percent. At this standard level, industry free cash flow is estimated to decrease by approximately 635.3 percent to -$325.5 million, compared to the base-case value of $60.8 million in 2018.

At TSL 3 conversion costs significantly increase causing free cash flow to become significantly negative in the year leading up to energy conservation standards and cause manufacturers to loss a substantial amount of INPV. Also, the percent change in INPV at TSL 3 is significantly negative due to the extremely large conversion costs. Manufacturers at this TSL would have a very difficult time in the short term to make the necessary investments to comply with new and amended energy conservation standards prior to when standards went into effect. Also, the long-term profitability of residential conventional oven manufacturers could be seriously jeopardized as some manufacturers would struggle to comply with standards at this TSL.

A high percentage of total shipments will need to be redesigned to meet efficiency levels prescribed at TSL 3. DOE projects that in 2019, only 7 percent of electric standard oven, free-standing shipments; 7 percent of electric standard oven, built-in/slide-in shipments; 12 percent of electric self-clean oven, free-standing shipments; 12 percent of electric self-clean oven, built-in/slide-in shipments; 8 percent of gas standard oven, free-standing shipments; 8 percent of gas standard oven, built-in/slide-in shipments; 13 percent of gas self-clean oven, free-standing shipments; and 13 percent of gas self-clean oven, built-in/slide-in shipments would meet the efficiency levels prescribed at TSL 3.

DOE expects significant conversion costs at TSL 3, which represents max tech. DOE expects product conversion costs to significantly increase from $67.9 million at TSL 2 to $401.5 million at TSL 3. Large increases in product conversion are due to the vast majority of shipments needing extensive redesign as well as a significant increase in testing and recertification for redesigned products. DOE estimates that capital conversion costs will also significantly increase from $42.0 million at TSL 2 to $528.0 million at TSL 3. Capital conversion costs are driven by investments in production equipment to accommodate for forced convection and reduced conduction losses in the electric and gas oven product classes.

At TSL 3, under the preservation of gross margin markup scenario, the shipment weighted-average MPC increases by 12.7 percent relative to the base-case MPC. In this scenario, INPV impacts are significantly negative because the $929.5 million in conversion costs significantly outweighs the modest increase in shipment weighted-average MPC.

Under the preservation of operating profit markup scenario, the 12.7 percent MPC increase is again significantly outweighed by a lower average manufacturer markup of 1.19 (compared to 1.20 used in the base case) and $929.5 million in conversion costs, resulting in significantly negative impacts at TSL 3.

REFERENCES

[1] Securities and Exchange Commission, Annual 10-K Reports, Various Years, Washington DC. <www.sec.gov>.

[2] Standard and Poors Financial Services LLC, Company Credit Ratings, Various Companies, New York, NY. <www2.standardandpoors.com>.

[3] AHAM – AHAM Members. Last Accessed December 2, 2014. <http://www.aham.org/ht/d/Organizations/pid/2344/divisions/Y>

[4] McKinsey & Company, Inc. *Valuation: Measuring and Managing the Value of Companies*, 3rd Edition, Copeland, Koller, Murrin. New York: John Wiley & Sons, 2000.

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 potential standards on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the impacts 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 appendix 15A to this TSD, and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014).[4] For site combustion of natural gas or petroleum fuels, the combustion emissions of CO_2 and NO_X are estimated using emissions intensity factors from a publication of the Environmental Protection Agency (EPA).[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 by multiplying the emissions intensity factor by the energy savings calculated in the national impact analysis (chapter 10). This chapter presents the results of the emissions analysis. The emissions factors used in the calculations are provided in Appendix 13A. For power sector emissions, the factors depend on the sector and end use. The results presented here use factors from the power plant types that supply electricity for cooking in homes.

13.2 AIR QUALITY REGULATIONS AND EMISSIONS IMPACTS

Each annual version of the Annual Energy Outlook (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. [a]

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 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.

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[a] 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.

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 marginal mercury emissions reductions using the reference and side cases published with *AEO 2014*, which incorporate the MATS.

13.3 EMISSIONS IMPACT RESULTS

Table 13.3.1 presents the estimated cumulative emissions reductions for the lifetime of products sold in 2019-2048 for each TSL. Negative values indicate that emissions increase.

Table 13.3.1 Cumulative Emissions Reduction for Potential Standards for Conventional Cooking Products

	TSL		
	1	**2**	**3**
Power Sector and Site Emissions			
CO_2 (million metric tons)	8.98	38.6	68.2
SO_2 (thousand tons)	7.44	29.1	51.8
NO_X (thousand tons)	6.95	32.2	56.7
Hg (tons)	0.023	0.090	0.160
N_2O (thousand tons)	0.126	0.499	0.885
CH_4 (thousand tons)	0.882	3.51	6.22
Upstream Emissions			
CO_2 (million metric tons)	0.524	2.52	4.42
SO_2 (thousand tons)	0.091	0.356	0.632
NO_X (thousand tons)	7.47	36.6	64.2
Hg (tons)	0.000	0.001	0.001
N2O (thousand tons)	0.004	0.018	0.032
CH_4 (thousand tons)	43.6	218	381
Total Emissions			
CO_2 (million metric tons)	9.50	41.1	72.6
SO_2 (thousand tons)	7.53	29.5	52.4
NO_X (thousand tons)	14.4	68.8	121
Hg (tons)	0.023	0.091	0.161
N2O (thousand tons)	0.131	0.517	0.918
CH_4 (thousand tons)	44.4	221	387

Figure 13.3.1 through Figure 13.3.6 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 2019-2048.

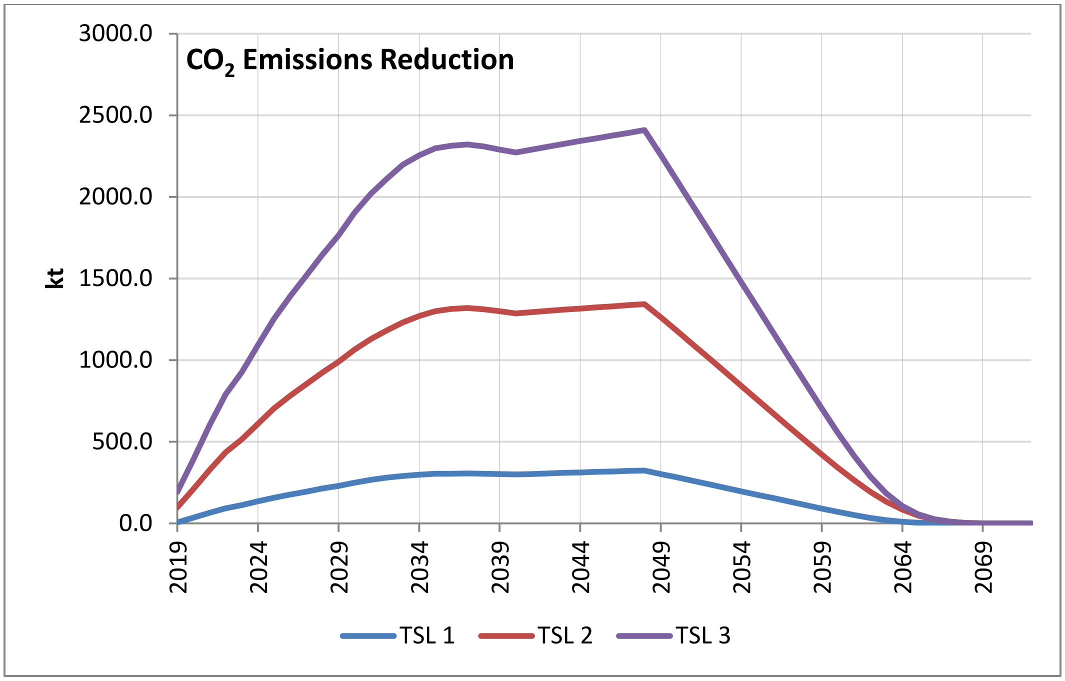

Figure 13.3.1 Conventional Cooking Products: CO_2 Total Emissions Reduction

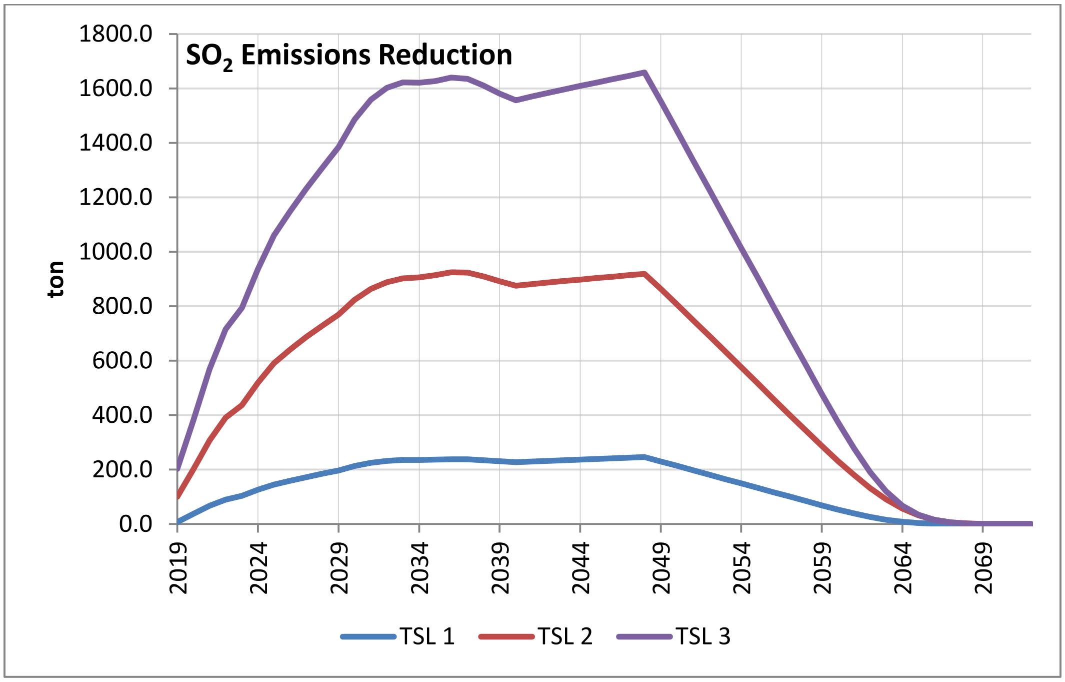

Figure 13.3.2 Conventional Cooking Products: SO_2 Total Emissions Reduction

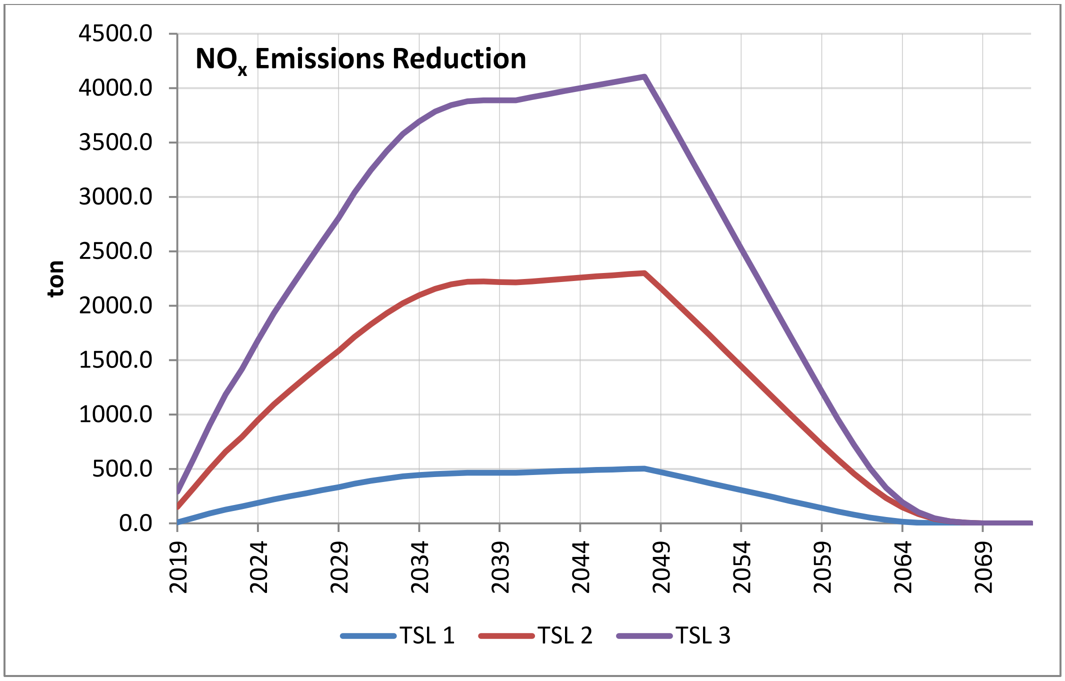

Figure 13.3.3 Conventional Cooking Products: NO_x Total Emissions Reduction

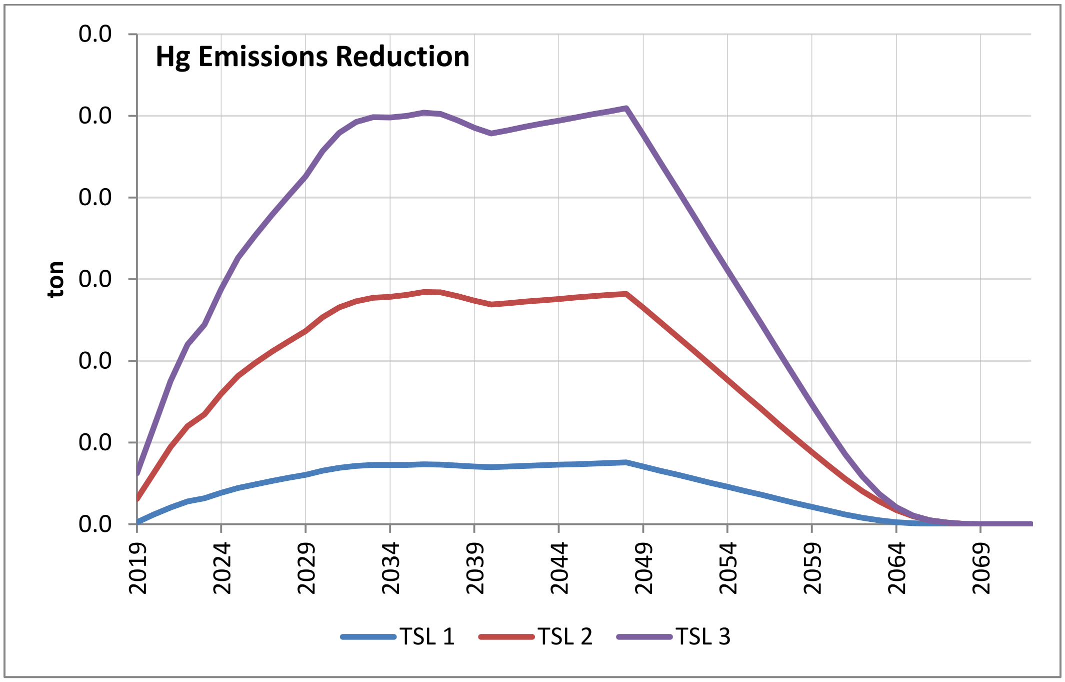

Figure 13.3.4 Conventional Cooking Products: Hg Total Emissions Reduction

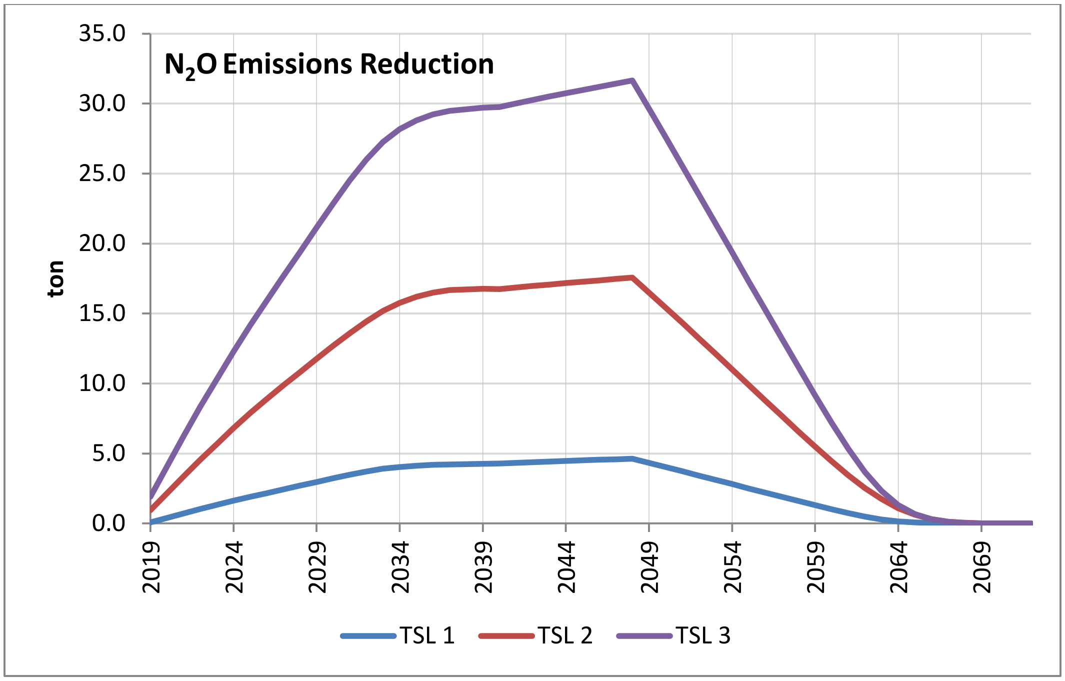

Figure 13.3.5 Conventional Cooking Products: N_2O Total Emissions Reduction

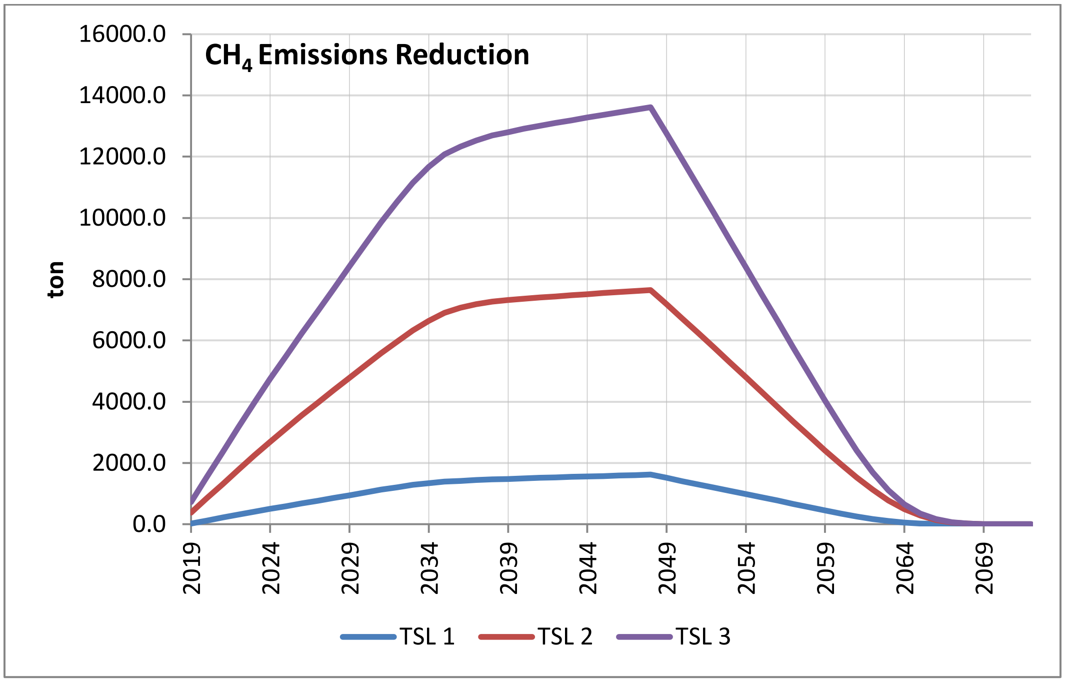

Figure 13.3.6 Conventional Cooking Products: CH_4 Total Emissions Reduction

REFERENCES

1. Energy Information Administration, *Annual Energy Outlook 2014 with Projections to 2040*, June 2013. Washington, DC. <http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf>

2. U.S. Environmental Protection Agency, *Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources*. 1998. http://www.epa.gov/ttn/chief/ap42/index.html

3. Coughlin, K., *Projections of Full-Fuel-Cycle Energy and Emissions Metrics*, 2013. Lawrence Berkeley National Laboratory. Report No. LBNL-6025E.

4. Coughlin, K., *Utility Sector Impacts of Reduced Electricity Demand*, 2014. Lawrence Berkeley National Laboratory. Report No. LBNL-6864E. http://www.osti.gov/scitech/biblio/1165372/

CHAPTER 14. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

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CHAPTER 14. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

14.1 INTRODUCTION

As part of its assessment of the effects of potential energy conservation standards for conventional cooking products, 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 this rulemaking. 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 2014$. For the four SCC values, the values of emissions in 2015 were $12.2, $41.2, $63.4, and $121 per metric ton avoided (values expressed in 2014$). 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 conventional cooking products. 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 the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ precursor reduced by electricity generating units. The estimates were developed by Krewski et al. (2009) and are reported in EPA's Office of Air Quality Planning and Standards report "Technical Support Document: Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors."[5] Table 14.4.1 summarizes the monetized values estimated in 2010$ for NO_X emission reductions in 2016, 2020, 2025 and 2030, at discount rates of 3 percent and 7 percent. DOE applied the GDP price deflator to adjust the values to 2014$. For the two NO_X values, the values of emissions in 2016 were $5562 and $4920 per ton avoided (values expressed in 2014$). DOE further interpolated the values between the intervals, and extrapolated the values after 2030 using the relevant growth rates for 2016–2030. DOE then multiplied the NO_X emissions reduction estimated for each year by the NO_X value for that year under each discount rate. To calculate a present value of the stream of monetary values, DOE discounted the values calculated under each discount rate using the same discount rate that had been used to obtain the NO_X values.

Table 14.4.1 Summary of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ precursor reduced by Electricity Generating Units (2010$)

Year	Discount Rate (%)	
	3	7
2016	5200	4600
2020	5400	4900
2025	5800	5200
2030	6200	5600

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 Conventional Cooking Products

TSL	SCC Case*			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
	Million 2014$			
Primary Energy Emissions				
1	62	288	458	893
2	267	1239	1969	3837
3	473	2194	3485	6794
Upstream Emissions				
1	3.54	16.6	26.5	51.5
2	17.1	80	127	248
3	30	141	224	436
Full-Fuel-Cycle Emissions				
1	65.5	305	484	944
2	284	1319	2096	4085
3	503	2335	3709	7230

* For each of the four cases, the corresponding global SCC value for emissions in 2015 is $12.2, $41.2, $63.4, and $121 per metric ton (2014$).

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 Conventional Cooking Products

TSL	SCC Case*			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
	Million 2014$			
Primary Energy Emissions				
1	4.3 to 14.3	20.2 to 66.3	32.1 to 105.3	62.5 to 205.3
2	18.7 to 61.3	86.7 to 285.0	137.8 to 452.8	268.6 to 882.4
3	33.1 to 108.8	153.6 to 504.6	244.0 to 801.7	475.6 to 1562.7
Upstream Emissions				
1	0.2 to 0.8	1.2 to 3.8	1.9 to 6.1	3.6 to 11.9
2	1.2 to 3.9	5.6 to 18.4	8.9 to 29.3	17.4 to 57.0
3	2.1 to 6.9	9.8 to 32.3	15.7 to 51.5	30.5 to 100.2
Full-Fuel-Cycle Emissions				
1	4.6 to 15.1	21.3 to 70.1	33.9 to 111.4	66.1 to 217.2
2	19.9 to 65.3	92.3 to 303.4	146.7 to 482.1	285.9 to 939.5
3	35.2 to 115.7	163.4 to 537.0	259.6 to 853.1	506.1 to 1662.9

* For each of the four cases, the corresponding global SCC value for emissions in 2015 is $12.2, $41.2, $63.4, and $121 per metric ton (2014$).

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 3-percent and 7-percent discount rates.

Table 14.5.3 Estimates of Present Value of NO_X Emissions Reduction under TSLs for Conventional Cooking Products

TSL	3% discount rate	7% discount rate
	Million 2014$	
Primary Energy Emissions		
1	24.6	9.71
2	114	45.2
3	201	80.1
Upstream Emissions		
1	25.9	9.74
2	127	48.4
3	223	85.1
Full-Fuel-Cycle Emissions		
1	50.4	19.4
2	241	93.5
3	424	165

* The corresponding NO_X values for emissions in 2016 are $5562 and $4920 per ton (2014$).

REFERENCES

1. *Presidential Documents--Executive Order 12866--Regulatory Planning and Review*, October 4, 1993. <http://www.archives.gov/federal-register/executive-orders/pdf/12866.pdf>

2. National Research Council, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*, 2010. National Academies Press. Washington, DC. <http://www.nap.edu/catalog.php?record_id=12794>

3. Interagency Working Group on Social Cost of Carbon, *Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866*, February, February 2010. United States Government. Washington, D.C. <http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf>

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

5. U.S. Environmental Protection Agency (EPA), *Technical Support Document - Estimating the Benefit per Ton of Reducing* $PM_{2.5}$ *Precursors from 17 Sectors*, 2013. Office of Air and Radiation, Office of Air Quality Planning and Standards, Research Triangle Park, NC. < http://www2.epa.gov/sites/production/files/2014-10/documents/sourceapportionmentbpttsd.pdf>

CHAPTER 15. UTILITY IMPACT ANALYSIS

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15.1 INTRODUCTION

In the utility impact analysis, the U.S. Department of Energy (DOE) analyzes 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 the 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.

The methodology is presented in appendix 15A. The methodology is described in more detail in K. Coughlin, "Utility Sector Impacts of Reduced Electricity Demand."[3]

This chapter presents the results for conventional cooking products.

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

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[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]

energy conservation standards. DOE represents these marginal impacts using time series of *impact factors.*

The impact factors are calculated based on output from NEMS for the *AEO 2014*. 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 types and technologies may change. Technology changes lead to a change in the proportion of fuel consumption to electricity generated (referred to as the heat rate). 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 defined impact factors describing the change in emissions, installed capacity, and fuel consumption per unit reduction of site electricity demand. The impact factors vary by sector and end-use, as well as by year. DOE multiplied the impact factors by the stream of site energy savings calculated in the NIA (chapter 10) to produce estimates of the utility impacts. The emissions impact factors are presented in appendix 15A, and the marginal heat rates in appendix 10B. For conventional cooking products DOE used the impact factors for cooking in homes.

15.3 UTILITY IMPACT RESULTS

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. The changes have been calculated based on the impact factors for capacity presented in appendix 15A. Units are megawatts of capacity per gigawatt-hour of site electricity use (MW/GWh).[b] Note that a negative number means an increase in capacity under a TSL.

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[b] These units are identical to GW/TWh.

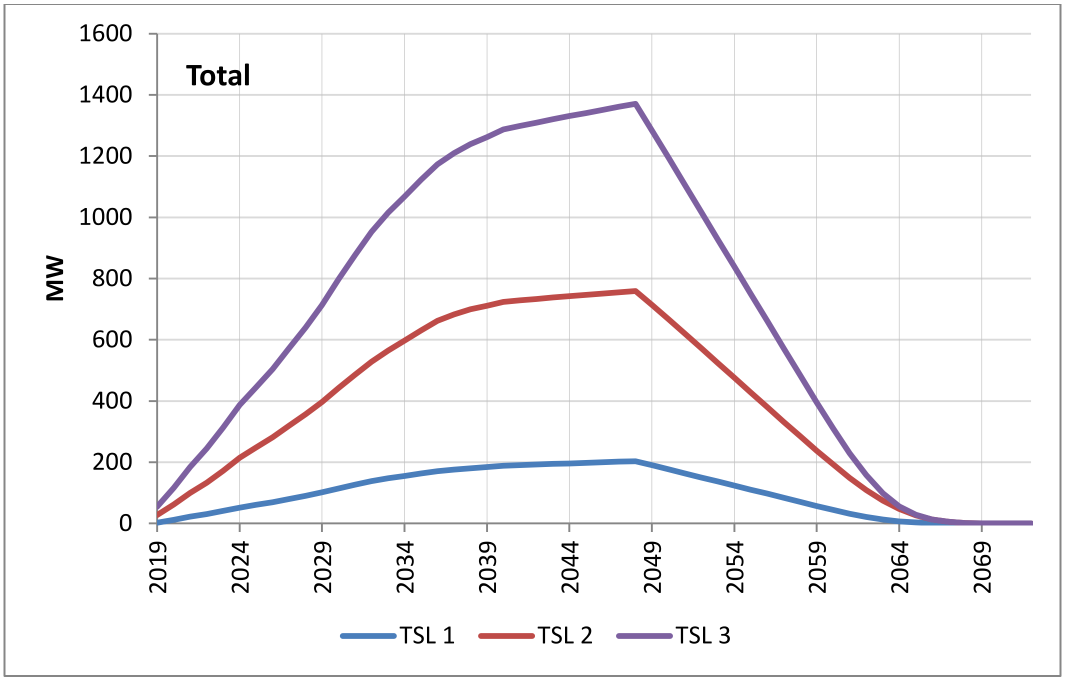

Figure 15.3.1 Conventional Cooking Products: Total Electric Capacity Reduction

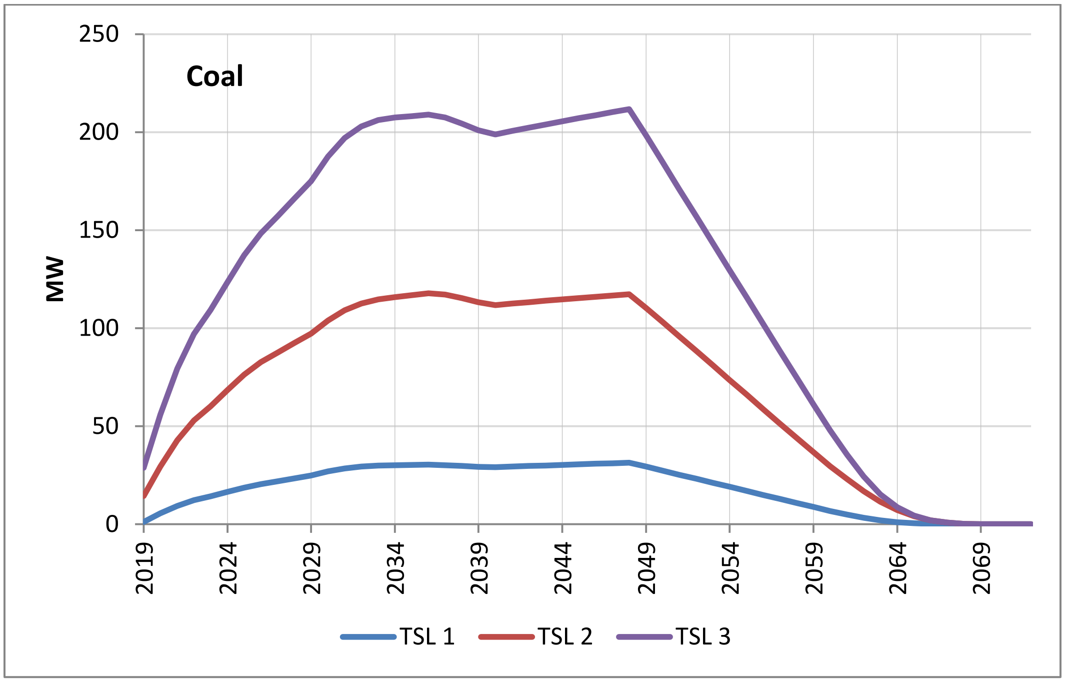

Figure 15.3.2 Conventional Cooking Products: Coal Capacity Reduction

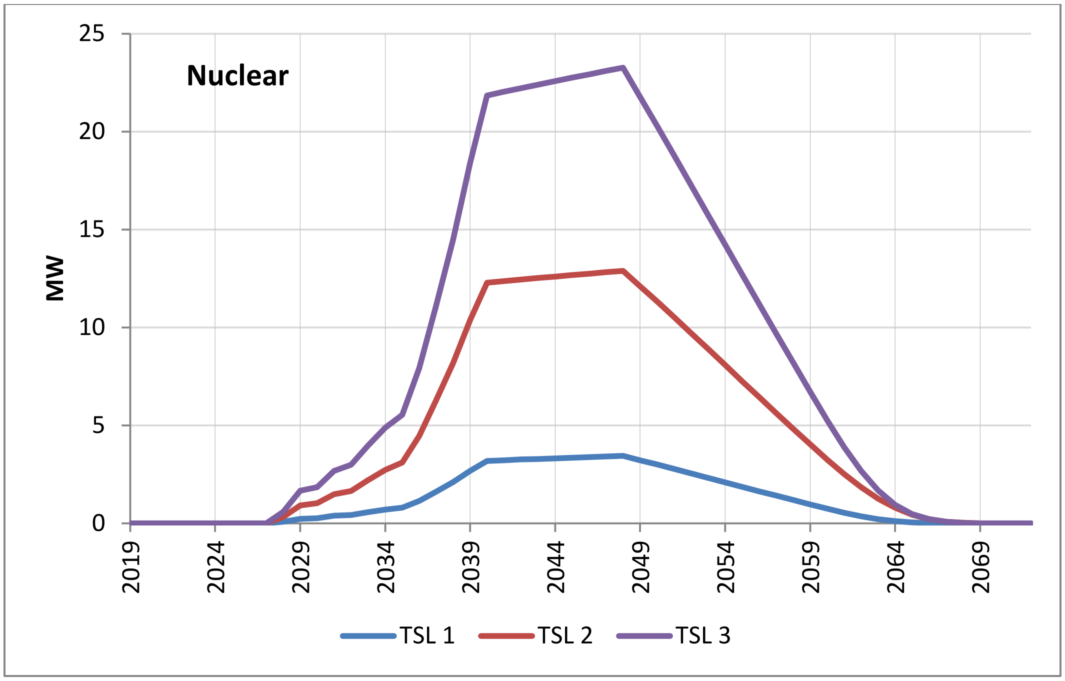

Figure 15.3.3 Conventional Cooking Products: Nuclear Capacity Reduction

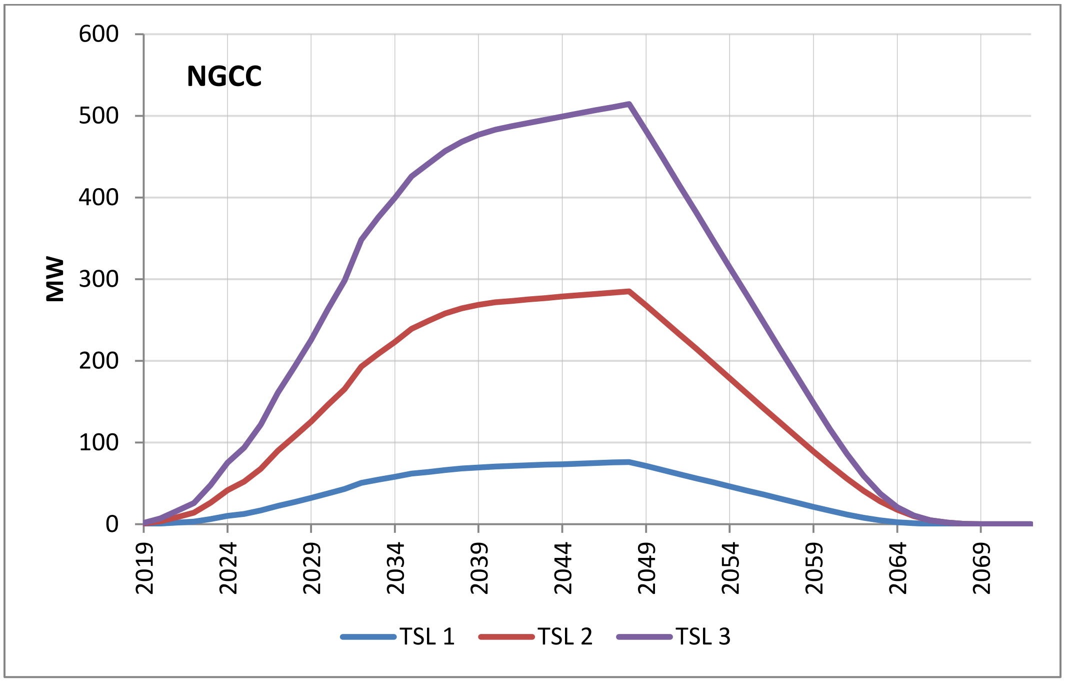

Figure 15.3.4 Conventional Cooking Products: Gas Combined Cycle Capacity Reduction

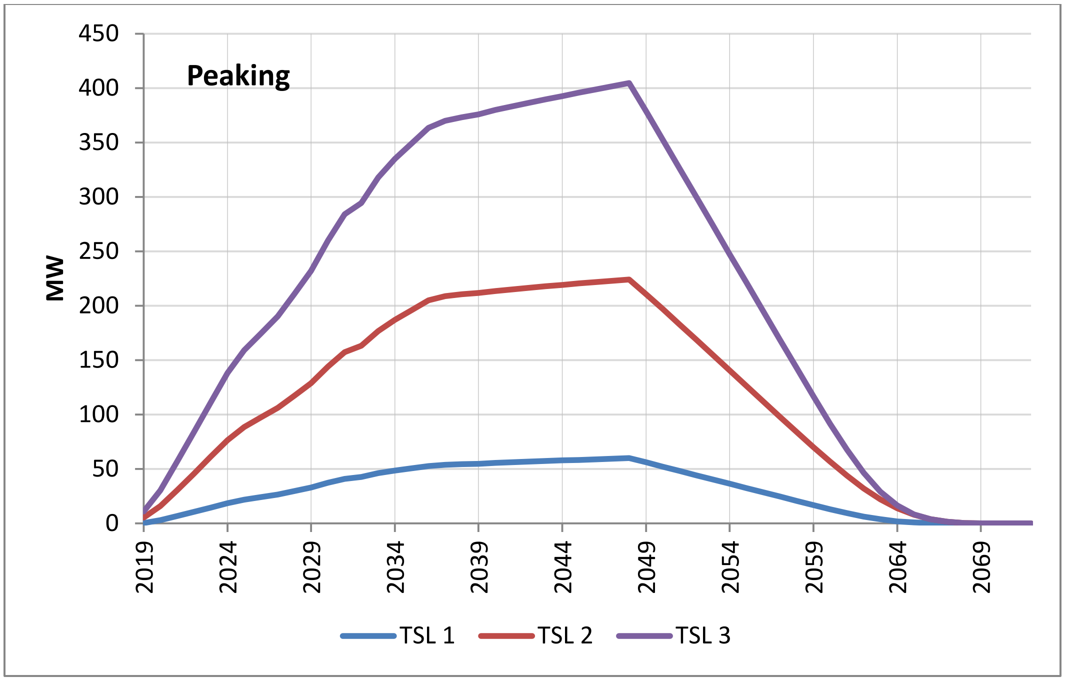

Figure 15.3.5 Conventional Cooking Products: Peaking Capacity Reduction

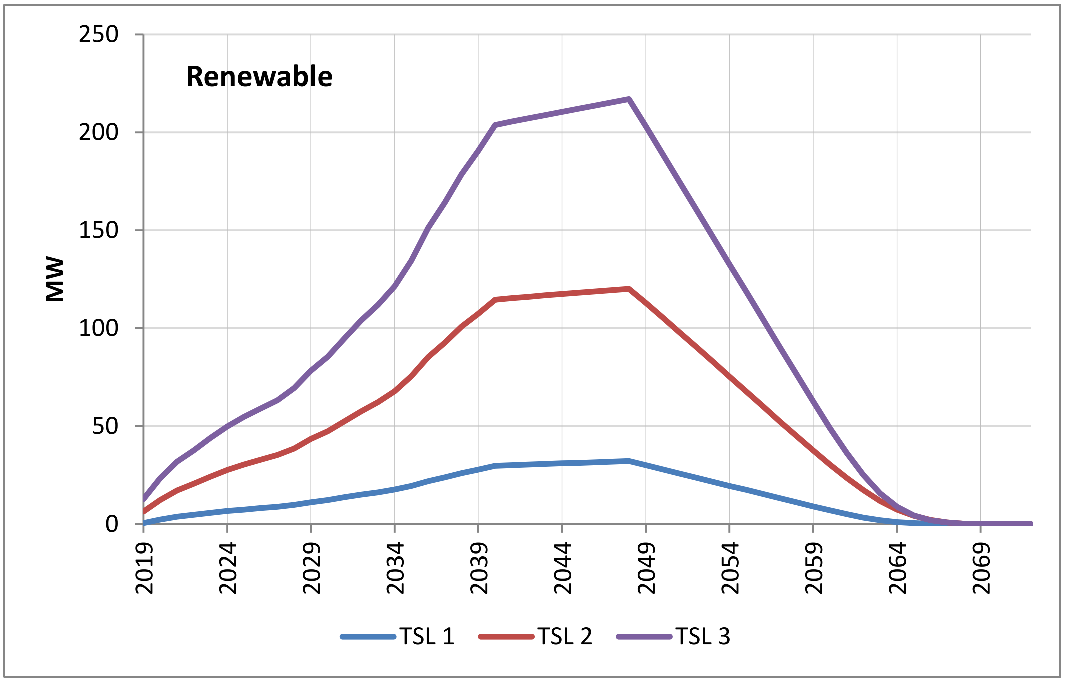

Figure 15.3.6 Conventional Cooking Products: Renewables Capacity Reduction

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. The change by fuel type has been calculated based on factors calculated as described in appendix 15A.

