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

CONSUMER CONVENTIONAL COOKING PRODUCTS

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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 by the U.S. Department of Energy (DOE) in the supplemental notice of proposed rulemaking (SNOPR) for consumer conventional cooking products.

1.2 SUMMARY OF THE NATIONAL BENEFITS

DOE's analyses indicate that amended standards would save a significant amount of energy. Relative to the case without new and amended standards, the lifetime energy savings from consumer conventional cooking products purchased in the 30-year period that begins in the assumed year of compliance with the proposed standards (2027–2056) amount to 0.46 quadrillion Btu ("quads").[a] This represents a savings of 3.4 percent relative to the energy use of these products in the no-new-standards case.

The cumulative net present value (NPV) of total consumer costs and savings of the proposed standards for consumer conventional cooking products ranges from $0.65 billion (at a 7-percent discount rate) to $1.71 billion (at a 3-percent discount rate). This NPV expresses the estimated total value of future operating-cost savings minus the estimated increased product and installation costs for consumer conventional cooking products purchased in 2027–2056.

In addition, the proposed standards are projected to yield significant environmental benefits. DOE estimates that the proposed standards would result in cumulative emission reductions (over the same period as for energy savings) of 21.9 million metric tons (Mt)[b] of carbon dioxide (CO_2), 2.2 thousand tons of sulfur dioxide (SO_2), 51.8 thousand tons of nitrogen oxides (NO_X), 244.9 thousand tons of methane (CH_4), 0.1 thousand tons of nitrous oxide (N_2O), and 0.01 tons of mercury (Hg).[c]

DOE estimates climate benefits from a reduction in greenhouse gases (GHG) using four different estimates of the social cost of CO_2 (SC-CO_2), the social cost of methane (SC-CH_4), and the social cost of nitrous oxide (SC-N_2O). Together these represent the social cost of GHG (SC-GHG). DOE used interim SC-GHG values developed by an Interagency Working Group on the

[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 no-new-standards case, which reflects key assumptions in the *Annual Energy Outlook 2022* (*AEO 2022*) Reference case. *AEO 2022* represents current federal and state legislation and final implementation of regulations as of the time of its preparation.

Social Cost of Greenhouse Gases (IWG).[d] For presentational purposes, the climate benefits associated with the average SC-GHG at a 3-percent discount rate are $1.17 billion. (DOE does not have a single central SC-GHG point estimate and it emphasizes the importance and value of considering the benefits calculated using all four SC-GHG estimates.)

DOE also estimates health benefits from SO_2 and NO_X emissions reductions.[e] DOE estimates the present value of the health benefits would be $0.61 billion using a 7-percent discount rate, and $1.63 billion using a 3-percent discount rate. DOE is currently only monetizing $PM_{2.5}$ and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct $PM_{2.5}$ emissions.

Table 1.2.1 summarizes the economic benefits and costs expected to result from the proposed standards for consumer conventional cooking products. In the table, total benefits for both the 3-percent and 7-percent cases are presented using the average GHG social costs with 3-percent discount rate, but the Department emphasizes the importance and value of considering the benefits calculated using all four SC-GHG cases.

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[d] See Interagency Working Group on Social Cost of Greenhouse Gases, Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide. Interim Estimates Under Executive Order 13990, Washington, D.C., February 2021 www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.

[e] DOE estimated the monetized value of SO_2 and NO_X emissions reductions associated with site and electricity savings using benefit per ton estimates from the scientific literature.

Table 1.2.1 Summary of National Economic Benefits and Costs of Proposed Energy Conservation Standards for Consumer Conventional Cooking Products (Trial Standard Level (TSL) 2)

	billion 2021$
3% discount rate	
Consumer Operating Cost Savings	2.28
Climate Benefits*	1.17
Health Benefits**	1.63
Total Benefits†	5.08
Consumer Incremental Product Costs‡	0.56
Net Benefits	4.51
7% discount rate	
Consumer Operating Cost Savings	0.95
Climate Benefits* (3% discount rate)	1.17
Health Benefits**	0.61
Total Benefits†	2.74
Consumer Incremental Product Costs‡	0.31
Net Benefits	2.43

Note: This table presents the costs and benefits associated with consumer conventional cooking products shipped in 2027–2056. These results include benefits to consumers which accrue after 2056 from the products shipped in 2027–2056.
* Climate benefits are calculated using four different estimates of the social cost of carbon (SC-CO_2), methane (SC-CH_4), and nitrous oxide (SC-N_2O) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). Together these represent the global SC-GHG. For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown, but the Department does not have a single central SC-GHG point estimate. On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.
** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. DOE is currently only monetizing $PM_{2.5}$ and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct $PM_{2.5}$ emissions.
† Total and net benefits include those consumer, climate, and health benefits and can be quantified and monetized. For presentation purposes, total and net benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate, but the Department does not have a single central SC-GHG point estimate. DOE emphasizes the importance and value of considering the benefits calculated using all four SC-GHG estimates.
‡ Costs include incremental equipment costs as well as installation costs.