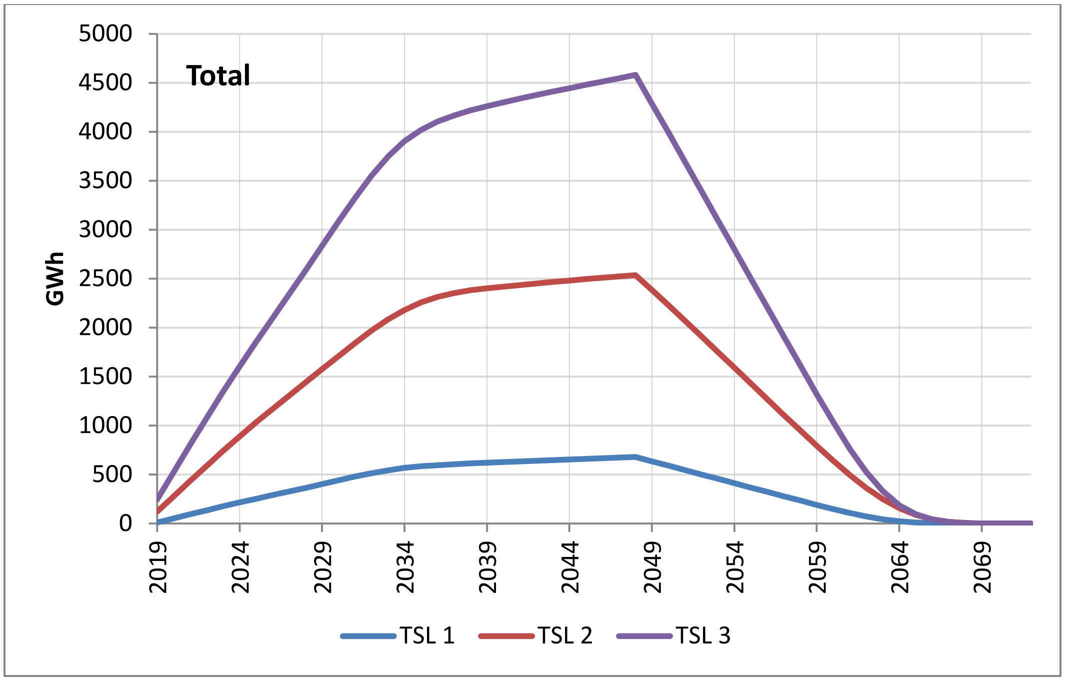

Figure 15.3.7 Conventional Cooking Products: Total Generation Reduction

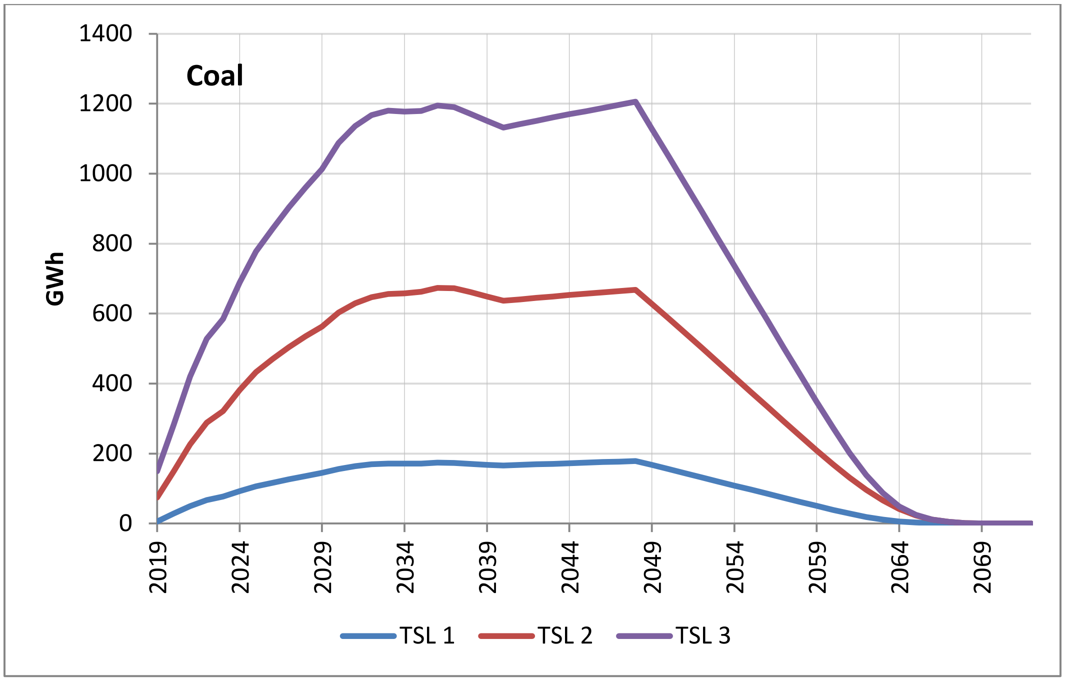

Figure 15.3.8 Conventional Cooking Products: Coal Generation Reduction

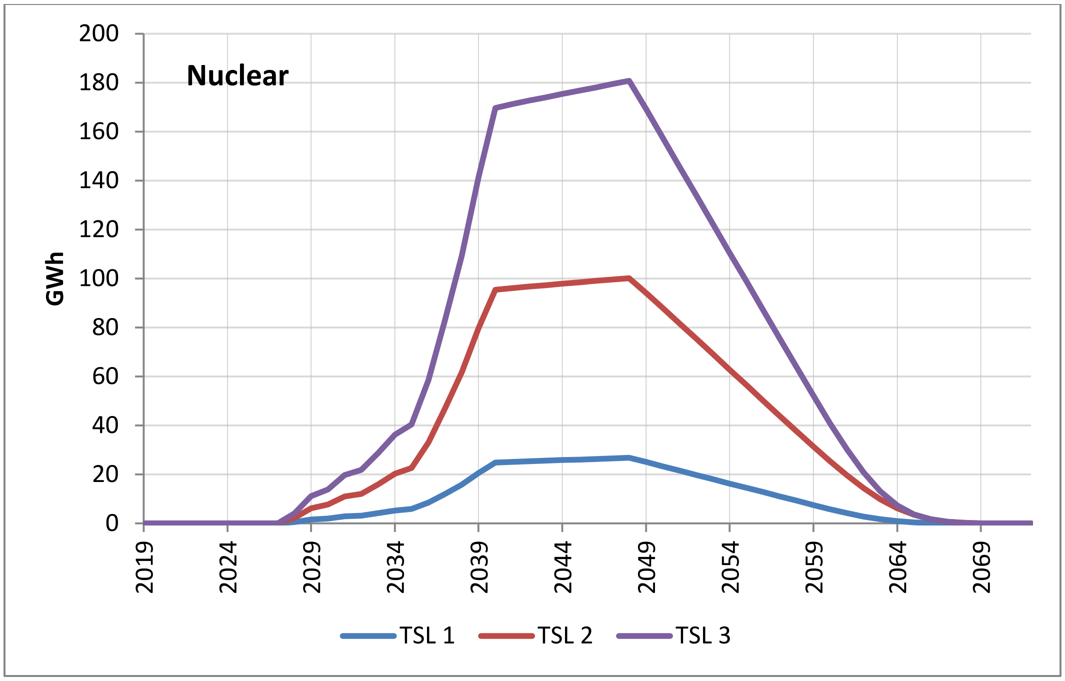

Figure 15.3.9 Conventional Cooking Products: Nuclear Generation Reduction

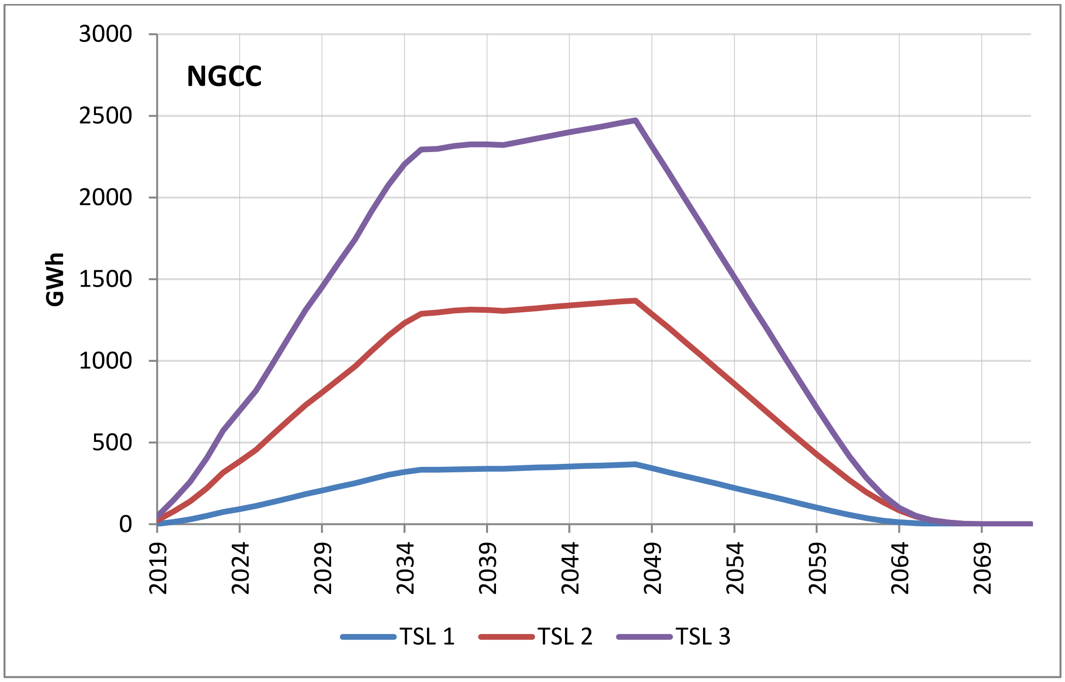

Figure 15.3.10 Conventional Cooking Products: Gas Combined Cycle Generation Reduction

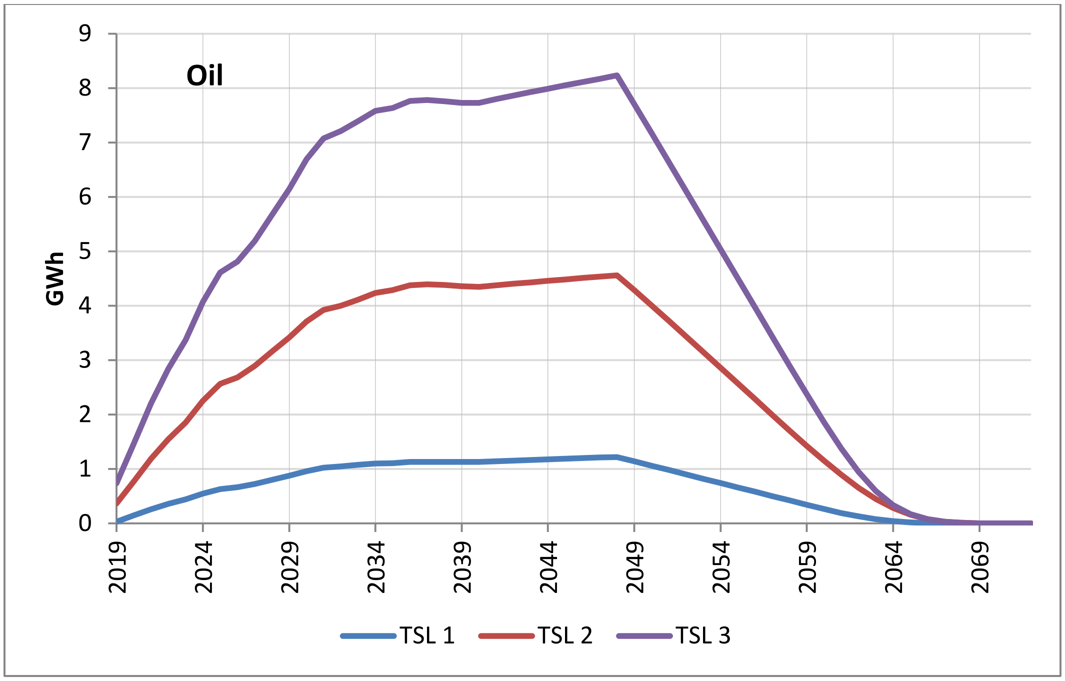

Figure 15.3.11 Conventional Cooking Products: Oil Generation Reduction

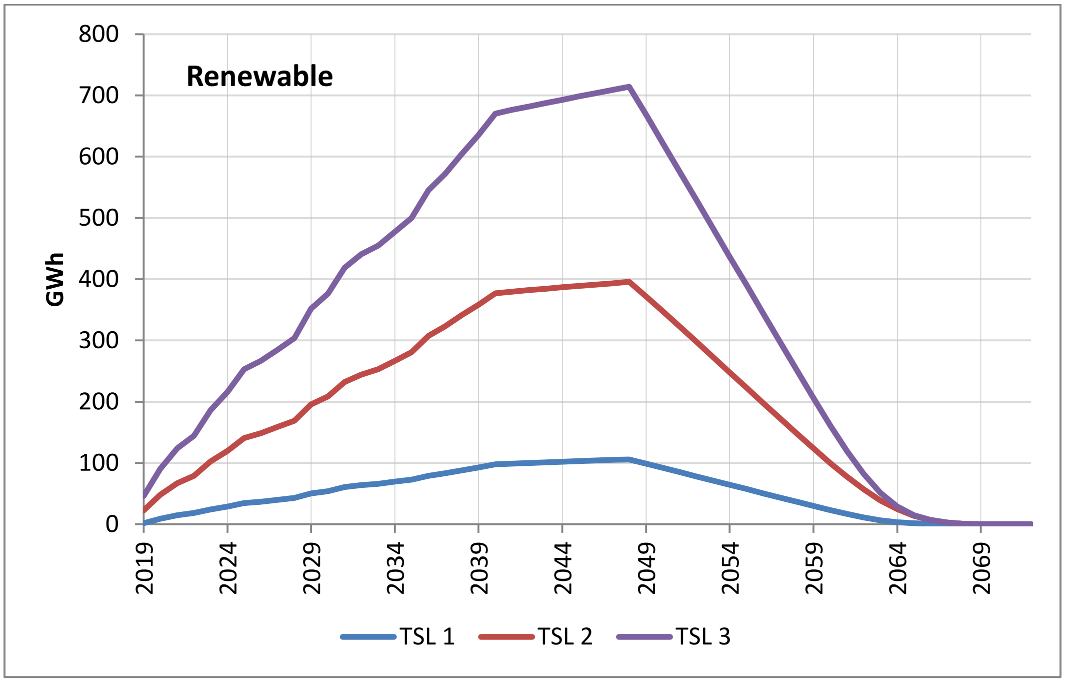

Figure 15.3.12 Conventional Cooking Products: Renewables Generation Reduction

15.3.3 Results Summary

Table 15.3.1 presents a summary of the utility impact results for conventional cooking products.

Table 15.3.1 Conventional Cooking Products: Summary of Utility Impact Results

	TSL		
	1	**2**	**3**
Installed Capacity Reduction (MW)			
2020	11.6	61.6	117
2025	60.7	248	445
2030	115	443	798
2035	163	631	1123
2040	188	724	1287
Electricity Generation Reduction (GWh)			
2020	52.2	278	269
2025	253	1031	1001
2030	443	1710	1661
2035	584	2257	2191
2040	629	2418	2347

REFERENCES

1 U.S. Department of Energy-Energy Information Administration. *National Energy Modeling System: An Overview, 2009*. Report No. DOE/EIA-0581 (2009). (Last Accessed August 10, 2014.) http://www.eia.gov/oiaf/aeo/overview/

2 U.S. Department of Energy-Energy Information Administration. *Annual Energy Outlook 2014 with Projections to 2040*. Report No. DOE/EIA-03832014. Washington, D.C. http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf

3 Coughlin, K. *Utility Sector Impacts of Reduced Electricity Demand*, 2014. Lawrence Berkeley National Laboratory. Report No. LBNL-6864E. http://www.osti.gov/scitech/biblio/1165372/

CHAPTER 16. EMPLOYMENT IMPACT ANALYSIS

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16.1 INTRODUCTION

DOE's employment impact analysis for cooking products 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 ovens. Job increases or decreases reported in this chapter are separate from the direct cooking product manufacturing 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 the ImSET 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 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. Since input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. DOE therefore includes 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 relationships between different sectors of the economy and the spending flows among them. Different sectors have different levels of labor intensity, thus 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 national 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.

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. Third, utility sector investment funds are released for use in other sectors of the economy. When consumers use less energy, utilities experience relative reductions in demand which leads to reductions in utility sector investment and employment.

DOE also notes that the employment impacts estimated with ImSET for the entire economy differ from the employment impacts in the cooking 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 cooking product standards 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. DOE presents the summary impact.

Conceptually, one can consider the impact of the rule in its first year on three aggregate sectors, the cooking product manufacturing sector, the energy generation sector, and the general consumer good 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 cooking 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 cooking 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 (*e.g.* 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 2019, rounded to the nearest hundred jobs. Approximately 24% of electric cooking products and 28% of gas cooking products are domestically produced, with the remainder imported. The net employment impact estimate is sensitive to assumptions regarding the return to the U.S. economy of money spent on imported cooking products. The two scenarios bounding the ranges presented in Table 16.4.1 represent situations in which none of the money spent on imported cooking products returns to the U.S. economy and all of the money spent on imported cooking products returns to the U.S. economy. The U.S. trade deficit in recent years suggests that between 50% and 75% of the money spent on imported cooking products is likely to return, with employment impacts falling within the ranges presented below.

Table 16.4.1 Net National Short-term Change in Employment (1000s of Jobs)

Trial Standard Level	2019	2024
TSL 1	0.0	0.0 to0.1
TSL 2	-0.3 to 0.3	0.4 to 2.1
TSL 3	-5.8 to -1.4	-4.0 to -0.1

For context, the Office of Management of Budget currently assumes that the unemployment rate may decline to 5.3% in 2017.[5] The unemployment rate in 2019 is projected to be 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 electricity to decline over time and demand for other goods to increase. Since the electricity generation sector is 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 electricity generation towards consumer goods. Note that in long-run equilibrium there is no net effect on total employment since 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. The ImSET model projections, assuming no price or wage effects until 2024, are included in the second column of Table 16.4.1.

REFERENCES

1 Scott, M., JM Roop, RW Schultz, DM Anderson, KA Cort, The Impact of DOE Building Technology Energy Efficiency Programs on U.S. Employment, Income, and Investment. *Energy Economics*, 2008. 30(5): pp. 2283-2301

2 Roop, J. M., M. J. Scott, and R. W. Schultz, *ImSET: Impact of Sector Energy Technologies*, 2005. Pacific Northwest National Laboratory. Richland, WA. Report No. PNNL- 15273.

3 Scott, M. J., D. J. Hostick, and D. B. Belzer, *ImBuild: Impact of Building Energy Efficiency Programs*, April, 1998. Pacific Northwest National Laboratory. Richland, WA. Report No. PNNL-11884. Prepared for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

4 Minnesota IMPLAN Group Inc., *IMPLAN Professional: User's Guide, Analysis Guide, Data Guide*, 1997. Stillwater, MN.

5 Office of Management and Budget, *Fiscal Year 2013 Mid-Session Review: Budget of the U.S. Government*, Washington, DC. < <http://www.whitehouse.gov/sites/default/files/omb/budget/fy2013/assets/13msr.pdf>

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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 levels as the ones in the proposed trial standard levels for the conventional cooking products 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 standards for five of the eight product classes of conventional cooking products covered by this rulemaking.[a]

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 in Table 17.1.1 (excluding the alternative of "No New Regulatory Action"). Section 17.4 presents the results of the policy alternatives.

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[a] For this RIA, DOE did not evaluate the following product classes, as their cumulative shipments represented together less than 2% of the total shipments of conventional cooking products: Electric Standard Ovens Built-In/Slide-In, Gas Standard Ovens – Built-In/Slide-In, Gas Self-Clean Ovens – Built-In/Slide-In.

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 conventional cooking products. 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 meets the efficiency levels corresponding to each 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 levels set for each TSL. The shipments of equipment for any given year reflect a distribution of efficiency levels. DOE assumed, for each TSL, that new energy efficiency standards would affect 100 percent of the shipments of products that did not meet the TSL target levels in the base case,[b] 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 conventional cooking products 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.

- National Energy Savings (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 (2019-2048).
- Net Present Value (NPV), represents the value of net monetary savings in 2015, expressed in 2014$, from equipment purchased during the 30-year analysis period starting in the effective date of the policy (2019-2048). DOE calculated the NPV as the difference between the present values of installed equipment cost and operating

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[b] The base case for the NIA is a market-weighted average energy efficiency calculated from units at several efficiency levels.

expenditures in the base case and the present values of those costs in each policy case. DOE calculated operating expenses (including energy costs) for the life of the product.

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' response 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 conventional cooking products 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 standards (the target level), according to the minimum energy efficiency set for each 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 17.1.2 shows the energy efficiencies from the technologies stipulated for conventional cooking products for each TSL.

Table 17.1.2 Energy Efficiency by TSL (IAEC)

	TSL 1	**TSL 2**	TSL 3
Electric Standard Ovens – Freestanding	284.6	**259.2**	207.3
Electric Self-Clean Ovens – Freestanding	345.1	**345.1**	278.1
Electric Self-Clean Ovens – Built-In/Slide-In	351.0	**351.0**	282.9
Gas Standard Ovens – Freestanding	2,118.2	**1,414.8**	1,347.0
Gas Self-Clean Ovens – Freestanding	1,848.2	**1,668.7**	1,591.0

DOE assumed that the effects of non-regulatory policies would last from the effective date of standards—2019—through the end of the analysis period, which is 2048.

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 therefore not additive, and 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 conventional cooking products.

17.3 NON-REGULATORY POLICY ASSUMPTIONS

The following subsections describe DOE's analysis of the impacts of the five non-regulatory policy alternatives to the standards proposed for conventional cooking products. (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 more efficient 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 conventional cooking products 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 equipment. This policy provides a consumer rebate for purchasing conventional cooking products that operate at the same efficiency levels as stipulated in each 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.,[c] 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

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[c] XENERGY is now owned by KEMA, Inc. (www.kema.com)

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 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 conventional cooking products by determining, for each 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 conventional cooking products. It gathered data on utility or agency rebates throughout the nation for this equipment, and used this data to calibrate the customized penetration curves it developed for each product class covered by this RIA so they can best reflect the market barrier levels that consumer rebates for conventional cooking products would face. Section 17.3.2.2 shows the resulting interpolated curves used in the analysis.

17.3.2.2 Analysis

DOE estimated the effect of increasing the B/C ratio of conventional cooking products via a rebate that would pay for all of the increased installed cost of units that meet the target efficiency levels compared to units meeting the baseline efficiency level.[d] To inform its estimate of an appropriate rebate amount, DOE performed a thorough nationwide search for existing rebate programs for conventional cooking products. DOE could not find rebate programs for this product so it estimated a rebate value for each product class covered in this RIA by assuming that a rebate would cover all increased installed costs. DOE applied this in the calculation of the B/C ratio of conventional cooking products under the effect of consumer rebates. (Appendix

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[d] The baseline technology is defined in the engineering analysis, Chapter 5, as the technology that represents the basic characteristics of conventional cooking products. A baseline unit typically is one that just meets current Federal energy conservation standards and provides basic consumer utility.

17A, identifies the rebate programs and details the methodology DOE used to estimate a market representative rebate amount.) DOE assumed that rebates would remain in effect at the same level throughout the forecast period (2019-2048).

DOE first calculated the B/C ratio of a cooking product without a rebate using the difference in total installed costs (C) and lifetime operating cost savings[e] (B) between a unit meeting the target level and a 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 each TSL on the B/C ratio of conventional cooking products shipped in the first year of the analysis period.

Table 17.3.1 Benefit/Cost Ratios Without and With Rebates

	TSL 1	**TSL 2**	TSL 3
Electric Standard Ovens – Freestanding			
B/C Ratio Without Rebate	11.2	**2.4**	0.6
Rebate Amount (2014$)	1.13	**10.85**	96.76
B/C Ratio With Rebate	infinite	**infinite**	infinite
Estimated Market Barriers	High	**Mod**	Low
Electric Self-Clean Ovens – Freestanding			
B/C Ratio Without Rebate	11.2	**11.2**	0.5
Rebate Amount (2014$)	1.13	**1.13**	85.13
B/C Ratio With Rebate	infinite	**infinite**	infinite
Estimated Market Barriers	High	**High**	No-Low
Electric Self-Clean Ovens – Built-In/Slide-In			
B/C Ratio Without Rebate	11.2	**11.2**	0.5
Rebate Amount (2014$)	1.13	**1.13**	85.13
B/C Ratio With Rebate	infinite	**infinite**	infinite
Estimated Market Barriers	High	**High**	No-Low
Gas Standard Ovens – Freestanding			
B/C Ratio Without Rebate	0.0	**13.6**	4.3
Rebate Amount (2014$)	n/a	**16.96**	54.19
B/C Ratio With Rebate	n/a	**infinite**	infinite
Estimated Market Barriers	n/a	**High**	Mod-High
Gas Self-Clean Ovens – Freestanding			
B/C Ratio Without Rebate	12.1	**21.3**	4.7
Rebate Amount (2014$)	1.12	**9.96**	45.17
B/C Ratio With Rebate	infinite	**infinite**	infinite
Estimated Market Barriers	High	**High**	Mod-High

* No-Low: No-to-Low market barriers; Mod: Moderate market barriers; Low-Mod: Low-to-Moderate market barriers; Mod-High: Moderate-to-High market barriers; xHigh: Extremely-High market barriers; Hg-xHg: High-to-Extremely-High market barriers.

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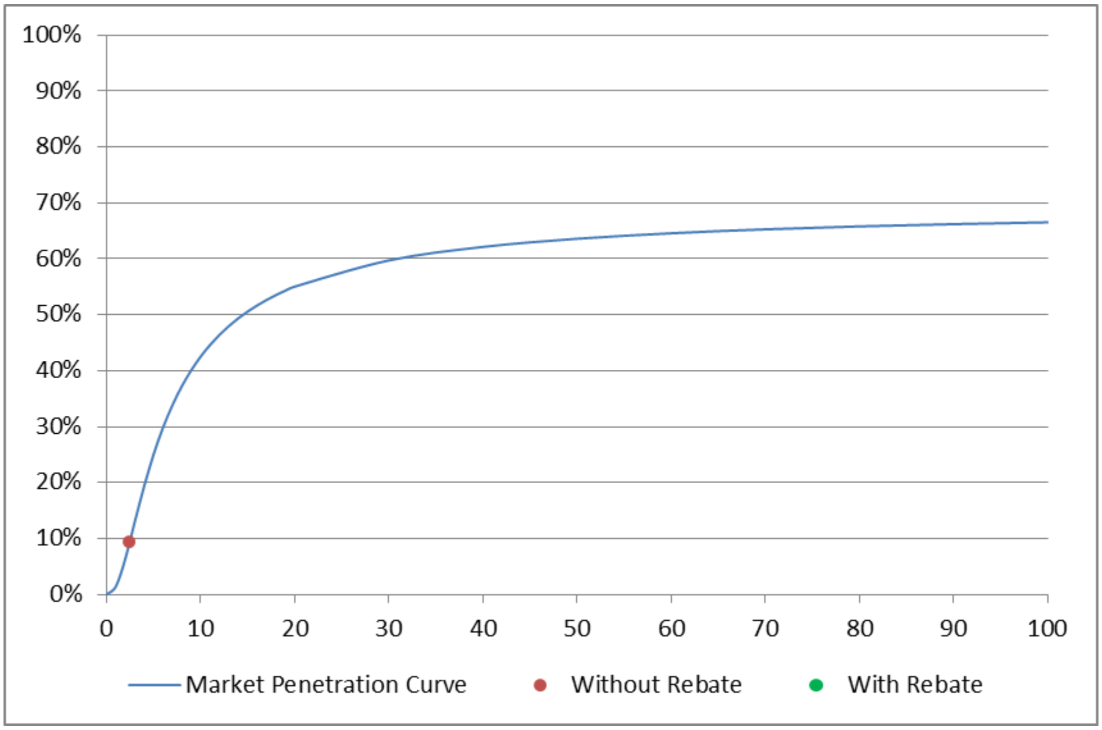
[e] The cash flow of the operating cost savings is discounted to the purchase year using a 7 percent discount rate.

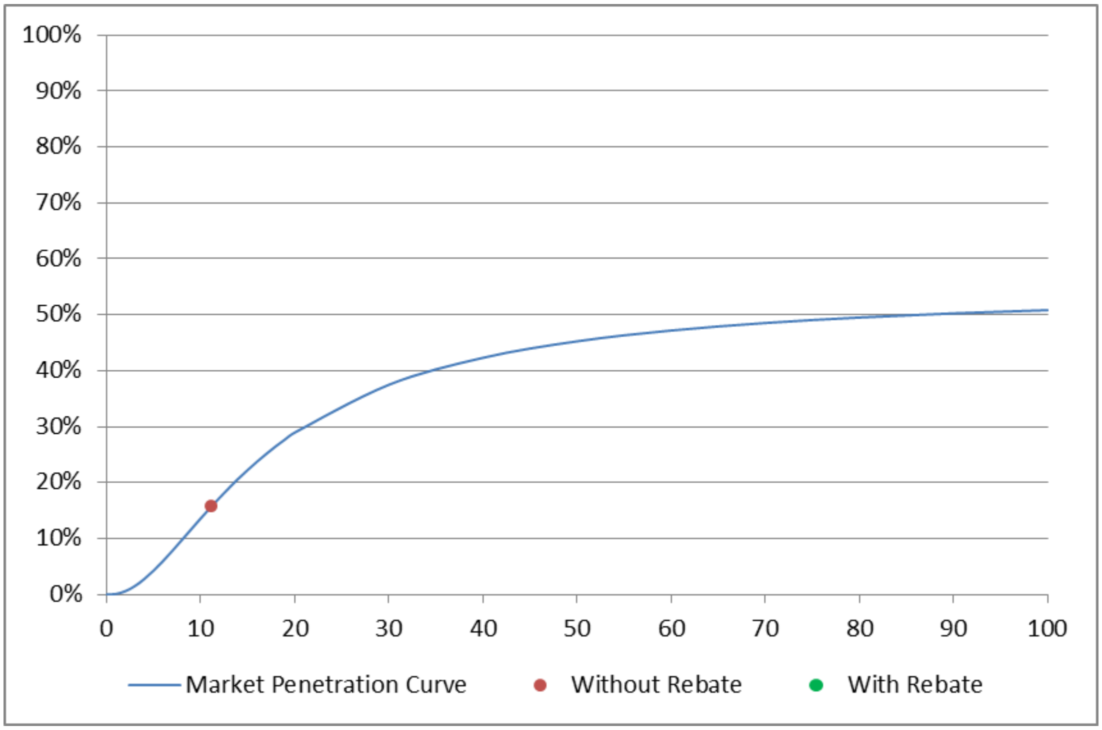
DOE used the B/C ratio along with the customized penetration curves shown in Figure 17.3.1 to estimate the percentage of consumers who would purchase conventional cooking products that meet the target levels both with and without a rebate incentive. The estimated levels of market barriers corresponding to the penetration curves DOE calculated to represent the market behavior for conventional cooking products at the proposed TSL are indicated (highlighted) in Table 17.3.1. DOE assumed the estimated market barriers would remain the same over the whole analysis period. In Figure 17.3.1, due to DOE's assumption that rebates would offset incremental costs in full, which would eventually lead all product classes to present infinite benefit-cost ratio with rebates, none of the charts include the point corresponding to that benefit-cost ratio. As for Gas Standard Ovens – Freestanding and Gas Self-Clean Ovens – Freestanding, the base case market penetration is below the expected penetration of a product with same benefit-cost ratio in a market with extremely-high level of market barriers.

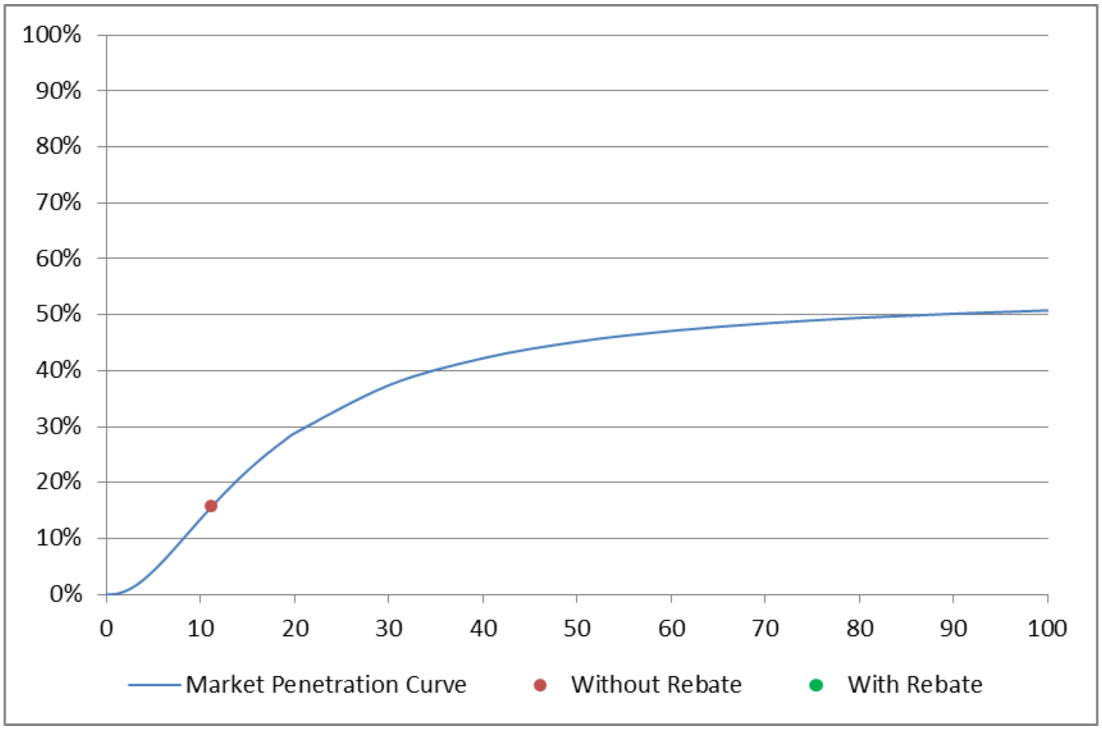
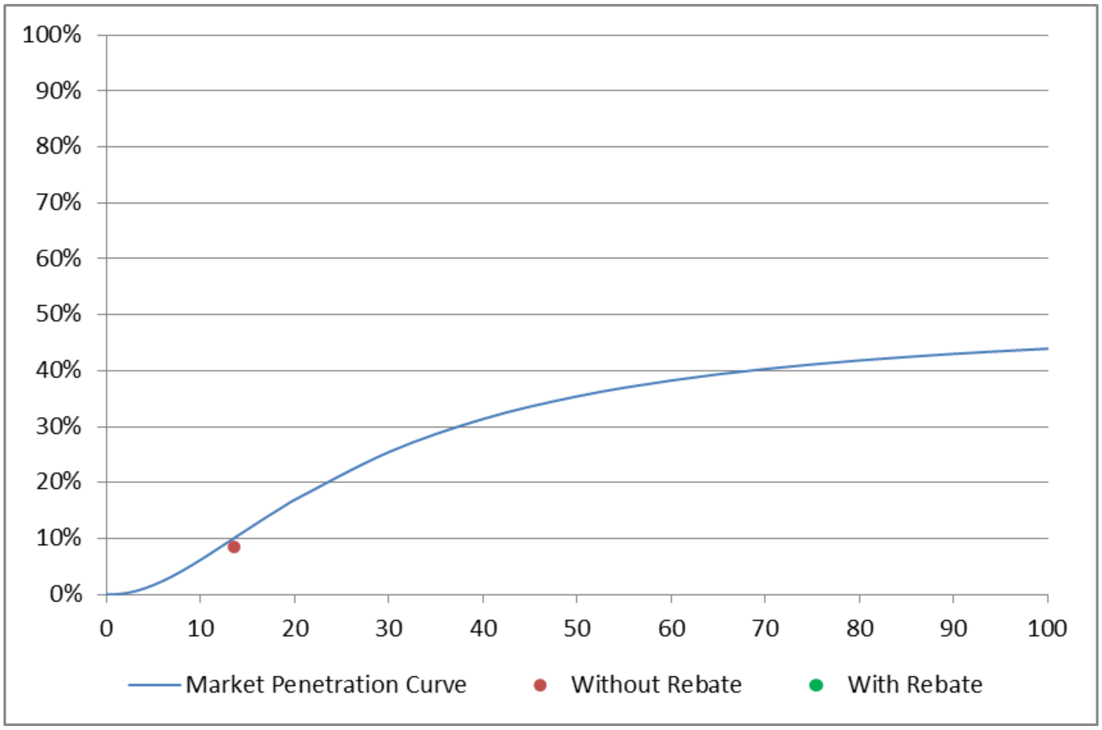
TSL #2

Electric Standard Ovens – Freestanding



Electric Self-Clean Ovens – Freestanding



Electric Self-Clean Ovens – Built-In/Slide-In	
Gas Standard Ovens – Freestanding	

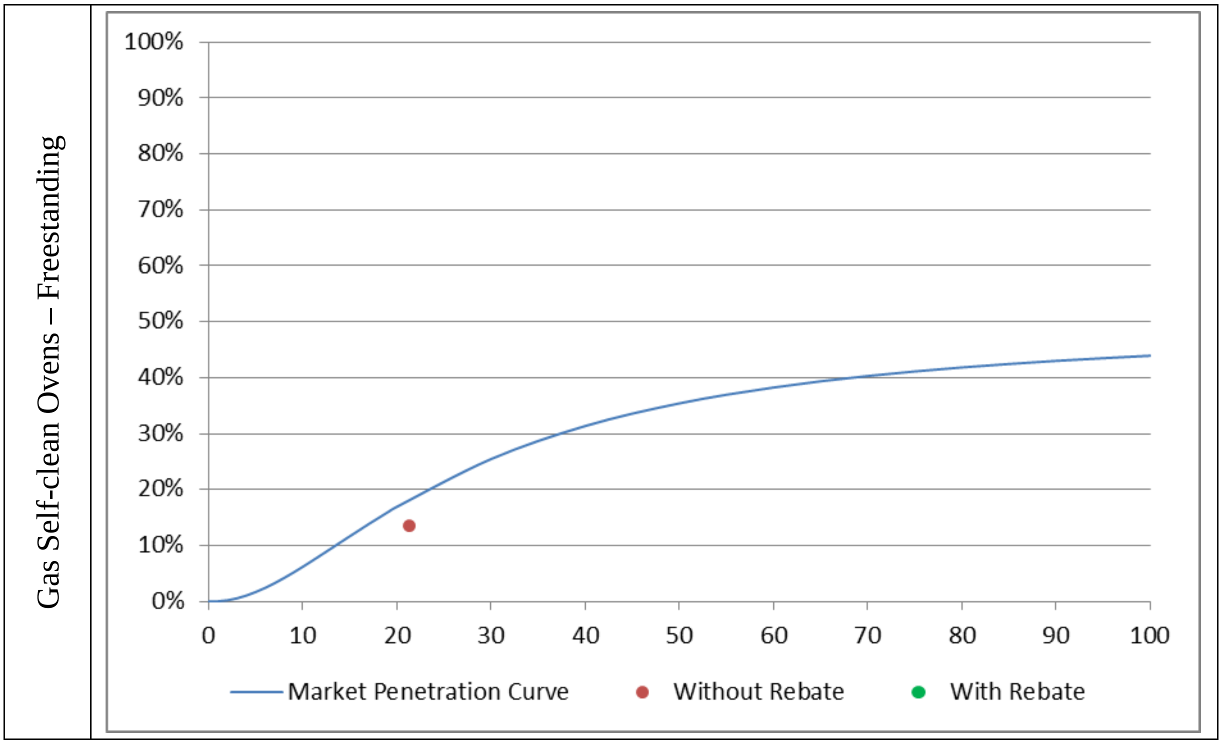


Figure 17.3.1 Market Penetration Curves for Conventional Cooking Products

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 conventional cooking products regarding the market penetration of products in 2019 that meet the target levels at each TSL given a consumer rebate.

Table 17.3.2 Market Penetrations in 2019 Attributable to Consumer Rebates

	TSL 1	**TSL 2**	TSL 3
Electric Standard Ovens – Freestanding			
Base-Case Market Share	9.7%	**9.3%**	6.8%
Policy Case Market Share	50.0%	**68.9%**	77.5%
Increased Market Share	40.4%	**59.6%**	70.7%
Electric Self-Clean Ovens – Freestanding			
Base-Case Market Share	15.8%	**15.8%**	11.7%
Policy Case Market Share	54.8%	**54.8%**	81.5%
Increased Market Share	39.0%	**39.0%**	69.9%
Electric Self-Clean Ovens – Built-In/Slide-In			
Base-Case Market Share	15.8%	**15.8%**	11.7%
Policy Case Market Share	54.8%	**54.8%**	81.5%
Increased Market Share	39.0%	**39.0%**	69.9%
Gas Standard Ovens – Freestanding			
Base-Case Market Share	42.5%	**8.3%**	7.7%
Policy Case Market Share	42.5%	**50.0%**	61.0%
Increased Market Share	0.0%	**41.7%**	53.3%
Gas Self-Clean Ovens – Freestanding			
Base-Case Market Share	13.6%	**13.4%**	12.6%
Policy Case Market Share	52.7%	**50.0%**	62.8%
Increased Market Share	39.1%	**36.6%**	50.1%

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 for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of consumer rebates for conventional cooking products. Because energy prices increase and equipment prices decrease over time, the B/C ratios increase over the forecast period. Since the B/C ratios grow in higher proportions than the base case market shares do, the estimated market barriers increase over time and eventually reduce the market penetration of more efficient technologies over the forecast 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 conventional cooking products, 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 conventional cooking products 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 increase in 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 customized penetration curves it developed for conventional cooking products (See Figure 17.3.1).

Table 17.3.3 summarizes DOE's assumptions for conventional cooking products regarding the market penetration of products in 2019 that meet the target levels at each TSL given a consumer tax credit.

Table 17.3.3 Market Penetrations in 2019 Attributable to Consumer Tax Credits

	TSL 1	**TSL 2**	TSL 3
Electric Standard Ovens – Freestanding			
Base-Case Market Share	9.7%	**9.3%**	6.8%
Policy Case Market Share	33.9%	**45.1%**	49.2%
Increased Market Share	24.2%	**35.8%**	42.4%
Electric Self-Clean Ovens – Freestanding			
Base-Case Market Share	15.8%	**15.8%**	11.7%
Policy Case Market Share	39.2%	**39.2%**	53.6%
Increased Market Share	23.4%	**23.4%**	41.9%
Electric Self-clean Ovens – Built-In/Slide-In			
Base-Case Market Share	15.8%	**15.8%**	11.7%
Policy Case Market Share	39.2%	**39.2%**	53.6%
Increased Market Share	23.4%	**23.4%**	41.9%
Gas Standard Ovens – Freestanding			
Base-Case Market Share	42.5%	**8.3%**	7.7%
Policy Case Market Share	42.5%	**33.3%**	39.7%
Increased Market Share	0.0%	**25.0%**	32.0%
Gas Self-Clean Ovens – Freestanding			
Base-Case Market Share	13.6%	**13.4%**	12.6%
Policy Case Market Share	37.1%	**35.4%**	42.7%
Increased Market Share	23.5%	**22.0%**	30.1%

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 for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of consumer tax credits for conventional cooking products that meet the efficiency levels for the proposed TSL. Because the market penetration for consumer tax credits is proportional to the market penetration DOE calculated for consumer rebates, the former follows a similar trend over the forecast 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 conventional cooking products that meet the target efficiency levels at each 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.[f] Because the direct price effect is approximately equivalent to the announcement effect,[10] DOE estimated that a manufacturer tax credit would induce half the

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[f] 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.

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 increase in penetration rates predicted for the rebate policy to estimate the effects of a manufacturer tax credit policy. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the customized penetration curves it developed for conventional cooking products. (See Figure 17.3.1).

Table 17.3.4 summarizes DOE's assumptions for conventional cooking products regarding the market penetration of products in 2019 that meet the target levels at each TSL given a manufacturer tax credit.

Table 17.3.4 Market Penetrations in 2019 Attributable to Manufacturer Tax Credits

	TSL 1	**TSL 2**	TSL 3
Electric Standard Ovens – Freestanding			
Base-Case Market Share	9.7%	**9.3%**	6.8%
Policy Case Market Share	21.8%	**27.2%**	28.0%
Increased Market Share	12.1%	**17.9%**	21.2%
Electric Self-Clean Ovens – Freestanding			
Base-Case Market Share	15.8%	**15.8%**	11.7%
Policy Case Market Share	27.5%	**27.5%**	32.6%
Increased Market Share	11.7%	**11.7%**	21.0%
Electric Self-Clean Ovens – Built-In/Slide-In			
Base-Case Market Share	15.8%	**15.8%**	11.7%
Policy Case Market Share	27.5%	**27.5%**	32.6%
Increased Market Share	11.7%	**11.7%**	21.0%
Gas Standard Ovens – Freestanding			
Base-Case Market Share	42.5%	**8.3%**	7.7%
Policy Case Market Share	42.5%	**20.8%**	23.7%
Increased Market Share	0.0%	**12.5%**	16.0%
Gas Self-Clean Ovens – Freestanding			
Base-Case Market Share	13.6%	**13.4%**	12.6%
Policy Case Market Share	25.3%	**24.4%**	27.7%
Increased Market Share	11.7%	**11.0%**	15.0%

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 for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of manufacturer tax credits for conventional cooking products. Because the market penetration for manufacturer tax credits is proportional to the market penetration DOE calculated for consumer rebates, the former follows a similar trend over the forecast period as the latter.

17.3.5 Voluntary Energy Efficiency Targets

DOE assumed that voluntary energy efficiency targets would lead manufacturers of conventional cooking products to gradually stop producing units that operate below the efficiency levels set for each 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 conventional cooking products, DOE observed that the level of market barriers for more efficient conventional cooking products are in the range of low- to high levels 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 conventional cooking products 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 conventional cooking products.[g] 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.

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[g] 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.

Table 17.3.5 Market Barrier Changes Attributable to Voluntary Energy Efficiency Targets (TSL #2)

	Base Case	Voluntary Energy Efficiency Targets
Electric Standard Ovens – Freestanding	Moderate	Low
Electric Self-Clean Ovens – Freestanding	High	Moderate-High
Electric Self-Clean Ovens – Built-In/Slide-In	High	Moderate-High
Gas Standard Ovens – Freestanding	High	Moderate-High
Gas Self-clean Ovens – Freestanding	High	Moderate-High

Table 17.3.6 summarizes DOE's assumptions for conventional cooking products regarding the market penetration of products in 2019 that meet the target levels at each TSL given voluntary energy efficiency targets. Table 17.3.7 expands on Table 17.3.6 to include, for the proposed TSL, DOE's assumptions regarding the market penetration of units in selected years.

Table 17.3.6 Market Penetrations in 2019 Attributable to Voluntary Energy Efficiency Targets

	TSL 1	**TSL 2**	TSL 3
Electric Standard Ovens – Freestanding			
Base-Case Market Share	9.7%	**9.3%**	6.8%
Policy Case Market Share	11.2%	**12.9%**	7.8%
Increased Market Share	1.5%	**3.5%**	1.0%
Electric Self-Clean Ovens – Freestanding			
Base-Case Market Share	15.8%	**15.8%**	11.7%
Policy Case Market Share	16.6%	**16.6%**	14.3%
Increased Market Share	0.9%	**0.9%**	2.7%
Electric Self-Clean Ovens – Built-In/Slide-In			
Base-Case Market Share	15.8%	**15.8%**	11.7%
Policy Case Market Share	16.7%	**16.7%**	14.4%
Increased Market Share	0.9%	**0.9%**	2.7%
Gas Standard Ovens – Freestanding			
Base-Case Market Share	42.5%	**8.3%**	7.7%
Policy Case Market Share	42.5%	**12.3%**	9.2%
Increased Market Share	0.0%	**4.0%**	1.6%
Gas Self-Clean Ovens – Freestanding			
Base-Case Market Share	13.6%	**13.4%**	12.6%
Policy Case Market Share	15.0%	**21.2%**	14.0%
Increased Market Share	1.4%	**7.7%**	1.4%

Table 17.3.7 Market Penetrations in Selected Years Attributable to Voluntary Energy Efficiency Targets for TSL 2

	2019	2028	2048
Electric Standard Ovens – Freestanding			
Base-Case Market Share	9.3%	9.3%	9.2%
Policy Case Market Share	12.9%	43.9%	49.7%
Increased Market Share	3.5%	34.6%	40.4%
Electric Self-Clean Ovens – Freestanding			
Base-Case Market Share	15.8%	15.6%	15.4%
Policy Case Market Share	16.6%	27.1%	33.7%
Increased Market Share	0.9%	11.5%	18.3%
Electric Self-Clean Ovens – Built-In/Slide-In			
Base-Case Market Share	15.8%	15.6%	15.4%
Policy Case Market Share	16.7%	27.3%	33.9%
Increased Market Share	0.9%	11.6%	18.5%
Gas Standard Ovens – Freestanding			
Base-Case Market Share	8.3%	8.3%	8.3%
Policy Case Market Share	12.3%	31.7%	37.1%
Increased Market Share	4.0%	23.4%	28.9%
Gas Self-Clean Ovens – Freestanding			
Base-Case Market Share	13.4%	13.4%	13.4%
Policy Case Market Share	21.2%	41.5%	45.0%
Increased Market Share	7.7%	28.1%	31.6%

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 for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of voluntary energy efficiency targets for conventional cooking products that meet the efficiency levels for the proposed TSL. Because of the decrease in the market barriers level over the first 10 years of the analysis period, the market penetration of more efficient conventional cooking products significantly increases over that period. For the remaining 20 years of the forecast period the increase in market penetration keeps growing because, even though the market barriers level remains constant (at 2028 level), the increase in energy prices and decrease in equipment price lead to increasing B/C ratios and eventually to higher market penetrations.

17.3.6 Bulk Government Purchases

Bulk government purchases can lead to Federal, State, and local governments purchasing large quantities of products that meet a certain, target efficiency level. Combining the market demands of multiple public sectors 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.