The benefits and costs of the proposed standards can also be expressed in terms of annualized values. The monetary values for the total annualized net benefits are (1) the reduced consumer operating costs, minus (2) the increase in product purchase prices and installation costs, plus (3) the value of the benefits of GHG and NO_X and SO_2 emission reductions, all annualized.[f] The national operating savings are domestic private U.S. consumer monetary savings that occur as a result of purchasing the covered products and are measured for the lifetime of consumer conventional cooking products shipped in 2027–2056. The benefits associated with reduced emissions achieved as a result of the proposed standards are also calculated based on the lifetime of consumer conventional cooking products shipped in 2027–2056.

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 and health benefits from reduced NO_X and SO_2 emissions, and the 3-percent discount rate case for climate benefits from reduced GHG emissions, the estimated cost of the proposed standards is $32.5 million per year in increased equipment costs, while the estimated annual benefits are $100.8 million per year in reduced equipment operating costs, $67.0 million in climate benefits, and $64.9 million in health benefits. In this case, the net benefit would amount to $200.3 million per year.

Using a 3-percent discount rate for all benefits and costs, the estimated cost of the proposed standards is $32.2 million per year in increased equipment costs, while the estimated annual benefits are $130.7 million per year in reduced operating costs, $67.0 million in climate benefits, and $93.8 million in health benefits. In this case, the net benefit would amount to $259.2 million per year.

[f] To convert the time-series of costs and benefits into annualized values, DOE calculated a present value in 2022, 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.*, 2030), and then discounted the present value from each year to 2022. 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.

Table 1.2.2 Annualized Benefits and Costs of Proposed Energy Conservation Standards for Consumer Conventional Cooking Products (TSL 2)

	Primary Estimate	Low-Net-Benefits Estimate	High-Net-Benefits Estimate
	million 2021$/year		
3% discount rate			
Consumer Operating Cost Savings	130.7	124.7	137.9
Climate Benefits*	67.0	65.3	68.4
Health Benefits**	93.8	91.4	95.6
Total Benefits†	291.5	281.4	301.8
Consumer Incremental Product Costs‡	32.2	36.1	31.4
Net Benefits	259.2	245.2	270.4
7% discount rate			
Consumer Operating Cost Savings	100.8	96.5	105.8
Climate Benefits* (3% discount rate)	67.0	65.3	68.4
Health Benefits**	64.9	63.4	66.0
Total Benefits†	232.8	225.3	240.2
Consumer Incremental Product Costs‡	32.5	35.8	31.8
Net Benefits	200.3	189.5	208.4

Note: This table presents the costs and benefits associated with consumer conventional cooking products shipped in 2027–2056. These results include benefits to consumers which accrue after 2056 from the products shipped in 2027–2056. The Primary, Low Net Benefits, and High Net Benefits Estimates utilize projections of energy prices from the *AEO 2022* Reference case, Low Economic Growth case, and High Economic Growth case, respectively. In addition, incremental equipment costs reflect a medium decline rate in the Primary Estimate, a low decline rate in the Low Net Benefits Estimate, and a high decline rate in the High Net Benefits Estimate. Note that the Benefits and Costs may not sum to the Net Benefits due to rounding.

* Climate benefits are calculated using four different estimates of the global SC-GHG. For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown, but the Department does not have a single central SC-GHG point estimate, and it emphasizes the importance and value of considering the benefits calculated using all four SC-GHG estimates. On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and presents monetized benefits where appropriate and permissible under law.

** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. DOE is currently only monetizing (for SO_2 and NO_X) $PM_{2.5}$ and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct $PM_{2.5}$ emissions. The health benefits are presented at real discount rates of 3 and 7 percent.

† Total benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate, but the Department does not have a single central SC-GHG point estimate.

‡ Costs include incremental equipment costs as well as installation costs.

1.3 OVERVIEW OF STANDARDS FOR CONSUMER CONVENTIONAL COOKING PRODUCTS

The National Appliance Energy Conservation Act of 1987 (NAECA), Public Law 100-12, amended the Energy Policy and Conservation Act, as amended (EPCA),[g] Public Law 94-163 (42 U.S.C. 6291–6317, as codified) 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 consumer 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 a final rule on April 8, 2009 ("April 2009 Final Rule") amending the energy conservation standards for consumer 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. 74 FR 16040. 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, 16085.[h]

EPCA also requires that, not later than 6 years after the issuance of a final rule establishing or amending a standard, DOE publish a notice of proposed rulemaking (NOPR) proposing new standards or a notification 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:

1) the economic impact of the standard on the manufacturers and on the consumers of the products subject to such a standard;

[g] All references to EPCA in this document refer to the statute as amended through the Energy Act of 2020, Pub. L. 116-260 (Dec. 27, 2020), which reflect the last statutory amendments that impact Parts A and A-1 of EPCA.
[h] 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 has since 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. A separate rulemaking is underway addressing energy conservation standards for microwave ovens. See https://www.regulations.gov/docket/EERE-2017-BT-STD-0023/document.