Most of the previous bulk government purchase (procurement) initiatives at the Federal, State, and municipal levels have not tracked data on numbers of purchases or degree of compliance with procurement specifications. In many cases, procurement programs are decentralized, being part of larger State or regional initiatives. DOE based its assumptions regarding the effects of this policy on studies the Federal Energy Management Program (FEMP) performed regarding the savings potential of its procurement specifications for appliances and other products. FEMP, however, does not track purchasing data, because of the complex range of purchasing systems, large number of vendors, and so on. States, counties, and municipalities have demonstrated increasing interest and activity in “green purchasing." Although many of the programs target office equipment, the growing infrastructure for developing and applying efficient purchasing specifications indicates that bulk government purchase programs are feasible.[23, 24]

DOE assumed that government agencies would administer bulk purchasing programs for conventional cooking products. At the federal level, this type of program could lead to FEMP procurement guidelines for conventional cooking products, which would refer to the target levels of the proposed TSL as the minimum efficiency levels of conventional cooking products to be purchased by federal government agencies. DOE reviewed its own previous research on the potential for market transformation through bulk government purchases. Its major study analyzed several scenarios based on the assumption that 20 percent of Federal equipment purchases in 2000 already incorporated energy efficiency requirements based on FEMP guidelines. One scenario in the DOE report showed energy efficient purchasing ramping up during 10 years from 20 percent to 80 percent of all Federal purchases.[25] Based on this study, DOE estimated that a bulk government purchase program instituted within a 10-year period would result in at least 80 percent of government-purchased conventional cooking products meeting the target efficiency level.

DOE assumed that bulk government purchases would affect a subset of housing units for which government agencies purchased or influenced the purchase of conventional cooking products. This subset would consist primarily of public housing and housing on military bases. According to the 2009 Residential Energy Consumption Survey (RECS 2009), the percentage of all U.S. households that are housing units in public housing authority ranges – depending on the product class – from 4.2 percent to 4.8 percent (see Table 17.3.8).[26] DOE therefore estimated that those percentages of the U.S. housing units constitute, for each product class, the population to which this policy would apply.

Table 17.3.8 Percentage of U.S. Households in Public Housing Authority

Electric Standard Ovens – Freestanding	4.2%
Electric Self-Clean Ovens – Freestanding	4.2%
Electric Self-Clean Ovens – Built-In/Slide-In	4.2%
Gas Standard Ovens – Freestanding	4.8%
Gas Self-Clean Ovens – Freestanding	4.8%

DOE estimated that starting in 2019, each year of a bulk government purchase policy would result in an increasing percent of shipments of government-purchased units beyond the base case that would meet the target efficiency level. DOE estimated that within 10 years (by

2028 bulk government purchasing programs would result in 80 percent[h] of the market for conventional cooking products used in publicly owned housing meeting the target level. DOE modeled the bulk government purchase program assuming that the market share for conventional cooking products achieved in 2028 would be at least maintained throughout the rest of the forecast period.

Table 17.3.9 summarizes DOE's assumptions for conventional cooking products regarding the market penetration of products in 2019 that meet the target levels at each TSL given bulk government purchases.

Table 17.3.9 Market Penetrations in 2019 Attributable to Bulk Government Purchases

	TSL 1	**TSL 2**	TSL 3
Electric Standard Ovens – Freestanding			
Base-Case Market Share	9.7%	**9.3%**	6.8%
Policy Case Market Share	9.8%	**9.6%**	7.1%
Increased Market Share	0.2%	**0.3%**	0.3%
Electric Self-clean Ovens – Freestanding			
Base-Case Market Share	15.8%	**15.8%**	11.7%
Policy Case Market Share	16.0%	**16.0%**	12.0%
Increased Market Share	0.2%	**0.2%**	0.3%
Electric Self-clean Ovens – Built-In/Slide-In			
Base-Case Market Share	15.8%	**15.8%**	11.7%
Policy Case Market Share	16.0%	**16.0%**	12.0%
Increased Market Share	0.2%	**0.2%**	0.3%
Gas Standard Ovens – Freestanding			
Base-Case Market Share	42.5%	**8.3%**	7.7%
Policy Case Market Share	42.5%	**8.6%**	8.0%
Increased Market Share	0.0%	**0.3%**	0.3%
Gas Self-Clean Ovens – Freestanding			
Base-Case Market Share	13.6%	**13.4%**	12.6%
Policy Case Market Share	13.8%	**13.7%**	13.0%
Increased Market Share	0.2%	**0.3%**	0.3%

The increased market shares attributable to bulk government purchases shown in Table 17.3.9 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of bulk government purchases for conventional cooking products. Market penetrations increase over the first 10 years of the forecast period, and steady for the rest of the analysis period.

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[h] The 80 percent target to be achieved within 10 years may not be reached, as it is constrained by the market share below the target level in the base case scenario.

17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

Figure 17.4.1 through Figure 17.4.5 show the effects of each non-regulatory policy alternative on the market penetration of more efficient conventional cooking products. Relative to the base case, the alternative policy cases 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.

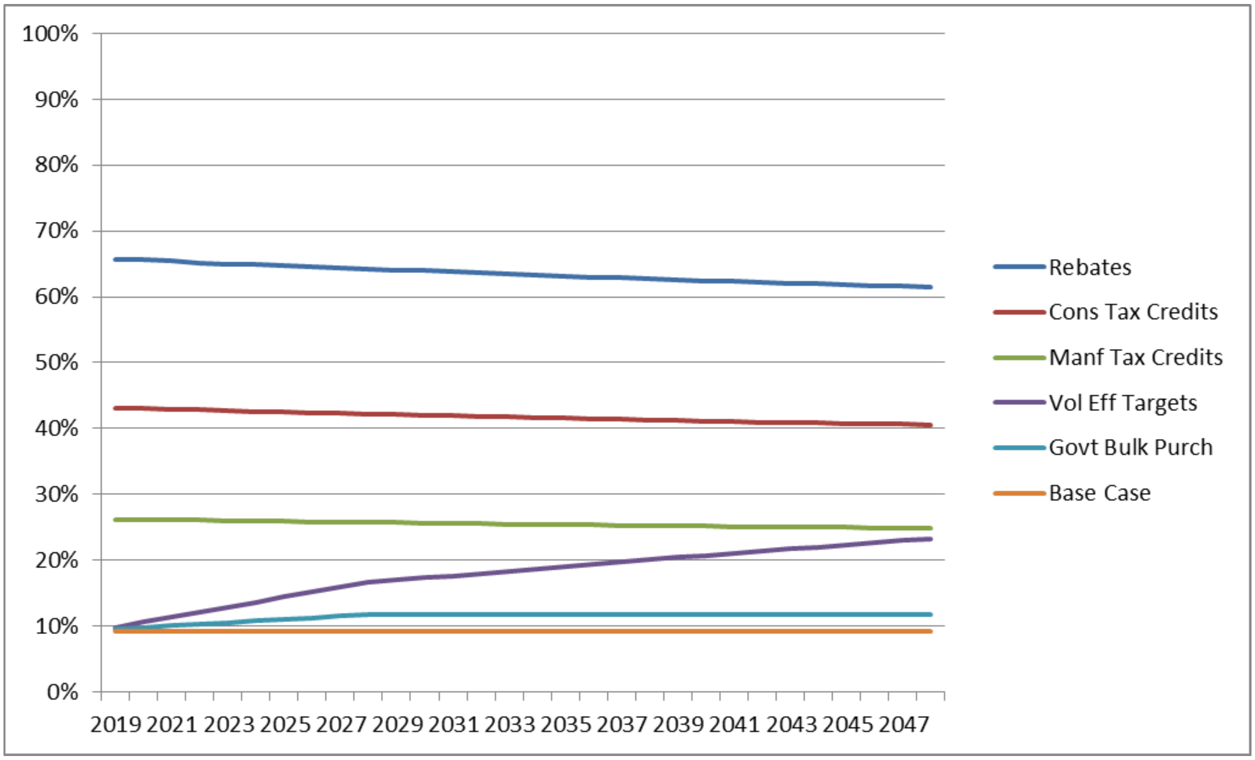

Figure 17.4.1 Market Penetration of Efficient Electric Standard Ovens – Freestanding (TSL 2)

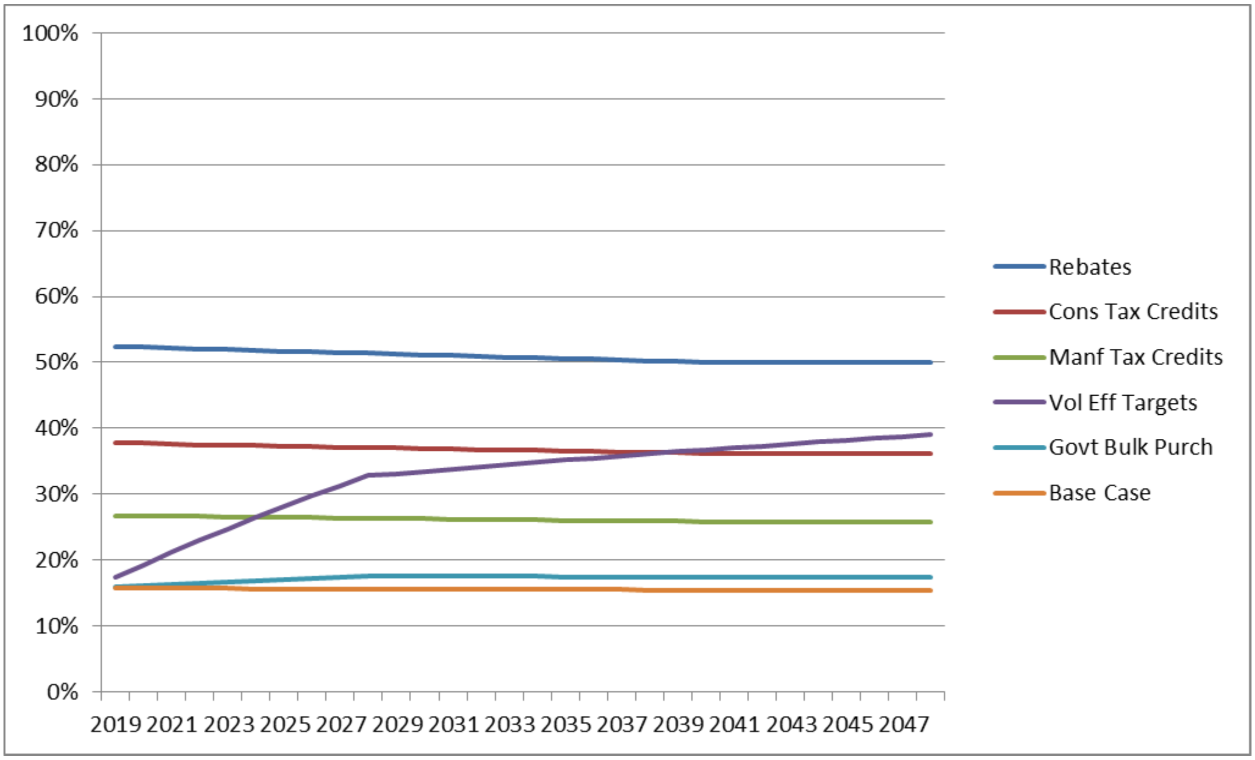

Figure 17.4.2 Market Penetration of Efficient Electric Self-clean Ovens – Freestanding (TSL 2)

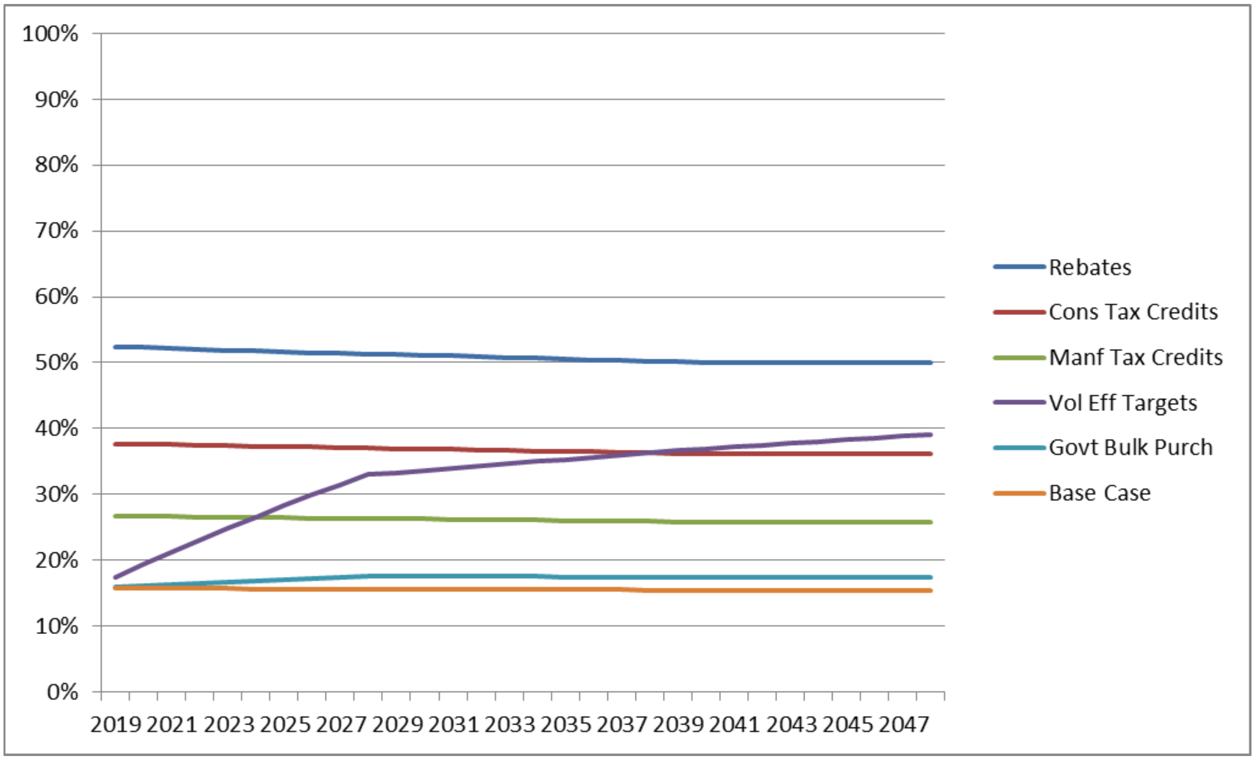

Figure 17.4.3 Market Penetration of Efficient Electric Self-Clean Ovens – Built-In/Slide-In (TSL 2)

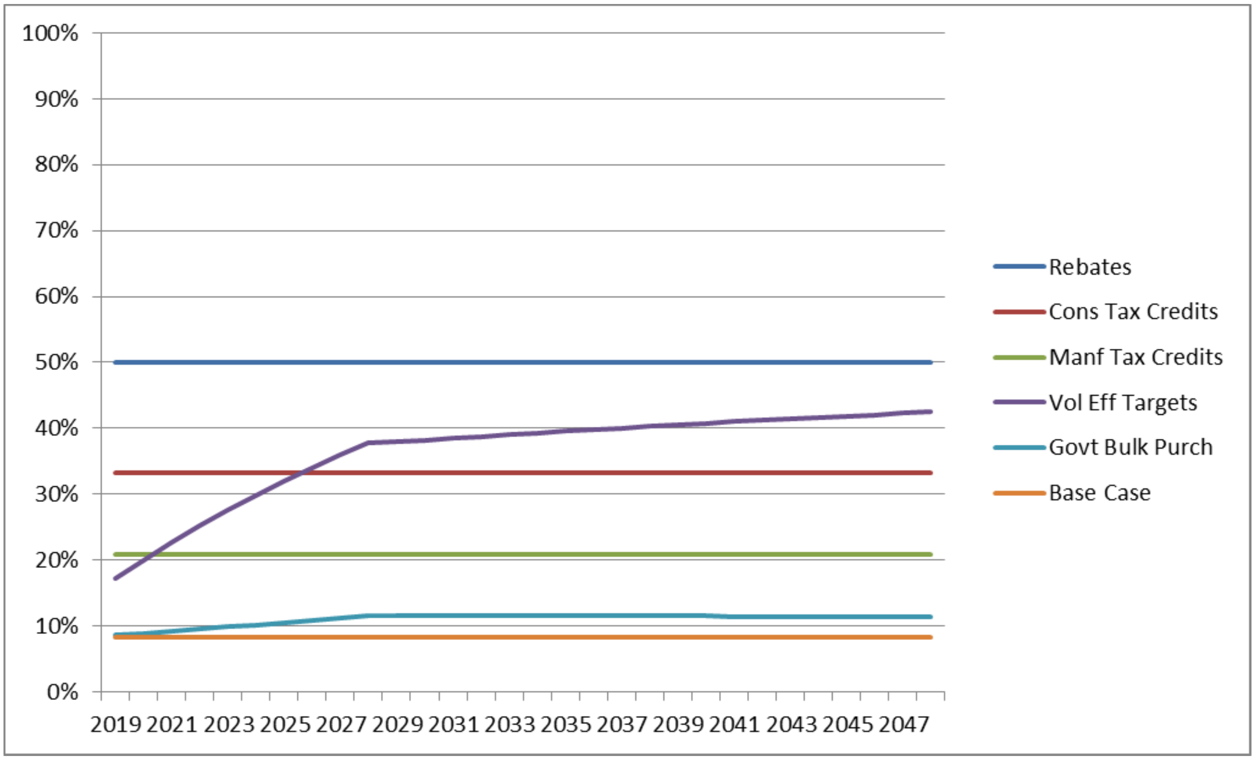

Figure 17.4.4 Market Penetration of Efficient Gas Standard Ovens – Freestanding (TSL 2)

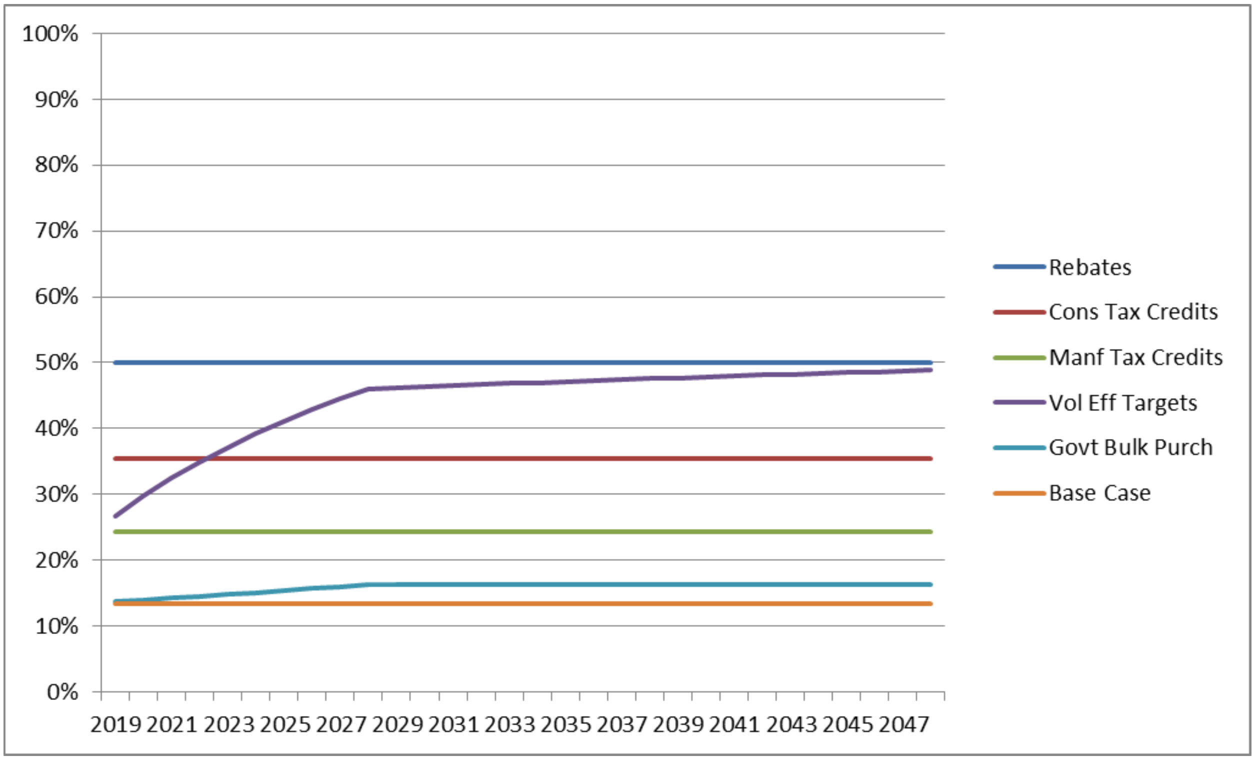

Figure 17.4.5 Gas Self-Clean Ovens – Freestanding (TSL 2)

Table 17.4.1shows the national energy savings and net present value for the five non-regulatory policy alternatives analyzed in detail for conventional cooking products. The target level for each policy corresponds to the same efficient technology proposed for standards in TSL 2. The case in which no regulatory action is taken with regard to conventional cooking products 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).[i] 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 consumer rebates, followed by consumer and manufacturer tax credits, and voluntary energy efficiency targets. Savings for these four alternative policy measures range from 9.3 percent to 67.7 percent of the savings from standards at TSL 2. Bulk government purchases have the lowest cumulative energy savings. Overall, the energy saving benefits from the alternative policies, range from 0.6 percent to 67.7 percent of the benefits from the proposed standards.

Table 17.4.1 Impacts of Non-Regulatory Policy Alternatives (TSL 2)

Policy Alternative	**Energy Savings*** *quads*		**Net Present Value*** *million 2014$*	
			7% Disc Rate	3% Disc Rate
Consumer Rebates	0.421	(67.7%)**	2519.9	6143.9
Consumer Tax Credits	0.253	(40.6%)	1511.9	3686.3
Manufacturer Tax Credits	0.126	(20.3%)	756.0	1843.2
Voluntary Energy Efficiency Targets	0.058	(9.3%)	426.9	1793.3
Bulk Government Purchases	0.004	(0.6%)	25.6	62.6
Proposed Standards	0.622	(100.0%)	3991.0	9790.4

* For products covered in this RIA, shipped 2019-2048.

**The percentages show how the energy savings from each policy alternative compare to the energy savings from the proposed standards (represented in the table as 100%).

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[i] 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.

REFERENCES

1. Rufo, M. and F. Coito, *California's Secret Energy Surplus: The Potential for Energy Efficiency*, 2002. XENERGY Inc. (Last accessed March, 2014.) <www.issuelab.org/resource/californias_secret_energy_surplus_the_potential_for_energy_efficiency>

2. ICF International, *Arizona Public Service Energy Efficient Market Potential Study*, 2007. Fairfax, VA.

3. Mosenthal, P., Telephone Conversation with Barbara Atkinson of LBNL, *personal communication.* Optimal Energy. January, 2008.

4. Lee, A., Telephone Conversation with Barbara Atkinson of LBNL, *personal communication.* Quantec, LLC. January, 2008.

5. Rufo, M., Telephone Conversation with Barbara Atkinson of LBNL, *personal communication.* Itron, Inc. January 2008 and March 2009.

6. Itron Inc. and KEMA Inc., *California Energy Efficiency Potential Study*, 2008. (Last accessed March, 2014.) <http://calmac.org/publications/PGE0264_Final_Report.pdf>

7. Global Energy Partners LLC, *AmerenUE Demand Side Management (DSM) Market Potential Study*, 2010. (Last accessed March, 2014.) <www.ameren.com/-/media/missouri-site/Files/Environment/Renewables/AmerenUEVolume2MarketResearchReport2.pdf>

8. Coito, F., E-mail to Barbara Atkinson of LBNL, *personal communication.* KEMA, Inc. June, 2010.

9. Blum, H., B. Atkinson, and A. Lekov, *A Framework for Comparative Assessments of Energy Efficiency Policy Measures,* May, 2011. Report No. LBNL-4749E. <http://escholarship.org/uc/item/4t32x6vr>

10. Lawrence Berkeley National Laboratory, *Energy End-Use Forecasting: Analysis of Tax Credits for Efficient Equipment,* 1998. LBNL Technology Evaluation Modeling and Assessment Group (Last accessed March, 2014.) <http://enduse.lbl.gov/Projects/TaxCredits.html>

11. Train, K., *Customer Decision Study: Analysis of Residential Customer Equipment Purchase Decisions*, 1994. Prepared for Southern California Edison by Cambridge Systematics, Pacific Consulting Services, The Technology Applications Group, and California Survey Research Services.

12. U.S. Department of Energy: Office of Codes and Standards, *Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers, and Freezers, Including Environmental Assessment and Regulatory Impact Analysis*, November, 1995. Washington, DC. Report No. DOE/EE-0064.

13. *Energy Policy Act of 2005*, in *119 STAT. 594 Public Law 109-58. Section 1333, 26 USC 25C note*,. 2005. www.gpo.gov/fdsys/pkg/BILLS-109hr6pcs/pdf/BILLS-109hr6pcs.pdf

14. *American Recovery and Reinvestment Act of 2009*, 2009. Government Printing Office. (Last accessed March, 2014.) <http://www.gpo.gov/fdsys/pkg/BILLS-111hr1enr/pdf/BILLS-111hr1enr.pdf>

15. Tax Incentives Assistance Project, *Consumer Tax Incentives: Home Heating & Cooling Equipment.*, 2011. (Last accessed March, 2014.) <www.energytaxincentives.org/consumers/heating-cooling.php>

16. Tax Incentives Assistance Project, *The Tax Incentives Assistance Project (TIAP)*, 2013. (Last accessed March, 2014.) <http://energytaxincentives.org/>

17. U.S. Department of Energy - Energy Efficiency & Renewable Energy, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment, Residential Dishwashers, Dehumidifiers, and Cooking Products, and Commercial Clothes Washers*, 2008. Washington, DC.

18. Tax Incentives Assistance Project, *Manufacturers Incentives*, (Last accessed March, 2014.) <http://energytaxincentives.org/builders/appliances.php>

19. Feldman, S., L. Hoegfen, L.Wilson-Wright, and A. Li, *Modelling the Effects of U.S. ENERGY STAR® Appliance Programs. In Energy Savings: What Works and Who Delivers?*, May 30-June 4, 2005. ECEEE Summer Study Proceedings. Mandelieu La Napoule, France. <www.eceee.org/conference_proceedings/eceee/2005c/Panel_4/4228feldman/paper>

20. Rosenberg, M., *The Impact of Regional Programs on the Market Share of Energy Star® Appliances*, August 20-22, 2003. Seattle, WA. Published in the 2003 International Energy Program Evaluation Conference Proceedings.

21. Titus, E. and S. Feldman, *Tracking the Effectiveness of Energy-Efficient Appliance Programs in the U.S.*, August 20-22, 2003. In 2003 International Energy Program Evaluation Conference Proceedings. Seattle, WA.

22. Blum, H., Atkinson B., and Lekov, A., *A Framework for Comparative Assessments of Energy Efficiency Policy Measures*, May, 2011.

23. Smith, N., Telephone conversation with Barbara Atkinson of LBNL, *personal communication.* National Association of State Procurement Officials. April, 2008.

24. Responsible Purchasing Network, (Last accessed March, 2014.) <www.responsiblepurchasing.org/>

25. Harris, J. and F. Johnson, Potential Energy, Cost, and CO2 Savings from Energy-Efficient Government Purchase. *ACEEE: Summer Study on Energy Efficiency in Buildings*, 2000: pp. 147-166 <http://www.aceee.org/files/proceedings/2000/data/papers/SS00_Panel4_Paper13.pdf>

26. U.S. Department of Energy: Energy Information Administration, *Residential Energy Consumption Survey (RECS)*, 2009. (Last accessed December, 2013.) <http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=microdata>

APPENDIX 6A. DETAILED DATA FOR EQUIPMENT PRICE MARKUPS

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APPENDIX 6A. DETAILED DATA FOR EQUIPMENT PRICE MARKUPS

6A.1 STATE SALES TAX RATES

Table 6A.4.1 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	5.95
Alaska	1.30	Louisiana	8.80	Ohio	7.10
Arizona	7.15	Maine	5.50	Oklahoma	8.40
Arkansas	8.90	Maryland	6.00	Oregon	--
California	8.40	Massachusetts	6.25	Pennsylvania	6.35
Colorado	6.10	Michigan	6.00	Rhode Island	7.00
Connecticut	6.35	Minnesota	7.20	South Carolina	7.00
Delaware	--	Mississippi	7.05	South Dakota	5.45
Dist. of Columbia	5.75	Missouri	7.40	Tennessee	9.45
Florida	6.65	Montana	--	Texas	7.95
Georgia	7.05	Nebraska	6.05	Utah	6.65
Hawaii	4.35	Nevada	7.95	Vermont	6.10
Idaho	6.05	New Hampshire	--	Virginia	5.60
Illinois	8.00	New Jersey	6.95	Washington	8.90
Indiana	7.00	New Mexico	6.60	West Virginia	6.05
Iowa	6.80	New York	8.45	Wisconsin	5.45
Kansas	7.90	North Carolina	6.90	Wyoming	5.50

Source: The Sales Tax Clearinghouse at https://thestc.com/STRates.stm (Accessed on July 18, 2014).

APPENDIX 7A. CONVENTIONAL OVENS: DETERMINATION OF ENERGY-USING COMPONENTS

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APPENDIX 7A.
CONVENTIONAL OVENS: DETERMINATION OF ENERGY-USING COMPONENTS

7A.1 INTRODUCTION

As presented in chapter 7, section 7.2, based on recent survey data, DOE determined that the representative annual energy consumption of an electric range is 287.5 kWh per year. DOE disaggregated the range energy consumption into two portions - one allocated to the oven and the other portion allocated to the cooking top. In addition, because oven energy use may consist of several energy-using components (i.e., cooking, ignition, self-clean, and clock) and potential increases in efficiency may affect only a subset of these components, DOE had to disaggregate oven energy consumption into its specific energy-using components. The following sections detail: (1) DOE's method for disaggregating the representative electric range energy consumption into the various energy-using components of electric ovens; and (2) DOE's method for establishing the representative energy use of gas cooking product energy-using components based on the values that were determined for the electric cooking product energy-using components.

7A.2 METHODOLOGY FOR DISAGGREGATING ELECTRIC RANGE ANNUAL ENERGY CONSUMPTION

As noted above, DOE determined that the representative annual energy consumption of an electric range is 287.5 kWh per year. Based on the following equation, DOE assumed the energy consumption was equal to the sales weighted-average of standard and self-clean oven energy consumption plus the cooking top energy consumption. Also included is the standby power associated with electric ovens.

$$
\begin{aligned}
UEC_{elec\,cooking} &= 287.5\,kWh/yr \\
&= MSe_{SC} \times \left(E_{CO\_SC} + Ees \times S_e\right) + \left(1 - MSe_{SC}\right) \times E_{CO\_STD} + E_{CA} + \left(P_{S\tan dby} \times 8760 \times 0.001\right)
\end{aligned}
$$

where:

$UEC_{elec\ cooking}$ = Annual energy consumption of electric cooking (kWh/yr),
MSe_{SC} = Market share of electric ovens that are self-clean, 68.4%,[1]
E_{CO_SC} = Annual cooking energy consumption of self-clean electric ovens (kWh/yr),
Ees = Typical self-clean energy consumption per cycle for electric self-clean ovens, 32.8 kWh (as reported in Chapter 7, Table 7.2.3),
S_e = Number of self-clean cycles per year for electric self-clean ovens according to the DOE test procedure, 4,[2]

E_{CO_STD} =	Annual cooking energy consumption of standard electric ovens (kWh/yr),
E_{CA} =	Annual energy consumption of electric cooking tops (kWh/yr),
$P_{Standby}$ =	Power input for standby (watts), 3,[a]
8760 =	Hours in a year, and
0.001 =	Conversion to convert watts in kW.

DOE estimated the annual cooking energy consumption of electric self-clean ovens as a fraction of the cooking energy consumption of a standard electric oven. This fraction was taken from the ratio of energy consumption as established by the DOE test procedure. The following equation represents the calculation used by DOE:

$$\boldsymbol{E_{CO\_SC} = Re_{SC\_STD} \times E_{CO\_STD}}$$

$$\boldsymbol{E_{CA} = Re_{CT\_STD} \times E_{CO\_STD}}$$

where,

Re_{SC_STD} =	Ratio of annual self-clean electric oven cooking energy to annul standard electric cooking energy.

To calculate the above ratios, DOE took the annual useful cooking energy output values from the DOE test procedure and divided them by the baseline cooking efficiencies reported in chapter 7, Table 7.2.2.

$$\mathrm{Re}_{SC\_STD} = \frac{(O_O / EFFeo_{SC})}{(O_O / EFFeo_{STD})} = 1.1757$$

where,

O_O =	Annual useful cooking energy output for ovens according to the DOE test procedure, 29.3 kWh,[2]
$EFFeo_{SC}$ =	Cooking efficiency of the baseline self-clean electric oven, 10.06%,
$EFFeo_{STD}$ =	Cooking efficiency of the baseline standard electric oven, 11.89%, and

---

[a] DOE assumed a baseline standby consumption of 3 watts for purposes of disaggregating the electric range annual energy consumption into its energy-using components. As reported in Chapter 7, the baseline standby power consumption for electric standard and self-clean ovens are 1.7 watts.

With the annual cooking energy consumption of self-clean electric ovens expressed as a function of standard electric oven annual cooking energy consumption, DOE solved for the standard electric oven annual cooking energy consumption by the using the following equation:

$$E_{CO\_STD} = \frac{287.5 - MSe_{SC} \times Ees \times S_e - P_{S\tan dby} \times 8760 \times 0.001}{MSe_{SC} \times \mathrm{Re}_{SC\_STD} + 1 - MSe_{SC} + \mathrm{Re}_{CT\_STD}}$$

$$= \frac{287.5 - 68.4\% \times 8.2 \times 4 - 2 \times 8760 \times 0.001}{68.4\% \times 1.1757 + 1 - 68.4\% + 1.0494} = 114.1 kWh/yr$$

With the standard electric oven annual cooking energy consumption established (E_{AO_STD}), DOE solved for the self-clean electric oven annual cooking energy consumption values by using the following equation:

$$E_{CO\_SC} = \mathrm{Re}_{SC\_STD} \times E_{CO\_STD}$$

$$= 1.1757 \times 114.1 = 123.9 kWh/yr$$

Table 7A.2.1 summarizes the energy-using components of electric cooking products. Also provided are the annual useful cooking energy output values—one set based on the DOE test procedure and another set deduced from the lower annual energy consumption values.

Table 7A.2.1 Electric Cooking Products: Energy-Using Components

Energy-Use Components	**Standard Oven**		**Self-Clean Oven**	
	Free-Standing	Built-In/Slide-In	Free-Standing	Built-In/Slide-In
Cooking Efficiency	10.9%	10.6%	9.9%	9.7%
Cooking Energy (kWh/yr)	114.1	114.1	123.9	123.9
Self-clean Energy (kWh/yr)			32.8	32.8
Standby (kWh/yr)	19.2	19.2	19.2	19.2
Total (kWh/yr)	133.3	133.3	175.9	175.9
	Annual Useful Cooking Energy Output (O_O for ovens)			
Current DOE test procedure (kWh)	29.3	29.3	29.3	29.3
Based on electric range annual cooking energy of 287.5 kWh/yr (kWh)	12.4	12.4	12.4	12.4

7A.3 METHODOLOGY FOR ESTABLISHING GAS COOKING ENERGY-USING COMPONENTS

DOE estimated the annual energy consumption of gas cooking products based on the lower (revised) annual useful cooking energy output values that DOE deduced from the electric range annual energy consumption of 287.5 kWh per year. As represented by the following equation, DOE assumed that the ratio of the revised-to-current annual useful energy output values for electric cooking products applied to gas cooking products as well:

$$O_{O\_GAS\_REV} = O_{O\_GAS\_DOE} \times \frac{O_{O\_ELEC\_REV}}{O_{O\_ELEC\_DOE}} = 88.8\,kBtu \times \frac{12.4\,kWh}{29.3\,kWh} = 37.7\,kBtu$$

where:

$O_{O\_GAS\_REV}$ = Revised annual useful cooking energy output for gas ovens,
$O_{O\_GAS\_DOE}$ = DOE test procedure aannual useful cooking energy output for gas ovens,
$O_{O\_ELEC\_REV}$ = Revised annual useful cooking energy output for electric ovens, and
$O_{O\_ELEC\_DOE}$ = DOE test procedure annual useful cooking energy output for electric ovens.

With the revised annual useful cooking output values known for gas cooking products, DOE used the following test procedure equations to calculate the annual cooking energy consumption of gas cooking products. In the equations below, DOE used the baseline cooking efficiencies reported in chapter 7, Table 7.2.2.

$$E_{CO\_SC\_GAS} = \frac{O_{O\_GAS\_REV}}{EFFgo_{SC}} = \frac{37.7kBtu}{5.7\%} = 657.7\,kBtu/yr$$

$$E_{CO\_STD\_GAS} = \frac{O_{O\_GAS\_REV}}{EFFgo_{STD}} = \frac{37.7kBtu}{4.4\%} = 863.1kBtu/yr$$

where:

$E_{CO\_SC\_GAS}$ = Annual cooking energy consumption of gas self-clean ovens,
$EFFgo_{SC}$ = Cooking efficiency of the baseline self-clean gas oven, 5.7%,
$E_{CO\_STD\_GAS}$ = Annual cooking energy consumption of gas standard ovens, and
$EFFgo_{STD}$ = Cooking efficiency of the baseline standard gas oven, 4.4%.

Table 7A.3.1 summarizes the energy-using components of gas cooking products. Also provided are the annual useful cooking energy output values—one set based on the DOE test procedure and the other based on the revised set of values. Ignition, self-clean, and clock standby energy consumption values are described and reported in chapter 7, Tables 7.2.2 for gas standard ovens, and self-clean ovens, respectively.

Table 7A.3.1 Gas Cooking Products: Energy-Using Components

Energy-Using Components	**Standard Oven**		**Self-clean Oven**	
	Freestanding	**Built-In/Slide-In**	**Freestanding**	**Built-In/Slide-In**
Cooking Efficiency	4.6%	4.6%	6.0%	6.0%
Cooking Energy (kBtu/yr)	863.1	863.1	657.7	657.7
Self-clean Energy				
Gas (kBtu/yr)			217.8	217.8
Electric (kWh/yr)			5.8	5.8
Ignition				
Gas (kBtu/yr)				
Electric (kWh/yr)	43.5	43.5	43.5	43.5
Standby (kWh/yr)*			19.2	
Total				
Gas (kBtu/yr)	1,011.6	1,011.6	1,043.7	1,043.7
Annual Useful Cooking Energy Output (O_O for ovens)				
Current DOE test procedure (kBtu)	88.8	88.8	88.8	88.8
Revised values (kBtu)	37.7	37.7	37.7	37.7

REFERENCES

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1 U.S. Energy Information Administration, *Residential Energy Consumption Survey 2009*, Washington, DC. <http://www.eia.gov/consumption/residential/data/2009/>.

2 U.S. Office of the Federal Register. *Code of Federal Regulations, Title 10, Energy. Part 430, Subpart B, Appendix I: Uniform Test Method for Measuring the Energy Consumption of Conventional Ranges, Conventional Cooking Tops, Conventional Ovens, and Microwave Ovens*, 2006. Washington, DC.

APPENDIX 8A. USER INSTRUCTIONS FOR LIFE-CYCLE COST AND PAYBACK PERIOD SPREADSHEET

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APPENDIX 8A. USER INSTRUCTIONS FOR LIFE-CYCLE COST AND PAYBACK PERIOD SPREADSHEET

8A.1 DEFINITIONS

The interested reader can examine and reproduce detailed results of the U.S. Department of Energy's (DOE's) life-cycle cost (LCC) and payback period (PBP) analysis for conventional cooking products by using Microsoft Excel spreadsheets available on DOE's website at http://energy.gov/eere/buildings/appliance-and-equipment-standards-program.
To fully execute the spreadsheets requires both Microsoft Excel and Crystal Ball software. Both applications are commercially available. Crystal Ball is available at www.decisioneering.com.

The latest version of the workbook, which is posted on the DOE website, was tested using Microsoft Excel 2010. The LCC and PBP workbook for conventional cooking products comprises the following worksheets.

Summary	Presents the results of an analysis in terms of average LCC, LCC savings, and simple PBP for all conventional cooking product classes. A table includes, for each efficiency level considered, installed price; lifetime operating cost; LCC average savings; and the percentage of customers that would incur a net cost from each standard level. The user can stipulate three parameters for a simulation run: whether the AEO energy price trend reflects an economic case that is reference, low-growth, or high-growth (reference is default); the number of simulation runs to be performed within a range of 1000–10,000 (10,000 is default); and equipment price trend, i.e., price based on PPI trend, or constant equipment price.
LCC & Payback	The *LCC&Payback* worksheet shows LCC and PBP calculation results for different efficiency levels for a single Residential Energy Consumption Survey (RECS) 2009 household. During a Crystal Ball simulation, the spreadsheet records the LCC and PBP values for every sampled household.
Rebuttable Payback	The *Rebuttable Payback* worksheet contains the installation costs, cooking efficiencies, energy use calculations, and the simple PBP calculations for each efficiency level.
RECS Sample	The *RECS Sample* worksheet contains the RECS 2009 household data for each product type. During a Crystal Ball simulation, DOE

	uses these household characteristics to determine the analysis parameters.
Repair and Maintenance	Gives repair and maintenance costs by age for all product classes at every efficiency level.
Energy Use	Provides energy use components for all product classes at every efficiency level.
Base-Case Efficiency Distribution	Gives the market shares for efficiency levels in the base case.
Equipment Prices	Develops total installed cost for conventional cooking products in 2014$. This sheet provides baseline and incremental manufacturer costs, retail price, sales tax, and installation cost for all product classes and each efficiency level. Includes the assumptions used about markups and sales tax.
Energy Prices	Contains the regional prices in 2014$ for electricity used in the LCC and PBP analysis.
Energy Price Trends	Contains the electricity price trends for the reference, high, and low economic growth scenarios based on AEO 2015.
Discount Rate	Contains data from which an average discount rate and a distribution of discount rates are determined.
Lifetime	Presents the average lifetime, in years, for all product classes, the Weibull parameters used for the survival function, and a graph of the Weibull retirement function for ovens.
Forecast Cells	Gives details regarding base-case efficiency distributions for all conventional cooking product classes. Median, minimum, maximum, and average values are given, along with 5th, 25th, 50th, 75th, and 95th percentile values. Included are product prices and details of the LCC and PBP (LCC savings in terms of money, energy, and the percentages of customers that would experience a net cost, no impact, or net savings from each efficiency level).

8A.2 BASIC INSTRUCTIONS

Basic instructions for operating the LCC spreadsheet are provided below.

1. After downloading the LCC file from DOE’s website, use Microsoft Excel to open it. At the bottom of the workbook, click on the tab for the sheet labeled *Summary*.

2. Use Excel’s “View/Zoom” command in the top menu bar to change the size of the display so that it fits your monitor.

3. Use the graphical interface in the spreadsheet to choose parameters or enter data. You can change the default choices for the three inputs listed under "User Input" (energy price trend, start year, and number of simulation runs). To change a default input, select the desired value from the drop-down choices by the input box.

4. After selecting the desired parameters, click the “Run” button. The spreadsheet will minimize until the simulation is complete, and will then re-open with the updated results.

APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN LCC ANALYSIS

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APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN 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 first: 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 means that 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 in as much 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 either a 1, 2, 3, 4, 5, or 6 will come up, but you do not know which for any particular roll. It's the same with 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. Types of probability distributions include those in Figure 8B.5.1.

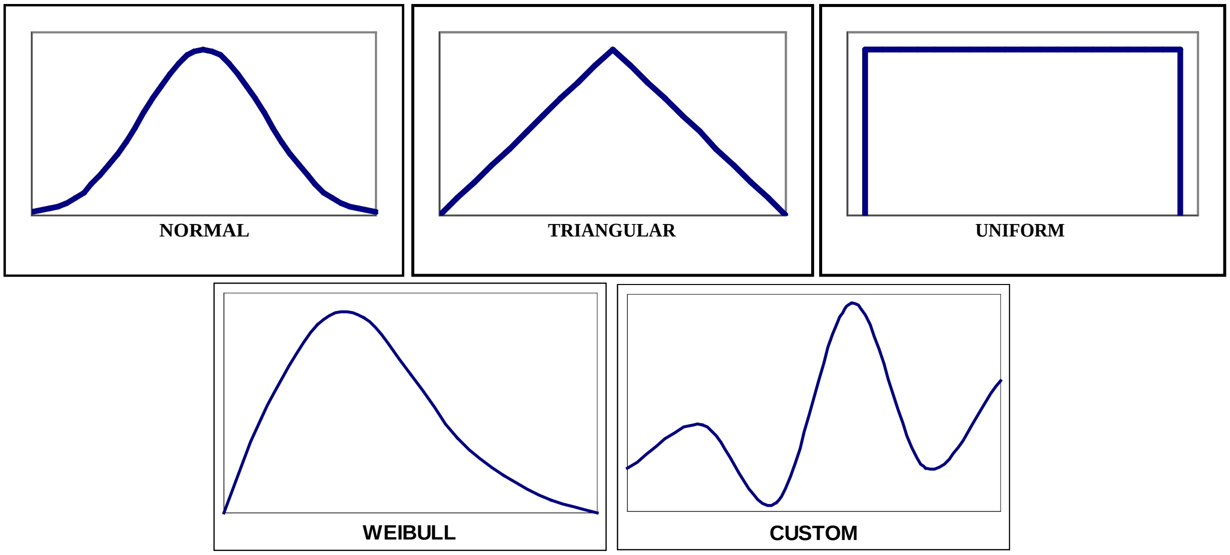

Figure 8B.5.1 **Normal, Triangular, Uniform, Weibull, and Custom Probability Distributions**

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. LIFETIME DISTRIBUTIONS

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8C.1 INTRODUCTION

The U.S. Department of Energy (DOE) characterized the lifetime of both fuel types of conventional cooking products being considered for new energy efficiency standards (electric and gas conventional cooking products). DOE characterized conventional cooking products lifetimes using a Weibull probability distribution that ranged from the minimum to maximum lifetime estimates, as described in chapter 8, section 8.2.3. The Weibull distribution is recommended for evaluating lifetime data, because it can be shaped to match low, most likely (or average), and high values. The probability of exceeding the high value is contained in the long tail of the Weibull distribution.[1,2]

8C.2 DERIVATION OF WEIBULL DISTRIBUTION PARAMETERS

Weibull distributions utilize available data to assign low, average, and high values to a random variable that has unknown distribution parameters. DOE applied Weibull distributions to product lifetime data to derive low, average, and high lifetime values, along with a percentile containing a high value. A similar approach is described in a technical note to the software Crystal Ball, which uses a most likely value in place of an average value.[3] The Weibull distribution can be defined as:

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x-L}{\alpha}\right)^{\beta-1} \exp^{-\left(\frac{x-L}{\alpha}\right)^{\beta}}$$

Where:

L = location,
α = scale, and
β = shape.

The cumulative distribution therefore is:

$$F(x) = 1 - \exp^{-\left(\frac{x-L}{\alpha}\right)^{\beta}}$$

Based on available data, Weibull distribution parameters are specified as follows.

1. The output deviates must be greater than the expert opinion of low value.
2. The average, X_{avg}, must be equal to the average value from the available data.
3. The high value, xb, must correspond to some particular percentile point (*e.g.*, 95 percent or 90 percent).

The values for the parameters in the equations were determined using the approach outlined in Crystal Ball's technical note.[3]

Crystal Ball can be used to check a solution by specifying a Weibull distribution that has the calculated parameters (location, scale, and shape) in an assumption cell, then generating a forecast that equals that assumption. The forecast histogram and statistics will confirm whether the Weibull distribution matches the desired shape.

This solution can be checked using Crystal Ball by specifying a Weibull distribution with the calculated parameters (location, scale, and shape) in an assumption cell and generate a forecast that equals the assumption. Forecast histogram and statistics verify that the Weibull distribution matches the desired shape.

Table 8C.2.1shows the average, minimum, maximum lifetime, and maximum percentile values used to determine the Weibull distribution parameters alpha and beta. For conventional cooking products, DOE developed two lifetime estimates based on product fuel type—one for electricity and another for natural gas. DOE estimated that product lifetimes did not vary based on whether the product was a cooktop or an oven. DOE estimated that the maximum lifetime percentile for both fuel types was 99 percent.

Table 8C.2.1 Conventional Cooking Products

Product Fuel Type	**Expert Opinion Values**				**Weibull Parameters**	
	Minimum *years*	**Average** *years*	**Maximum** *years*	**Maximum percentile** *%*	**Alpha (scale)**	**Beta (shape)**
Electric	10.0	15.0	19.0	99	14.87	7.99
Gas	12.0	17.0	22.0	99	17.06	7.35

Figure 8C.2.1 through Figure 8C.2.4 show the Weibull distribution as well as the cumulative Weibull distribution for each fuel type of conventional cooking products.

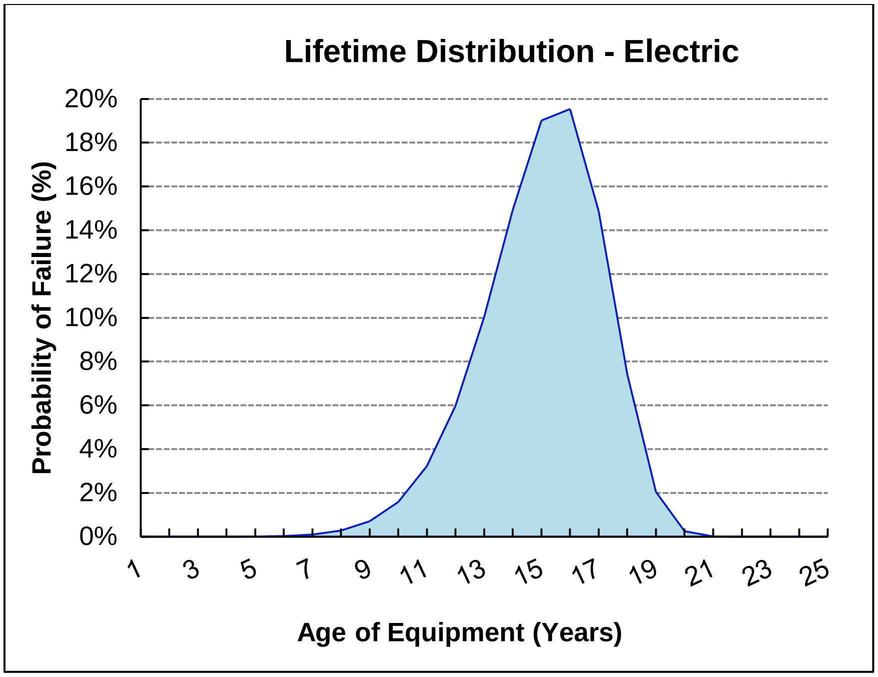

Figure 8C.2.1 **Surviving Probability of Electric Cooking Products**

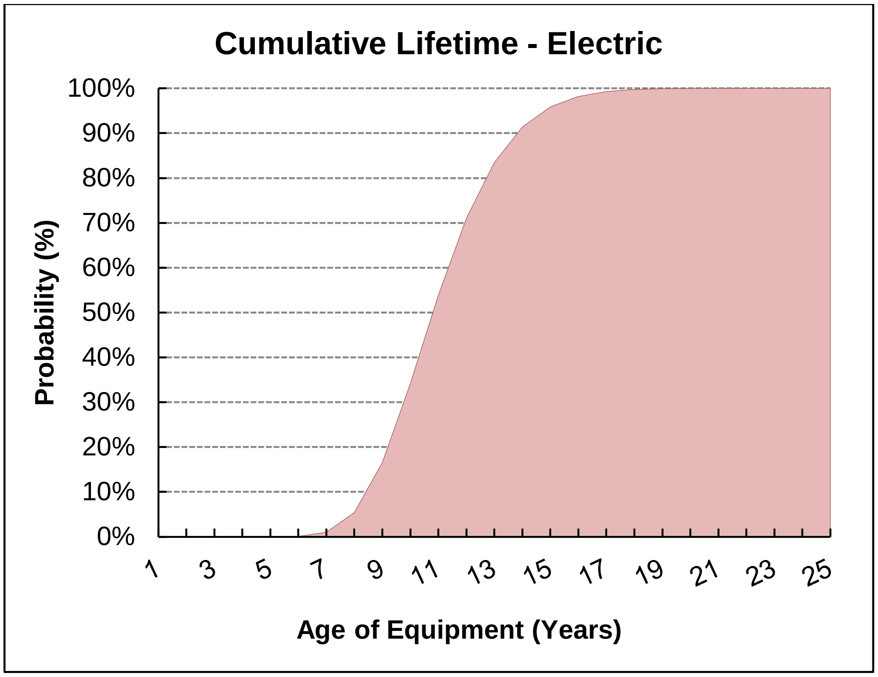

Figure 8C.2.2 **Cumulative Lifetime Length of Electric Cooking Products**

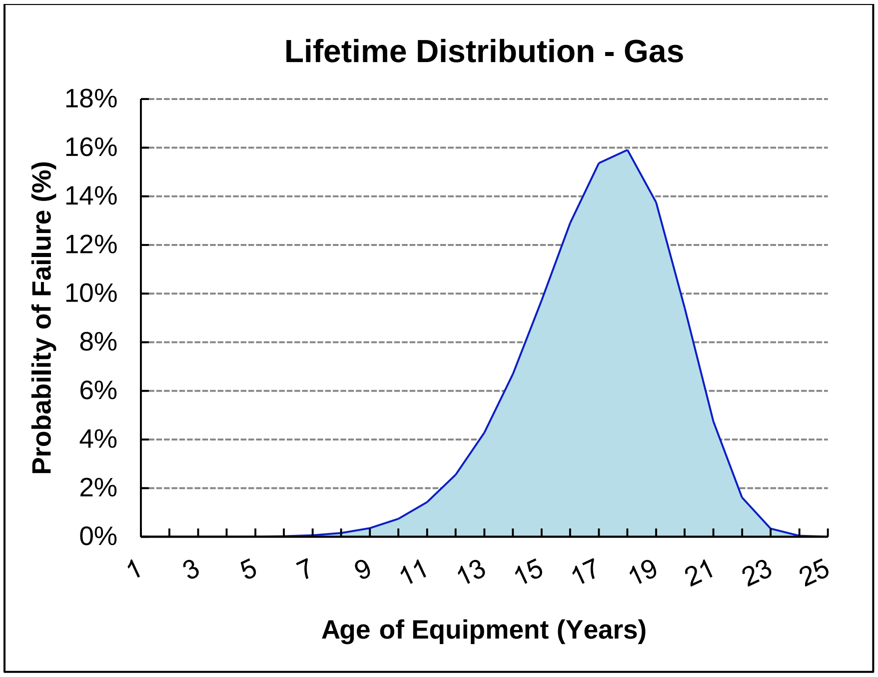

Figure 8C.2.3 **Surviving Probability of Gas Cooking Products**

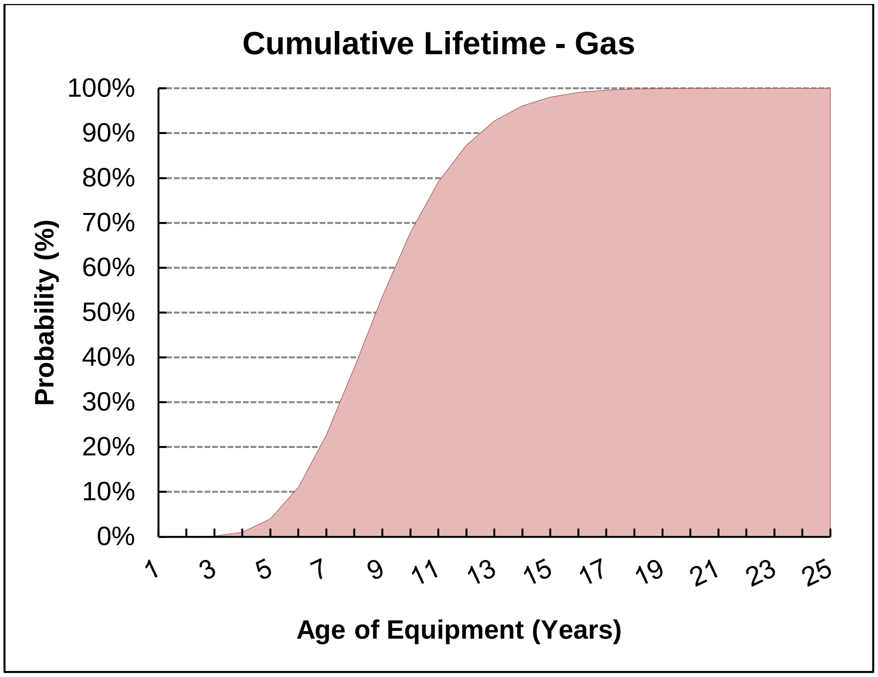

Figure 8C.2.4 **Cumulative Lifetime Length of Gas Cooking Products**

REFERENCES

1 Barnes, P. R., J. W. Van Dyke, B. W. McConnell, S. M. Cohn, and S. L. Purucker, *The Feasibility of Replacing or Upgrading Utility Distribution Transformers During Routine Maintenance*, 1995. Oak Ridge National Laboratory. Oak Ridge, TN. Report No. Report No. ORNL-6804/R1. <http://www.ornl.gov/~webworks/cpr/v823/rpt/78562.pdf>

2 Karr, T., Making the Most of Life Test Data. *Appliance Magazine*, 2003. <http://www.appliancemagazine.com/print.php?article=197&zone=1&first=1>

3 Crystal Ball, *Technote: Derivation of Weibull Distribution Parameters When the Minimum, Most Likely Value, and a Percentile are Known*, 2007. (Last accessed November, 2013.) <http://www.crystalball.com/support/simulation/cbl_gen_021A.html>

APPENDIX 8D. DISTRIBUTIONS FOR DISCOUNT RATES

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8D.1 INTRODUCTION

The U.S. Department of Energy (DOE) derived 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 DISTRIBUTIONS 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.

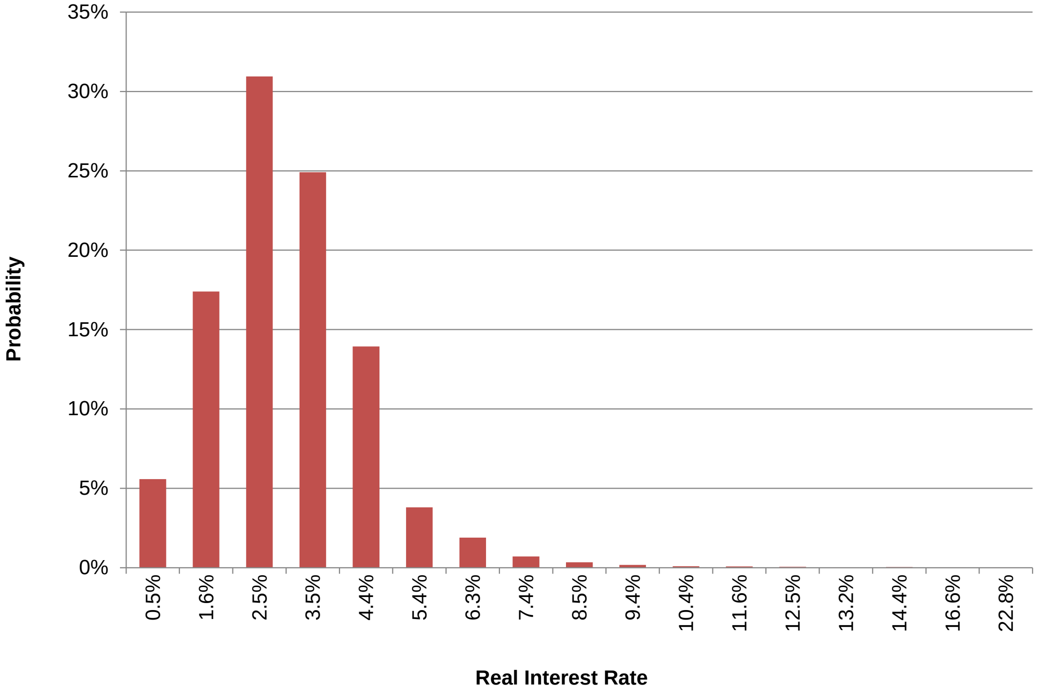

Figure 8D.2.1 Distribution of Mortgage Interest Rates

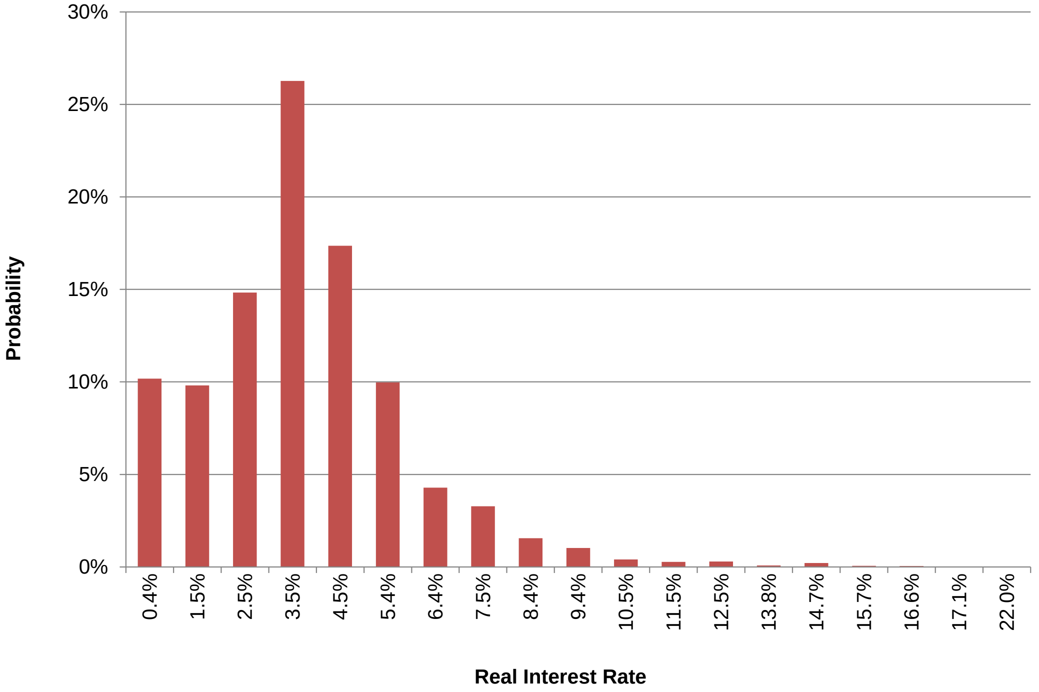

Figure 8D.2.2 Distribution of Home Equity Loan Interest Rates

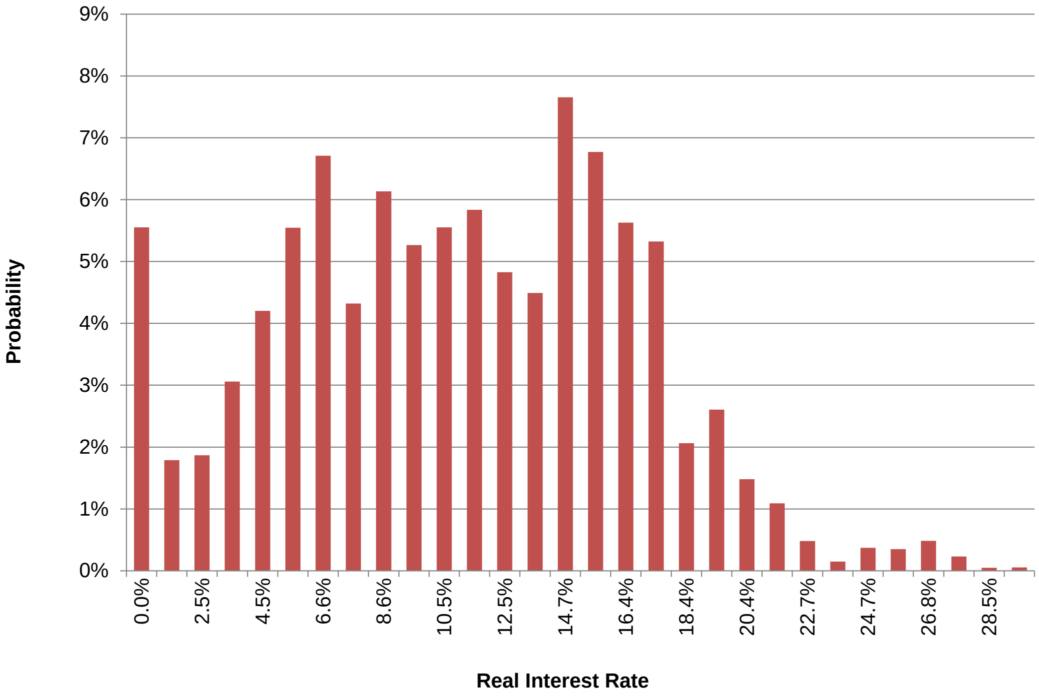

Figure 8D.2.3 Distribution of Credit Card Interest Rates

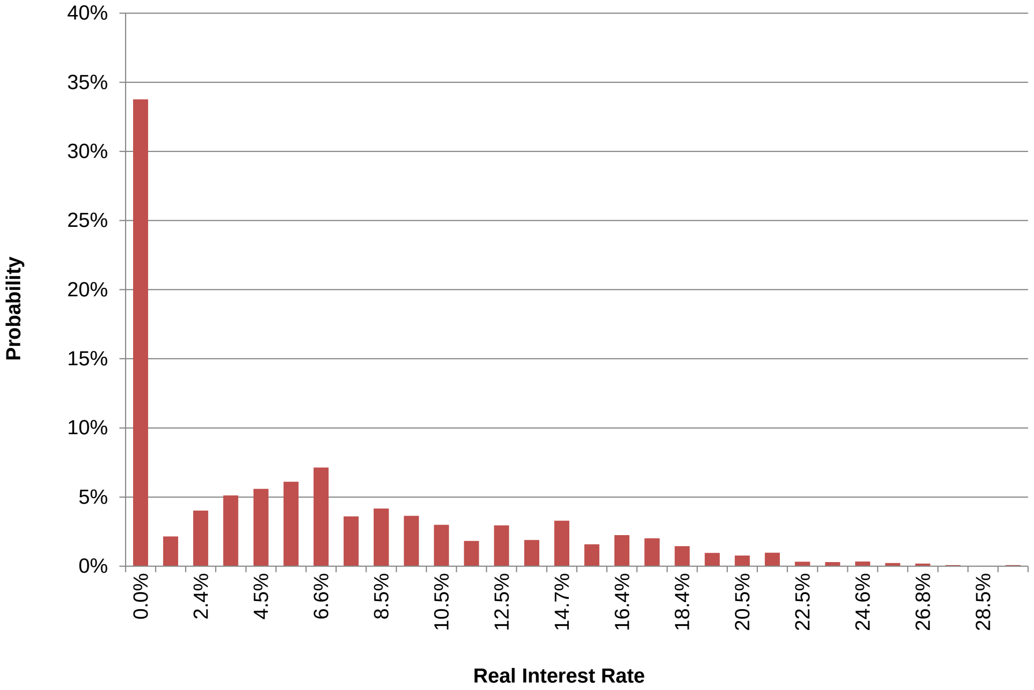

Figure 8D.2.4 Distribution of Installment Loan Interest Rates

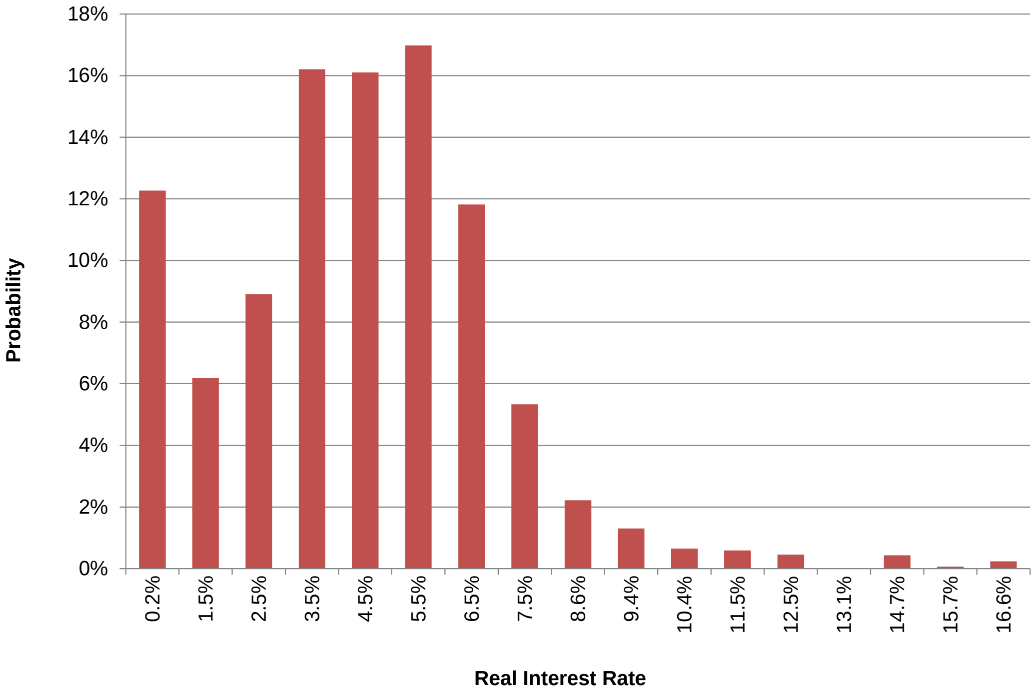

Figure 8D.2.5 Distribution of Other Residence Loan Interest Rates

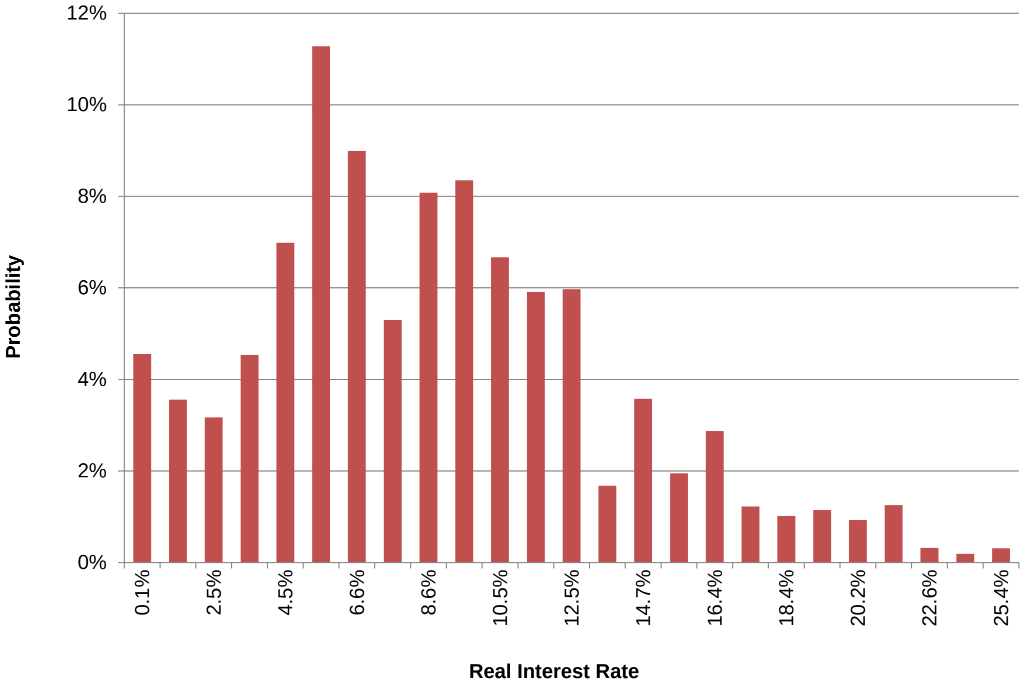

Figure 8D.2.6 Distribution Other Lines of Credit Loan Interest Rates

8D.3 DISTRIBUTIONS OF RATES FOR EQUITY CLASSES

Figure 8D.3.1 through Figure 8D.3.7 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.

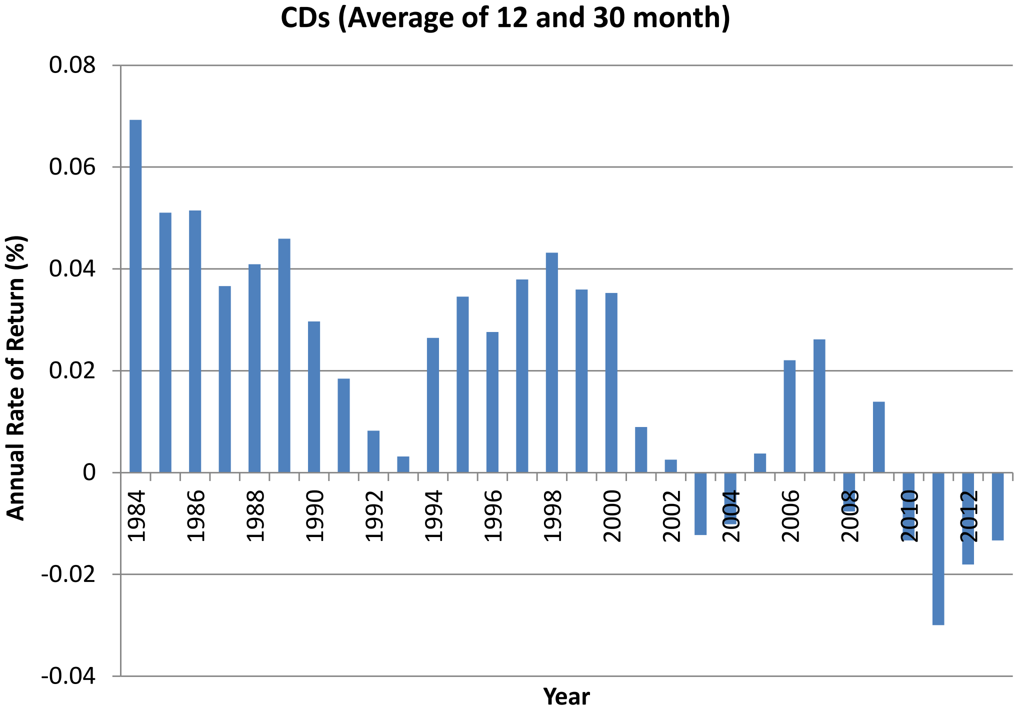

Figure 8D.3.1 Distribution of Annual Rates of Return on CDs

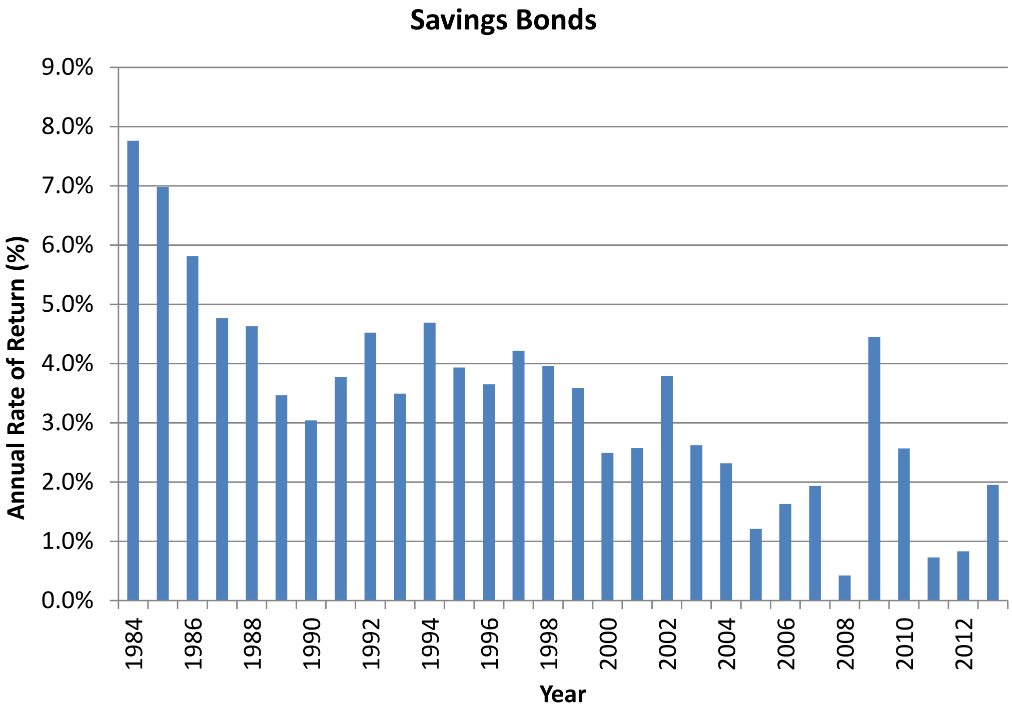

Figure 8D.3.2 Distribution of Annual Rates of Return on Savings Bonds

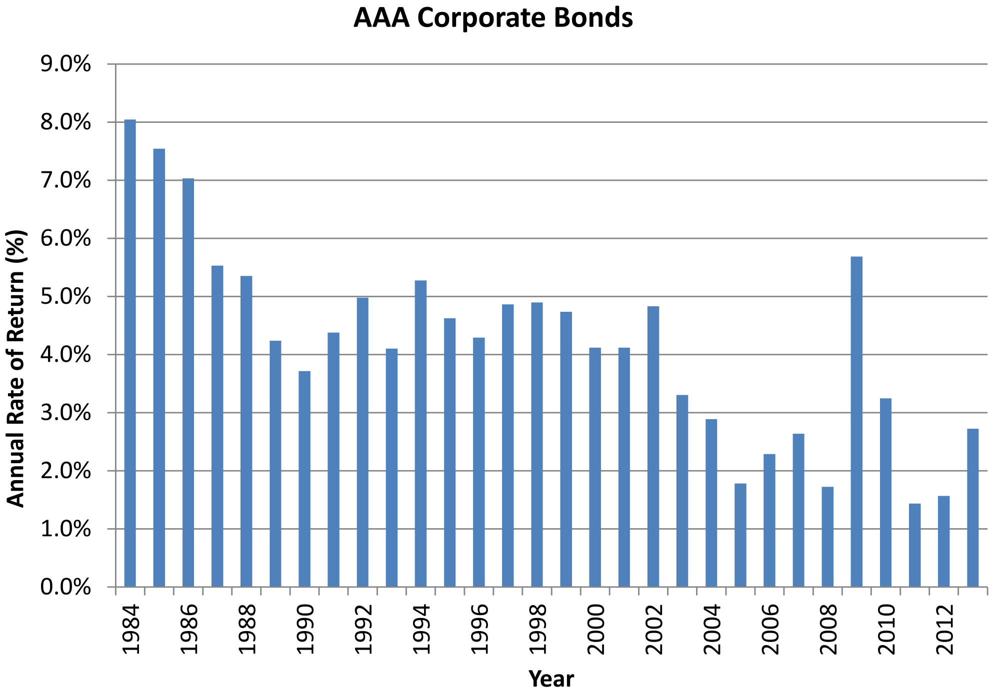

Figure 8D.3.3 Distribution of Annual Rates of Return on Corporate AAA Bonds

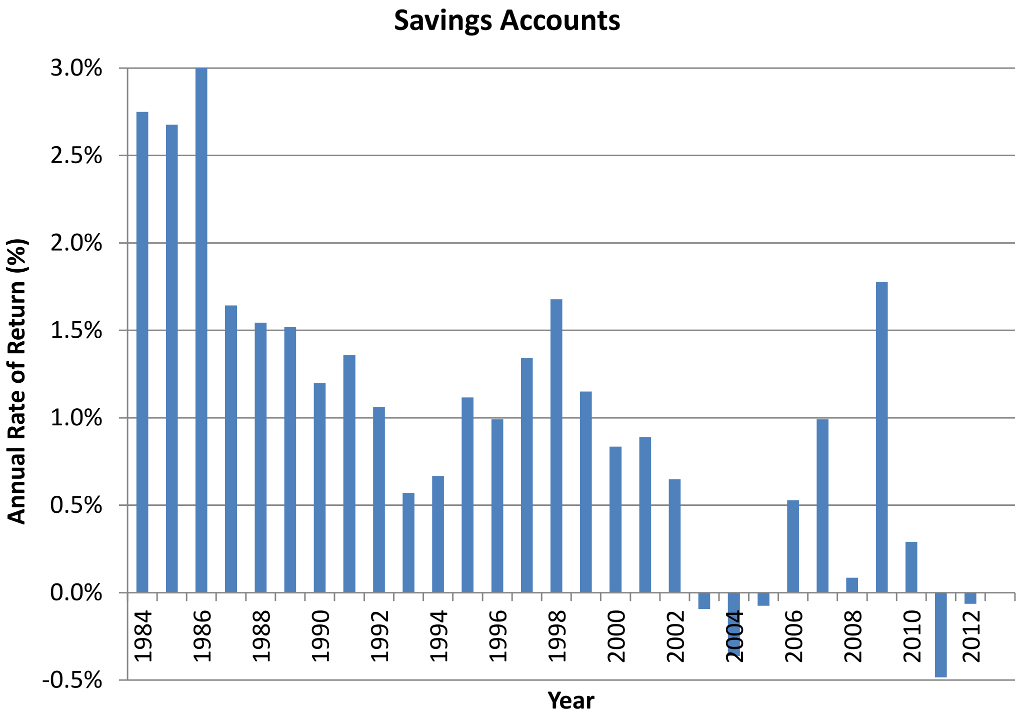

Figure 8D.3.4 Distribution of Annual Rates of Return on Savings Accounts

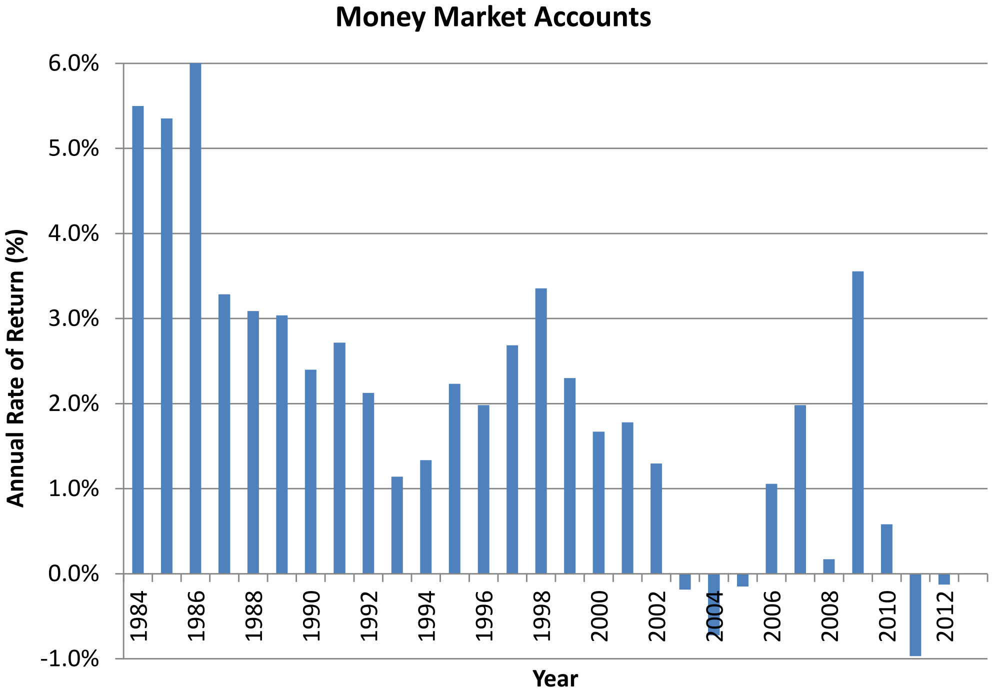

Figure 8D.3.5 Distribution of Annual Rates of Return on Money Market Accounts

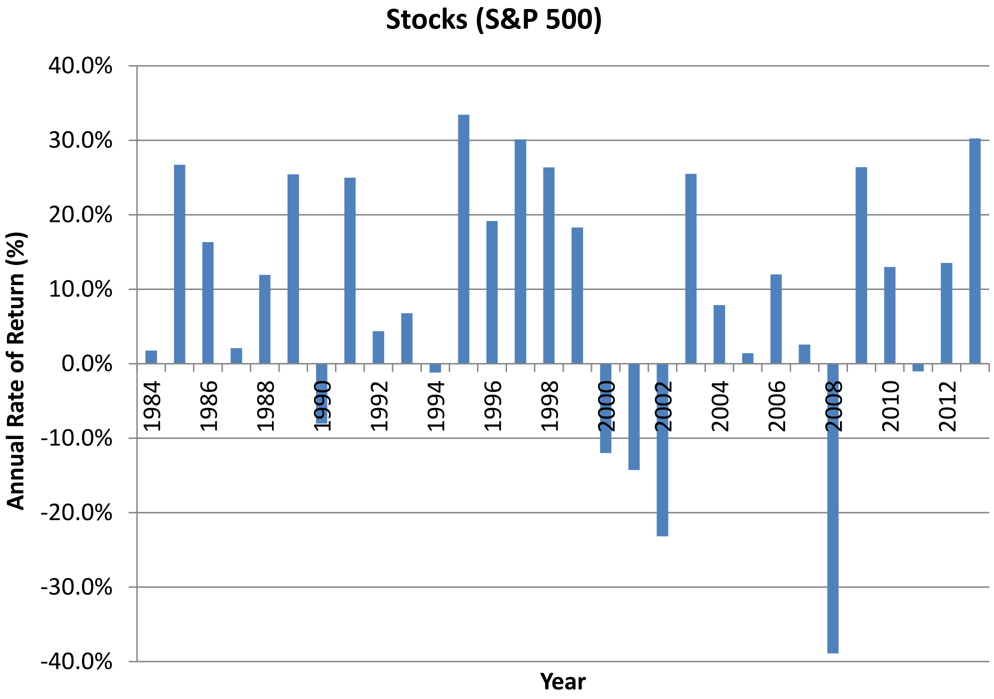

Figure 8D.3.6 Distribution of Annual Rates of Return on the S&P 500

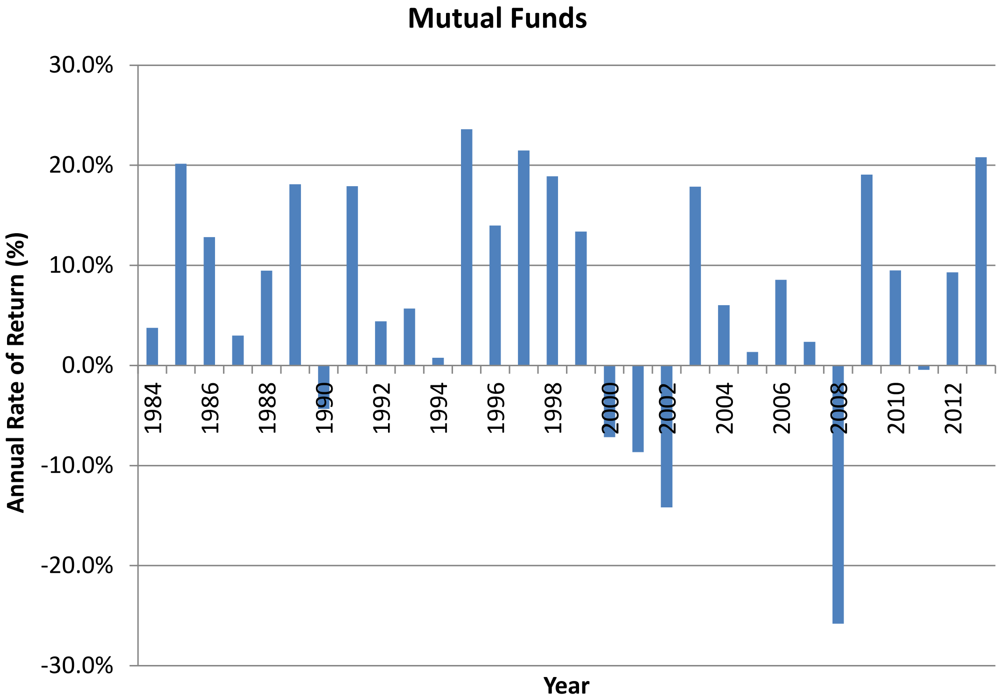

Figure 8D.3.7 Distribution of Annual Rates of Return on Mutual Funds

8D.4 DISTRIBUTION OF REAL EFFECTIVE DISCOUNT RATES BY INCOME GROUP

Figure 8D.4.1 and Table 8D.4.1 presents the distributions of real discount rates for each income group.

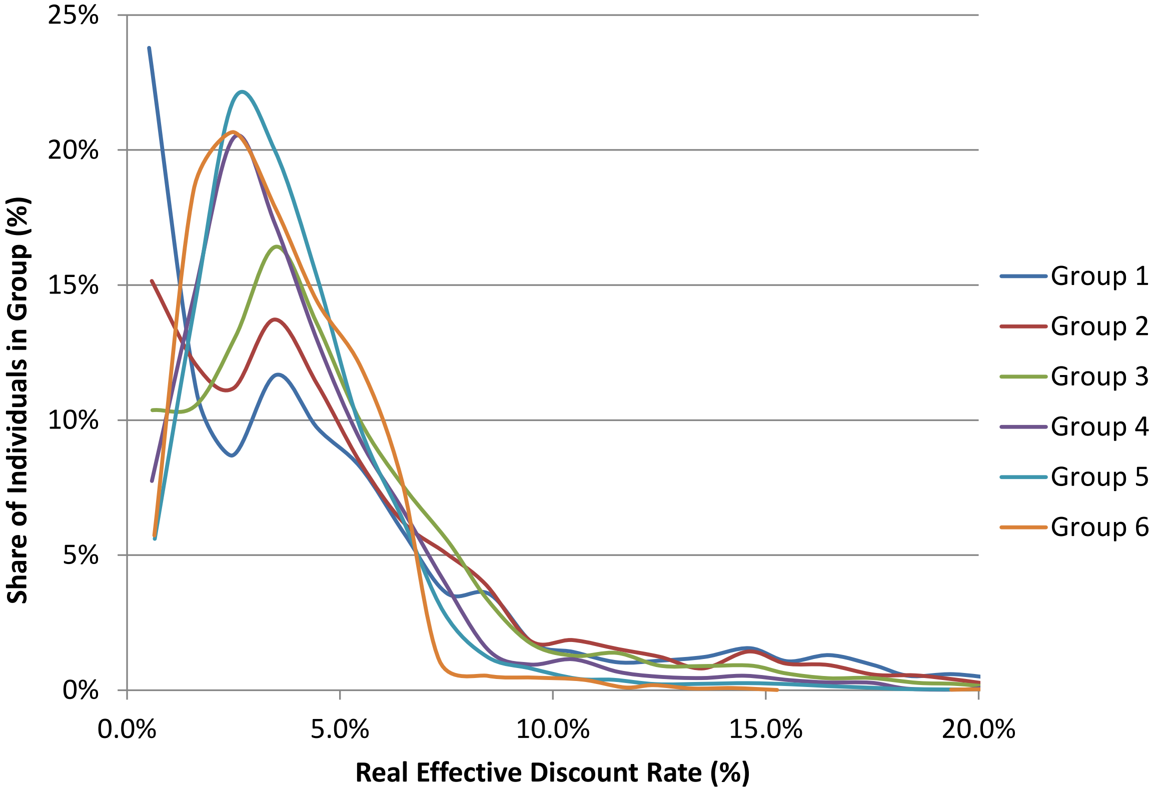

Figure 8D.4.1 Distribution of Real Discount Rates by Income Group

Table 8D.4.1 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

REFERENCES

1 The Federal Reserve Board, Survey of Consumer Finances 1995, 1998, 2001, 2004, 2007, 2010. <http://www.federalreserve.gov/pubs/oss/oss2/scfindex.html>

2 The Federal Reserve Board, *Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: CDs (secondary market), Maturity: 6-month, Frequency: Annual, Description: Average rate on 6-month negotiable certificates of deposit (secondary market), quoted on an investment basis*, 2013. <www.federalreserve.gov/releases/H15/data.htm>

3 The Federal Reserve Board, *Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: State and local bonds, Maturity: 20-year, Frequency: Monthly, Description: Bond buyer go 20-bond municipal bond index*, 2013. <www.federalreserve.gov/releases/H15/data.htm>

4 The Federal Reserve Board, *Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: Corporate bonds/Moody's Seasoned AAA, Frequency: Annual, Description: Moody's yield on seasoned corporate bonds—all industries, AAA*, 2013. <www.federalreserve.gov/releases/H15/data.htm>

5 Mortgage-X - Mortgage Information Service, *Cost of Savings Index (COSI) Index History*, 2013. <http://mortgage-x.com/general/indexes/default.asp>

6 Damodaran Online Data Page, *The Data Page: Historical Returns on Stocks, Bonds and Bills - United States*, 2013. Damodaran. <http://pages.stern.nyu.edu/~adamodar/>

APPENDIX 10A. USER INSTRUCTIONS FOR SHIPMENTS AND NATIONAL IMPACT ANALYSIS SPREADSHEETS

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APPENDIX 10A. USER INSTRUCTIONS FOR SHIPMENTS AND NATIONAL IMPACT ANALYSIS SPREADSHEETS

10A.1 INTRODUCTION

The interested reader can examine and reproduce detailed results of the U.S. Department of Energy's (DOE's) shipments and national impact analysis (NIA) for conventional cooking products using Microsoft Excel spreadsheets that are available on DOE's website. <http://www.eere.energy.gov/buildings/appliance_standards/>

The latest version of the Microsoft Excel shipments and NIA workbook, which is posted on the DOE website, was tested using Microsoft Excel 2010. To execute the spreadsheet requires Microsoft Excel 2010 or a later version. The NIA spreadsheet performs calculations to forecast the change in national energy use and net present value due to an energy conservation standard. The energy use and associated costs and savings attributable to a given standard are determined first by calculating the shipments and then the energy use and costs for all products shipped under that standard. The differences between results under the standard case and the base case then can be compared and the nationwide energy savings and net present values (NPVs) determined.