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.

(42 U.S.C. 6295(o)(2)(B)(i)(I)–(VII))

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* 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))

DOE must periodically review its already established energy conservation standards for a covered product no later than 6 years from the issuance of a final rule establishing or amending a standard for a covered product. (42 U.S.C. 6295(m)) This 6-year look-back provision requires that DOE publish either a determination that standards do not need to be amended or a NOPR, including new proposed standards (proceeding to a final rule, as appropriate). (42 U.S.C. 6295(m)(1)) EPCA further provides that, not later than 3 years after the issuance of a final determination not to amend standards, DOE must publish either a notice of determination that standards for the product do not need to be amended, or a NOPR including new proposed energy conservation standards (proceeding to a final rule, as appropriate). (42 U.S.C. 6295(m)(3)(B)) DOE must make the analysis on which a determination is based publicly available and provide an opportunity for written comment. (42 U.S.C. 6295(m)(2))

A determination that amended standards are not needed must be based on consideration of whether amended standards will result in significant conservation of energy, are technologically feasible, and are cost effective. (42 U.S.C. 6295(m)(1)(A) and (n)(2)) An evaluation of cost effectiveness requires that DOE consider savings in operating costs throughout the estimated average life of the covered products in the type (or class) compared to any increase in the price, initial charges, or maintenance expenses for the covered products that are likely to result from the standard. (42 U.S.C. 6295(n)(2) and (o)(2)(B)(i)(II))

On February 12, 2014, DOE published a request for information (RFI) notice to initiate the mandatory review process imposed by EPCA ("February 2014 RFI"). As part of the February 2014 RFI, DOE sought input from the public to assist with its determination on whether new or amended standards pertaining to consumer conventional cooking products are warranted. 79 FR 8337.[i]

On June 10, 2015, DOE published a NOPR ("June 2015 NOPR") proposing new and amended energy conservation standards for conventional ovens. 80 FR 33030. In the June 2015 NOPR, DOE noted that it was deferring its decision regarding whether to adopt amended energy conservation standards for conventional cooking tops, pending further rulemaking.[j]

On September 2, 2016, DOE published an SNOPR ("September 2016 SNOPR") proposing new and amended energy conservation standards for conventional cooking tops based on the amendments to the test procedure as proposed in a test procedure SNOPR published on August 22, 2016 ("August 2016 TP SNOPR;" 81 FR 57374). 81 FR 60784. In the September 2016 SNOPR, DOE also revised its proposal from the June 2015 NOPR for conventional ovens from a performance-based standard to a prescriptive standard given that DOE had proposed to repeal the test procedure for conventional ovens in the August 2016 TP SNOPR. 81 FR 60784, 60793–60794. (The history of the test procedures for conventional cooking tops and conventional ovens is discussed in greater detail in chapter 3 of this SNOPR TSD.)[k]

On December 14, 2020, DOE published a notification of proposed determination (NOPD) proposing not to amend the energy conservation standards for consumer conventional cooking products ("December 2020 NOPD"). 85 FR 80982. In the December 2020 NOPD, DOE initially determined that amended energy conservation standards for consumer conventional cooking products would not be economically justified and would not result in a significant conservation of energy. The tentative determination in the December 2020 NOPD hinged, in significant part, on DOE's proposal to screen out all identified technology options that would improve the performance of gas cooking tops to efficiencies above the baseline efficiency level. 85 FR 80982, 81003–81004. DOE noted in the December 2020 NOPD that the estimates for

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[i] The February 2014 RFI document is available at: https://www.regulations.gov/document/EERE-2014-BT-STD-0005-0001.

[j] The June 2015 NOPR document is available at: https://www.regulations.gov/document/EERE-2014-BT-STD-0005-0014.

[k] The September 2016 SNOPR document is available at: https://www.regulations.gov/document/EERE-2014-BT-STD-0005-0054.

energy savings associated with a specific technology option for gas cooking tops, optimized burner and grate design, may vary depending on the test procedure, and thus DOE screened out this technology option from further analysis of gas cooking tops. *Id.* at 85 FR 81004. At the time of the December 2020 NOPD, DOE had withdrawn its test procedure for conventional cooking tops. However, DOE additionally stated in the December 2020 NOPD that it would reevaluate the energy savings associated with this technology option if it considered performance standards in a future rulemaking.[l]

On August 22, 2022, DOE published a final rule ("August 2022 TP Final Rule") establishing a new test procedure for conventional cooking tops. Testing conducted by DOE and outside parties using the test procedure yielded repeatable and reproducible results. DOE concluded, therefore, that the test procedure was representative of energy use during an average use cycle. 87 FR 51492. The test procedure established in the August 2022 TP Final Rule was used to evaluate energy conservation standards for conventional cooking tops for this SNOPR analysis, including consideration of the optimized burner and grate design technology option for gas cooking tops that was screened out in the analysis for the December 2020 NOPD.[m]

For this rulemaking, 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 docket for energy conservation standards for consumer conventional cooking products at: www.regulations.gov/docket/EERE-2014-BT-STD-0005/document.