The shipments and NIA workbook for oven products comprises the following worksheets.

Inputs and Summary	This sheet contains user input selections under "User Inputs" and summary tables calculating Cumulative Energy Savings and NPV for the selected standard level. The sheet contains the efficiency levels being considered for the selected product classes and the associated incremental prices. This sheet also contains efficiency weighted average energy use and equipment price for the base and standards cases for the selected product classes.
LCC Inputs	This sheet contains the inputs from the Life-cycle cost analysis.
Efficiency Distribution_ Oven	This sheet contains base case and standards case efficiency trends for ovens.
Historical Shipment	This sheet contains data for historical sales and market share of each cooking product class.
Base Case Ship._Electric Cooking Products	This sheet calculates the estimation of base case shipments for electric cooking products.
Base Case Ship._Gas Cooking Products	This sheet calculates the estimation of base case shipments for gas cooking products.
Base Case Ship. Cooking Top & Oven	This sheet calculates the estimation of base case shipments for cooking tops and ovens.
Oven Base & Stds Case	This sheet calculates the estimation of base case and standards case

	shipments for ovens. It also calculates the energy savings and operating cost savings. The energy and operating cost savings in a single year are the difference between the base case energy use and operating costs for that year and the standard case energy use and operating costs in the same year.
Housing Projections	This sheet provides projected new housing construction starts by housing type.
Price Trend	The sheet contains the projections for default, low and high product price trends.
Energy Prices	This worksheet contains projected average electricity and gas prices for the three economic scenarios.
Heat Rates	The sheet contains the site-to-power plants and full-fuel-cycle conversion factors that are used in the primary and full-fuel-cycle energy savings calculations.
Lifetime	This sheet contains the probability of survival of a cooking unit at a given age of the unit by its fuel type. The sheet also provides the average lifetime of a unit by its fuel type.

10A.2 BASIC INSTRUCTIONS

Basic instructions for operating the NIA spreadsheets are as follows:

1. Once the NIA spreadsheets have been downloaded from the Web, open the file using Excel. At the bottom, click on the tab for the worksheet Inputs and Summary.

2. Use 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 model parameters listed in the box labelled “User Inputs”. The parameters are:
    a. Discount Rate: To the change value, type in the desired Discount Rate (3% or 7%).
    b. Economic Growth: To change the growth scenario, use the drop-down arrow and select the desired Growth level (Reference, Low, or High).
    c. Trial Standards Level (TSL): To change level, use the drop-down menu and select the desired trial standards level (TSL 1, TSL 2 or TSL 3).
    d. Learning Sensitivity: To change the price trend, use the drop-down menu and select the desired price scenario (Default, High, or Low).

4. Once the parameters have been set, the results are automatically updated and are reported in the “National Impact Summary” table for each product category to the right of the “User Inputs” box.

APPENDIX 10B. FULL-FUEL-CYCLE MULTIPLIERS

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APPENDIX 10B. FULL-FUEL-CYCLE MULTIPLIERS

10B.1 INTRODUCTION

This appendix summarizes the methods the U.S. Department of Energy (DOE) used to calculate the full-fuel-cycle (FFC) energy savings estimated from potential standards for conventional cooking products. 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 method of analysis previously encompassed only site energy and the energy lost through generation, transmission, and distribution of electricity. In 2011 DOE announced its intention, based on recommendations from the National Academy of Sciences, to use FFC measures of energy use and emissions when analyzing proposed energy conservation standards.[1] This appendix summarizes the methods DOE used to incorporate impacts of the full fuel cycle into the analysis.

This analysis uses several terms to describe aspects of energy use. The physical sources of energy are primary fuels such as coal, natural gas, or liquid fuel. Primary energy is equal to the heat content (British thermal units [Btu]) of the primary fuel used to produce an end-use service. Site energy use is defined as the energy consumed at the point of use in a house or establishment. When natural gas or petroleum fuels are consumed at the site (for example in an on-site furnace), site energy is identical to primary energy, with both equal to the heat content of the primary fuel consumed.

For electricity generated by an off-site power plant, site energy is measured in kilowatt-hours (kWh). In such a case the primary energy is equal to the quads (quadrillion Btu) of primary energy required to generate and deliver electricity to the site. For the FFC analysis, 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 plus upstream energy use.

Both primary fuels and electricity are used in upstream activities. The treatment of electricity in full-fuel-cycle analysis must distinguish between electricity generated by fossil fuels and uranium and electricity generated from renewable sources (wind, solar, and hydro). For the former, the upstream fuel cycle relates to the amount of fuel consumed at the power plant. There is no upstream component for the latter, because no fuel *per se* is used.

10B.2 METHODOLOGY

The mathematical approach to determining FCC is discussed in Coughlin (2012).[2] Details on analyzing the fuel production chain are presented in Coughlin (2013).[3] The methods used to calculate FFC energy use are summarized here. When all energy quantities are normalized to the same units, FFC energy use can be represented as the product of the primary energy use and an FFC multiplier. Mathematically the FFC multiplier is a function of a set of parameters that represent the energy intensity and material losses at each stage of energy production. Those parameters depend only on physical data, so the calculations require no assumptions about prices or other economic factors. Although the parameter values often differ by geographic region, this analysis utilizes national averages.

The fuel cycle parameters are defined as follows.

- a_x is the quantity of fuel *x* burned per unit of electricity produced, on average, for grid electricity. The calculation of a_x includes a factor to account for losses incurred through the transmission and distribution systems.
- b_y is the amount of grid electricity used in producing 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* produced).

All the parameters are calculated as functions of an annual time step; hence, when evaluating the effects of potential new standards, a time series of annual values is used to estimate the FFC energy and emissions savings in each year of the analysis period and cumulatively. Fossil fuel quantities are converted to energy units using the heat content factor q_x. To convert electricity in kWh to primary energy units, on-site electricity consumption is multiplied by the site-to-power-plant energy use factor, described in chapter 10. The site-to-power-plant energy use factor is defined as the ratio of the total primary energy consumption by the electric power sector (in quads) divided by the total electricity generated each year.

The FFC multiplier is denoted μ (mu). A separate multiplier is calculated for each fuel used on site. Also calculated is a multiplier for electricity that reflects the fuel mix used in its generation. The multipliers are dimensionless numbers applied to primary energy savings to obtain the FFC energy savings. The upstream component of the energy savings is proportional to (μ-1). The fuel type is denoted by a subscript on the multiplier μ.

When DOE estimates energy savings attributable to appliance standards, the method for performing the full-fuel-cycle analysis utilizes data and projections published in the *Annual Energy Outlook (AEO)*; in the case of c, the *AEO2014*.[4] Table 10B.2.1 summarizes the *AEO2014* data used as inputs to the calculation of various parameters. The column titled “AEO Table” gives the name of the table that provided the reference data.

Table 10B.2.1 Dependence of FFC Parameters on *AEO* Inputs

Parameter(s)	Fuel(s)	*AEO* Table	Variables
q_x	All	Conversion factors	MMBtu per physical unit
a_x	All	Electricity supply, disposition, prices, and emissions Energy consumption by sector and source	Generation by fuel type Electric energy consumption by the power sector
b_c, c_{nc}, c_{pc}	Coal	Coal production by region and type	Coal production by type and sulfur content
b_p, c_{np}, c_{pp}	Petroleum	Refining industry energy consumption Liquid fuels supply and disposition International liquids supply and disposition Oil and gas supply	Refining-only energy use Crude supply by source Crude oil imports Domestic crude oil production
c_{nn}	Natural gas	Oil and gas supply Natural gas supply, disposition, and prices	U.S. dry gas production Pipeline, lease, and plant fuel
z_x	All	Electricity supply, disposition, prices, and emissions	Power sector emissions

The AEO2014 does not provide all the information needed to estimate total energy use in the fuel production chain. Coughlin (2013) describes the additional data sources needed to complete the analysis. The time dependence in the FFC multipliers for conventional cooking products, however, arises exclusively from variables taken from the AEO2014.

10B.3 ENERGY MULTIPLIERS FOR THE FULL FUEL CYCLE

FFC energy multipliers for selected years are presented in Table 10B.3.1. The 2040 value was held constant for the analysis period beyond 2040, which is the last year in the AEO2014 projection. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation throughout the forecast period.

Table 10B.3.1 Energy Multipliers for the Full Fuel Cycle (Based on *AEO2014*)

	2019	2020	2025	2030	2035	2040
Electricity	1.043	1.044	1.045	1.046	1.047	1.047
Natural gas	1.108	1.109	1.111	1.113	1.114	1.114
Petroleum fuels	1.176	1.176	1.176	1.174	1.172	1.170

REFERENCES

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1 U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy. Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment. Statement of Policy for Adopting Full Fuel Cycle Analyses into Energy Conservation Standards Program. *Federal Register.* August 18, 2011. Vol. 76, no. 160*:* pp. 51281–51289.

2 Coughlin, K. A Mathematical Analysis of Full Fuel Cycle Energy Use. *Energy*. 2012. 37(1): pp. 698–708. (Last accessed June 22, 2014.) <http://www.sciencedirect.com/science/article/pii/S0360544211006803>

3 Coughlin, K. *Projections of Full-Fuel-Cycle Energy and Emissions Metrics*. 2013. Lawrence Berkeley National Laboratory. Report No. LBNL-6025E.

4 U.S. Energy Information Administration. *Annual Energy Outlook 2014 with Projections to 2040*. April 2014. DOE/EIA-0383(2014). Washington, D.C. (Last accessed June 22, 2014.) <http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf >

APPENDIX 10C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS USING ALTERNATIVE PRODUCT PRICE FORECASTS

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APPENDIX 10C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS USING ALTERNATIVE PRODUCT PRICE FORECASTS

10C.1 INTRODUCTION

The NPV results presented in chapter 10 are based on future price projection derived from historical PPI data from the Bureau of Labor Statistics (BLS). DOE collected PPI data of “gas household ranges, ovens, surface cooking units and equipment” from 1982 to 2014 to project future price for gas ovens, and PPI data of “electric household ranges, ovens, surface cooking units and equipment” from 1970 to 2014 to project future price for electric ovens. DOE also investigated the impact of different product price forecasts on the consumer net present value (NPV) for the trial standard levels of both types of ovens. The two price sensitivity scenarios DOE considered for both types of ovens are based on the same PPI series used in their default case but covering different periods of time to estimate a low price decline scenario and a high price decline scenario respectively.

10C.2 PRICE SCENARIOS FOR GAS OVENS

For the price sensitivity analysis for gas ovens, DOE used the same experience curve approach as the default case to forecast their future price. The low price decline scenario is based on the “gas household ranges, ovens, surface cooking units and equipment” PPI series from 1998 to 2014, and the high price decline scenario is based on the “gas household ranges, ovens, surface cooking units and equipment” PPI series from 1982 to 1997. In the experience curve method, the real cost of production is related to the cumulative production, or experience, with a manufactured product. DOE modeled the experience curve by fitting the inflation –adjusted PPI series to the corresponding cumulative shipments, a proxy of cumulative production, of gas ovens. The percentage reduction in cost that occurs with each doubling of cumulative production is known as the learning rate.

To estimate an experience rate parameter, a least-squares power-law fit was performed on the unified price index versus cumulative shipments. The form of the fitting equation is:

$$P(X) = P_o X^{-b},$$

where the two parameters, b (the learning rate parameter) and P_o (the price or cost of the first unit of production), are obtained by fitting the model to the data. DOE notes that the cumulative shipments on the right hand side of the equation can have a dependence on price, so there is an issue with simultaneity where the independent variable is not truly independent. DOE’s use of a simple least squares fit is equivalent to an assumption of no significant first price elasticity effects in the cumulative shipments variable.

Figure 10C.2.1 and Figure 10C.2.2 present the fit of experience curve for gas ovens under low price decline and high price decline scenarios.

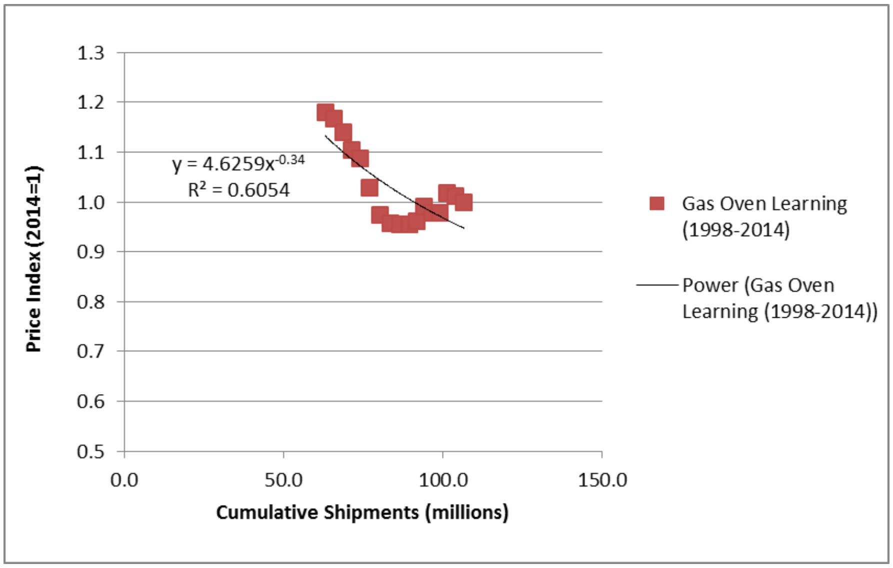

Figure 10C.2.1 **Low Price Decline Scenario: Relative Price versus Cumulative Shipments of Gas Ovens**

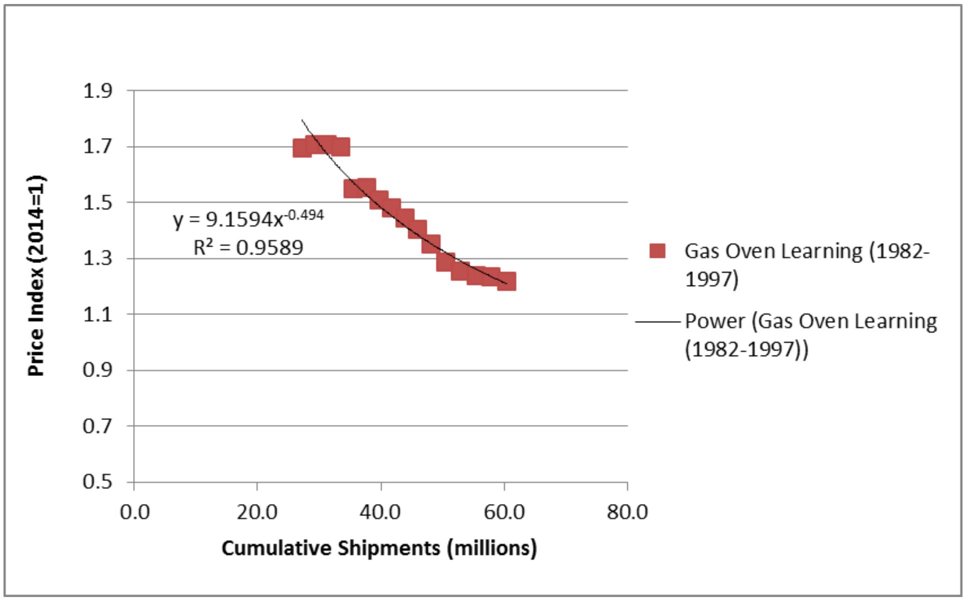

Figure 10C.2.2 **High Price Decline Scenario: Relative Price versus Cumulative Shipments of Gas Ovens**

For the low price decline scenario, the regression performed as power-law fit results in an R-square of 0.61, which indicates an acceptable fit to the data. The parameter values obtained are:

P_o = $4.63^{+4.411}_{-2.258}$ (95% confidence), and
b = 0.3396±0.151 (95% confidence)

The estimated experience rate for the low price decline scenario (defined as the fractional reduction in price expected from each doubling of cumulative production) is $21.0^{+7.8}_{-8.7}$% (95% confidence).

For the high price decline scenario, the regression performed as power-law fit results in an R-square of 0.96, which indicates a great fit to the data. The parameter values obtained are:

P_o = $9.16^{+2.25}_{-1.81}$ (95% confidence), and
b = 0.49±0.059 (95% confidence)

The estimated experience rate for the high price decline scenario (defined as the fractional reduction in price expected from each doubling of cumulative production) is $29.0^{+2.8}_{-2.9}$% (95% confidence).

DOE then derived two price factor indices for gas ovens, and the price index value in a given year is a function of the experience rate and the cumulative production projection through that year, which is based on the shipments forecast described in chapter 9.

10C.3 PRICE SCENARIOS FOR ELECTRIC OVENS

DOE used the same experience curve approach as the default case to forecast future prices of electric ovens. The low price decline scenario is based on the “electric household ranges, ovens, surface cooking units and equipment” PPI series from 1970 to 1992, and the high price decline scenario is based on the “electric household ranges, ovens, surface cooking units and equipment” PPI series from 1993 to 2014. Similar to the approach described above, DOE modeled the experience curve by fitting the inflation –adjusted PPI series to the corresponding cumulative shipments, a proxy of cumulative production, of electric ovens with power-law functional form.

Figure 10C.3.1and Figure 10C.3.2 present the fit of experience curve for electric ovens under low price decline and high price decline scenarios.

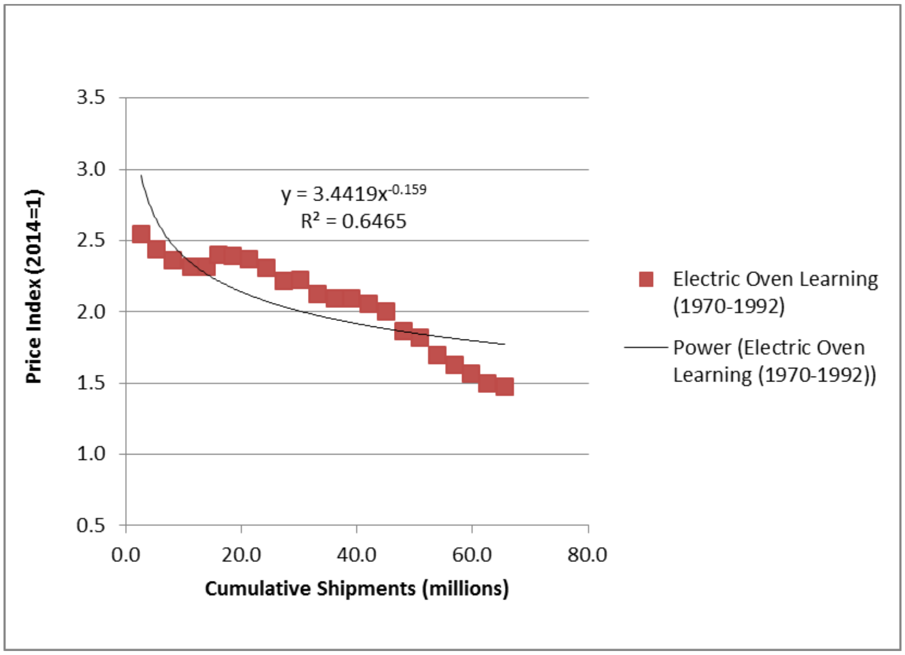

Figure 10C.3.1 **Low Price Decline Scenario: Relative Price versus Cumulative Shipments of Electric Ovens**

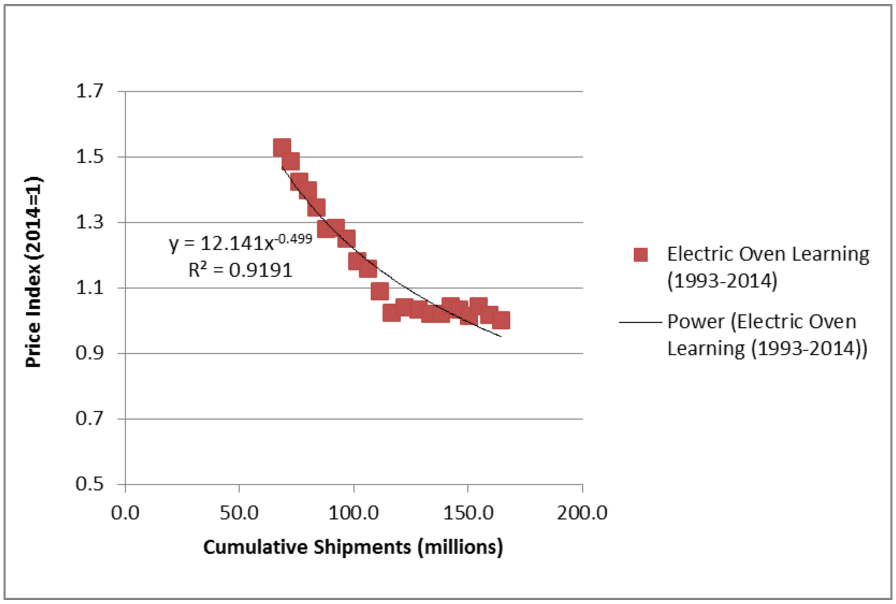

Figure 10C.3.2 **High Price Decline Scenario: Relative Price versus Cumulative Shipments of Electric Ovens**

For the low price decline scenario, the regression performed as power-law fit results in an R-square of 0.65, which indicates an acceptable fit to the data. The parameter values obtained are:

P_o = $3.44^{+0.675}_{-0.564}$ (95% confidence), and
b = 0.159±0.053 (95% confidence)

The estimated experience rate for the low price decline scenario (defined as the fractional reduction in price expected from each doubling of cumulative production) is $10.4^{+3.2}_{-3.4}$% (95% confidence).

For the high price decline scenario, the regression performed as power-law fit results in an R-square of 0.92, which indicates a good fit to the data. The parameter values obtained are:

P_o = $12.14^{+4.68}_{-3.38}$ (95% confidence), and
b = 0.50±0.069 (95% confidence)

The estimated experience rate for the high price decline scenario (defined as the fractional reduction in price expected from each doubling of cumulative production) is $29.2^{+3.3}_{-3.5}$% (95% confidence).

DOE then derived two price factor indices for electric ovens, and the price index value in a given year is a function of the experience rate and the cumulative production projection through that year, which is based on the shipments forecast described in chapter 9.

10C.4 SUMMARY

Table 10C.4.1 shows the summary of the learning rate and average annual price decline rate for the product price index in each scenario. Figure 10C.4.1 and Figure 10C.4.2 shows the resulting price trends for gas and electric ovens respectively.

Table 10C.4.1 Price Trend Scenarios

Product	Scenario	Price Trend	Learning Rate *%*	Annual Price Decline Rate *%*
Gas Ovens	Default	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1982 to 2014)	28.4	1.00
	Low Price Decline	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1998 to 2014)	21.0	0.70

	High Price Decline	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1982 to 1997)	29.0	1.02
Electric Ovens	Default	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1970 to 2014)	19.2	0.80
	Low Price Decline	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1970 to 1992)	10.4	0.41
	High Price Decline	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1993 to 2014)	29.2	1.29

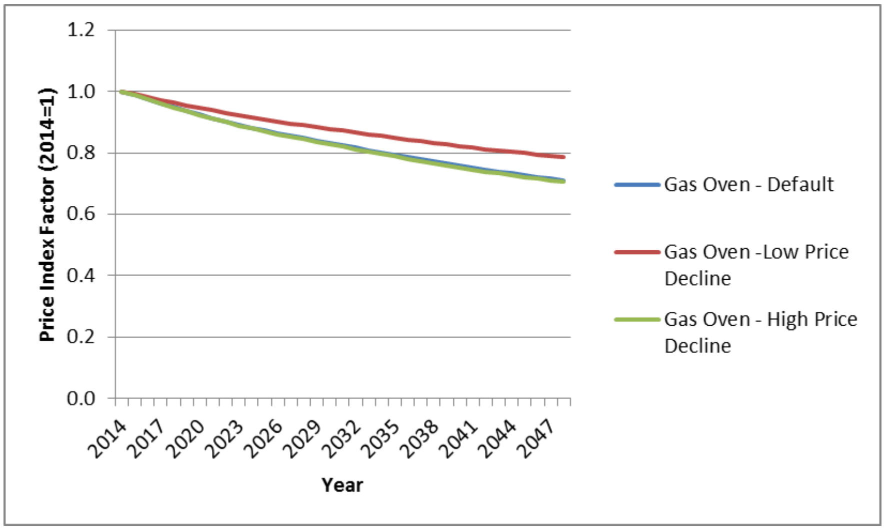

Figure 10C.4.1 Gas Oven Price Factor Indexes for the Default Case and Sensitivity Cases

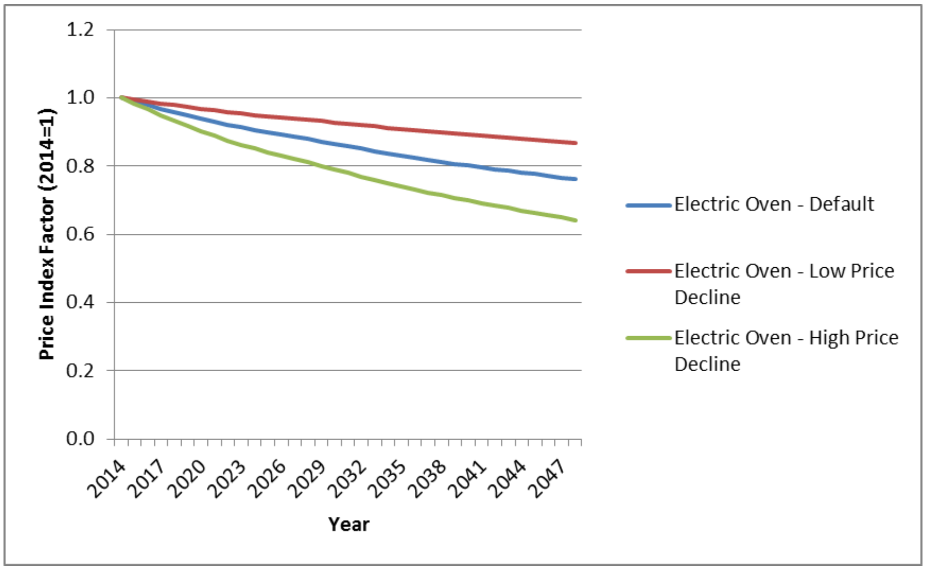

Figure 10C.4.2 Electric Oven Price Factor Indexes for the Default Case and Sensitivity Cases

10C.5 CONVENTIONAL COOKING PRODUCTS NPV RESULTS USING ALTERNATIVE LEARNING RATES

Table 10C.5.1 Conventional Cooking Products: Net Present Value of Consumer Impacts Under Alternative Product Price Forecasts (3 Percent Discount Rate, billion 2014$)

Price Trend	Product Class	TSL1	TSL2	TSL3
Default	Electric Standard Oven, Freestanding	0.172	0.311	-0.569
	Electric Standard Oven, Built-In/Slide-In	0.004	0.007	-0.015
	Electric Self-Clean Oven, Freestanding	0.539	0.539	-1.005
	Electric Self-Clean Oven, Built-In/Slide-In	0.161	0.161	-0.310
	Gas Standard Oven, Freestanding	0.000	3.595	3.061
	Gas Standard Oven, Built-In/Slide-In	0.000	0.672	0.572
	Gas Self-Clean Oven, Freestanding	0.283	5.478	4.716
	Gas Self-Clean Oven, Built-In/Slide-In	0.015	0.282	0.242
Low Price Decline	Electric Standard Oven, Freestanding	0.171	0.300	-0.713
	Electric Standard Oven, Built-In/Slide-In	0.004	0.007	-0.018
	Electric Self-Clean Oven, Freestanding	0.536	0.536	-1.317
	Electric Self-Clean Oven, Built-In/Slide-In	0.160	0.160	-0.400
	Gas Standard Oven, Freestanding	0.000	3.583	3.012
	Gas Standard Oven, Built-In/Slide-In	0.000	0.669	0.563

Price Trend	Product Class	TSL1	TSL2	TSL3
	Gas Self-Clean Oven, Freestanding	0.281	5.466	4.646
	Gas Self-Clean Oven, Built-In/Slide-In	0.014	0.281	0.239
High Price Decline	Electric Standard Oven, Freestanding	0.173	0.324	-0.401
	Electric Standard Oven, Built-In/Slide-In	0.004	0.007	-0.012
	Electric Self-Clean Oven, Freestanding	0.542	0.542	-0.642
	Electric Self-Clean Oven, Built-In/Slide-In	0.161	0.161	-0.205
	Gas Standard Oven, Freestanding	0.000	3.605	3.103
	Gas Standard Oven, Built-In/Slide-In	0.000	0.674	0.580
	Gas Self-Clean Oven, Freestanding	0.284	5.489	4.777
	Gas Self-Clean Oven, Built-In/Slide-In	0.015	0.282	0.245

Table 10C.5.2 Conventional Cooking Products: Net Present Value of Consumer Impacts Under Alternative Product Price Forecasts (7 Percent Discount Rate, billion 2014$)

Price Trend	Product Class	TSL1	TSL2	TSL3
Default	Electric Standard Oven, Freestanding	0.072	0.115	-0.488
	Electric Standard Oven, Built-In/Slide-In	0.002	0.003	-0.014
	Electric Self-Clean Oven, Freestanding	0.213	0.213	-0.961
	Electric Self-Clean Oven, Built-In/Slide-In	0.065	0.065	-0.299
	Gas Standard Oven, Freestanding	0.000	1.550	1.235
	Gas Standard Oven, Built-In/Slide-In	0.000	0.288	0.229
	Gas Self-Clean Oven, Freestanding	0.117	2.310	1.868
	Gas Self-Clean Oven, Built-In/Slide-In	0.006	0.119	0.096
Low Price Decline	Electric Standard Oven, Freestanding	0.072	0.110	-0.558
	Electric Standard Oven, Built-In/Slide-In	0.002	0.003	-0.016
	Electric Self-Clean Oven, Freestanding	0.212	0.212	-1.112
	Electric Self-Clean Oven, Built-In/Slide-In	0.065	0.065	-0.344
	Gas Standard Oven, Freestanding	0.000	1.544	1.211
	Gas Standard Oven, Built-In/Slide-In	0.000	0.287	0.225
	Gas Self-Clean Oven, Freestanding	0.116	2.304	1.834
	Gas Self-Clean Oven, Built-In/Slide-In	0.006	0.119	0.095
High Price Decline	Electric Standard Oven, Freestanding	0.073	0.121	-0.406
	Electric Standard Oven, Built-In/Slide-In	0.002	0.003	-0.012
	Electric Self-Clean Oven, Freestanding	0.215	0.215	-0.784
	Electric Self-Clean Oven, Built-In/Slide-In	0.066	0.066	-0.247

Price Trend	Product Class	TSL1	TSL2	TSL3
	Gas Standard Oven, Freestanding	0.000	1.555	1.255
	Gas Standard Oven, Built-In/Slide-In	0.000	0.289	0.233
	Gas Self-Clean Oven, Freestanding	0.117	2.315	1.896
	Gas Self-Clean Oven, Built-In/Slide-In	0.006	0.120	0.098

APPENDIX 10D. NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS

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APPENDIX 10D. NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS

10D.1 INTRODUCTION

This appendix presents national energy savings (NES) and net present value (NPV) results using inputs from alternative economic growth scenarios. The scenarios use the energy price and housing starts forecasts in the High Economic Growth case and the Low Economic Growth case from EIA's *Annual Energy Outlook 2015* (AEO 2015).[1]

Figure 10D.1.1 shows the projection for new housing starts. Figure 10D.1.2 and Figure 10D.1.3 show residential electricity prices and natural gas prices under the different economic growth scenarios, respectively. *AEO2015* provides a projection to 2040. To estimate the trend after 2040, DOE followed guidelines that the EIA had provided to the Federal Energy Management Program, which called for using the average rate of change for electricity and natural gas during 2030–2040, respectively.

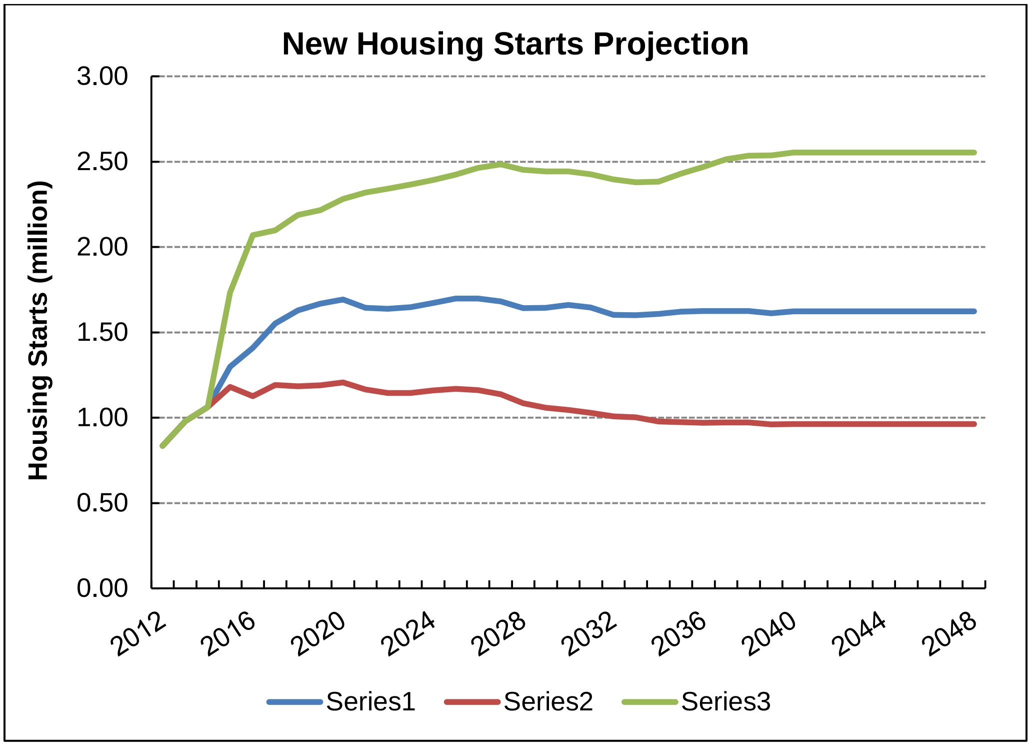

Figure 10D.1.1 **New Housing Starts Projection under Alternative AEO2015 Economic Growth Scenarios**

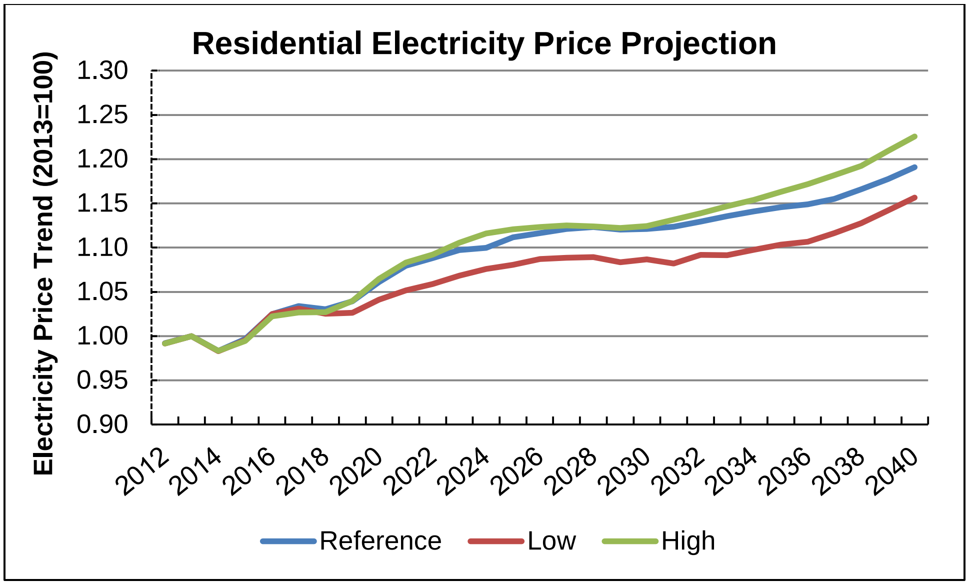

Figure 10D.1.2 **Average Residential Electricity Price Projection under Alternative AEO2015 Economic Growth Scenarios**

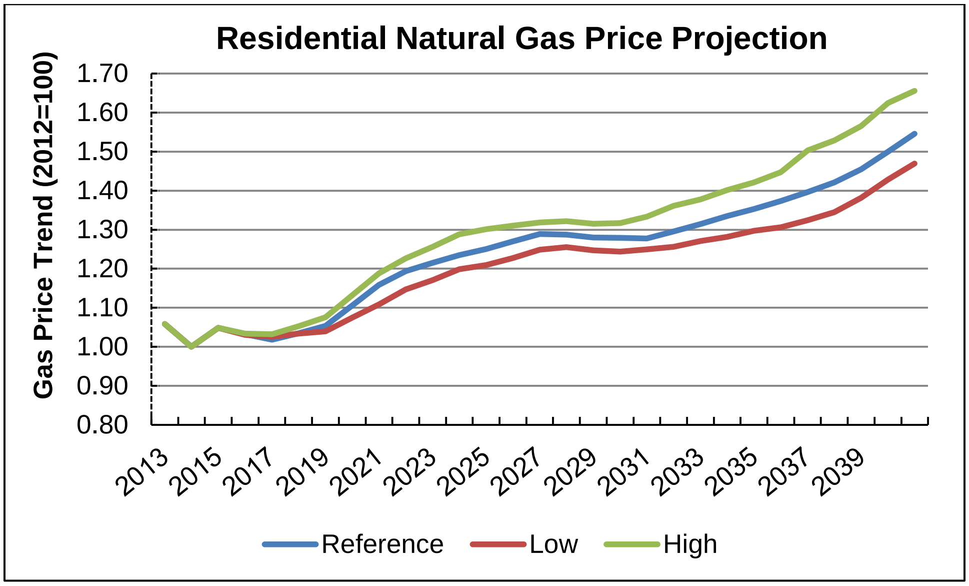

Figure 10D.1.3 **Average Residential Natural Gas Price Forecasts under Alternative AEO2015 Economic Growth Scenarios**

10D.2 NIA RESULTS FOR HIGH ECONOMIC GROWTH SCENARIO

Table 10D.2.1 Cumulative Full-Fuel Cycle Energy Savings in Quads, High Economic Growth Scenario

Product Class	TSL1	TSL2	TSL3
Electric Standard Oven, Freestanding	0.028	0.069	0.193
Electric Standard Oven, Built-In/Slide-In	0.001	0.001	0.004
Electric Self-Clean Oven, Freestanding	0.087	0.087	0.449
Electric Self-Clean Oven, Built-In/Slide-In	0.025	0.025	0.130
Gas Standard Oven, Freestanding	0.000	0.236	0.243
Gas Standard Oven, Built-In/Slide-In	0.000	0.044	0.046
Gas Self-Clean Oven, Freestanding	0.044	0.307	0.325
Gas Self-Clean Oven, Built-In/Slide-In	0.002	0.016	0.017
All	**0.187**	**0.786**	**1.407**

Table 10D.2.2 Cumulative Net Present Value of Consumer Benefits, High Economic Growth Scenario

Discount Rates	Product Class	TSL 1	TSL 2	TSL 3
3% (billion 2013$)	Electric Standard Oven, Freestanding	0.202	0.370	-0.594
	Electric Standard Oven, Built-In/Slide-In	0.004	0.008	-0.016
	Electric Self-Clean Oven, Freestanding	0.634	0.634	-1.022
	Electric Self-Clean Oven, Built-In/Slide-In	0.188	0.188	-0.318
	Gas Standard Oven, Freestanding	0.000	3.963	3.390
	Gas Standard Oven, Built-In/Slide-In	0.000	0.741	0.634
	Gas Self-Clean Oven, Freestanding	0.318	6.033	5.216
	Gas Self-Clean Oven, Built-In/Slide-In	0.016	0.310	0.268
7% (billion 2013$)	Electric Standard Oven, Freestanding	0.083	0.135	-0.530
	Electric Standard Oven, Built-In/Slide-In	0.002	0.003	-0.015
	Electric Self-Clean Oven, Freestanding	0.261	0.261	-1.025
	Electric Self-Clean Oven, Built-In/Slide-In	0.080	0.080	-0.319
	Gas Standard Oven, Freestanding	0.000	1.688	1.352
	Gas Standard Oven, Built-In/Slide-In	0.000	0.314	0.251
	Gas Self-Clean Oven, Freestanding	0.129	2.514	2.042
	Gas Self-Clean Oven, Built-In/Slide-In	0.007	0.130	0.105

10D.3 RESULTS FOR LOW ECONOMIC GROWTH SCENARIO

Table 10D.3.1 Cumulative Full-Fuel Cycle Energy Savings in Quads, Low Economic Growth Scenario

Product Class	TSL1	TSL2	TSL3
Electric Standard Oven, Freestanding	0.022	0.054	0.150
Electric Standard Oven, Built-In/Slide-In	0.000	0.001	0.003
Electric Self-Clean Oven, Freestanding	0.068	0.068	0.350
Electric Self-Clean Oven, Built-In/Slide-In	0.020	0.020	0.102
Gas Standard Oven, Freestanding	0.000	0.201	0.206
Gas Standard Oven, Built-In/Slide-In	0.000	0.038	0.039
Gas Self-Clean Oven, Freestanding	0.037	0.259	0.275
Gas Self-Clean Oven, Built-In/Slide-In	0.002	0.013	0.014
All	**0.149**	**0.653**	**1.139**

Table 10D.3.2 Cumulative Net Present Value of Consumer Benefits, Low Economic Growth Scenario

Discount Rates	Product Class	TSL 1	TSL 2	TSL 3
3% (billion 2013$)	Electric Standard Oven, Freestanding	0.150	0.267	-0.553
	Electric Standard Oven, Built-In/Slide-In	0.003	0.006	-0.015
	Electric Self-Clean Oven, Freestanding	0.469	0.469	-0.998
	Electric Self-Clean Oven, Built-In/Slide-In	0.140	0.140	-0.308
	Gas Standard Oven, Freestanding	0.000	3.300	2.800
	Gas Standard Oven, Built-In/Slide-In	0.000	0.616	0.523
	Gas Self-Clean Oven, Freestanding	0.254	5.033	4.317
	Gas Self-Clean Oven, Built-In/Slide-In	0.013	0.259	0.222
7% (billion 2013$)	Electric Standard Oven, Freestanding	0.064	0.099	-0.463
	Electric Standard Oven, Built-In/Slide-In	0.002	0.003	-0.013
	Electric Self-Clean Oven, Freestanding	0.199	0.199	-0.905
	Electric Self-Clean Oven, Built-In/Slide-In	0.061	0.061	-0.282
	Gas Standard Oven, Freestanding	0.000	1.435	1.138
	Gas Standard Oven, Built-In/Slide-In	0.000	0.266	0.211
	Gas Self-Clean Oven, Freestanding	0.106	2.139	1.722
	Gas Self-Clean Oven, Built-In/Slide-In	0.005	0.110	0.089

REFERENCES

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1 U.S. Department of Energy-Energy Information Administration. *Annual Energy Outlook 2015 with Projections to 2040,* 2015. Washington, DC. Report Number: DOE/EIA-0383(2015).
< http://www.eia.gov/forecasts/aeo/>

APPENDIX 12A. MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

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APPENDIX 12A. MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

2014

12A.1 MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

Introduction

As part of the rulemaking process for amending energy conservation standards for residential conventional cooking products, the Department of Energy (DOE) is conducting a manufacturer impact analysis (MIA). In this analysis, DOE uses publicly available information and information provided by manufacturers during confidential interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

This questionnaire is a part of the MIA process and is intended to inform the Department's understanding of how changes in the energy conservation standard may affect manufacturers of residential conventional cooking products. All information provided in response to this questionnaire will be treated as confidential. The topics below range from general questions about the key issues facing the industry in light of amended energy conservation standards to specific requests to validate industry average financial parameters used to model industry cash flow.

Topics covered will include:

1) Engineering
2) Key Issues
3) Company Overview And Organizational Characteristics
4) Markups And Profitability
5) Shipment Projections
6) Industry Average Financial Parameters
7) Conversion Costs
8) Cumulative Regulatory Burden
9) Direct Employment Impacts
10) Manufacturing Capacity / Exports / Foreign Competition / Outsourcing
11) Industry Consolidation
12) Impacts On Small Businesses

The questions in this interview guide refer to the product classes and potential efficiency levels described in Table A through Table G and the design options listed in Table H.

Table A Gas Cooking Top Product Classes and Potential Efficiency Levels

Level	**Efficiency Level Source**	**2009 Standards Rulemaking**		**Proposed Test Procedure Cooking Efficiency**	**Proposed IAEC (*kBtu*)**
		Cooking Efficiency	**EF**		
Baseline	2009 TSD (Electronic Ignition)	0.399	0.399	0.365	1445.0
1	2009 TSD Max-Tech (Sealed Burners)	0.420	0.420	0.384	1372.7

Baseline: Cooktop cooking efficiency = 39.9%, four conventional 9,000 BTU/hr burners and electronic ignition.
(1) Sealed Burners: Cooking efficiency increase = 4.8% (relative percent).

Table B Electric Open (Coil) Element Cooking Top Product Classes and Potential Efficiency Levels

Level	**Efficiency Level Source**	**2009 Standards Rulemaking**		**Proposed Test Procedure Cooking Efficiency**	**Proposed IAEC (*kWh*)**
		Cooking Efficiency	**EF**		
Baseline	2009 TSD (Baseline)	0.737	0.737	0.674	256.7
1	2009 TSD (Improved Contact Conductance)	0.769	0.769	0.704	246.0

Baseline: Cooktop cooking efficiency = 73.7%, two 6-inch 1,250 W and two 8-inch 2,100 W elements.
(1) Improved Contact Conductance: Cooking efficiency increase = 4.3% (relative percent).

Table C Electric Smooth Element Cooking Top Product Classes and Potential Efficiency Levels

Level	Efficiency Level Source	2009 Standards Rulemaking		Proposed Test Procedure Cooking Efficiency	Proposed IAEC (*kWh*)
		Cooking Efficiency	EF		
Baseline	2009 TSD (Baseline)	0.742	0.742	0.679	280.6
1	Baseline + Switch-Mode Power Supply (SMPS)	0.742	0.742	0.679	268.6
2	Baseline + 1 W Standby	0.742	0.742	0.679	263.5
3	2009 TSD (Halogen Lamp Element) + 1 W Standby	0.753	0.753	0.689	259.8
4	Induction + SMPS	-	-	0.746	245.9
5	Induction + 1 W Standby	-	-	0.746	240.7

Baseline: Cooktop cooking efficiency = 74.2%, two 6-inch 1,500 W and two 8-inch 2,000 W solid disk elements, 3 W standby power.

(1) Baseline + SMPS 1.6 W standby power.

(2) Baseline + 1 W standby power.

(3) 2 + Halogen Element: Cooking efficiency increase = 1.5% (relative percent), two small 1,200 W and two large 1,800 W circular lamps.

(4) Induction: Proposed TP cooking efficiency increase = 9.8% (relative percent), SMPS 1.6 W standby power.

(5) 4 + 1 W standby power.

Table D Gas Standard Oven (with or without a catalytic line) Product Classes and Potential Efficiency Levels

Level	Efficiency Level Source	2009 Standards Rulemaking		Proposed IAEC (*kBtu*)
		EF	Annual Energy Consumption (*kBtu)*	
Baseline	2009 TSD (Electric Glo-bar Ignition)	0.0536	1656.7	2076.5
1	2009 TSD (Electric Glo-bar Ignition) + SMPS	0.0536	1656.7	1932.0
2	2009 TSD (Improved Insulation) + SMPS	0.0566	1568.9	1844.2
3	2009 TSD (2 + Electronic Spark Ignition) + SMPS	0.0616	1442.4	1717.7
4	2009 TSD (3 + Improved Door Seals) + SMPS	0.0622	1427.3	1702.6
5	2009 TSD (4 + Reduced Vent Rate) + SMPS	0.0625	1420.1	1695.4
6	2009 TSD (5 + Reduced Conduction Losses) + SMPS	0.0630	1410.6	1685.9
7	2009 TSD (6 + Forced Convection) + SMPS	0.0653	1360.7	1636.0
8	2009 TSD (7) + 1W Standby	0.0653	1360.7	1499.1

Baseline: Cooking efficiency = 5.8% (electric glo-bar ignition = 176 Wh, 2 inches of 1.09 lb/cubic foot insulation), 10.7 W standby power, 175 Wh fan-only mode per-cycle energy use.
(2) 1 + Improved Insulation: Cooking efficiency increase = 4.9% (relative percent)
(3) 2 + Electronic Spark Ignition: Decrease in electricity consumption = 176 Wh
(4) 3 + Improved Door Seals: Cooking efficiency increase = 1.0% (relative percent)
(5) 4 + Reduced Vent Rate: Cooking efficiency increase = 0.5% (relative percent)
(6) 5 + Reduced Conduction Losses: Cooking efficiency increase = 0.05 (absolute percentage points)
(7) 6 + Forced Convection: Cooking efficiency increase = 4.8% (relative percent), added electricity consumption = 15 Wh
(8) 7 + 1 W standby power.

Table E Gas Self-Clean Oven Product Classes and Potential Efficiency Levels

Level	Efficiency Level Source	2009 Standards Rulemaking		Proposed IAEC (*kBtu*)
		EF	Annual Energy Consumption (*kBtu*)	
Baseline	2009 TSD (Baseline)	0.0540	1644.4	1965.0
1	2009 TSD (Baseline) + SMPS	0.0540	1644.4	1820.5
2	2009 TSD (Forced Convection) + SMPS	0.0625	1420.8	1596.9
3	2009 TSD (2) + Electronic Spark Ignition + SMPS	0.0680	1306.3	1482.3
4	2009 TSD (3 + Improved Door Seals) + SMPS	0.0685	1295.9	1472.0
5	2009 TSD (4 + Reduced Conduction Losses) + SMPS	0.0687	1291.8	1467.8
6	2009 TSD (5) + 1 W Standby	0.0687	1291.8	1330.9

Baseline: Cooking efficiency = 7.13%, clock power = 3.6 W, 2 inches of 1.90lb/cubic foot insulation, electronic ignition = 176 Wh, self-cleaning energy consumption = 43,158 Btu, 10.7 W standby power, 175 Wh fan-only mode per-cycle energy use.

(1) Baseline + SMPS 5.7 W standby power

(2) 1 + Forced Convection: Cooking efficiency increase = 23% (relative percent), added electricity consumption (during cooking and cleaning cycles) = 15 Wh

(3) 2 + Electronic Spark Ignition: Decrease in electricity consumption = 176 Wh

(4) 3 + Improved Door Seals: Cooking efficiency increase = 1.0% (relative percent)

(5) 4 + Reduced Conduction Losses: Cooking efficiency increase = 0.05 (absolute percentage points)

Table F Electric Standard Oven (with or without a catalytic line) Product Classes and Potential Efficiency Levels

Level	Efficiency Level Source	2009 Standards Rulemaking		Proposed IAEC (*kWh*)
		EF	Annual Energy Consumption (*kWh)*	
Baseline	2009 TSD (Baseline)	0.1066	274.9	370.0
1	2009 TSD (Baseline) + SMPS	0.1066	274.9	327.7
2	2009 TSD (Reduced Vent Rate) + SMPS	0.1113	263.3	316.1
3	2009 TSD (2 + Improved Insulation) + SMPS	0.1163	251.9	304.8
4	2009 TSD (3 + Improved Door Seals) + SMPS	0.1181	248.1	300.9
5	2009 TSD (4 + Reduced Conduction Losses) + SMPS	0.1184	247.5	300.3
6	2009 TSD (5 + Forced Convection) + SMPS	0.1209	242.3	295.2
7	2009 TSD (6) + 1 W Standby	0.1209	242.3	255.0

Baseline: Cooking efficiency = 12.15%, 2 inches of 1.09 lb/cubic foot insulation, 10.7 W standby power, 175 Wh fan-only mode per-cycle energy use.
(1) Baseline + SMPS 5.7 W standby power.
(2) 1 + Reduced Vent Rate: Cooking efficiency increase = 0.62 (absolute percentage points)
(3) 2 + Improved Insulation: Cooking efficiency increase = 0.52% (relative percent)
(4) 3 + Improved Door Seals: Cooking efficiency increase = 0.24 (absolute percentage points)
(5) 4 + Reduced Conduction Losses: Cooking efficiency increase = 0.05 (absolute percentage points)
(6) 5 + Forced Convection: Cooking efficiency increase = 0.33 (absolute percentage points), added electricity consumption = 15 Wh
(7) 6 + 1 W standby power.

Table G Electric Self-Clean Oven Product Classes and Potential Efficiency Levels

Level	Efficiency Level Source	2009 Standards Rulemaking		Proposed IAEC (*kWh*)
		EF	Annual Energy Consumption (*kWh)*	
Baseline	2009 TSD (Baseline)	0.1099	266.6	360.0
1	2009 TSD (Baseline) + SMPS	0.1099	266.6	317.7
2	2009 TSD (Reduced Conduction Losses) + SMPS	0.1102	265.9	317.0
3	2009 TSD (2 + Forced Convection) + SMPS	0.1123	260.9	312.0
4	2009 TSD (3) + 1 W Standby	0.1123	260.9	271.9

Baseline: Cooking efficiency = 13.79%, 2 inches of 1.09 lb/cubic foot insulation, self-cleaning energy consumption = 5,286 Wh, 10.7 W standby power, 175 Wh fan-only mode per-cycle energy use.

(1) Baseline + SMPS 5.7 W standby power

(2) 1 + Reduced Conduction Losses: Cooking efficiency increase = 0.05 (absolute percentage points)

(3) 2 + Forced Convection: Cooking efficiency increase = 0.33 (absolute percentage points), added electricity consumption = 15 Wh

(4) 3 + 1 W standby power

Table H Potential Design Options

Design Options
Gas cooking tops: • Reflective surfaces • Sealed burners • Thermostatically controlled burners
Open (coil) element electric cooking tops: • Improved contact conductance • Reflective surfaces
Smooth element electric cooking tops: • Radiant elements • Halogen elements • Induction elements • Low-standby-loss electronic controls
Gas and electric ovens: • Bi-radiant oven (electric only) • Electronic spark ignition (gas only) • Forced convection • Improved insulation • Improved door seals • Oven separator • Reduced conduction losses • Reduced thermal mass • Reduced vent rate • Steam cooking • Low-standby-loss electronic controls

Table I Manufacturer Model Energy Use

			Oven Annual Energy Consumption				Cooktop Annual Energy Consumption	
Brand	**Model**	**Product Class**	**Cooking, E_{CO} (*kWh or Btu*)[1]**	**Self-Clean, E_{SC} (*kWh or Btu*)[1]**	**Standby/Off Mode, E_{OTLP} (*kWh*)**	**Fan-Only Mode, E_{OF} × N (*kWh*)**	**Cooking E_{CA}/E_{CC} (*kWh or Btu*)**	**Standby/Off Mode, E_{CTSO} (*kWh*)**

[1] For gas cooking products, please include both the primary and secondary energy consumption in these modes.

1. ENGINEERING

1.1 Because there are currently no energy conservation standards or energy labeling requirements for conventional cooking products, would you please provide the energy use information requested in Table I above with regards to models that you manufacture? For cooking tops, please provide energy use information according to the test procedure proposed in the January 30, 2013 NOPR (78 FR 6232) if possible. Otherwise, please indicate that the energy use information is based on the current DOE test procedure in appendix I.

1.2 Which design features impacting energy use are generally incorporated into a "baseline" unit in each product class listed in Table A through Table G? What are the typical costs associated with the major components of the baseline products in each of these product classes (e.g. heaters, gas valves/burners, ignition systems, insulation, controls, etc.)?

1.3 As part of the previous standards rulemaking, DOE established the product classes listed in Table A through Table G, differentiating classes by energy source (electric vs. gas), coil vs. smooth cooking tops, and standard vs. self-clean ovens. [1] For the current rulemaking, DOE is considering whether separate product classes should be established for commercial-style (professional-style) gas cooking products[2] or residential-style units with higher input rates. Do you believe separate product classes are warranted for these products? If so, how should these product classes be defined (in particular with respect to burner input rates, number of high input rate burners, cooking top grate materials, oven cavity volume, or any other characteristics)? Are there other product classes that DOE should consider?

1.4 DOE is proposing to analyze the efficiency levels listed in Table A through Table G. Do you

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[1] EPCA requires that a rule prescribing standards for a class of covered products shall specify a level of energy use or efficiency higher or lower than that which applies for such class for any group of covered products which have the same function or intended use, if the Secretary determines that covered products within such group – (A) consume a different kind of energy; or (B) have a capacity or other performance-related feature that justifies a higher or lower standard, considering the utility of the feature to the consumer and other factors deemed appropriate by the Secretary. (42 U.S.C. 6295(q))

[2] As part of the previous standards rulemaking, DOE considered commercial-style gas cooking tops to be those products that incorporate cooking tops with higher input rate burners (i.e., greater than 14,000 Btu/(h and heavy-duty grates that provide faster cooking and the ability to cook larger quantities of food in larger cooking vessels. DOE considered commercial-style gas ovens to have higher input rates (i.e., greater than 22,500 Btu/h) and dimensions to accommodate larger cooking utensils or greater quantity of food items, as well as features to optimize cooking performance.

agree with the proposed efficiency levels? If not, can you suggest appropriate values? For ovens, the cost-efficiency relationships are predicated on ovens with a cavity volume of 3.9 ft^3. For cooking tops, the proposed efficiency levels are based on the test procedure proposed in the January 2013 NOPR. Can you please provide data showing the difference in measured efficiency for cooking tops using the current DOE test procedure in appendix I, which uses an aluminum test block, compared to the test procedure proposed in the January 2013 NOPR, which uses a hybrid test block (a stainless steel alloy 430 base and an aluminum body).

1.5 If you believe commercial-style gas cooking products or residential-style units with higher input rates or any other product types should be analyzed as separate product classes, can you suggest baseline, max-tech, and if necessary, gap fill efficiency levels for these product classes?

1.6 How does efficiency/energy use scale with oven cavity volume? Do you have data showing the effects of energy use versus oven cavity volume and, if so, can you provide this data? As part of the previous rulemaking, DOE presented the linear equations for both electric and gas ovens relating EF to oven cavity volume (no distinction was found to exist between standard and self-cleaning ovens). The values of the slopes were determined to be -0.0157 for electric ovens and -0.0073 for gas ovens[3]. Are these slopes representative of the relationship between EF and oven cavity volume?

1.7 Does oven efficiency/energy use have a strong relationship with electric heater input or gas burner firing rate (or a combination of heat input/firing rate and oven cavity volume)? If so, can you please provide data showing this relationship?

1.8 Which design features impacting energy use are incorporated into products to reach each incremental efficiency level for each product class? What are the costs of the individual design options selected for each efficiency level? Are the incremental manufacturing costs at each efficiency level specified in Table 12A.1 through Table 12A.3 representative of costs your company would incur? If not, please provide a quantitative indication of the differences in

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[3] For the slope, energy factor is expressed as a decimal and the volume in cubic feet.

costs and design changes. For active mode design changes, the incremental costs are based on data from the previous standards rulemaking (April 2009 Final Rule), updated using the producer price index (PPI). Because standby power design changes were not considered as part of the previous standards rulemaking, DOE determined incremental cost data separately for standby power design changes based on product teardowns and reverse engineering.

Table 12A.1 Cost-Efficiency Relationships – Cooking Tops

Product Class	**Level**	**Proposed IAEC**	**Incremental Cost (*$2013*)**	**Comments**
Gas cooking tops	Baseline (Electronic Ignition)	1445.0 kBtu	-	
	1 (Sealed Burners)	1372.7 kBtu	$23.74	
Open (coil) element electric cooking tops	Baseline	256.7 kWh	-	
	1 (Improved Contact Conductance)	246.0 kWh	$2.71	
Smooth element electric cooking tops	Baseline	280.6 kWh	-	
	1 (Baseline + SMPS)	268.6 kWh	Not Available	
	2 (Baseline + 1 W Standby)	263.5 kWh	Not Available	
	3 (Halogen Lamp Element + 1 W Standby)	259.8 kWh	$105.77 + Standby	
	4 (Induction + SMPS)	245.9 kWh	$335.27 + Standby	
	5 (Induction + 1 W Standby)	240.7 kWh	$335.27 + Standby	

Table 12A.2 Cost-Efficiency Relationships – Gas Ovens

Product Class	Level	Proposed IAEC (*kBtu)*	Incremental Cost (*$2013*)	Comments
Gas ovens – standard ovens with or without a catalytic line	Baseline (Electric Glo-bar Ignition)	2076.5	-	
	1 (Electric Glo-bar Ignition + SMPS)	1932.0	Not Available	
	2 (Improved Insulation + SMPS)	1844.2	$4.25 + Standby	
	3 (2 + Electronic Spark Ignition + SMPS)	1717.7	$22.06 + Standby	
	4 (3 + Improved Door Seals + SMPS)	1702.6	$23.34 + Standby	
	5 (4 + Reduced Vent Rate + SMPS)	1695.4	$25.26 + Standby	
	6 (5 + Reduced Conduction Losses + SMPS)	1685.9	$29.57 + Standby	
	7 (6 + Forced Convection + SMPS)	1636.0	$55.86 + Standby	
	8 (7 + 1W Standby)	1499.1	$55.86 + Standby	
Gas ovens – self-clean ovens	Baseline	1965.0	-	
	1 (Baseline + SMPS)	1820.5	Not Available	
	2 (Forced Convection + SMPS)	1596.9	$13.07 + Standby	
	3 (2 + Electronic Spark Ignition + SMPS)	1482.3	$22.66 + Standby	
	4 (3 + Improved Door Seals + SMPS)	1472.0	$24.11 + Standby	
	5 (4 + Reduced Conduction Losses + SMPS)	1467.8	$29.30 + Standby	
	6 (5 + 1 W Standby)	1330.9	$29.30 + Standby	

Table 12A.3 Cost-Efficiency Relationships – Electric Ovens

Product Class	**Level**	**Proposed IAEC (*kWh*)**	**Incremental Cost (*$2013*)**	**Comments**
Electric ovens – standard ovens with or without a catalytic line	Baseline	370.0	-	
	1 (Baseline + SMPS)	327.7	Not Available	
	2 (Reduced Vent Rate + SMPS)	316.1	$1.94 + Standby	
	3 (2 + Improved Insulation + SMPS)	304.8	$5.75 + Standby	
	4 (3 + Improved Door Seals + SMPS)	300.9	$10.13 + Standby	
	5 (4 + Reduced Conduction Losses + SMPS)	300.3	$14.34 + Standby	
	6 (5 + Forced Convection + SMPS)	295.2	$61.37 + Standby	
	7 (6 + 1 W Standby)	255.0	$61.37 + Standby	
Electric ovens – self-clean ovens	Baseline	360.0	-	
	1 (Baseline + SMPS)	317.7	Not Available	
	2 (Reduced Conduction Losses + SMPS)	317.0	$5.19 + Standby	
	3 (2 + Forced Convection + SMPS)	312.0	$52.21 + Standby	
	4 (3 + 1 W Standby)	271.9	$52.21 + Standby	

1.9 How does the selection of design options and associated costs and efficiency improvement compare for residential-style gas cooking products with lower input rates versus commercial-style gas cooking products and residential-style units with higher input rates? How do commercial-style gas cooking products and residential-style units with higher input rates compare to residential-style gas cooking products with lower input rates in terms of achievable efficiency levels? What unique challenges do commercial-style gas cooking products and residential-style units with higher input rates encounter when trying to improve energy efficiency?

1.10 Are any of the design options listed in Table H more effective in residential-style or commercial-style cooking products? Are there any other design options for improving efficiency that are not listed in the table? If so, what is the incremental cost associated with implementing those design options?

1.11 What percentage of commercial-style gas cooking products and residential-style units with higher input rates are equipped with a standing pilot light?

1.12 Does your company collect consumer usage information that can be provided in detail or summary (e.g., number of annual cooking cycles, cooking cycle length, cooking modes selected, cookware dimensions, etc.)?

1.13 Are installation costs a function of efficiency? Maintenance costs? Repair costs? If yes, please characterize this relationship by providing incremental installation, maintenance, and/or repair cost data. How do these installation/maintenance/repair costs compare for commercial-style gas cooking products?

1.14 Information gathered from analysis of common industry practices were used to formulate factory parameters for manufacturers. Please comment on the following factory parameter assumptions listed in Table 12A.4.

Table 12A.4 Factory Parameters

Parameter	Estimate	Manufacturer Feedback
Actual Annual Production Volume (units/year)	REDACTED	
Work Days Per Year (days)	REDACTED	
Assembly Shifts Per Day (shifts)	REDACTED	
Fabrication Shifts Per Day (shifts)	REDACTED	
Fabrication Labor Wages ($/hr)	REDACTED	
Assembly Labor Wages ($/hr)	REDACTED	
Assembly Worker Hours Per Year	REDACTED	
Fabrication Worker Hours Per Year	REDACTED	
Length of Shift (hrs)	REDACTED	
Units Per Day	REDACTED	
Average Equipment Installation Cost (% of purchase price)	REDACTED	
Fringe Benefits Ratio	REDACTED	
Indirect to Direct Labor Ratio	REDACTED	
Average Scrap Recovery Value	REDACTED	
Worker Downtime	REDACTED	
Burdened Assembly Labor Wage ($/hr)	REDACTED	
Burdened Fabrication Labor Wage ($/hr)	REDACTED	
Supervisor Span (workers/supervisor)	REDACTED	
Supervisor Wage Premium (over fabrication and assembly wage)	REDACTED	

1.15 Do you believe that the current test procedures in Appendix I and the proposed test procedure amendments in the January 2013 TP NOPR (78 FR 6232), are appropriate for measuring performance? If not, can you suggest an alternative method (providing specific details on test conditions, such as test load size, temperature rises, etc.)? Can you also suggest appropriate test methods for commercial-style gas cooking products or residential-style units with higher input rates? Can you also provide data showing the effects of the test procedure change on the measured efficiency/energy-use as compared to the existing test procedure? Can you comment on the following issues related to the test procedure:

a. Test load size for gas cooktop burners having input rates > 14,000 Btu/hr
    i. What range of cookware diameters are commercial-style gas cooktops and residential-style units with higher input rates designed for use with?
b. Test load size for gas ovens having input rates > 22,500 Btu/hr
c. Test load size for electric cooktops
    i. What is the maximum surface unit diameter you produce for electric coil cooktops?
    ii. What is the maximum surface unit diameter you produce for smooth electric cooktops?
    iii. What percentage of your electric cooktop shipments have non-circular surface units (e.g., square, oval, rectangular bridge)? Are the non-circular markings on the glass-ceramic surface decorative or are the underlying radiant elements also non-circular? Is the same true of induction elements?

2 KEY ISSUES

DOE is interested in understanding the impact of amended energy conservation standards on manufacturers of residential conventional cooking products. This section provides an opportunity for manufacturers to identify high-priority issues that DOE should take into consideration when conducting the Manufacturer Impact Analysis.

2.1 In general, what are the key concerns for your company regarding the amended energy conservation standards rulemaking for residential conventional cooking products?

2.2 For the issues you have identified, how significant are they for different product classes and/or efficiency levels?

2.3 How would amended energy conservation standards affect your ability to compete in the marketplace? Would you expect your market share to change?

3 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

3.1 Do you have a parent company and/or subsidiary? If so, please provide their name(s).

3.2 What is your company's approximate market share of the residential conventional cooking products market? Does this vary significantly for any particular product class that you manufacture?

3.3 Do you manufacture any products other than residential conventional cooking products? If so, what other products do you manufacture? Do you manufacturer them in the same facilities as your residential conventional cooking products? What percentage of your overall revenue is derived from sales of residential conventional cooking products?

3.4 What are your product line niches and relative strengths in the residential conventional cooking products market?

3.5 Where are your production facilities located, and what type of product is manufactured at each location? Please provide production figures for your company's manufacturing at each location by product class.

Table 12A-5 Manufacturing locations

Location	Product Class(es)	Employees (Production)	Employees (Non-production)	Units/Yr Produced
e.g. - Brunswick, ME	*e.g. - Gas Cooking Top Products,* *Gas Ovens – Self-Cleaning*	*e.g. - 350*	*e.g. - 75*	*e.g. - 8,500 Total (4000 and 4500 respectively)*

3.6 Are higher efficiency products built at different plants than lower efficiency products of the same equipment class?

4 MARKUPS AND PROFITABILITY

One of the primary objectives of the Manufacturer Impact Analysis is to assess the impact of amended energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how an amended energy conservation standard may impact your company's markup structure and profitability. The manufacturer markup is a multiplier applied to manufacturer production costs to cover research and development, selling, general, and administrative expenses, and profit. It is not a profit margin. The manufacturer production cost multiplied by the manufacturer markup covers all costs involved in manufacturing as well as profit for the product.

4.1 DOE estimated a markup of 1.205 for all product classes. Please comment on the accuracy of this figure and whether or not it may vary by product class.

4.2 Within each product class, do the per-unit mark-ups vary by efficiency level? Is the markup for more efficient designs different than the markup for baseline models?

4.3 What factors besides efficiency affect markups in the same product class?

4.4 Would you expect amended energy conservation standards to affect your profitability? If so, please explain why.

5 SHIPMENT PROJECTIONS

An amended energy conservation standard can change overall shipments by altering product attributes, marketing approaches, product availability, and price. Having an accurate estimate of these changes allows DOE to better examine impacts on profitability due to amended standards. DOE's shipments model includes forecasts for the base case shipments (i.e., total industry shipments absent amended energy conservation standards) and the standards case shipments (i.e., total industry shipments with amended energy conservation standards).

5.1 Can you provide your historical shipments of commercial-style gas residential conventional cooking products for the last 10 years?

5.2 Can you provide the historical market share (last 5 years) of your shipments by efficiency level for each product class?

5.3 Can you provide the historical market share (last 5 years) of your shipments by standby level for each product class?

5.4 Are there any anticipated or observed differences in the repair and maintenance costs or lifetime of induction type cooking units, compared to their conventional smooth top counterpart?

5.5 In the residential conventional cooking products industry, which party in the supply chain typically pays for shipping of the product to the distributor warehouse?

5.6 If the manufacturer pays for shipping costs, is it industry practice to mark-up shipping costs?

5.7 Do any of the efficiency levels trigger substantial increases in shipping costs? If so, which ones and for which products?

5.8 Currently, what fraction of your sales are high efficiency products, i.e., products that exceed the baseline efficiency level?

5.9 How do you think amended energy conservation standards will impact the sales of more efficient products? For example, would customers continue to buy products that exceed the energy conservation standard level? Would your response change for higher mandated efficiency levels?

5.10 Are there any types of equipment that you expect will soon be phased out in the absence of an amended standard?

6 FINANCIAL PARAMETERS

Using publicly available data, Navigant Consulting, Inc. (NCI) has developed a "straw man" model of financial performance for the residential conventional cooking products manufacturing industry. This section attempts to understand how your company's financial situation differs from our industry aggregate picture.

6.1 Please compare the financial parameters for the business unit responsible for manufacturing residential conventional cooking products to those tabulated below.

Table 12A-6 Financial Parameters for Residential Conventional Cooking Products Manufacturing

GRIM Input	Definition	Industry Estimated Value	Your Actual
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	19.5%	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	9.1%	
Working Capital	Current assets less current liabilities (percentage of revenues)	4.5%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	11.2%	
R&D	Research and development expenses (percentage of revenues)	2.4%	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.0%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	3.3%	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	83.0%	

6.2 Are the figures in Table 6-1 representative of the residential conventional cooking products industry as a whole? If not, why?

6.3 Do any of the financial parameters in Table 6-1 change for a particular subgroup of manufacturers? Please describe any differences.

7 CONVERSION COSTS

An increase in energy conservation standards may cause the industry to incur capital and product conversion costs to meet the amended energy conservation standard. The Manufacturer Impact Analysis considers three types of conversion expenditures:

- Capital conversion costs – One-time investments in plant, property, and equipment (PPE) required to manufacture products that comply with amended energy conservation standards. These may be incremental changes or upgrades to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.
- Product conversion costs – One-time investments in research, product development, testing, marketing and other costs for redesigning and bringing to market products that comply with amended energy conservation standards.
- Stranded assets – The residual undepreciated value of assets replaced before the end of their useful lives as a direct result of the change in energy conservation standard.

With a detailed understanding of the conversion costs necessitated by different standard levels, DOE can better model the impact on the residential conventional cooking products industry resulting from amended energy conservation standards.

7.1 At your manufacturing facilities, would amended energy conservation standards be difficult to implement? If so, would your company modify existing facilities or develop new facilities?

7.2 What level of conversion costs do you anticipate incurring at each efficiency level? Please provide dollar amounts as well as descriptions of the investment in the tables that follow. In the description column, DOE is interested in understanding the kind of changes that would need to be implemented in production lines and production facilities. Where applicable, please quantify the number and cost of new production equipment that would be required to meet the specified efficiency levels.

Table 12A-7 Conversion Costs – Cooking Tops

Product Class	Efficiency Level (EL)	Proposed IAEC	Estimated Capital Conversion Costs	Estimated Product Conversion Costs	Estimated Stranded Assets
Gas cooking tops	Baseline	1445.0 kBtu	-	-	-
	EL 1	1372.7 kBtu			
Open (coil) element electric cooking tops	Baseline	256.7 kWh	-	-	-
	EL 1	246.0 kWh			
Smooth element electric cooking tops	Baseline	280.6 kWh	-	-	-
	EL 1	268.6 kWh			
	EL 2	263.5 kWh			
	EL 3	259.8 kWh			
	EL 4	245.9 kWh			
	EL 5	240.7 kWh			

Table 12A-8 Conversion Costs – Gas Ovens

Product Class	Efficiency Level (EL)	Proposed IAEC	Estimated Capital Conversion Costs	Estimated Product Conversion Costs	Estimated Stranded Assets
Gas ovens – standard ovens with or without a catalytic line	Baseline	2076.5 kBtu	-	-	-
	EL 1	1932.0 kBtu			
	EL 2	1844.2 kBtu			
	EL 3	1717.7 kBtu			
	EL 4	1702.6 kBtu			
	EL 5	1695.4 kBtu			
	EL 6	1685.9 kBtu			
	EL 7	1636.0 kBtu			
	EL 8	1499.1 kBtu			
Gas ovens – self-clean ovens	Baseline	1965.0 kBtu	-	-	-
	EL 1	1820.5 kBtu			
	EL 2	1596.9 kBtu			
	EL 3	1482.3 kBtu			
	EL 4	1472.0 kBtu			
	EL 5	1467.8 kBtu			
	EL 6	1330.9 kBtu			

Table 12A-9 Conversion Costs – Electric Ovens

Product Class	Efficiency Level (EL)	Proposed IAEC	Estimated Capital Conversion Costs	Estimated Product Conversion Costs	Estimated Stranded Assets
Electric ovens – standard ovens with or without a catalytic line	Baseline	370.0 kWh	-	-	-
	EL 1	327.7 kWh			
	EL 2	316.1 kWh			
	EL 3	304.8 kWh			
	EL 4	300.9 kWh			
	EL 5	300.3 kWh			
	EL 6	295.2 kWh			
	EL 7	255.0 kWh			
Electric ovens – self-clean ovens	Baseline	360.0 kWh	-	-	-
	EL 1	317.7 kWh			
	EL 2	317.0 kWh			
	EL 3	312.0 kWh			
	EL 4	271.9 kWh			

7.3 Please comment on any potential stranded assets that may result from an amended energy conservation standard.

7.4 For any efficiency levels that would require new production equipment, please describe how much downtime would be required. What impact would downtime have on your business?

7.5 Please provide any additional qualitative information that might help DOE understand the type and nature of your conversion investments, including plant and tooling changes and product development efforts required for different efficiency levels and equipment classes.

8 CUMULATIVE REGULATORY BURDEN

Cumulative regulatory burden refers to the burden that industry faces from overlapping effects of new or revised DOE standards, and/or other regulatory actions affecting the same product or industry.

8.1 Are there other recent or impending standards that manufacturers of residential conventional cooking products face from DOE, other US federal agencies, state regulators, foreign governmental agencies, or other standard setting bodies? If so, please identify the regulation and the corresponding possible effective dates for those regulations in the table below.

Table 12A-10 Other Regulations Identified by DOE

Regulation	Effective Date(s)	Expected Expenses / Comments
DOE's Amended Energy Conservation Standards for Other Products		
International Energy Efficiency Standards		
State Emission Requirements and Other State Regulations		
Industry Standards and Codes		

8.2 Under what circumstances would you be able to coordinate expenditures related to these other regulations with an amended energy conservation standard, thereby lessening the cumulative burden?

9 DIRECT EMPLOYMENT IMPACT ASSESSMENT

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in residential conventional cooking product manufacturing employment and to solicit manufacturer views on how domestic employment patterns might be affected by amended energy conservation standards.

9.1 Would your domestic employment levels be expected to change significantly under amended energy conservation standards? If so, please identify particular standard levels which may trigger changes in employment.

9.2 Would the workforce skills necessary under amended energy conservation standards require extensive retraining or replacement of employees at your manufacturing facilities?

10 MANUFACTURING CAPACITY/EXPORTS/FOREIGN COMPETITION/OUTSOURCING

A disparity between domestic and foreign energy conservation standards could impact exports or imports. Labor content and material changes, resulting from amended energy conservation standards, may impact sourcing decisions.

How would amended energy conservation standards impact your company's manufacturing capacity, in both the short term and the long term?

10.1 What percentage of your U.S. made residential conventional cooking products is exported?

10.2 Absent amended energy conservation standards, are production facilities being relocated to foreign countries?

10.3 Would amended energy conservation standards impact your domestic vs. foreign manufacturing decision?

10.4 What percentage of the U.S. market for residential conventional cooking products is imported? Would amended energy conservation standards have an impact on foreign competition?

10.5 Do any foreign manufacturers of residential conventional cooking products also have North American production facilities?

11 INDUSTRY CONSOLIDATION

Amended energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that would result from amended energy conservation standards.

11.1 Do you know of any occurrences of industry consolidation that have happened within the last 10 years? If so, please comment on them.

11.2 In the absence of amended energy conservation standards, do you expect any industry consolidation? Please describe your expectations.

11.3 How would industry competition change as a result of amended conservation standards?

11.4 To your knowledge, are there any niche manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact?

11.5 To your knowledge, are there any component manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact?

12 IMPACTS ON SMALL BUSINESS

12.1 The Small Business Association (SBA) considers manufacturers of residential conventional cooking products which employ 750 or fewer employees[4] to be small businesses. By this definition, is your company considered a small business?

12.2 Below is a list of small business manufacturers of residential conventional cooking products compiled by DOE. Are there any small manufacturers that should be added to (or removed from) this list? Are there specific manufacturers on this list that may be more severely impacted by an amended energy conservation standard than others?

- Acme Kitchenettes
- American Range
- Brown Stove Works, Inc.
- Capital Cooking
- Dacor
- Evo, Inc.
- Kenyon International Inc.
- Peerless Premier
- Summit Appliances

12.3 Are there any reasons that a small business might be at a disadvantage relative to a larger business under amended energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

12.4 To your knowledge, are there any small businesses manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, would small business manufacturers have different incremental impacts from amended energy conservation standards than the rest of the industry?

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[4] DOE uses the SBA small business size standards effective January 22, 2014 to determine whether a company is a small business. To be categorized as a small business, a residential conventional cooking product manufacturer and its affiliates may employ a maximum of 750 employees. The 750 employee threshold includes all employees in a business's parent company and any other subsidiaries.

APPENDIX 12B. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

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APPENDIX 12B. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

12B.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 equipment types with regulations taking effect over a period of time, and of multiple regulations on the same equipment.

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.

12B.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 – computed by multiplying equipment unit prices at each efficiency level by the appropriate manufacturer markup.

(3) ***Material:*** The portion of COGS that includes materials.

(4) ***Labor:*** The portion of cost of goods sold (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, the 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 (R&D) 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 equipment 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 ***Cost of Goods Sold ((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 in 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

equipment 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)***.

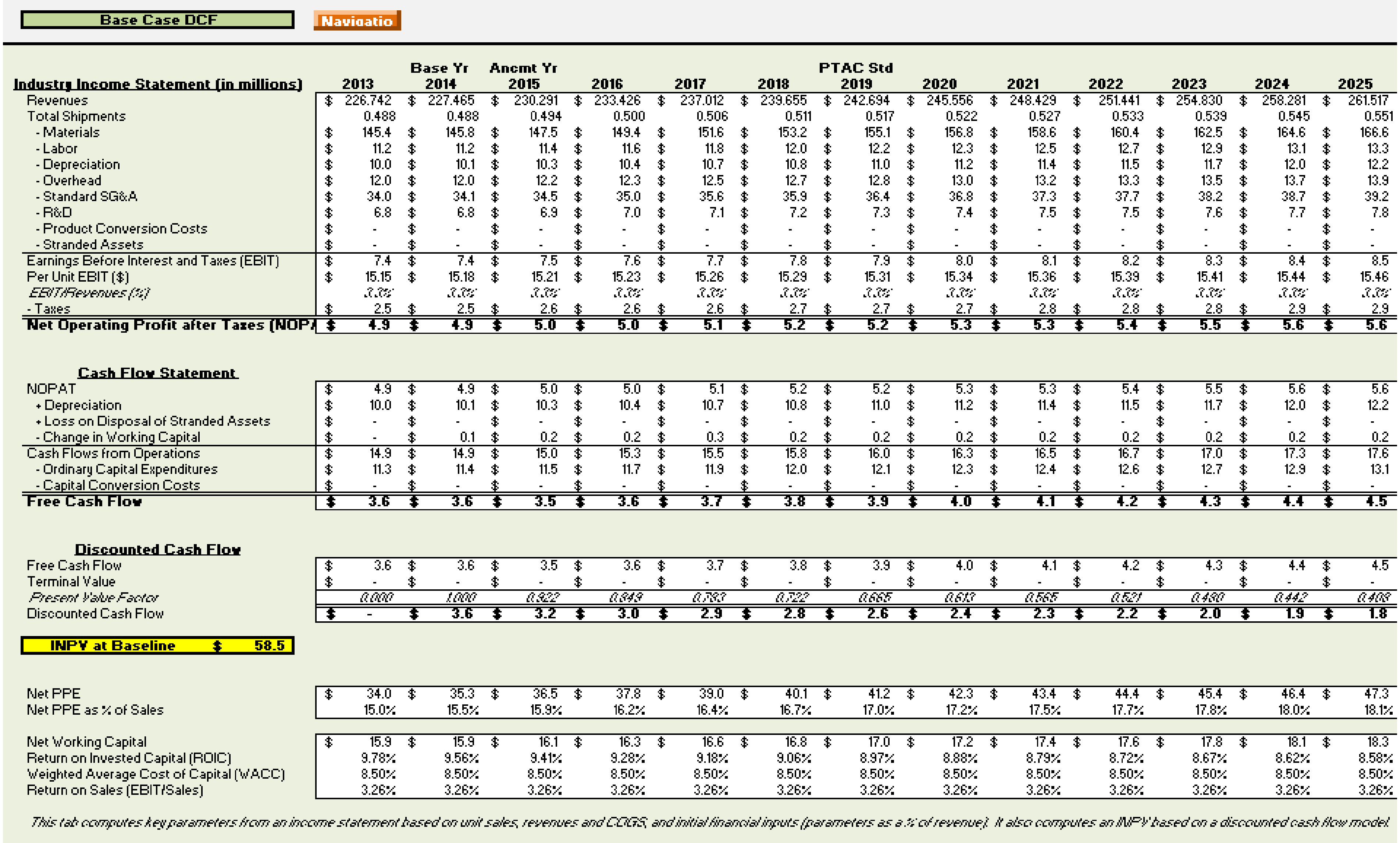
(23) ***Terminal Value:*** Estimate of the continuing value of the industry after the analysis period. Computed by growing the Free Cash Flow at a constant rate in perpetuity.

(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 2048, the discounted cash flow includes the discounted ***Terminal Value (23)***.

(26) ***Industry Value thru the end of 2048:*** The sum of ***Discounted Cash Flows (25)***.

Table 12B.1 Detailed Cash Flow Example



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 13A. EMISSIONS ANALYSIS METHODOLOGY

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APPENDIX 13A. EMISSIONS ANALYSIS METHODOLOGY

13A.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 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 appendix 15A of this TSD and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014).[2] This Appendix describes the development of the upstream emissions factors, and combustion factors for CH_4 and N_2O.

13A.2 POWER SECTOR AND SITE EMISSIONS FACTORS

Marginal emissions factors are calculated by looking at the difference, over the full analysis period, between the AEO reference case and the policy side cases. The analysis produces a set of emissions intensity factors that quantify the reduction in emissions of a given pollutant per unit reduction of site consumption of electricity. Distinct factors are calculated for the residential and commercial sectors, and for each of the end uses that are modeled explicitly in NEMS as listed in the tables below. Total emissions reductions are estimated by multiplying the intensity factors times the energy savings calculated in the national impact analysis (chapter 10).

The AEO does not publish estimates of the CH_4 and N_2O emissions associated with combustion of fossil fuels. For these pollutants, the power sector emissions are estimated using emissions intensity factors published by the EPA[3]. This publication provides emissions intensity factors for different grades of coal, petroleum fuels and natural gas. DOE uses these fuel-specific emissions factors to develop time-dependent emissions factors as a function of the changing fuel mix in the power sector.

Site combustion of fossil fuels in buildings (for example in water-heating, space-heating or cooking applications) also produces emissions of CO_2 and other pollutants. DOE used emissions factors published by the Environmental Protection Agency[3], which are constant in time. These factors are presented in Table 13A.4.1.

13A.3 UPSTREAM FACTORS

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 FFC accounting approach is described briefly in appendix 10B and in Coughlin (2013)[4]. When demand for a particular fuel is reduced, there is a corresponding reduction in the upstream activities associated with production of that fuel (mining, refining etc.) These upstream activities also consume energy and therefore produce combustion emissions. The FFC accounting estimates the total consumption of electricity, natural gas and petroleum-based fuels in these upstream activities. The relevant combustion emissions factors are then applied to this fuel use to determine the total upstream emissions intensities from combustion, per unit of fuel delivered to the consumer.

In addition to combustion emissions, extraction and processing of fossil fuels also produces fugitive emissions of CO_2 and CH_4. Fugitive emissions of CO_2 are small relative to combustion emissions, comprising about 2-3 percent of total CO_2 emissions for natural gas and 1-2 percent for petroleum fuels. In contrast, the fugitive emissions of methane from fossil fuel production are relatively large compared to combustion emissions of CH_4. 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.

Fugitive emissions factors for CO_2 and methane from coal mining and natural gas production were estimated based on a review of recent studies compiled by Burnham (2011).[5] 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.[6,7] As more data are made available, DOE will continue to update these estimated emissions factors.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. 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 13A.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, so some components of the upstream fuel cycle (particularly off-road mobile engines) can contribute significantly to the upstream NO_x emissions factors.

13A.4 DATA TABLES

Summary tables of all the emissions factor data used by DOE for rules using *AEO 2014* are presented in the tables below. Table 13A.4.1 provides combustion emissions factors for fuels commonly used in buildings. Table 13A.4.2 to Table 13A.4.7 present the marginal power sector emissions factors as a function of sector and end use for a selected set of years. Table 13A.4.8 to Table 13A.4.10 provide the upstream emissions factors for all pollutants, for site electricity, natural gas and petroleum fuels. In all cases, the emissions factors are defined relative to site use of the fuel.