DOE can also provide quantitative outputs from its analyses upon request.

1.5 STRUCTURE OF THE DOCUMENT

This SNOPR 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.

[l] The December 2020 NOPD document is available at: https://www.regulations.gov/document/EERE-2014-BT-STD-0005-0075.
[m] The August 2022 TP Final Rule document is available at: https://www.regulations.gov/document/EERE-2021-BT-TP-0023-0024.

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 Analysis: discusses the methods used for establishing markups for converting manufacturer prices to customer product costs.
Chapter 7	Energy Use Analysis: discusses the process used for generating energy use estimates for the considered products as a function of standard levels.
Chapter 8	Life-Cycle Cost and Payback Period 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.
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: describes the methods used for estimating the impacts of potential standards on national energy consumption and national economic benefit to consumers and presents results of the analysis.
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 national emissions of sulfur dioxide, nitrogen oxides, and mercury—as well as on carbon dioxide and other greenhouse gas emissions.

Chapter 14	Monetization of Emissions Reduction Benefits: describes the methods used for estimating monetary benefits likely to result from reduced emissions expected to result from potential standards.
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	Cooking Products: 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 for Consumer Conventional Cooking Products
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CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Pursuant to the Energy Policy and Conservation Act, as amended (EPCA),[a] Public Law 94-163 (42 U.S.C. 6291–6317, as codified) the U.S. Department of Energy (DOE) must follow specific statutory criteria for prescribing new or amended standards for covered products, including consumer conventional cooking products. In prescribing new or amended standards for covered products DOE must consider, among other things, the opportunity for energy savings, as well as the potential costs to consumers, and impacts on consumer choice. Any new or amended standard for a covered product must be designed to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A)) Furthermore, DOE may not adopt any standard that would not result in the significant conservation of energy. (42 U.S.C. 6295(o)(3)) Moreover, DOE may not prescribe a standard if DOE determines by rule that the standard is not technologically feasible or economically justified. (42 U.S.C. 6295(o)(3)(B)) This chapter describes the general analytical framework that DOE uses to evaluate whether new or amended standards for conventional cooking products would be economically justified. 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 provides an overview of the analytical components of the standards-setting process that may be conducted as part of an energy conservation standards rulemaking. 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.

[a] All references to EPCA in this document refer to the statute as amended through the Energy Act of 2020, Pub. L. 116-260 (Dec. 27, 2020), which reflect the last statutory amendments that impact Parts A and A-1 of EPCA.