Table 13A.4.1 Site Combustion Emissions Factors

Species	**Natural Gas lb/mmcf**	**Distillate Oil lb/1000 gal**	**Propane lb/1000 gal**	**Kerosene lb/1000 gal**
CO_2	1.20E+05	2.25E+04	1.25E+04	2. 24E+04
SO_2	6.00E-01	142*(S)	0.1*(S)	142*(S)
NOx	9.60E+01	1.90E+01	1.40E+01	1.80E+01
N_2O	2.20E+00	1.76E-01	1.10E-01	1.76E-01
CH_4	2.30E+00	9.04E-01	5.95E-01	9.04E-01

Table 13A.4.2 Power Sector Emissions Factors for CO_2 (tons of CO_2 per kWh of site electricity use)

	2020	**2025**	**2030**	**2035**	**2040**
Commercial Sector					
cooking	7.91E-04	7.03E-04	6.34E-04	5.80E-04	5.30E-04
lighting	7.95E-04	7.05E-04	6.37E-04	5.82E-04	5.32E-04
office equipment (non-pc)	7.78E-04	6.93E-04	6.26E-04	5.73E-04	5.25E-04
office equipment (pc)	7.78E-04	6.93E-04	6.26E-04	5.73E-04	5.25E-04
other uses	7.83E-04	6.97E-04	6.29E-04	5.76E-04	5.27E-04
refrigeration	8.10E-04	7.17E-04	6.46E-04	5.90E-04	5.39E-04
space cooling	7.67E-04	6.83E-04	6.17E-04	5.66E-04	5.21E-04
space heating	8.21E-04	7.26E-04	6.54E-04	5.97E-04	5.43E-04
ventilation	8.10E-04	7.17E-04	6.47E-04	5.91E-04	5.39E-04
water heating	7.97E-04	7.07E-04	6.38E-04	5.83E-04	5.33E-04
Industrial Sector					
all uses	7.83E-04	6.97E-04	6.29E-04	5.76E-04	5.27E-04
Residential Sector					
clothes dryers	7.97E-04	7.08E-04	6.39E-04	5.84E-04	5.33E-04
cooking	7.90E-04	7.02E-04	6.34E-04	5.80E-04	5.29E-04
freezers	8.09E-04	7.16E-04	6.46E-04	5.90E-04	5.38E-04
lighting	8.10E-04	7.17E-04	6.47E-04	5.91E-04	5.38E-04
other uses	7.97E-04	7.07E-04	6.38E-04	5.83E-04	5.32E-04
refrigeration	8.08E-04	7.16E-04	6.45E-04	5.89E-04	5.38E-04
space cooling	7.69E-04	6.85E-04	6.19E-04	5.68E-04	5.21E-04
space heating	8.18E-04	7.24E-04	6.52E-04	5.95E-04	5.42E-04
water heating	7.99E-04	7.09E-04	6.40E-04	5.85E-04	5.33E-04

Table 13A.4.3 Power Sector Emissions Factors for Hg (tons/TWh)

	2020	2025	2030	2035	2040
Commercial Sector					
cooking	2.39E-03	1.87E-03	1.57E-03	1.32E-03	1.18E-03
lighting	2.41E-03	1.88E-03	1.58E-03	1.33E-03	1.19E-03
office equipment (non-pc)	2.31E-03	1.80E-03	1.52E-03	1.27E-03	1.14E-03
office equipment (pc)	2.31E-03	1.80E-03	1.52E-03	1.27E-03	1.14E-03
other uses	2.34E-03	1.83E-03	1.54E-03	1.29E-03	1.15E-03
refrigeration	2.50E-03	1.95E-03	1.64E-03	1.38E-03	1.23E-03
space cooling	2.21E-03	1.72E-03	1.45E-03	1.21E-03	1.08E-03
space heating	2.59E-03	2.02E-03	1.70E-03	1.43E-03	1.27E-03
ventilation	2.50E-03	1.95E-03	1.64E-03	1.38E-03	1.23E-03
water heating	2.42E-03	1.89E-03	1.59E-03	1.33E-03	1.19E-03
Industrial Sector					
all uses	2.34E-03	1.83E-03	1.54E-03	1.29E-03	1.15E-03
Residential Sector					
clothes dryers	2.44E-03	1.91E-03	1.60E-03	1.35E-03	1.20E-03
cooking	2.40E-03	1.88E-03	1.58E-03	1.32E-03	1.18E-03
freezers	2.49E-03	1.95E-03	1.64E-03	1.37E-03	1.23E-03
lighting	2.52E-03	1.97E-03	1.66E-03	1.39E-03	1.24E-03
other uses	2.44E-03	1.91E-03	1.60E-03	1.34E-03	1.20E-03
refrigeration	2.49E-03	1.94E-03	1.64E-03	1.37E-03	1.23E-03
space cooling	2.23E-03	1.74E-03	1.46E-03	1.22E-03	1.09E-03
space heating	2.57E-03	2.01E-03	1.69E-03	1.42E-03	1.27E-03
water heating	2.46E-03	1.92E-03	1.62E-03	1.36E-03	1.21E-03

Table 13A.4.4 Power Sector Emissions Factors for NO_x (tons/MWh)

	2020	2025	2030	2035	2040
Commercial Sector					
cooking	2.39E-03	1.87E-03	1.57E-03	1.32E-03	1.18E-03
lighting	2.41E-03	1.88E-03	1.58E-03	1.33E-03	1.19E-03
office equipment (non-pc)	2.31E-03	1.80E-03	1.52E-03	1.27E-03	1.14E-03
office equipment (pc)	2.31E-03	1.80E-03	1.52E-03	1.27E-03	1.14E-03
other uses	2.34E-03	1.83E-03	1.54E-03	1.29E-03	1.15E-03
refrigeration	2.50E-03	1.95E-03	1.64E-03	1.38E-03	1.23E-03
space cooling	2.21E-03	1.72E-03	1.45E-03	1.21E-03	1.08E-03
space heating	2.59E-03	2.02E-03	1.70E-03	1.43E-03	1.27E-03
ventilation	2.50E-03	1.95E-03	1.64E-03	1.38E-03	1.23E-03
water heating	2.42E-03	1.89E-03	1.59E-03	1.33E-03	1.19E-03
Industrial Sector					
all uses	2.34E-03	1.83E-03	1.54E-03	1.29E-03	1.15E-03
Residential Sector					
clothes dryers	2.44E-03	1.91E-03	1.60E-03	1.35E-03	1.20E-03
cooking	2.40E-03	1.88E-03	1.58E-03	1.32E-03	1.18E-03
freezers	2.49E-03	1.95E-03	1.64E-03	1.37E-03	1.23E-03
lighting	2.52E-03	1.97E-03	1.66E-03	1.39E-03	1.24E-03
other uses	2.44E-03	1.91E-03	1.60E-03	1.34E-03	1.20E-03
refrigeration	2.49E-03	1.94E-03	1.64E-03	1.37E-03	1.23E-03
space cooling	2.23E-03	1.74E-03	1.46E-03	1.22E-03	1.09E-03
space heating	2.57E-03	2.01E-03	1.69E-03	1.42E-03	1.27E-03
water heating	2.46E-03	1.92E-03	1.62E-03	1.36E-03	1.21E-03

Table 13A.4.5 Power Sector Emissions Factors for SO_2 (tons/MWh)

	2020	2025	2030	2035	2040
Commercial Sector					
cooking	7.75E-04	6.05E-04	5.09E-04	4.27E-04	3.82E-04
lighting	7.81E-04	6.10E-04	5.13E-04	4.30E-04	3.85E-04
office equipment (non-pc)	7.49E-04	5.85E-04	4.92E-04	4.12E-04	3.68E-04
office equipment (pc)	7.49E-04	5.85E-04	4.92E-04	4.12E-04	3.68E-04
other uses	7.59E-04	5.92E-04	4.98E-04	4.18E-04	3.73E-04
refrigeration	8.10E-04	6.32E-04	5.32E-04	4.46E-04	3.99E-04
space cooling	7.15E-04	5.59E-04	4.70E-04	3.94E-04	3.51E-04
space heating	8.38E-04	6.54E-04	5.50E-04	4.62E-04	4.13E-04
ventilation	8.11E-04	6.33E-04	5.33E-04	4.47E-04	4.00E-04
water heating	7.85E-04	6.13E-04	5.15E-04	4.32E-04	3.86E-04
Industrial Sector					
all uses	7.59E-04	5.92E-04	4.98E-04	4.18E-04	3.73E-04
Residential Sector					
clothes dryers	7.92E-04	6.18E-04	5.20E-04	4.36E-04	3.90E-04
cooking	7.79E-04	6.08E-04	5.11E-04	4.29E-04	3.83E-04
freezers	8.08E-04	6.31E-04	5.31E-04	4.45E-04	3.98E-04
lighting	8.17E-04	6.38E-04	5.37E-04	4.50E-04	4.03E-04
other uses	7.91E-04	6.18E-04	5.20E-04	4.36E-04	3.90E-04
refrigeration	8.07E-04	6.30E-04	5.30E-04	4.45E-04	3.98E-04
space cooling	7.21E-04	5.64E-04	4.74E-04	3.97E-04	3.54E-04
space heating	8.33E-04	6.50E-04	5.47E-04	4.59E-04	4.11E-04
water heating	7.98E-04	6.23E-04	5.24E-04	4.40E-04	3.93E-04

Table 13A.4.6 Power Sector Emissions Factors for CH_4 (tons/MWh)

	2020	2025	2030	2035	2040
Commercial Sector					
Cooking	7.75E-05	6.21E-05	5.30E-05	4.54E-05	4.07E-05
Lighting	7.80E-05	6.25E-05	5.34E-05	4.57E-05	4.10E-05
office equipment (non-pc)	7.49E-05	6.01E-05	5.13E-05	4.39E-05	3.94E-05
office equipment (pc)	7.49E-05	6.01E-05	5.13E-05	4.39E-05	3.94E-05
other uses	7.58E-05	6.08E-05	5.19E-05	4.44E-05	3.99E-05
Refrigeration	8.08E-05	6.46E-05	5.52E-05	4.72E-05	4.24E-05
space cooling	7.15E-05	5.74E-05	4.90E-05	4.20E-05	3.77E-05
space heating	8.35E-05	6.68E-05	5.70E-05	4.88E-05	4.38E-05
Ventilation	8.09E-05	6.48E-05	5.53E-05	4.73E-05	4.25E-05
water heating	7.83E-05	6.28E-05	5.36E-05	4.59E-05	4.12E-05
Industrial Sector					
all uses	7.58E-05	6.08E-05	5.19E-05	4.44E-05	3.99E-05
Residential Sector					
clothes dryers	7.91E-05	6.34E-05	5.41E-05	4.63E-05	4.16E-05
Cooking	7.79E-05	6.24E-05	5.33E-05	4.56E-05	4.10E-05
Freezers	8.06E-05	6.45E-05	5.51E-05	4.71E-05	4.23E-05
Lighting	8.15E-05	6.53E-05	5.57E-05	4.77E-05	4.28E-05
other uses	7.91E-05	6.33E-05	5.41E-05	4.63E-05	4.16E-05
Refrigeration	8.05E-05	6.44E-05	5.50E-05	4.71E-05	4.23E-05
space cooling	7.22E-05	5.79E-05	4.95E-05	4.23E-05	3.81E-05
space heating	8.31E-05	6.64E-05	5.67E-05	4.85E-05	4.36E-05
water heating	7.97E-05	6.38E-05	5.45E-05	4.67E-05	4.19E-05

Table 13A.4.7 Power Sector Emissions Factors for N_2O (tons/MWh)

	2020	2025	2030	2035	2040
Commercial Sector					
cooking	1.12E-05	8.86E-06	7.54E-06	6.41E-06	5.75E-06
lighting	1.12E-05	8.93E-06	7.59E-06	6.46E-06	5.79E-06
office equipment (non-pc)	1.08E-05	8.57E-06	7.28E-06	6.20E-06	5.56E-06
office equipment (pc)	1.08E-05	8.57E-06	7.28E-06	6.20E-06	5.56E-06
other uses	1.09E-05	8.68E-06	7.38E-06	6.28E-06	5.63E-06
refrigeration	1.16E-05	9.24E-06	7.86E-06	6.69E-06	6.00E-06
space cooling	1.03E-05	8.18E-06	6.96E-06	5.92E-06	5.31E-06
space heating	1.20E-05	9.56E-06	8.13E-06	6.92E-06	6.20E-06
ventilation	1.17E-05	9.26E-06	7.87E-06	6.70E-06	6.01E-06
water heating	1.13E-05	8.97E-06	7.62E-06	6.48E-06	5.82E-06
Industrial Sector					
all uses	1.09E-05	8.68E-06	7.38E-06	6.28E-06	5.63E-06
Residential Sector					
clothes dryers	1.14E-05	9.06E-06	7.70E-06	6.55E-06	5.87E-06
cooking	1.12E-05	8.91E-06	7.58E-06	6.45E-06	5.78E-06
freezers	1.16E-05	9.23E-06	7.84E-06	6.67E-06	5.99E-06
lighting	1.18E-05	9.34E-06	7.94E-06	6.75E-06	6.06E-06
other uses	1.14E-05	9.05E-06	7.69E-06	6.54E-06	5.87E-06
refrigeration	1.16E-05	9.22E-06	7.83E-06	6.66E-06	5.98E-06
space cooling	1.04E-05	8.26E-06	7.02E-06	5.97E-06	5.35E-06
space heating	1.20E-05	9.51E-06	8.08E-06	6.88E-06	6.17E-06
water heating	1.15E-05	9.13E-06	7.76E-06	6.60E-06	5.92E-06

Table 13A.4.8 Electricity Upstream Emissions Factors

	Unit	2020	2025	2030	2035	2040
CO_2	kg/MWh	29.1	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	368	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	2,149	2,195	2,216	2,248	2,255

Table 13A.4.9 Natural Gas Upstream Emissions Factors

	Unit	2020	2025	2030	2035	2040
CO_2	kg/ mcf	7.1	7.2	7.3	7.4	7.4
SO_2	g/ mcf	0.030	0.031	0.031	0.032	0.032
NOx	g/ mcf	101	103	105	105	105
N_2O	g/ mcf	0.011	0.011	0.012	0.012	0.012
CH_4	g/ mcf	659	665	666	670	670

Table 13A.4.10 Fuel Oil Upstream Emissions Factors

	Unit	2020	2025	2030	2035	2040
CO_2	kg/bbl	70.8	70.3	69.9	68.9	68.3
SO_2	g/bbl	14.5	14.1	14.0	13.9	13.9
NOx	g/bbl	765	742	737	733	732
Hg	g/bbl	0.000007	0.000007	0.000007	0.000007	0.000007
N_2O	g/bbl	0.598	0.579	0.574	0.569	0.568
CH_4	g/bbl	897	905	902	888	877

REFERENCES

1. Energy Information Administration, *Annual Energy Outlook 2012 with Projections to 2035*, 2012. Washington, DC. <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>

2. Coughlin, K., *Utility Sector Impacts of Reduced Electricity Demand*, Forthcoming. Lawrence Berkeley National Laboratory.

3. US EPA, *Emissions Factors for Greenhouse Gas Inventories,* 2014. (Last accessed December 1, 2014.) <http://www.epa.gov/climateleadership/documents/emission-factors.pdf>

4. Coughlin, K., *Projections of Full-Fuel-Cycle Energy and Emissions Metrics*, 2013. Lawrence Berkeley National Laboratory. Report No. LBNL-6025E.

5. Burnham, A., J. Han, C. E. Clark, M. Wang, J. B. Dunn, I. Palou-Rivera,, Life-Cycle Greenhouse Gas Emissions of Shale Gas, Natural Gas, Coal, and Petroleum. *Environmental Science & Technology*, 2011. 46(2): pp. 619-627

6. U.S. Environmental Protection Agency, *Fugitive Emissions Reporting from the Petroleum and Natural Gas Industry*, 2009. U.S. Environmental Protection Agency. Washington, DC.

7. U.S. Environmental Protection Agency, *Oil and Natural Gas Sector: Standards of Performance for Crude Oil and Natural Gas Production, Transmission, and Distribution, Background Supplemental Technical Support Document for the Final New Source Performance Standards*, 2012. U.S. Environmental Protection Agency. Washington, DC.

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.

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

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[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).

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 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. 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).

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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).

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 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 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

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[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%, 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.

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.

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.

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[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).

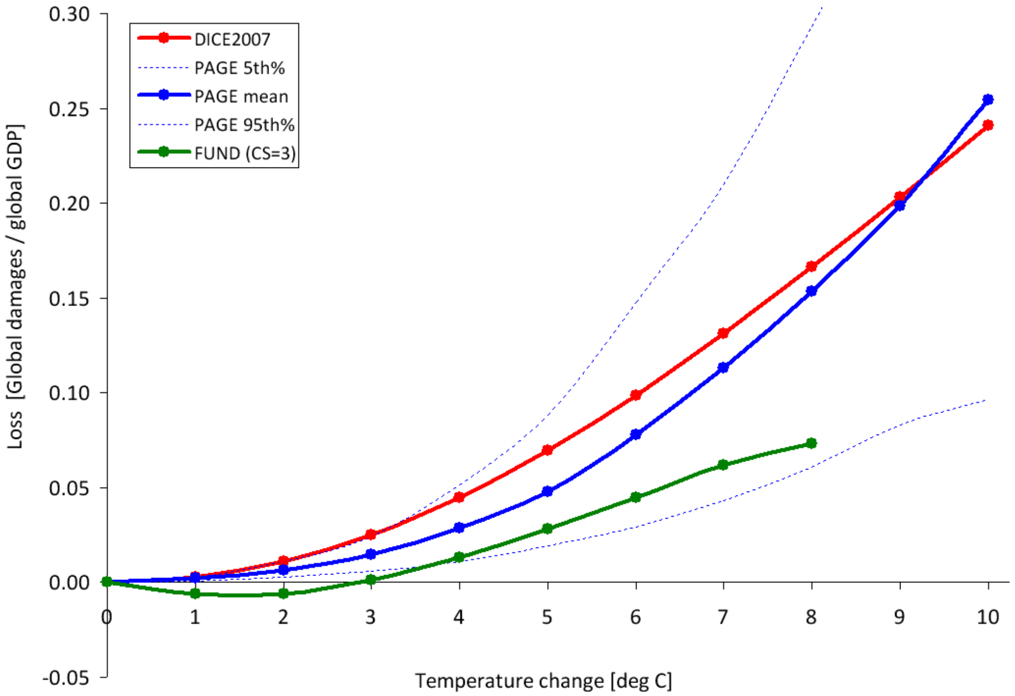

Figure 14A.4.1 Annual Consumption Loss as a Fraction of Global GDP in 2100 Due to an Increase in Annual Global Temperature in the DICE, FUND, and PAGE models[f]

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.

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[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.

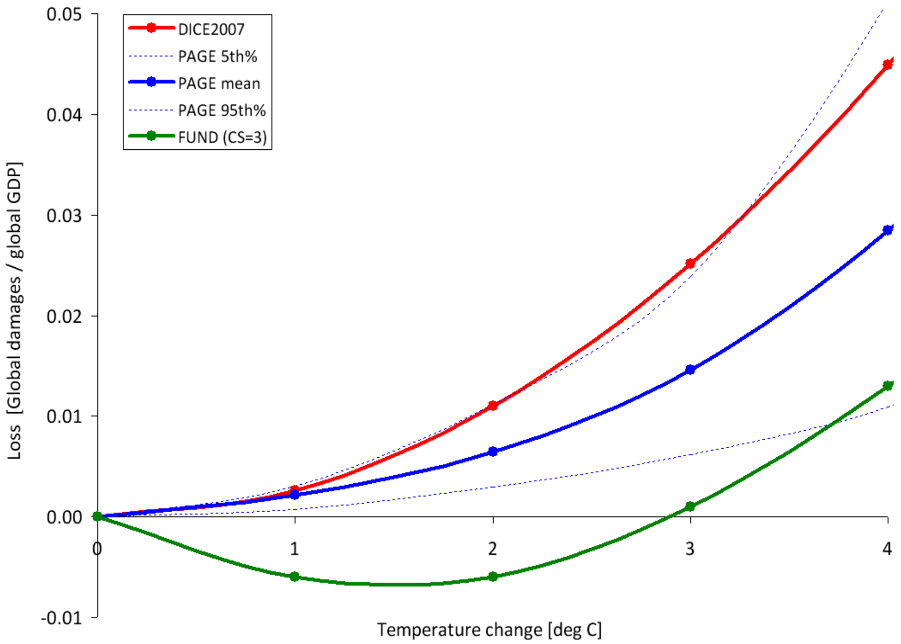

Figure 14A.4.2 Annual Consumption Loss for Lower Temperature Changes in DICE, FUND, and PAGE

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

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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.

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.

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

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[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.

[i] Based on 2008 GDP (in current US dollars) from the *World Bank Development Indicators Report*.

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 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):

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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).

> *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.

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
5th percentile	1.72	1.49	1.37	1.13
10th percentile	1.91	1.74	1.65	1.48
Mode	2.34	2.52	2.65	2.90
Median (50th percentile)	3.00	3.00	3.00	3.00
Mean	3.50	3.28	3.19	3.07
90th percentile	5.86	5.14	4.93	4.69
95th 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";[l]

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[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.

[l] 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 95th percentile that is more consistent with IPCC judgments and the literature. For example, setting the mean and mode equal to 3°C produced 95th 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.

(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 95th percentile of the calibrated Roe & Baker distribution (7.1 °C) is much closer to the mean and the median (7.2 °C) of the 95th percentiles of 21 previous studies summarized by Newbold and Daigneault (2009). It is also closer to the mean (7.5 °C) and 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.

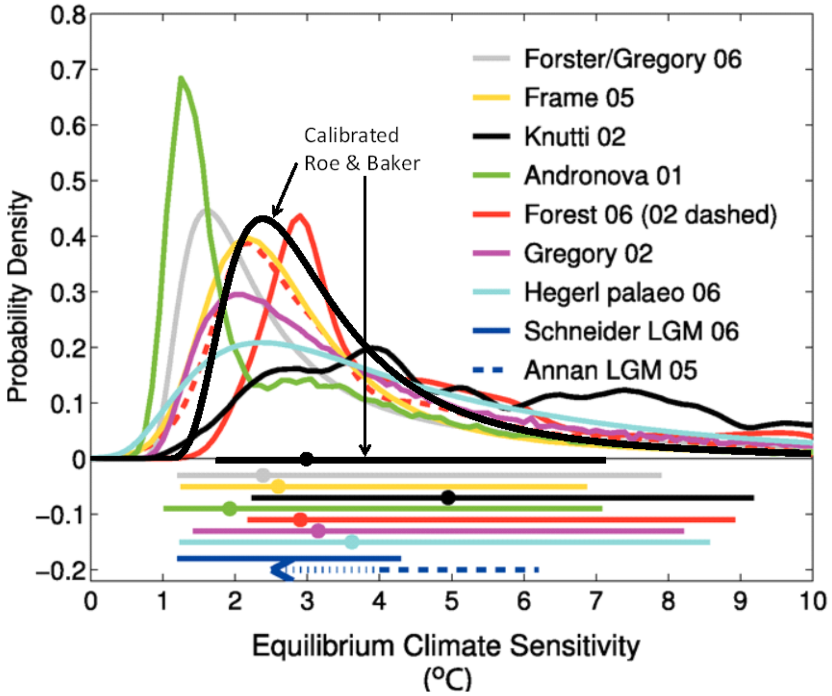

Figure 14A.4.3 Estimates of the Probability Density Function for Equilibrium Climate Sensitivity (°C)

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]

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.

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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.

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 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

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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.

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 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]

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[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.

[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).

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 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 $\rho = 0$ would unjustly discriminate against future generations (*e.g.*, Arrow et al. 1996, Stern et al. 2006). However, even in an inter-

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[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.

[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 $\eta = 1.49$ for 22 OECD countries. They also estimate $\rho = 1.08$ percent per year using data on mortality rates. Anthoff, et al. (2009b) estimate $\eta = 1.18$, and $\rho = 1.4$ percent. When they multiply the bivariate probability distributions from their work and Evans and Sezer (2005) together, they find $\eta = 1.47$, and $\rho = 1.07$.

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.

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).

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[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.)

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]

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.

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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, 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.

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.

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.

[aa] Calculations done by Pizer et al. using the original simulation program from Newell and Pizer (2003).

    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 95th 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 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

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.

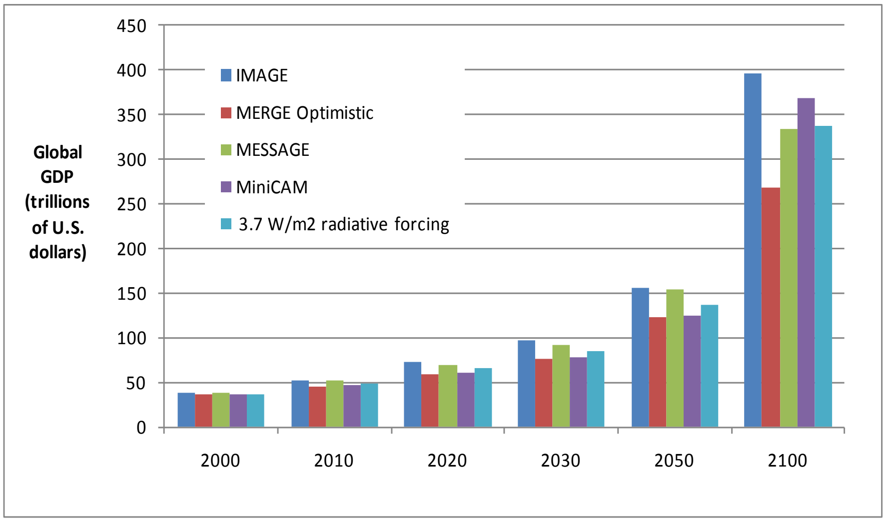

Figure 14A.5.1 Level of Global GDP across EMF Scenarios

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.

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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-

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[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 risk-averse for such scenarios, it is possible that regulatory policy should include a degree of risk-aversion.

[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).

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.

REFERENCES

1 Andronova, N., and M. Schlesinger. 2001. “Objective estimation of the probability density function for climate sensitivity.” *J. Geophys. Res*., 106(D19), 22605–22611.

2 Annan, J., et al., 2005. “Efficiently constraining climate sensitivity with paleoclimate simulations.” *Scientific Online Letters on the Atmosphere*, 1, 181–184.

3 Anthoff D, C. Hepburn, and R. Tol. 2009a. “Equity Weighting and the Marginal Damage Costs of Climate Change.” *Ecological Economics* 68:836-849.

4 Anthoff, D., R. Tol, and G. Yohe. 2009b. “Risk aversion, time preference, and the social cost of carbon.” *Environmental Research Letters* 4: 024002 (7pp).

5 Arrow, K. 2007. “Global climate change: a challenge to policy.” *Economist’s Voice* 4(3):Article 2.

6 Arrow, K. 2000. “A Comment on Cooper.” *The World Bank Research Observer*. vol 15, no. 2.

7 Arrow, K., et al. 1996. *Benefit-Cost Analysis in Environmental, Health, and Safety Regulation: A Statement of Principles*. Washington, D.C., AEI Press. pp. 13-14.

8 Arrow, K.J., et al. 1996. ”Intertemporal equity, discounting and economic efficiency,” in Climate Change 1995: Economic and Social Dimensions of Climate Change, Contribution of Working Group III to the *Second Assessment Report of the Intergovernmental Panel on Climate Change*.

9 Campbell, J., P. Diamond, and J. Shoven. 2001. “Estimating the Real Rate of Return on Stocks Over the Long Term.” Presented to the Social Security Advisory Board. August.

10 Campbell, K. et al. 2007. *The age of consequences: The foreign policy and national security implications of global climate change*. Center for Strategic & International Studies, 119 pp.

11 Castles, I. and D. Henderson. 2003. “The IPCC Emission Scenarios: An Economic-Statistical Critique.” *Energy and Environment* 14(2-3): 159-185.

12 Chetty, R. 2006. “A New Method of Estimating Risk Aversion.” *American Economic Review* 96(5): 1821–1834.

13 Dasgupta P. 2006. “Comments on the Stern Review’s economics of climate change.” University of Cambridge working paper.

14 Dasgupta P. 2008. “Discounting climate change.” *Journal of Risk and Uncertainty* 37:141-169.

15 Easterling, W., et al. 2007. *Climate Change 2007: Impacts, Adaptation, and Vulnerability*. Intergovernmental Panel on Climate Change, 976 pp.

16 Evans D., and H. Sezer. 2005. “Social discount rates for member countries of the European Union.” *J. Econ. Stud*. 32 47–59.

17 Forest, C., et al. 2002. “Quantifying uncertainties in climate system properties with the use of recent observations.” *Science* 295, 113.

18 Forest, D., P. Stone, and A. Sokolov. 2006. “Estimated PDFs of climate system properties including natural and anthropogenic forcings.” *Geophys. Res. Lett*., 33, L01705.

19 Forster, P., and J. Gregory. 2006. “The climate sensitivity and its components diagnosed from Earth radiation budget data.” *J. Clim*., 19, 39–52.

20 Frame, D., et al. 2005. “Constraining climate forecasts: The role of prior assumptions.” *Geophys. Res. Lett*., 32, L09702.

21 Gingerich, P. 2006. “Environment and evolution through the Paleocene-Eocene thermal maximum.” *Trends Ecol. Evol.* 21: 246-253.

22 Gollier, C. 2008. “Discounting with fat-tailed economic growth.” *Journal of Risk and Uncertainty* 37:171-186.

23 Gollier, C. and M. Weitzman (2009). "How Should the Distant Future be Discounted When Discount Rates are Uncertain?" Harvard University, mimeo, Nov 2009.

24 Gregory, J., et al. 2002a. “An observationally based estimate of the climate sensitivity.” *J. Clim*., 15(22), 3117–3121.

25 Groom, B., Koundouri, P., Panipoulou, E., Pantelidis, T. 2006. “An econometric approach to estimating long-run discount rates.” *Journal of Applied Econometrics.*

26 Hall R, and C. Jones . 2007. “The value of life and the rise in health spending.” Quarterly *Journal of Economics* 122(1):39-72.

27 Hansen, J.,M. Sato, P. Kharecha, G. Russell, D. W. Lea and M. Siddall. 2007. “Climate change and trace gases.” *Phil. Trans. Roy. Soc. A* 365: 1925-1954.

28 Hegerl G, et al. 2007. “Understanding and attributing climate change.” in Solomon S, et al. (eds) *Climate Change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

29 Hegerl, G., T. Crowley, W. Hyde, and D. Frame. 2006. “Constraints on climate sensitivity from temperature reconstructions of the past seven centuries.” *Nature* 440.

30 Holtsmark, B., and K. Alfsen. 2005. “PPP Correction of the IPCC Emission Scenarios – Does it Matter?” *Climatic Change* 68(1-2): 11-19.

31 Hope C. 2006. “The marginal impact of CO2 from PAGE2002: an integrated assessment model incorporating the IPCC’s five reasons for concern.” *The Integrated Assessment Journal* 6(1):19-56.

32 Hope C. 2008. “Optimal carbon emissions and the social cost of carbon under uncertainty.” *The Integrated Assessment Journal* 8(1):107-122.

33 Intergovernmental Panel on Climate Change (2007). “Summary for Policymakers.” In *Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

34 Just, R., D. Hueth, and A. Schmitz. 2004. *The Welfare Economics of Public Policy*. Glos UK: Edward Elgar Publishing Limited.

35 Knutti, R., T. Stocker, F. Joos, and G. Plattner. 2002. “Constraints on radiative forcing and future climate change from observations and climate model ensembles.” *Nature*, 416, 719–723.

36 Kriegler, E. et al. 2009. “Imprecise probability assessment of tipping points in the climate system.” *Proc. Natl. Acad. Sci.* 106: 5041-5046.

37 Kotlikoff, L. and D. Rapson. 2006. “Does It Pay, at the Margin, to Work and Save? – Measuring Effective Marginal Taxes on Americans’ Labor Supply and Saving.” National Bureau of Economic Research, Working Paper, No. 12533.

38 Le Treut H., et al. 2007. “Historical Overview of Climate Change.” in Solomon et al., *Climate Change 2007.*

39 Lenton, T., et al. 2008. “Tipping elements in the Earth’s climate system.” *Proc. Natl. Acad. Sci.* 105: 1786-1793.

40 Levy, M., et al. 2005. “Ecosystem conditions and human well-being.” In: *Ecosystems and Human Well-being: Current State and Trends, Volume 1.* [R. Hassan, R. Scholes, and N. Ash, eds.] Washington: Island Press. pp. 123-164.

41 Lind, R. 1990. “Reassessing the Government’s Discount Rate Policy in Light of New Theory and Data in a World Economy with a High Degree of Capital Mobility.” *Journal of Environmental Economics and Management* 18, S-8-S-28.

42 Mastrandre, M. 2009. “Calculating the benefits of climate policy: Examining the assumptions of Integrated Assessment Models.” Pew Center on Global Climate Change Working Paper, 60 pp.

43 Meehl, G, et al. 2007. “Global Climate Projections.” in Solomon et al., *Climate Change 2007.*

44 National Research Council (2009). *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. National Academies Press.

45 Newbold S, Daigneault A. 2009. “Climate response uncertainty and the benefits of greenhouse gas emissions reductions.” *Environmental and Resource Economics* 44:351-377.

46 Newell, R., and W. Pizer. 2003. Discounting the distant future: how much do uncertain rates increase valuations? *Journal of Environmental Economics and Management* 46: 52-71.

47 Nordhaus, W. 1994. “Expert Opinion on Climate Change.” *American Scientist* 82: 45-51.

48 Nordhaus, W. 2007a. *Accompanying notes and documentation on development of DICE-2007 model: notes on DICE-2007.delta.v8 as of September 21, 2007.*

49 Nordhaus, W. 2007b. “Alternative measures of output in global economic-environmental models: Purchasing power parity or market exchange rates?” *Energy Economics* 29: 349-372.

50 Nordhaus W. 2008. *A Question of Balance: Weighing the Options on Global Warming Policies*. New Haven, CT: Yale University Press.

51 Nordhaus, W. 2009. “An Analysis of the Dismal Theorem. Cowles Foundation Discussion Paper. No. 1686. January.

52 Nordhaus W., and Boyer J. 2000. *Warming the World: Economic Models of Global Warming*. Cambridge, MA: MIT Press.

53 Pindyck, R. 2009. “Uncertain Outcomes and Climate Change Policy.” NBER Working Paper, No. 15259. August.

54 Ramsey, F. 1928. “A Mathematical Theory of Saving.” *The Economic Journal* 38(152): 543-559.

55 Roe, G. 2008. “Feedbacks, timescales, and seeing red.” *Annual Review of Earth and Planetary Sciences* 37:5.1-5.23.

56 Roe, G., and M. Baker. 2007. “Why is climate sensitivity so unpredictable?” *Science* 318:629-632.

57 Schneider von Deimling, T., H. Held, A. Ganopolski, and S. Rahmstorf. 2006. “Climate sensitivity estimated from ensemble simulations of glacial climate.” *Clim. Dyn*., 27, 149–163.

58 Smith, J. et al. 2009. “Transient dwarfism of soil fauna during the Paleocene-Eocene Thermal Maximum.” *Proc. Natl. Acad. Sci.* 106: 17665-17660.

59 Stern, N., et al. (2006), *Stern Review: The Economics of Climate Change,* HM Treasury, London.

60 Stern N. 2008. “The economics of climate change.” *American Economic Review* 98(2):1-37.

61 Sterner, T., and U. Persson. 2008. An even Sterner review: Introducing relative prices into the discounting debate. *Rev. Env. Econ. Pol.* 2: 61-76.

62 Summers, L., and R. Zeckhauser. 2008. "Policymaking for Prosperity." Journal of Risk and Uncertainty 37: 115-140.

63 Szpiro, G. 1986. "Measuring Risk Aversion: An Alternative Approach." *The Review of Economics and Statistics* 68(1): 156-9.

64 Tol, R. 2002a. "Estimates of the damage costs of climate change. Part I: benchmark estimates." *Environmental and Resource Economics* 21:47-73.

65 Tol, R. 2002b. "Estimates of the damage costs of climate change. Part II: dynamic estimates." *Environmental and Resource Economics* 21:135-160.

66 Tol, R. 2006. "Exchange Rates and Climate Change: An Application of FUND." *Climatic Change* 75(1-2): 59-80.

67 Tol, R. 2009. "An analysis of mitigation as a response to climate change." Copenhagen Consensus on Climate. Discussion Paper.

68 U.S. Department of Defense. 2010. Quadrennial Defense Review Report. February.

69 Warren, R., et al. 2006. "Spotlight Impact Functions in Integrated Assessment." Tyndall Center for Climate Change Research, Working Paper 91.

70 Weitzman, M. 2009. "On modeling and interpreting the economics of catastrophic climate change." *Review of Economics and Statistics* 91:1-19.

71 Weitzman, M. 2007. "A review of The Stern Review of the Economics of Climate Change*.*" *Journal of Economic Literature* 45:703-724.

72 Weitzman, M. 1999. In Portney P.R. and Weyant J.P. (eds.), *Discounting and Intergenerational Equity*, Resources for the Future, Washington, D.C.

73 Weitzman, M. 1998. "Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate." *Journal of Environmental Economics and Management* 36 (3): 201-208.

74 Wing, S. et al. 2005. "Transient floral change and rapid global warming at the Paleocene-Eocene boundary." *Science* 310: 993-996.

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

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[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. {WGIII 3.2, TS.3, SPM}.*[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).

[gg] AR4 Synthesis Report, p. 44, http://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.

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.

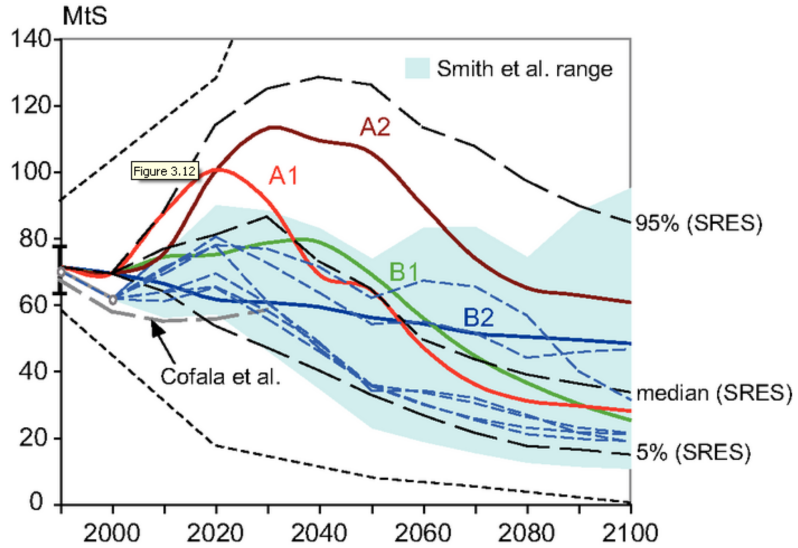

Figure 14A.9.2 Sulfur Dioxide Emission Scenarios

Notes: Thick colored lines depict the four SRES marker scenarios and black dashed lines show the median, 5th, and 95th 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, http://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.

[jj] United Nations. 2004. *World Population to 2300.* http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf

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.

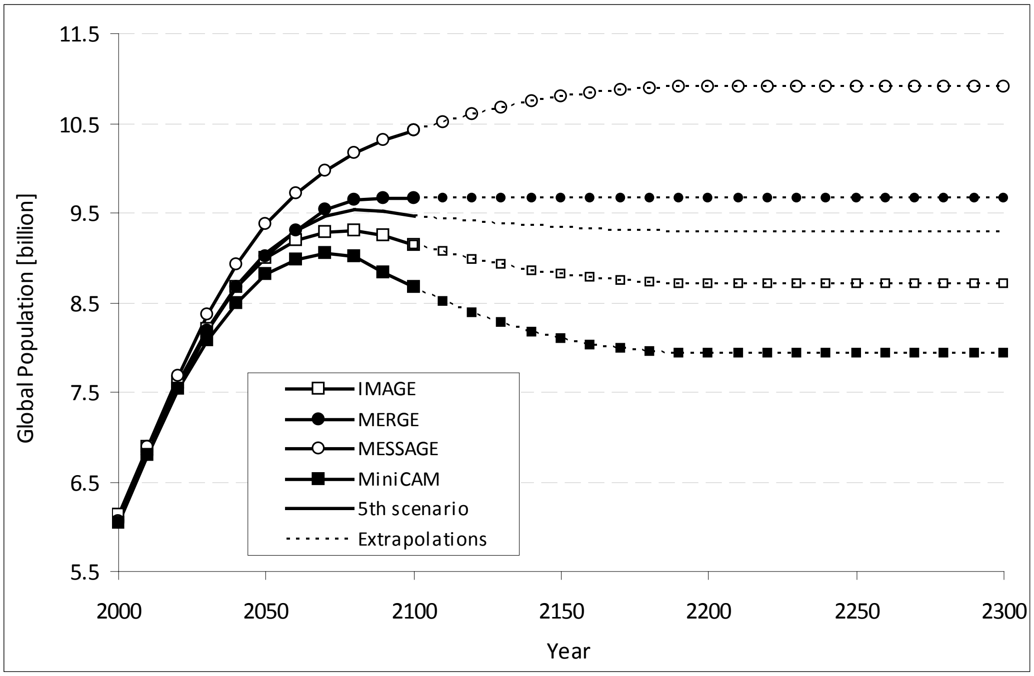

Figure 14A.9.3 Global Population, 2000-2300 (Post-2100 extrapolations assume the population growth rate changes linearly to reach a zero growth rate by 2200.)

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.

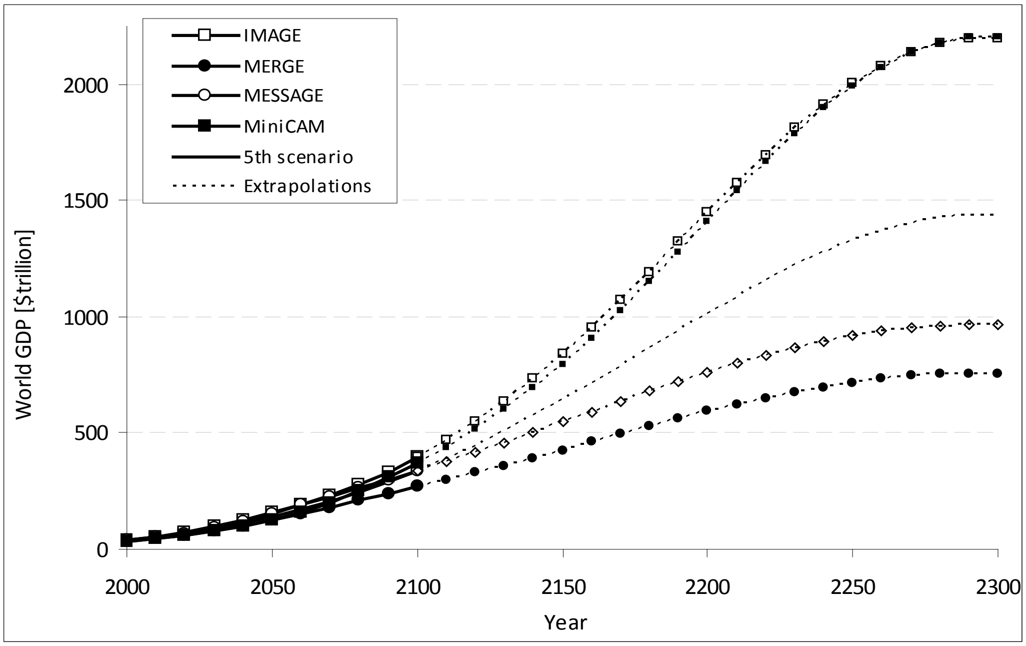

Figure 14A.9.4 World GDP, 2000-2300 (Post-2100 extrapolations assume GDP per capita growth declines linearly, reaching zero in the year 2300)

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.

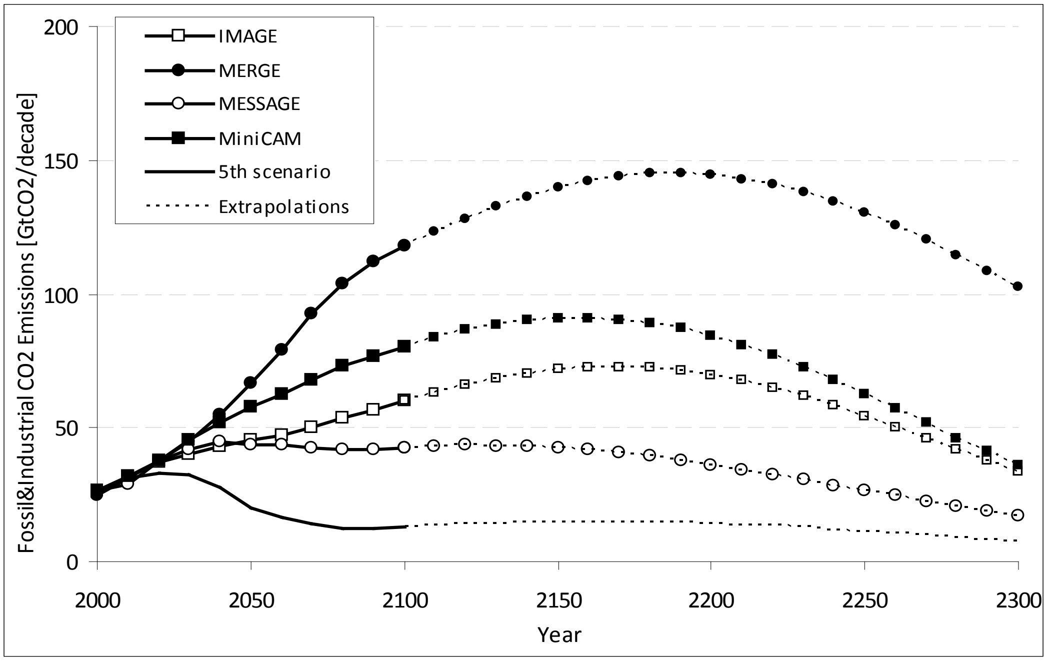

Figure 14A.9.5 Global Fossil and Industrial CO_2 Emissions, 2000-2300 (Post-2100 extrapolations assume growth rate of CO_2 intensity (CO_2/GDP) over 2090-2100 is maintained through 2300)

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.

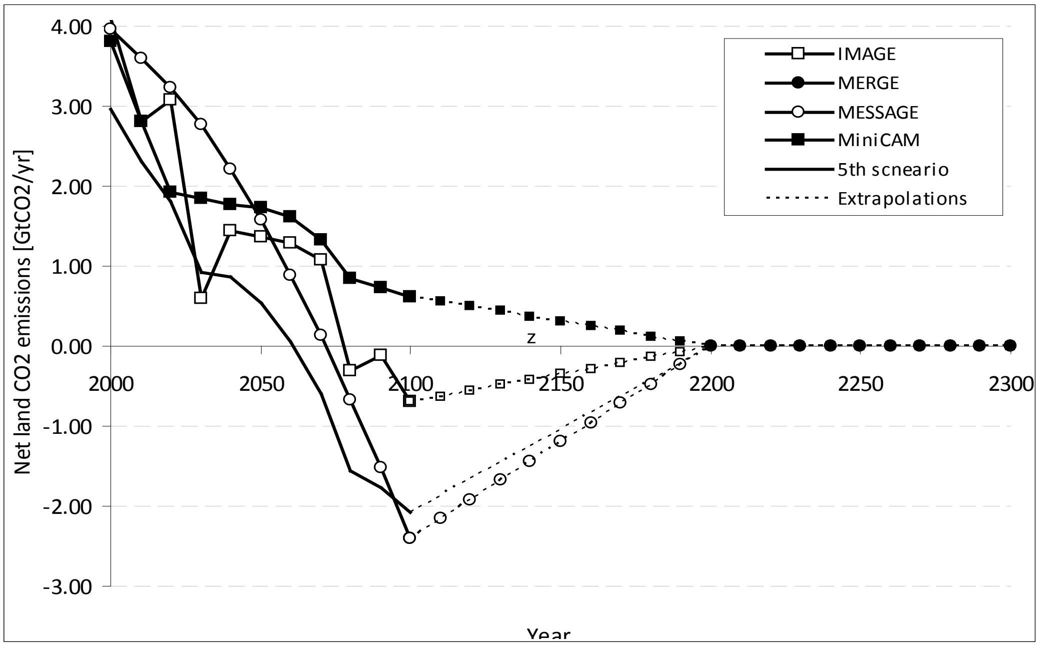

Figure 14A.9.6 **Global Net Land Use CO_2 Emissions, 2000-2300 (Post-2100 extrapolations assume emissions decline linearly, reaching zero in the year 2200)**[kk]

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).

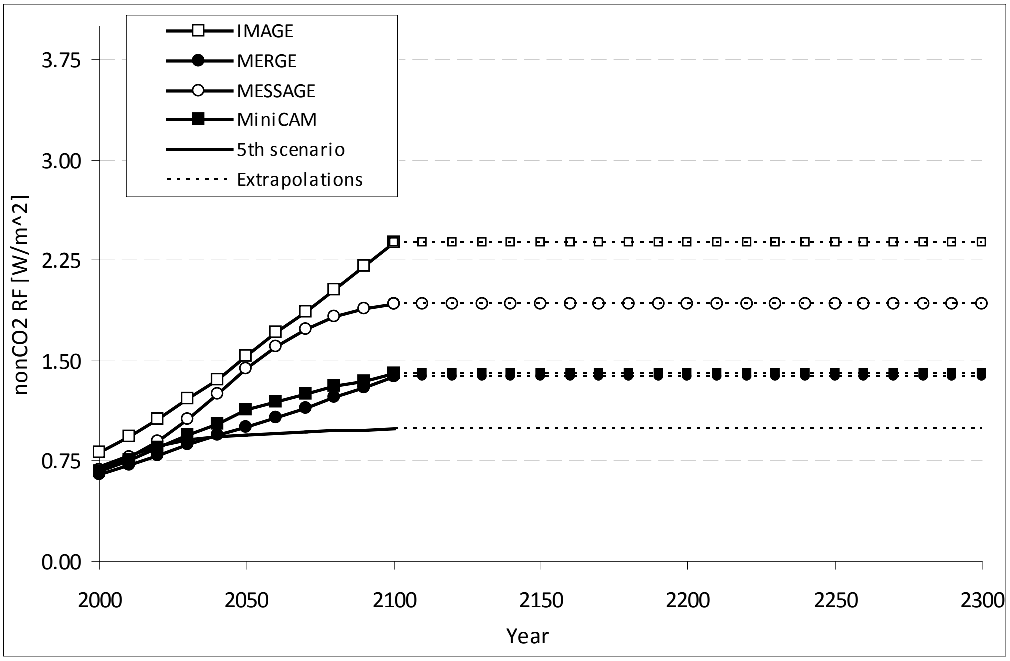

Figure 14A.9.7 **Global Non-CO_2 Radiative Forcing, 2000-2300 (Post-2100 extrapolations assume constant non-CO_2 radiative forcing after 2100)**

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.