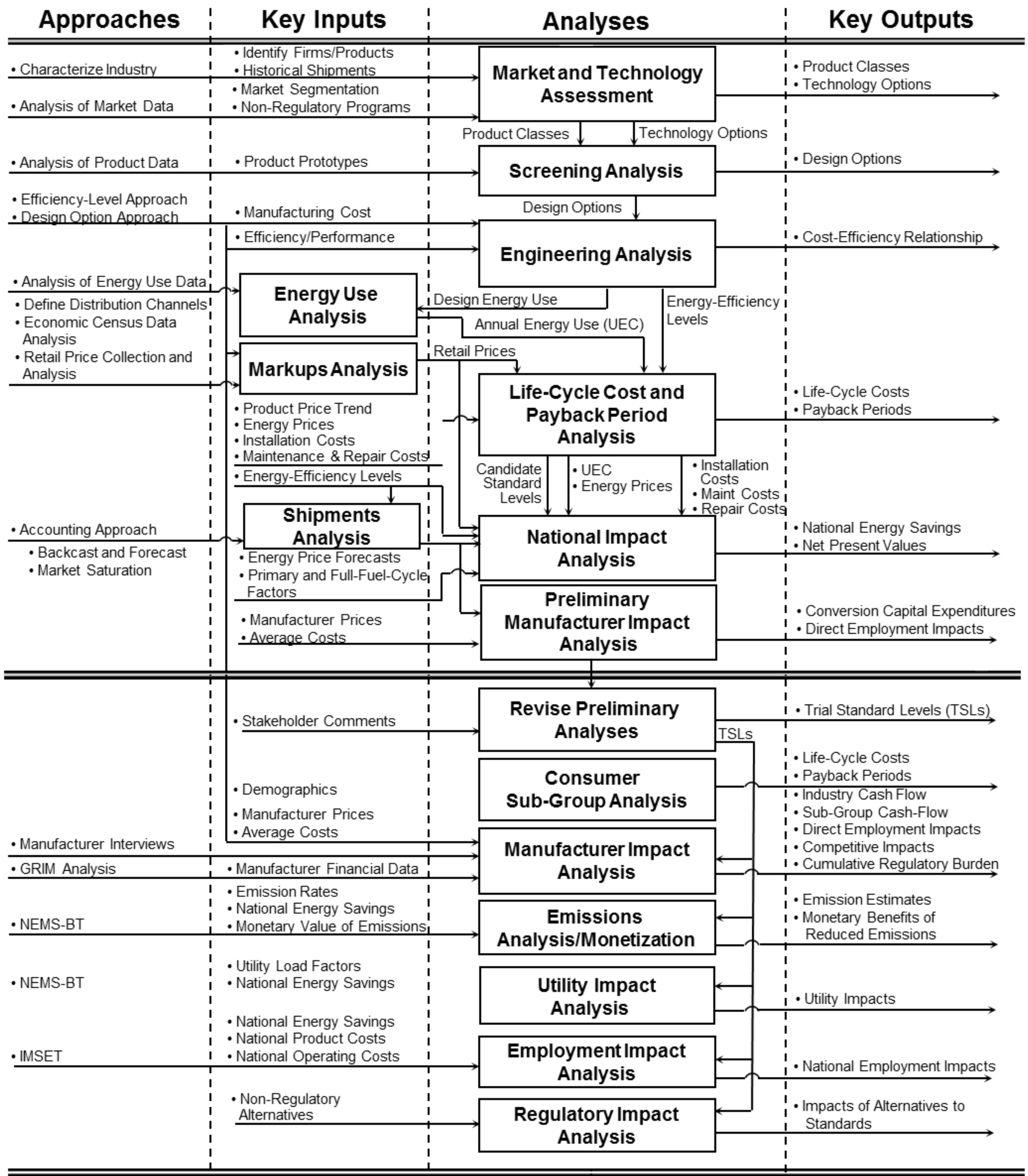

Figure 2.1.1 Flow Diagram of Analyses for the Rulemaking Process

Whether an analysis is conducted and the rulemaking stage at which it is presented will vary based on the statutory authority under which DOE is evaluating new or amended standards, the results of other analyses, and the preliminary stages of rulemaking undertaken by DOE (*e.g.*, a Framework Document and Preliminary Assessment, or an advanced notice of proposed rulemaking (ANOPR)) Not all of the analyses identified in Figure 2.1.1 may be conducted in a rulemaking. The analyses performed for this supplemental notice of proposed rulemaking (SNOPR) 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; would have adverse effects on health and safety; or represents a unique pathway to achieving a given efficiency level.
- 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 selling price (MSP) to the cost to the consumer.
- An energy use analysis to determine the annual energy use of the considered products in a representative set of users.
- 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 (MIA) 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 evaluation of potential energy conservation standards, 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 and market 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 consumer 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 consumer 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 this SNOPR 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 consumer 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 this SNOPR TSD includes the detailed list of all technology options identified for consumer 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; (4) have adverse impacts on health and safety; or (5) require unique-pathway proprietary technologies. Sections 6(b)(3) and 7(b) of 10 CFR Part 430, subpart C, appendix A ("appendix A"). 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; would have adverse impacts on health and safety; or require unique-pathway proprietary technologies. In the engineering analysis, DOE further considered efficiency enhancement options that it did not screen out in the screening analysis. Chapter 4 of this SNOPR TSD contains details on the screening analysis for consumer conventional cooking products.

2.4 ENGINEERING ANALYSIS

The purpose of the engineering analysis is to establish the relationship between the efficiency and cost of a product. There are two elements to consider in the engineering analysis; the selection of efficiency levels to analyze (*i.e.*, the "efficiency analysis") and the determination of product cost at each efficiency level (*i.e.*, the "cost analysis"). In determining the performance of higher-efficiency products, DOE considers technologies and design option combinations not eliminated by the screening analysis. For each product class, DOE estimates the baseline cost, as well as the incremental cost for the product at efficiency levels above the baseline. The output of the engineering analysis is a set of cost-efficiency "curves" that are used in downstream analyses (*i.e.*, the LCC and PBP analyses and the NIA).

The engineering analysis considered technologies not eliminated in the screening analysis, designated as design options. DOE considered the analyzed design options in developing the cost-efficiency curves.

DOE typically uses one of two approaches to develop energy efficiency levels for the engineering analysis: (1) relying on observed efficiency levels in the market (*i.e.*, the efficiency-level approach), or (2) determining the incremental efficiency improvements associated with incorporating specific design options to a baseline model (*i.e.*, the design-option approach). Using the efficiency-level approach, the efficiency levels established for the analysis are determined based on the market distribution of existing products (in other words, based on the range of efficiencies and efficiency level "clusters" that already exist on the market). Using the design option approach, the efficiency levels established for the analysis are determined through detailed engineering calculations and/or computer simulations of the efficiency improvements from implementing specific design options that have been identified in the technology assessment. DOE may also rely on a combination of these two approaches. For example, the efficiency-level approach (based on actual products on the market) may be extended using the design option approach to interpolate to define "gap fill" levels (to bridge large gaps between other identified efficiency levels) and/or to extrapolate to the max-tech level (particularly in cases where the max-tech level exceeds the maximum efficiency level currently available on the market).

In this SNOPR, DOE used a design-option approach, supplemented by testing. The design-option approach is appropriate for consumer conventional cooking products, given the lack of certification data to determine the market distribution of existing products and to identify efficiency level "clusters" that already exist on the market.