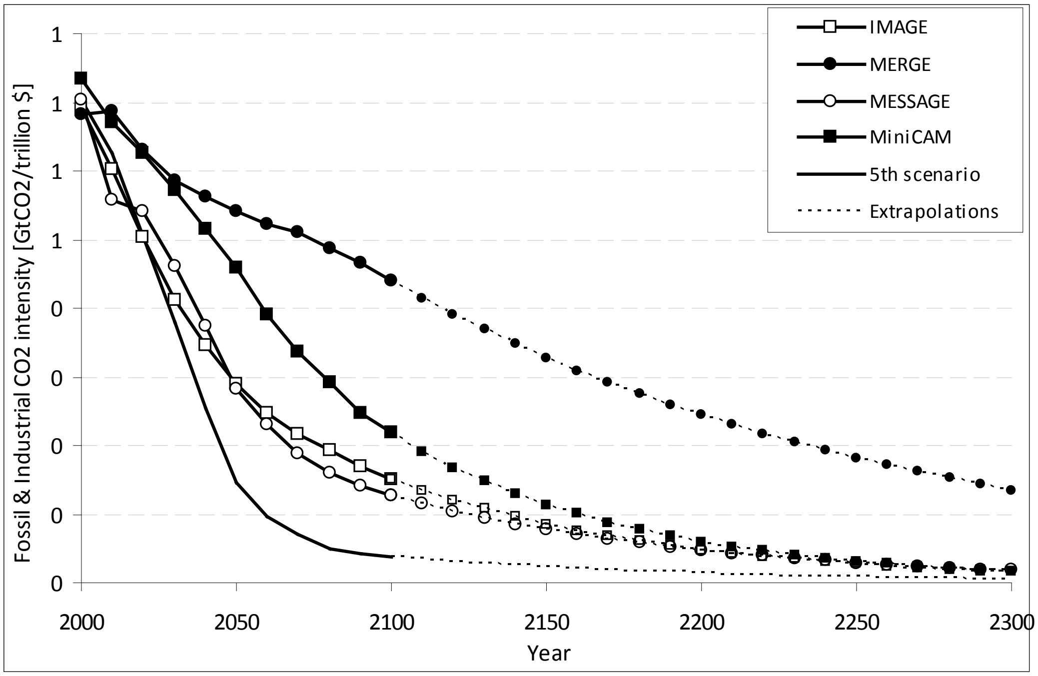

Figure 14A.9.8 **Global CO_2 Intensity (fossil & industrial CO_2 emissions/GDP), 2000-2300 (Post-2100 extrapolations assume decline in CO_2/GDP growth rate over 2090-2100 is maintained through 2300)**

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

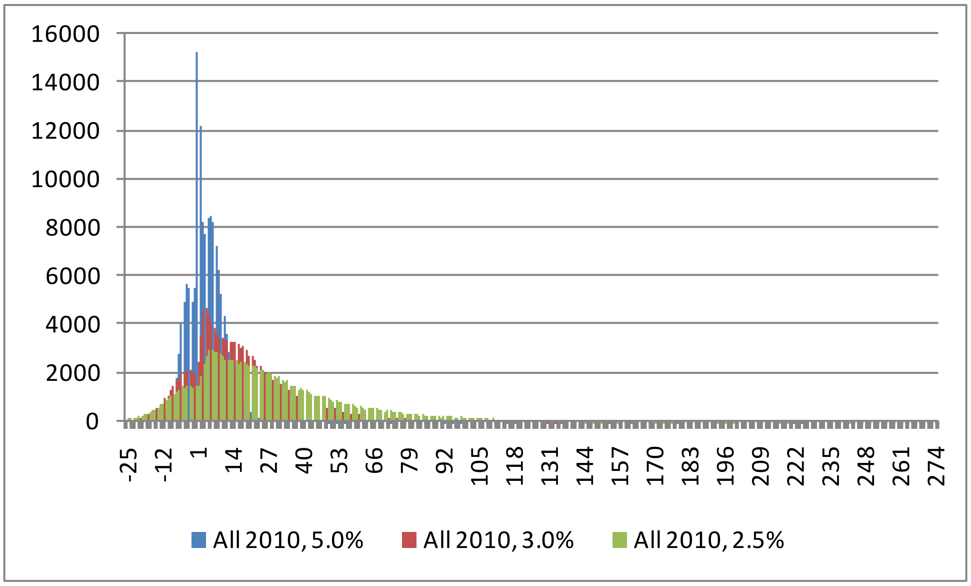

Figure 14A.9.9 Histogram of Global SCC Estimates in 2010 (2007$/ton CO_2), by discount rate

* 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] http://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 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.

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[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]

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 ^{o}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.

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

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[e] Documentation on the new sea level rise module of DICE is available on William Nordhaus' website at: http://nordhaus.econ.yale.edu/documents/SLR_021910.pdf.

[f] For a review of post-IPCC AR4 research on sea level rise, see Nicholls et al. (2011)[5] and NAS (2011).[6]

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.

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

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[g] http://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.

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.4.1 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.

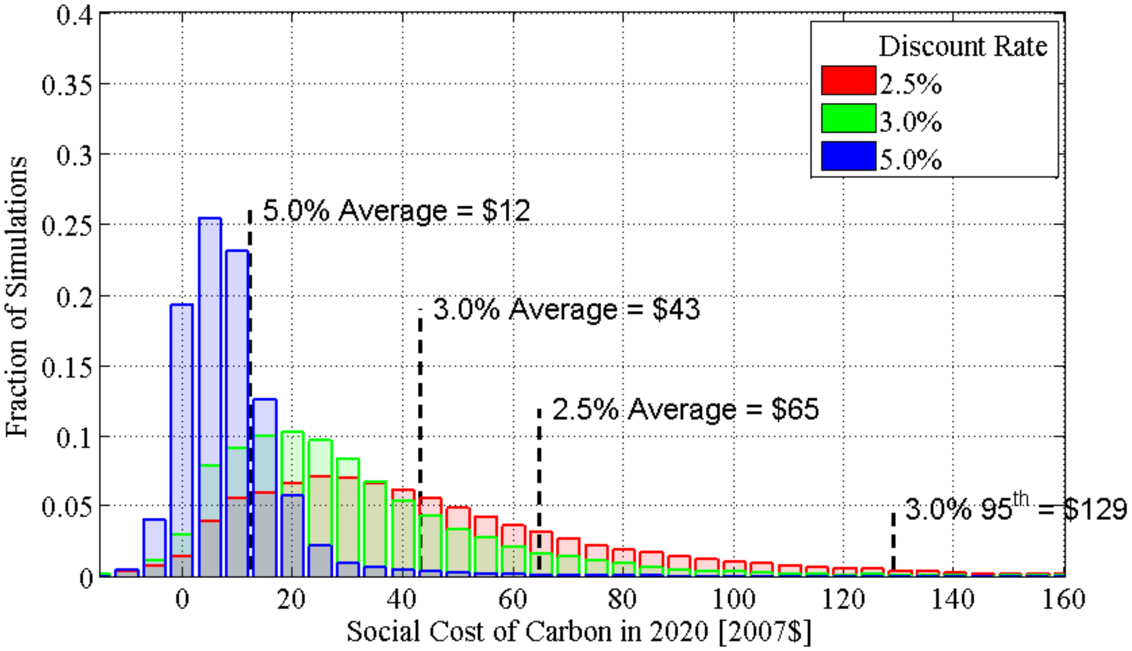

Figure 14B.4.1 Distribution of SCC Estimates for 2020 (in 2007$ per ton CO_2)

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.

REFERENCES

1 Interagency Working Group on Social Cost of Carbon, *Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866*, February, 2010. United States Government. <http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf>

2 Nordhaus, W., *A Question of Balance*. 2008. Yale University Press: New Haver.

3 Nordhaus, W., Economic aspects of global warming in a post-Copenhagen environment. *Proceedings of the National Academy of Sciences*, 2010. 107(26): pp. 11721-11726

4 Randall, D. A., R.A. Wood, S. Bony, R. Colman, T. Fichefet, J. Fyfe, V. Kattsov, A. Pitman, J. Shukla, J. Srinivasan, R.J. Stouffer, A. Sumi and K.E. Taylor, *Climate Models and Their Evaluation*. In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller, Editor. 2007. Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA

5 Nicholls, R. J., N. Marinova, J.A. Lowe, S. Brown, P. Vellinga, D. de Gusmão, J. Hinkel and R.S.J. Tol, Sea-level rise and its possible impacts given a ‘beyond 4°C world’ in the twenty-first century. *Phil. Trans. R. Soc. A* 2011. 369(1934): pp. 161-181

6 National Academy of Sciences, *Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia*. 2011. National Academies Press, Inc: Washington, DC.

7 Anthoff, D. and R. S. J. Tol, The uncertainty about the social cost of carbon: a decomposition analysis using FUND. *Climatic Change*, 2013(Forthcoming)

8 Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, *Changes in Atmospheric Constituents and in Radiative Forcing*. In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller Editor. 2007. Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA

9 Hope, C., Critical issues for the calculation of the social cost of CO2: why the estimates from PAGE09 are higher than those from PAGE2002. *Climatic Change*, 2012(Forthcoming)

10 Hope, C., *The PAGE09 Integrated Assessment Model: A Technical Description*. 2011, Cambridge Judge Business School <http://www.jbs.cam.ac.uk/fileadmin/user_upload/research/workingpapers/wp1104.pdf>

11 Hope, C., *The Social Cost of CO2 from the PAGE09 Model*. 2011, Cambridge Judge Business School <http://www.jbs.cam.ac.uk/fileadmin/user_upload/research/workingpapers/wp1105.pdf>

12 Hope, C., *New Insights from the PAGE09 Model: The Social Cost of CO2*. 2011, Cambridge Judge Business School <http://www.jbs.cam.ac.uk/fileadmin/user_upload/research/workingpapers/wp1108.pdf>

13 Hope, C., The Marginal Impact of CO2 from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern. *The Integrated Assessment Journal*, 2006. 6(1): pp. 19-56

14B.6 ANNEX

Table 14B.6.1 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.6.2 202 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	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.6.3 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.6.4 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 15A. UTILITY IMPACT ANALYSIS METHODOLOGY

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APPENDIX 15A. UTILITY IMPACT ANALYSIS METHODOLOGY

15A.1 INTRODUCTION

In the utility impact analysis, the U.S. Department of Energy (DOE) analyzes the changes in electric installed capacity and power generation that result for each trial standard level (TSL). These changes are estimated by multiplying the site savings of electricity by a set of *impact factors* which measure the corresponding change in generation by fuel type, installed capacity, and power sector emissions. This Appendix describes the methods that DOE used to calculate these impact factors. The methodology is more fully described in Coughlin (2014).[1]

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 is minimized.

15A.2 METHODOLOGY

DOE's national energy savings (NES) analysis calculates the expected reduction in electricity demand associated with a given trial standard level (TSL). These correspond to marginal reductions electricity demand, which in turn lead to marginal impacts on the electric power sector in the form of reduced generation, emissions, and installed capacity. DOE's

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approach calculates the relationship, at the margin, between changes in generation and changes in other power sector quantities. In principle marginal values provide a better estimate of the actual impact of energy conservation standards.

NEMS uses predicted growth in demand by sector and 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 dispatch of generation and 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 may 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 or fuel 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 of the green-house gases CO_2, N_2O and CH_4.

DOE's new approach examines a series of AEO side cases to estimate the relationship between marginal demand reductions and the resulting generation, 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 collected for 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, per unit of electricity demand added or subtracted at the margin, as a function of time. DOE also calculates fuel-specific marginal heat rates, equal to the primary energy (heat content) consumed per unit of electricity generated at the margin for that fuel. These differ from the average heat rate, equal to the total primary energy use divided by total generation for that fuel, because the technology mix for marginal plants is different from the average for the grid. (The marginal heat rates are presented in Appendix 10-B).The product of the fuel-share weight and the marginal heat rate defines coefficients that allocate a marginal reduction in end-use electricity demand to a reduction in quads of fuel use for each of the five fuel types.

5. A regression model is used to relate reductions in fuel consumption in quads by fuel type to reductions in emissions of power sector pollutants (CO_2, Hg, NO_X, SO_2). The model produces coefficients that define the change in total annual emissions of a given pollutant resulting from a unit change in total fuel consumption 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. Power sector emissions of the green-house gases CH_4 and N_2O are not tabulated in AEO. For these species, DOE used Environmental Protection Agency estimates of the emissions intensities (mass of pollutant per unit of fuel energy), combined with the fuel-share weights, to estimate the impact factors (ref epa ghg factors).[3]

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 fuel-share weights calculated in step 4 to produce the annual impact factors relating installed capacity changes to changes in end-use demand.

7. The impact factor 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 Reduced Electricity Demand.”[4]

15A.3 MODEL RESULTS

This section summarizes the impact factors for fuel share and capacity. The marginal heat rates are presented in appendix 10-B and emissions factors in appendix 13-A. Detailed results for the product considered in this rule-making can be found in chapter 13.

15A.3.1 Installed Capacity

The figures in this section show the total change in installed capacity per unit of electricity demand distributed over the five capacity types: coal), natural gas, peaking, renewables, and nuclear. Figure 15A.3.1 shows the results for commercial sector end uses, and Figure 15A.3.2 for residential end uses. The units are GW of installed capacity per TWh of reduced site electricity use. Each bar corresponds to one year, with factors calculated for the period 2019 through 2040. To extrapolate to years beyond 2040, DOE uses the 2040 values.

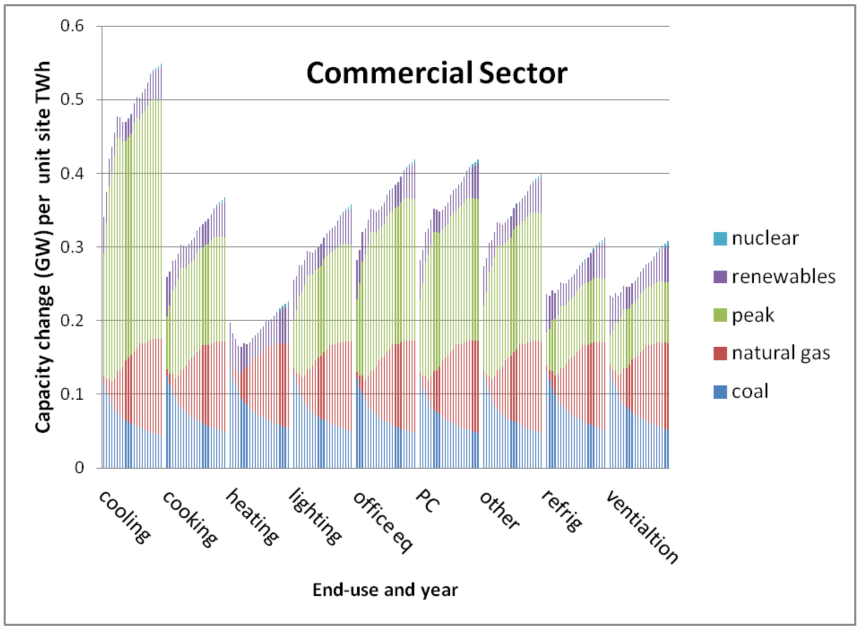

Figure 15A.3.1 Installed capacity impact factors for commercial end-uses

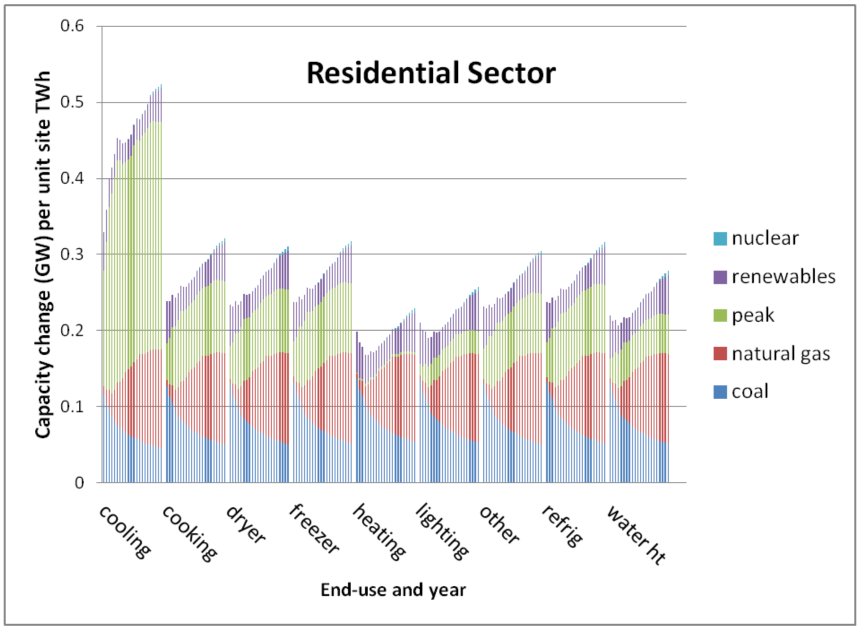

Figure 15A.3.2 Installed capacity impact factors for residential end-uses

15A.3.2 Electricity Generation

The figures below presents the distribution across fuel types of a unit reduction in generation for the commercial and residential sectors, referred to as fuel-share weights. The fuel types are coal, natural gas, petroleum, renewables and nuclear. DOE calculated these weights for all end uses, but for clarity the figures show only three: cooling (representative of peaking loads), lighting (representative of intermediate loads) and refrigeration (representative of base loads). To extrapolate to years beyond 2040, DOE uses the 2040 values.

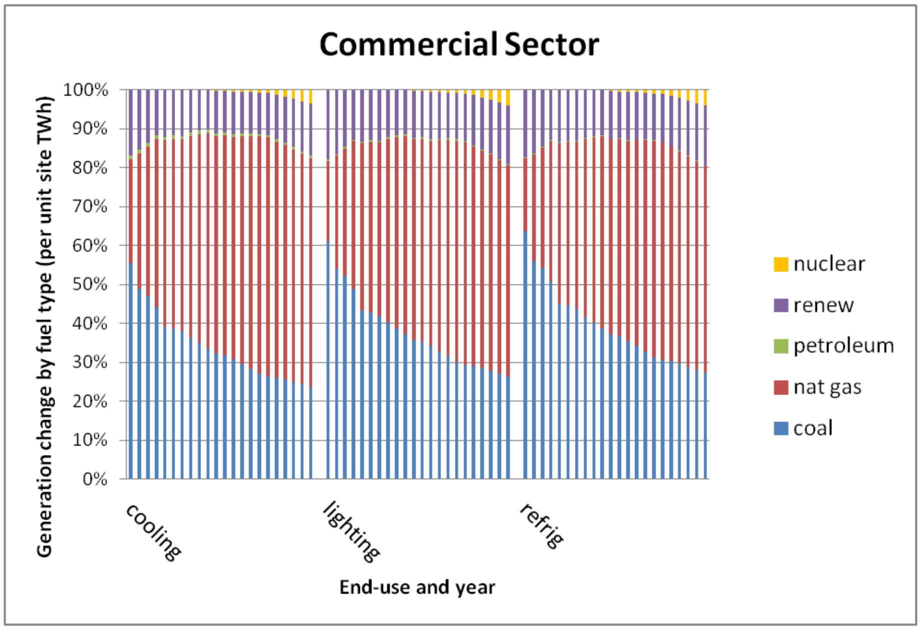

Figure 15A.3.3 Fuel-share weights for commercial end-uses

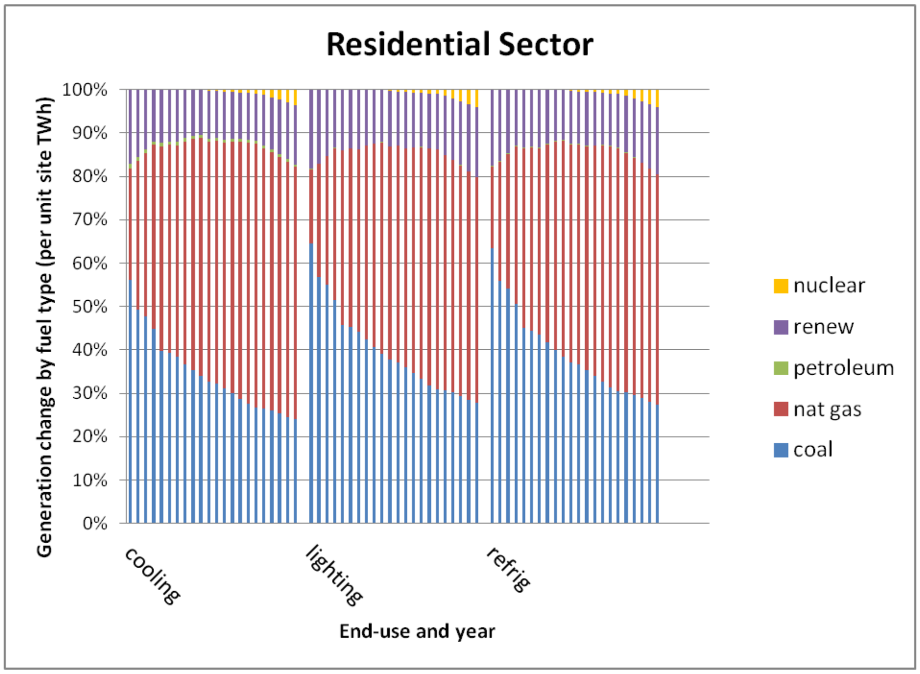

Figure 15A.3.4 Fuel-share weights for residential end-uses

REFERENCES

1 U.S. Department of Energy-Energy Information Administration, *National Energy Modeling System: An Overview*, 2009. Report No. DOE/EIA-0581(2009). <http://www.eia.gov/oiaf/aeo/overview/>

2 U.S. Department of Energy-Energy Information Administration., *Annual Energy Outlook 2014 with Projections to 2040.* . 2014. Washington, D.C.

3 US EPA, *Emissions Factors for Greenhouse Gas Inventories*, 2014. (Last accessed December 1, 2014.) <http://www.epa.gov/climateleadership/documents/emission-factors.pdf>

4 Coughlin, K., *Utility Sector Impacts of Reduced Electricity Demand.*: Lawrence Berkeley National Laboratory.

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;
- Market penetration curves used to analyze consumer rebates and voluntary energy efficiency targets, including:
    - Background material on XENERGY's approach,
    - DOE's adjustment of these curves for this analysis, and
    - The method DOE used to derive interpolated, customized curves;
- Detailed table of rebates offered for the considered product, as well as DOE's approach to estimate a market representative rebate value for this RIA; 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.5 show the annual increases in market shares of conventional cooking products meeting the target efficiency levels for the proposed TSL (TSL 2). DOE used these market share increases as inputs to the NIA-RIA spreadsheet model.

Table 17A.1 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Electric Standard Ovens, Freestanding (TSL 2)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets	Bulk Govt Purchases
2019	56.3%	33.8%	16.9%	0.5%	0.3%
2020	56.3%	33.8%	16.9%	1.3%	0.5%
2021	56.1%	33.6%	16.8%	2.1%	0.8%
2022	55.9%	33.5%	16.8%	2.9%	1.0%
2023	55.7%	33.4%	16.7%	3.6%	1.3%
2024	55.5%	33.3%	16.7%	4.4%	1.5%
2025	55.4%	33.2%	16.6%	5.2%	1.8%
2026	55.2%	33.1%	16.6%	5.9%	2.0%
2027	55.1%	33.0%	16.5%	6.7%	2.3%
2028	54.9%	33.0%	16.5%	7.5%	2.5%
2029	54.8%	32.9%	16.4%	7.8%	2.5%
2030	54.7%	32.8%	16.4%	8.1%	2.5%
2031	54.5%	32.7%	16.3%	8.4%	2.5%
2032	54.4%	32.6%	16.3%	8.8%	2.5%
2033	54.2%	32.5%	16.2%	9.1%	2.5%
2034	54.0%	32.4%	16.2%	9.5%	2.5%
2035	53.9%	32.3%	16.2%	9.8%	2.5%
2036	53.7%	32.2%	16.1%	10.2%	2.5%
2037	53.6%	32.2%	16.1%	10.5%	2.5%
2038	53.4%	32.1%	16.0%	10.9%	2.5%
2039	53.3%	32.0%	16.0%	11.2%	2.5%
2040	53.1%	31.9%	15.9%	11.5%	2.5%
2041	53.1%	31.8%	15.9%	11.9%	2.5%
2042	52.9%	31.8%	15.9%	12.2%	2.5%
2043	52.8%	31.7%	15.9%	12.5%	2.5%
2044	52.7%	31.6%	15.8%	12.8%	2.5%
2045	52.6%	31.5%	15.8%	13.1%	2.5%
2046	52.5%	31.5%	15.7%	13.5%	2.5%
2047	52.4%	31.4%	15.7%	13.8%	2.5%
2048	52.3%	31.4%	15.7%	14.1%	2.5%

Table 17A.2 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Electric Self-Clean Ovens, Freestanding (TSL 2)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets	Bulk Govt Purchases
2019	36.6%	21.9%	11.0%	1.6%	0.2%
2020	36.6%	22.0%	11.0%	3.5%	0.4%
2021	36.4%	21.9%	10.9%	5.4%	0.6%
2022	36.3%	21.8%	10.9%	7.3%	0.8%
2023	36.2%	21.7%	10.9%	9.1%	1.0%
2024	36.1%	21.7%	10.8%	10.8%	1.2%
2025	36.0%	21.6%	10.8%	12.5%	1.4%
2026	35.9%	21.6%	10.8%	14.1%	1.6%
2027	35.8%	21.5%	10.7%	15.7%	1.8%
2028	35.7%	21.4%	10.7%	17.2%	2.0%
2029	35.6%	21.4%	10.7%	17.5%	2.0%
2030	35.6%	21.3%	10.7%	17.9%	2.0%
2031	35.4%	21.3%	10.6%	18.2%	2.0%
2032	35.3%	21.2%	10.6%	18.6%	2.0%
2033	35.2%	21.1%	10.6%	18.9%	2.0%
2034	35.1%	21.1%	10.5%	19.3%	2.0%
2035	35.0%	21.0%	10.5%	19.6%	2.0%
2036	34.9%	21.0%	10.5%	20.0%	2.0%
2037	34.8%	20.9%	10.4%	20.3%	2.0%
2038	34.7%	20.8%	10.4%	20.7%	2.0%
2039	34.6%	20.8%	10.4%	21.0%	2.0%
2040	34.6%	20.7%	10.4%	21.3%	2.0%
2041	34.5%	20.7%	10.4%	21.6%	2.0%
2042	34.5%	20.7%	10.4%	21.9%	2.0%
2043	34.6%	20.7%	10.4%	22.2%	2.0%
2044	34.6%	20.7%	10.4%	22.5%	2.0%
2045	34.6%	20.7%	10.4%	22.7%	2.0%
2046	34.6%	20.7%	10.4%	23.0%	2.0%
2047	34.6%	20.8%	10.4%	23.3%	2.0%
2048	34.6%	20.8%	10.4%	23.6%	2.0%

Table 17A.3 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Electric Self-Clean Ovens, Built-In/Slide-In (TSL 2)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets	Bulk Govt Purchases
2019	36.5%	21.9%	11.0%	1.6%	0.2%
2020	36.6%	21.9%	11.0%	3.6%	0.4%
2021	36.4%	21.8%	10.9%	5.5%	0.6%
2022	36.3%	21.8%	10.9%	7.4%	0.8%
2023	36.2%	21.7%	10.8%	9.2%	1.0%
2024	36.1%	21.6%	10.8%	10.9%	1.2%
2025	36.0%	21.6%	10.8%	12.6%	1.4%
2026	35.8%	21.5%	10.8%	14.2%	1.6%
2027	35.8%	21.5%	10.7%	15.8%	1.8%
2028	35.7%	21.4%	10.7%	17.4%	2.0%
2029	35.6%	21.4%	10.7%	17.7%	2.0%
2030	35.5%	21.3%	10.6%	18.0%	2.0%
2031	35.4%	21.2%	10.6%	18.4%	2.0%
2032	35.3%	21.2%	10.6%	18.7%	2.0%
2033	35.2%	21.1%	10.6%	19.1%	2.0%
2034	35.1%	21.0%	10.5%	19.4%	2.0%
2035	35.0%	21.0%	10.5%	19.8%	2.0%
2036	34.9%	20.9%	10.5%	20.1%	2.0%
2037	34.8%	20.9%	10.4%	20.5%	2.0%
2038	34.7%	20.8%	10.4%	20.8%	2.0%
2039	34.6%	20.8%	10.4%	21.1%	2.0%
2040	34.5%	20.7%	10.4%	21.4%	2.0%
2041	34.5%	20.7%	10.4%	21.7%	2.0%
2042	34.5%	20.7%	10.4%	22.0%	2.0%
2043	34.6%	20.7%	10.4%	22.3%	2.0%
2044	34.6%	20.7%	10.4%	22.6%	2.0%
2045	34.6%	20.7%	10.4%	22.9%	2.0%
2046	34.6%	20.7%	10.4%	23.2%	2.0%
2047	34.6%	20.8%	10.4%	23.4%	2.0%
2048	34.6%	20.8%	10.4%	23.7%	2.0%

Table 17A.4 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Gas Standard Ovens, Freestanding (TSL 2)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets	Bulk Govt Purchases
2019	41.7%	25.0%	12.5%	8.9%	0.3%
2020	41.7%	25.0%	12.5%	11.7%	0.6%
2021	41.7%	25.0%	12.5%	14.4%	1.0%
2022	41.7%	25.0%	12.5%	16.9%	1.3%
2023	41.7%	25.0%	12.5%	19.3%	1.6%
2024	41.7%	25.0%	12.5%	21.5%	1.9%
2025	41.7%	25.0%	12.5%	23.7%	2.3%
2026	41.7%	25.0%	12.5%	25.7%	2.6%
2027	41.7%	25.0%	12.5%	27.6%	2.9%
2028	41.7%	25.0%	12.5%	29.5%	3.2%
2029	41.7%	25.0%	12.5%	29.7%	3.2%
2030	41.7%	25.0%	12.5%	30.0%	3.2%
2031	41.7%	25.0%	12.5%	30.2%	3.2%
2032	41.7%	25.0%	12.5%	30.5%	3.2%
2033	41.7%	25.0%	12.5%	30.8%	3.2%
2034	41.7%	25.0%	12.5%	31.0%	3.2%
2035	41.7%	25.0%	12.5%	31.3%	3.2%
2036	41.7%	25.0%	12.5%	31.5%	3.2%
2037	41.7%	25.0%	12.5%	31.8%	3.2%
2038	41.7%	25.0%	12.5%	32.0%	3.2%
2039	41.7%	25.0%	12.5%	32.3%	3.2%
2040	41.7%	25.0%	12.5%	32.5%	3.2%
2041	41.7%	25.0%	12.5%	32.7%	3.2%
2042	41.7%	25.0%	12.5%	32.9%	3.2%
2043	41.7%	25.0%	12.5%	33.1%	3.2%
2044	41.7%	25.0%	12.5%	33.4%	3.2%
2045	41.7%	25.0%	12.5%	33.6%	3.2%
2046	41.7%	25.0%	12.5%	33.8%	3.2%
2047	41.7%	25.0%	12.5%	34.0%	3.2%
2048	41.7%	25.0%	12.5%	34.2%	3.2%

Table 17A.5 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Gas Self-Clean Ovens, Freestanding (TSL 2)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets	Bulk Govt Purchases
2019	36.6%	22.0%	11.0%	13.4%	0.3%
2020	36.6%	22.0%	11.0%	16.4%	0.6%
2021	36.6%	22.0%	11.0%	19.1%	0.9%
2022	36.6%	22.0%	11.0%	21.5%	1.2%
2023	36.6%	22.0%	11.0%	23.7%	1.5%
2024	36.6%	22.0%	11.0%	25.8%	1.7%
2025	36.6%	22.0%	11.0%	27.7%	2.0%
2026	36.6%	22.0%	11.0%	29.4%	2.3%
2027	36.6%	22.0%	11.0%	31.1%	2.6%
2028	36.6%	22.0%	11.0%	32.6%	2.9%
2029	36.6%	22.0%	11.0%	32.8%	2.9%
2030	36.6%	22.0%	11.0%	33.0%	2.9%
2031	36.6%	22.0%	11.0%	33.1%	2.9%
2032	36.6%	22.0%	11.0%	33.3%	2.9%
2033	36.6%	22.0%	11.0%	33.4%	2.9%
2034	36.6%	22.0%	11.0%	33.6%	2.9%
2035	36.6%	22.0%	11.0%	33.8%	2.9%
2036	36.6%	22.0%	11.0%	33.9%	2.9%
2037	36.6%	22.0%	11.0%	34.1%	2.9%
2038	36.6%	22.0%	11.0%	34.2%	2.9%
2039	36.6%	22.0%	11.0%	34.3%	2.9%
2040	36.6%	22.0%	11.0%	34.5%	2.9%
2041	36.6%	22.0%	11.0%	34.6%	2.9%
2042	36.6%	22.0%	11.0%	34.7%	2.9%
2043	36.6%	22.0%	11.0%	34.8%	2.9%
2044	36.6%	22.0%	11.0%	35.0%	2.9%
2045	36.6%	22.0%	11.0%	35.1%	2.9%
2046	36.6%	22.0%	11.0%	35.2%	2.9%
2047	36.6%	22.0%	11.0%	35.3%	2.9%
2048	36.6%	22.0%	11.0%	35.5%	2.9%

17A.3 NIA-RIA INTEGRATED MODEL

For this analysis, DOE used its integrated NIA-RIA[a] model approach that the Department built on the NIA model discussed in Chapter 10 and documented in Appendix 10A.The resulting integrated NIA-RIA model features both the NIA and RIA inputs, analyses and results. It has the capability to generate results, by product class and TSL, for the mandatory standards and each of the RIA policies. Separate modules estimate increases in market penetration of more efficient equipment for consumer rebates, voluntary energy efficiency targets and bulk government purchases.[b] The consumer rebates module calculates benefit-cost (B/C) ratios and market barriers, and generates customized market penetration curves for each product class; the voluntary energy efficiency targets module relies on the market barriers calculated in the consumer rebates module to project a reduction in those barriers over the first ten years of the forecast period and estimate the market effects of such a reduction; and the bulk government purchases module scales down the market for conventional cooking products to housing units in public housing authority. A separate module summarizes the market impacts from mandatory standards and all policy alternatives, and an additional module produces all tables and figures presented in chapter 17 as well as the tables of market share increases for each policy reported in Section 17A.2 of this Appendix.

17A.4 MARKET PENETRATION CURVES

This section first discusses the theoretical basis for the market penetration curves that DOE used to analyze the Consumer Rebates and Voluntary Energy Efficiency Targets policies. Next it discusses the adjustments it made to the maximum penetration rates. It then refers to the method it used to develop interpolated penetration curves for conventional cooking products that meet the target efficiency levels at each TSL. The resulting curves are presented in chapter 17.

17A.4.1 Introduction

XENERGY, Inc.[c], 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

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[a] NIA = National Impact Analysis; RIA = Regulatory Impact Analysis

[b] As mentioned in Chapter 17, the increase in market penetrations for consumer tax credits and manufacturer tax credits are estimated as a fraction of the increase in market penetration of consumer rebates.

[c] XENERGY is now owned by KEMA, Inc. (www.kema.com)

conclusively develop a universally applicable model. Some key findings, however, generally are accepted in academia and industry.

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).

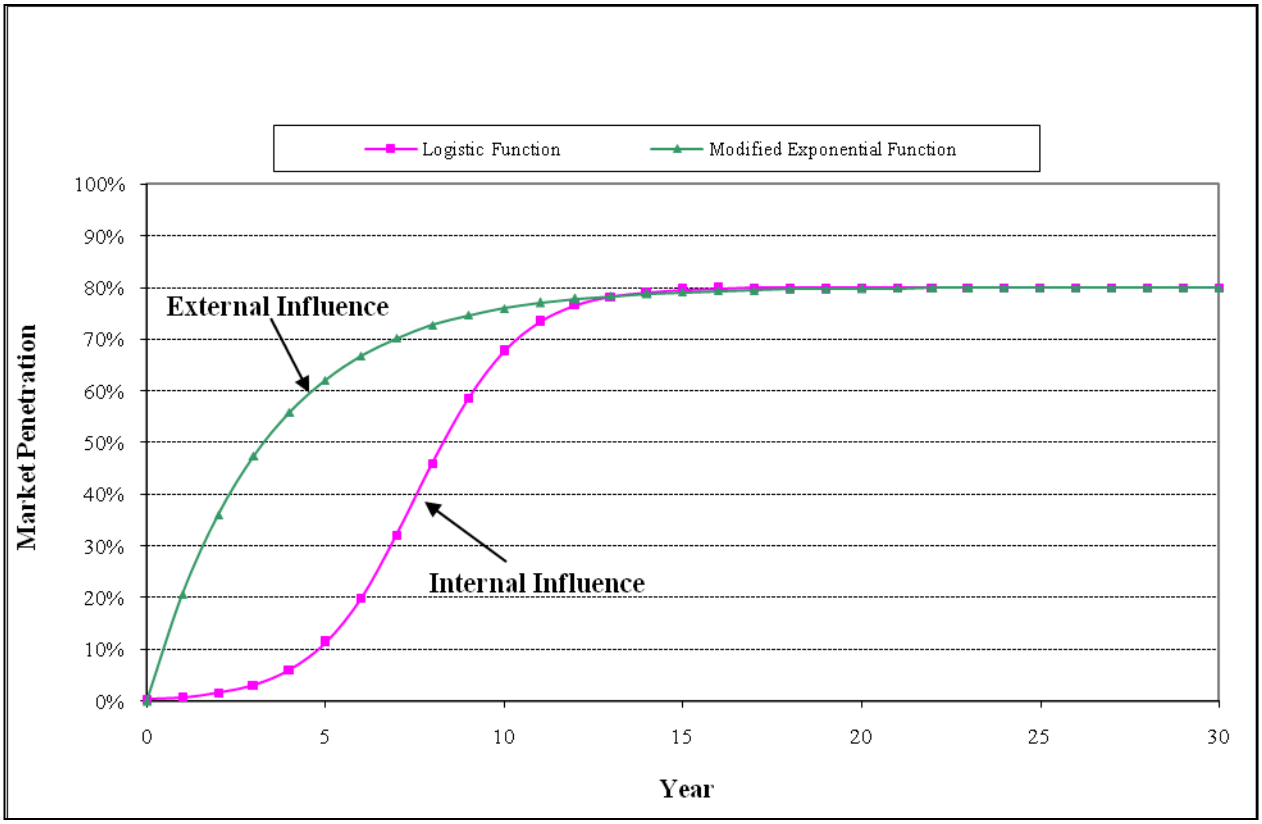

Figure 17A.4.1 S-Curves Showing Effects of External and Internal Sources on Adoption of New Technologies

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.[d] 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.[e] 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.

DOE used the above referred method to interpolate market implementation curves, to generate customized curves that were used to estimate the effects of consumer rebates and voluntary energy efficiency targets for each product class covered by this RIA. For consumer rebates, DOE derived such curves based on an algorithm that finds the market implementation curve that best fits, for the first year of the analysis period, the B/C ratio of the target efficiency level and the market penetration of equipment with that level of energy efficiency in the base case. For the analysis of voluntary energy efficiency targets, DOE departs from the market barriers level corresponding to the market implementation curve it derived for consumer rebates, to linearly decrease it over the ten initial years of the analysis period. For each year, as market barriers decline, the corresponding market implementation curve leads – for the same B/C ratio – to higher market penetrations.

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[d] The RIA chapter refers to these curves as *penetration curves*. This section, in references to the original source, uses the term *implementation curve*.

[e] 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 are considered in this RIA proportional to the impacts from rebates.

17A.5 CONSUMER REBATE PROGRAMS

DOE performed a nationwide search for rebate programs that offered incentives for conventional cooking products. Since DOE could not find rebate programs for this equipment, DOE assumed that a rebate program would pay for all of the increased installed cost of each product class at each TSL. Table 17A.6 presents the rebate amounts DOE estimated for each product class, at each TSL.

Table 17A.6 Rebates Amounts by TSL*

	TSL 1	TSL 2	TSL 3
Electric Standard Ovens, Freestanding	1.13	10.85	96.76
Electric Self-Clean Ovens, Freestanding	1.13	1.13	85.13
Electric Self-Clean Ovens, Built-In/Slide-In	1.13	1.13	85.13
Gas Standard Ovens, Freestanding	-	16..96	54.19
Gas Self-clean Ovens, Freestanding	1.12	9.96	45.17

* In 2014$.

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 distributors 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 any 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 each product class of conventional cooking products covered by this RIA. 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, Section 17.3.3, 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.

REFERENCES

1. Rufo, M. and F. Coito, *California's Secret Energy Surplus: The Potential for Energy Efficiency*, 2002. XENERGY Inc. (Last accessed March, 2014.) <www.issuelab.org/resource/californias_secret_energy_surplus_the_potential_for_energy_efficiency>

2. Hall, B. H. and B. Khan, Adoption of New Technology. *Working Paper No. E03-330*, 2003. Department of Economics, University of California, Berkeley, CA.

3. Lekvall. P and C. Wahlbin, "A Study of Some Assumptions Underlying Innovation Diffusion Functions". *Swedish Journal of Economics*, 1973

4. Geroski, P. A., Models of Technology Diffusion. *Research Policy*, 2000. 29: pp. 603-625

5. Van den Bulte, C., "Want to Know How Diffusion Speed Varies Across Countries and Products? Try a Bass Model". *Product Development & Management Association*, 2002. XXVI(4)

6. Rufo, M., Telephone Conversation with Barbara Atkinson of LBNL, *personal communication.* Itron, Inc. January 2008 and March 2009.

7. Blum, H., B. Atkinson, and A. Lekov, *A Framework for Comparative Assessments of Energy Efficiency Policy Measures*, May, 2011. Report No. LBNL-4749E. <http://escholarship.org/uc/item/4t32x6vr>

8. Tax Incentives Assistance Project, *Consumer Tax Incentives: Home Heating & Cooling Equipment.*, 2011. (Last accessed March, 2014.) <www.energytaxincentives.org/consumers/heating-cooling.php>

9. *Energy Policy Act of 2005*, in *119 STAT. 594 Public Law 109-58. Section 1333, 26 USC 25C note,*. 2005. www.gpo.gov/fdsys/pkg/BILLS-109hr6pcs/pdf/BILLS-109hr6pcs.pdf

10. *American Recovery and Reinvestment Act of 2009*, 2009. Government Printing Office. (Last accessed March, 2014.) <http://www.gpo.gov/fdsys/pkg/BILLS-111hr1enr/pdf/BILLS-111hr1enr.pdf>

11. Tax Incentives Assistance Project, *The Tax Incentives Assistance Project (TIAP)*, 2013. (Last accessed March, 2014.) <http://energytaxincentives.org/>

12. Foster, R., J. Grevatt, N. Lange, and T. Gee, *Efficiency Programs and Distributors: Opportunities to Fully Leverage the Supply Chain for Greater Impact*, August 12-17, 2012. American Council for an Energy-Efficient Economy. Asilomar, CA. <www.aceee.org/files/proceedings/2012/data/papers/0193-000198.pdf>

13. Tusa, C. S., D. Pierson, P. Mammola, and J. P. Vora, *JPM/HARDI 2011 HVAC Survey*, 2011. (Last accessed March, 2014.) <www.hardinet.org/mid-season-hvac-distributor-survey>

14. Internal Revenue Service, *SOI Tax Stats - Individual Income Tax Returns, Estimated Data Line Counts*, (Last accessed March, 2014.) <www.irs.gov/uac/SOI-Tax-Stats-Individual-Income-Tax-Returns,-Line-Item-Estimates>

15. Internal Revenue Service, *1979 Annual Report, Commissioner of Internal Revenue,* (Last accessed March, 2014.) <www.irs.gov/pub/irs-soi/79dbfullar.pdf>

16. Internal Revenue Service, *1980 Annual Report, Commissioner of Internal Revenue.,* (Last accessed March, 2014.) <www.irs.gov/pub/irs-soi/80dbfullar.pdf>

17. Internal Revenue Service, *1981 Annual Report: Commissioner of Internal Revenue and the Chief Counsel for the Internal Revenue Service,* (Last accessed March, 2014.) <www.irs.gov/pub/irs-soi/81dbfullar.pdf>

18. U.S. Department of the Treasury–Internal Revenue Service, *Form 8909: Energy Efficient Appliance Credit,* (Last accessed March, 2014.) <www.irs.gov/pub/irs-pdf/f8909.pdf>

19. *Emergency Economic Stabilization Act of 2008*, (Last accessed March, 2014.) <www.gpo.gov/fdsys/pkg/PLAW-110publ343/pdf/PLAW-110publ343.pdf>

20. Tax Incentives Assistance Project, *Manufacturers Incentives,* (Last accessed March, 2014.) <http://energytaxincentives.org/builders/appliances.php>

21. Database of State Incentives for Renewables and Efficiency (DSIRE), *Oregon Incentives/Policies for Renewable Energy, Residential Energy Tax Credit*, 2013. (Last accessed March, 2014.) <http://programs.dsireusa.org/system/program/detail/638>

22. Oregon Department of Energy, *HB 3672 (2011)Tax Credit Extension Bill*, 2013. (Last accessed March, 2014.) <www.oregon.gov/energy/CONS/docs/HB3672summary.pdf>

23. Oregon Department of Energy, *ODOE: Energy Conservation, Heat Pump Systems,* 2013. (Last accessed March, 2014.) <http://www.oregon.gov/energy/CONS/Pages/res/tax/HVAC-HP-AC.aspx>

24. Montana Department of Revenue, *Energy Related Tax Relief: Energy Conservation Installation Credit*, (Last accessed March, 2014.) <http://revenue.mt.gov/home/individuals/taxrelief_energy.aspx>