The cost analysis portion of the engineering analysis is conducted using one or a combination of cost approaches. The selection of the cost approach depends on a suite of factors, including the availability and reliability of public information, characteristics of the regulated product, the availability and timeliness of purchasing the product/equipment on the market. The cost approaches are summarized as follows:

- Physical teardowns: Under this approach, DOE physically dismantles a commercially available product, component-by-component, to develop a detailed bill of materials (BOM) for the product. The resulting BOM provides the basis for the manufacturer production cost (MPC) estimates.
- Catalog teardowns: In lieu of physically deconstructing a product, DOE identifies each component using parts diagrams (available from manufacturer websites or appliance repair websites, for example) to develop the BOM for the product, which once again provides the basis for the MPC estimates.
- Price surveys: If neither a physical nor catalog teardown is feasible (*e.g.*, for tightly integrated products such as fluorescent lamps, which are infeasible to disassemble and for which parts diagrams are unavailable) or would be cost-prohibitive and otherwise impractical (*e.g.*, for large commercial boilers), DOE conducts price surveys using publicly available pricing data published on major online retailer websites and/or by soliciting prices from distributors and other commercial channels.

In this SNOPR, DOE used the physical teardown approach supplemented by catalog teardowns of printed circuit boards to develop the MPC data. In addition, DOE considered cost-efficiency data from the TSD from the most recent standards final rule. In the MIA, DOE develops manufacturer markups to convert the MPCs to MSPs.

2.5 MARKUPS ANALYSIS

DOE performed a markups analysis to convert the MSP 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 MSP 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 this SNOPR TSD provides details on DOE's development of markups for consumer 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 this SNOPR TSD provides more detail about DOE's approach for characterizing energy use of consumer conventional cooking tops and ovens.

DOE relied on the California Residential Appliance Saturation Study (CA RASS) and the data from the Pecan Street Project[b] to establish the annual energy consumption of cooking tops and ovens. DOE determined a range of annual energy consumption of cooking products by utilizing the frequency of product usage data provided for each household in the representative sample of U.S. households based on the U.S. Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS) 2015. 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 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 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 consumer conventional cooking product 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 PBP 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

[b] Refer to chapter 7 of this SNOPR TSD for details about the studies.

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 this SNOPR TSD describes the results from the LCC and PBP analyses.

2.8 SHIPMENTS ANALYSIS

DOE projected future shipments of consumer conventional cooking tops and ovens 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 (2027–2056). To create the projections, DOE combined current-year shipments with results of a shipments model that incorporates key market drivers for consumer conventional cooking products. Chapter 9 of this SNOPR TSD provides additional details on the shipments analysis.

2.9 NATIONAL IMPACT ANALYSIS

The NIA assesses the NPV, to the nation, of total consumer LCC and 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 potential amended 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 this SNOPR TSD provides additional details regarding the NIA.

Several of the inputs for determining NES and NPV depend on the forecast trends in product energy efficiency. For the no-new-standards case, DOE uses the efficiency distributions developed for the LCC analysis, and assumes some a static distribution over the forecast period. In this analysis, DOE has used a roll-up scenario in developing its forecasts of efficiency trends after potential 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 NES 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 (FFC) 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 no-new-standards case (without amended 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 FFC measures of energy use and greenhouse gas (GHG) and other emissions in the NIA and emissions analyses included in future energy conservation standards rulemakings. 76 FR 51281 (Aug. 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 the National Energy Modeling System (NEMS) is the most appropriate tool for its FFC analysis and its intention to use NEMS for that purpose. 77 FR 49701 (Aug. 17, 2012). NEMS is a public domain, multi-sector, partial equilibrium model of the U.S. energy sector[c] that the EIA uses to prepare its *Annual Energy Outlook* (*AEO*). The FFC factors incorporate losses in production and delivery in the case of natural gas (including fugitive emissions) and additional energy used to produce and deliver the various fuels used by power plants. The approach used for this SNOPR is described in appendix 10B of this SNOPR TSD.

2.9.2 Net Present Value of Consumer Benefit

The inputs for determining the 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 no-new-standards case and a potential standards case. Because the more efficient equipment bought in a standards case usually costs more than equipment bought in the no-new-standards 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 no-new-standards 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 no-new-standards 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 this SNOPR TSD provides additional details regarding the NIA.

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[c] For more information on NEMS, refer to *The National Energy Modeling System: An Overview 2009*, DOE/EIA-0581(2009), October 2009. Available at http://www.eia.gov/forecasts/aeo/index.cfm.

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 this SNOPR TSD describes the consumer subgroup analysis.

2.11 MANUFACTURER IMPACT ANALYSIS

The MIA assesses the impacts of new and amended energy conservation standards on manufacturers of consumer conventional cooking 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 tailors the analytical framework based on interested parties' comments. In Phase I, DOE created a consumer conventional cooking product manufacturing industry profile and analyzed publicly available financial information to derive preliminary inputs for the Government Regulatory Impact Model (GRIM). In Phase II, DOE prepared an industry cash flow model. In Phase III, industry and subgroup cash flow and industry net present value were assessed through the use of the 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 this SNOPR TSD.

2.12 EMISSIONS ANALYSIS

In the emissions analysis, DOE estimates the reduction in power sector combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2), mercury (Hg), methane (CH_4) and nitrous oxide (N_2O) from potential energy conservation standards for the considered products, as well as emissions at the building site. In addition, DOE estimates emissions impacts in production activities (extracting, processing, and transporting fuels) that provide the energy inputs to power plants and for site combustion. Together, these emissions account for the full-fuel-cycle (FFC).

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site (where applicable) combustion emissions of CO_2, NO_X, SO_2, and Hg. The second component estimates the impacts of potential standards on emissions of two additional greenhouse gases, CH_4 and 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 upstream emissions include 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 analysis of power sector emissions uses marginal emissions factors that are derived from data in *AEO*. The *AEO* incorporates the projected impacts of existing air quality regulations on emissions. *AEO* generally represents current legislation and environmental regulations, including recent government actions, for which implementing regulations were available as of the time of its preparation.

The methodology is described in more detail in chapter 13 of this SNOPR TSD.

2.13 MONETIZATION OF EMISSIONS REDUCTION BENEFITS

DOE may consider the estimated monetary benefits likely to result from the reduced emissions of CO_2, CH_4, N_2O, SO_2, and NO_X that are expected to result from each of the potential standard levels considered in the next phase of the rulemaking, should DOE proceed to a NOPR. On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in *Louisiana v. Biden*, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.

To estimate the monetary value of reduced NO_X and SO_2 emissions from electricity generation attributable to the standard levels it considers, DOE uses benefit-per-ton estimates derived from analysis conducted by the EPA. For NO_X and SO_2 emissions from combustion at the site of product use, DOE uses another set of benefit-per-ton estimates published by the EPA.

For more detail on the monetization of emissions analysis, see chapter 14 of this SNOPR TSD.

2.14 UTILITY IMPACT ANALYSIS

In the utility impact analysis, DOE analyzed the changes in electric installed capacity and electricity generation that are projected for each considered trial standard level. For gas utilities, DOE also estimates the impacts on deliveries of natural gas to consumers. For electric utilities, the analysis is based on output of the DOE/EIA's 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 *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. For conventional cooking products, DOE used a methodology based on results published for the *AEO 2022* reference case and a set of side cases that implemented a variety of efficiency-related policies. Further detail is provided in chapter 15 of this SNOPR TSD.

2.15 EMPLOYMENT IMPACT ANALYSIS

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

2.16 REGULATORY IMPACT ANALYSIS

As part of its regulatory impact analysis (RIA), DOE identified major alternatives to standards that represent feasible policy options to reduce the energy consumption of conventional cooking products DOE evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each alternative to the effectiveness of the proposed standard. DOE recognized that voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties can substantially affect energy efficiency or reduce energy consumption. DOE based its assessment on the recorded impacts of any such initiatives to date, but also considered information presented by interested parties regarding the impacts current initiatives may have in the future. Further detail on the analysis is provided in chapter 17 of this SNOPR TSD.

[d] Livingston, O. and et al. *ImSET 4.0: Impact of Sector Energy Technologies Model Description and User's Guide*. 2015. Pacific Northwest National Laboratory. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24563.pdf.

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 consumer conventional cooking product industry 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 (chapters 5 and 8 of this supplemental notice of proposed rulemaking (SNOPR) technical support document (TSD)). Present and past industry structure and industry financial information help DOE in the process of conducting the manufacturer impact analysis (MIA) which can be found in chapter 12 of this SNOPR TSD.

3.2 PRODUCT DEFINITIONS

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[a] and/or one or more heating compartments. (10 CFR 430.2) As part of this rulemaking, DOE is evaluating new and amended energy conservation standards for all consumer conventional cooking products, namely, conventional cooking tops and conventional ovens.

DOE defines a combined cooking product as a household cooking appliance that combines a consumer conventional cooking top and/or oven with other appliance functionality, which may or may not include another cooking product. (10 CFR part 430, subpart B, appendix I1 ("Appendix I1")) In this analysis, DOE is not considering combined cooking products as a distinct product category and is not basing its product classes on that category. Instead, DOE is evaluating energy conservation standards for conventional cooking tops and conventional ovens separately. Because combined cooking products consist, in part, of a cooking top and/or oven, any cooking top or oven standards would apply to the individual components of the combined cooking product.

3.3 PRODUCT CLASSES

When evaluating energy conservation standards, DOE may establish separate standards for a group of covered products (*i.e.*, establish a separate product class) if DOE determines that separate standards are justified based on the type of energy used, or if DOE determines that a product's capacity or other performance-related feature justifies a different standard. (42 U.S.C. 6295(q)(1)(A) and (B)) In making a determination whether a performance related feature justifies a different standard, DOE must consider factors such as the utility to the consumer of

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[a] The term surface unit refers to burners for gas cooking tops and electric resistance heating elements or inductive heating elements for electric cooking tops. The term cooking zone is used in this SNOPR TSD, consistent with the test procedure language.

the feature and other factors DOE determines are appropriate. (42 U.S.C. 6295(q)(1)) Any rule prescribing such a standard must include an explanation of the basis on which such higher or lower level was established. (42 U.S.C. 6295(q)(2))

For consumer conventional cooking products, the product classes defined by DOE are based on energy source (*i.e.*, gas or electric) and consumer utility (*e.g.*, the ease of cleaning). 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 2009 standards rulemaking.[b]

DOE did not analyze gas and electric grills and griddles for this SNOPR because DOE is not aware of any data upon which it can base a determination of either adequacy of any test procedure to measure energy efficiency or energy efficiency characteristics of products in these niche classes.

3.3.1 Electric Cooking Tops

For electric cooking tops, DOE's 2009 TSD determined that the ease of cleaning smooth elements provides enhanced consumer utility over open (coil) elements. Because smooth elements typically use more energy than open (coil) elements, DOE defined the following product classes for electric cooking tops:

- Low or high wattage open (coil) elements; and
- Smooth elements.

As discussed in section 3.4 of this chapter, Appendix I1 includes methods 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 cooking zones on the cooking top. DOE considered whether induction cooking tops warrant establishing a separate product class.

As discussed in the notice of proposed determination (NOPD) that DOE published on December 14, 2020 ("December 2020 NOPD"), DOE notes that induction cooking tops provide the same basic function of cooking or heating food as do electric resistance heating cooking tops. 85 FR 80982, 80995. In addition, in considering whether there are any performance-related features that justify a higher energy use standard to establish a separate product class, DOE notes that the utility of speed of cooking, ease of cleaning, and requirements for specific cookware for induction cooking tops do not appear to be uniquely associated with differing energy use compared to other smooth element cooking tops with electric resistance heating elements. *Id*. DOE recognizes that induction cooking tops are compatible with only ferromagnetic cooking vessels. However, DOE does not identify any consumer utility unique to any specific type of cookware that would warrant establishing separate product classes. As discussed in chapter 8 of this SNOPR TSD, DOE considered the cost of replacing cookware as part of the LCC analysis. As discussed in chapter 5 of this SNOPR TSD, DOE also conducted standby testing on full-surface induction cooking tops to determine any impact of such technology on power

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[b] Available online at https://www.regulations.gov/document/EERE-2006-STD-0127-0097.

consumption in standby mode that would result in inherently higher annual energy consumption. Based on DOE's testing, the sensors required to detect the presence of a pot placed on the cooking surface do not remain active while the product is in standby mode and thus do not contribute to higher standby power. To the contrary, the standby power measured for the tested model with full-surface induction (0.25 watts (W)) was less than the average standby power of the other smooth electric cooking tops in DOE's test sample (2.25 W). For these reasons, DOE is not considering a separate product class for induction cooking products.

3.3.2 Gas Cooking Tops

For gas cooking top**s**, DOE analyzed a single product class.

As part of the 2009 energy conservation standards rulemaking for consumer conventional cooking products, DOE did not consider energy conservation standards for conventional gas cooking tops with high input rate burners ("HIR burners"), including products marketed as "commercial-style" or "professional-style," due to a lack of available data for determining efficiency characteristics of those products. DOE considered such products to be gas cooking tops with burner input rates greater than 14,000 British thermal units per hour (Btu/h). 74 FR 16040, 16054 (Apr. 8, 2009); 72 FR 64432, 64444–64445 (Nov. 15, 2007). In the 2009 analysis, DOE also stated that the DOE cooking products test procedures at that time may not adequately measure performance of gas cooking tops with HIR burners. 72 FR 64432, 64444–64445.

Based on DOE's review of conventional gas cooking tops available on the market, including their marketing literature, DOE determined that products marketed as commercial-style cannot be distinguished from standard residential-style products based on performance characteristics or consumer utility. While conventional gas cooking tops marketed as commercial-style typically have more than one burner rated above 14,000 Btu/h and continuous cast-iron grates, more than 50 percent of cooking top models marketed as residential-style also have one or more burners rated above 14,000 Btu/h and continuous cast-iron grates.

DOE considered whether separate product classes for commercial-style cooking tops are warranted by comparing the test energy consumption of burners in a sample of gas cooking tops tested by DOE according to Appendix I1. DOE measured the energy consumption of gas burners in a sample of 24 gas cooking tops, which included 11 models marketed as commercial-style. The number of burners per cooking top ranged from four to six. Figure 3.3.1 shows test energy consumption for each burner, normalized by the mass of the water test load and the final water temperature for that burner (as specified in Appendix I1), versus burner input rate for each burner in the test sample. Because the mass of the test load depends on the input rate of the burner, the test energy consumption must be normalized for comparison. The higher the ratio of test energy consumption to test load mass (*i.e.*, the normalized per-burner test energy consumption), the less efficient the burner.

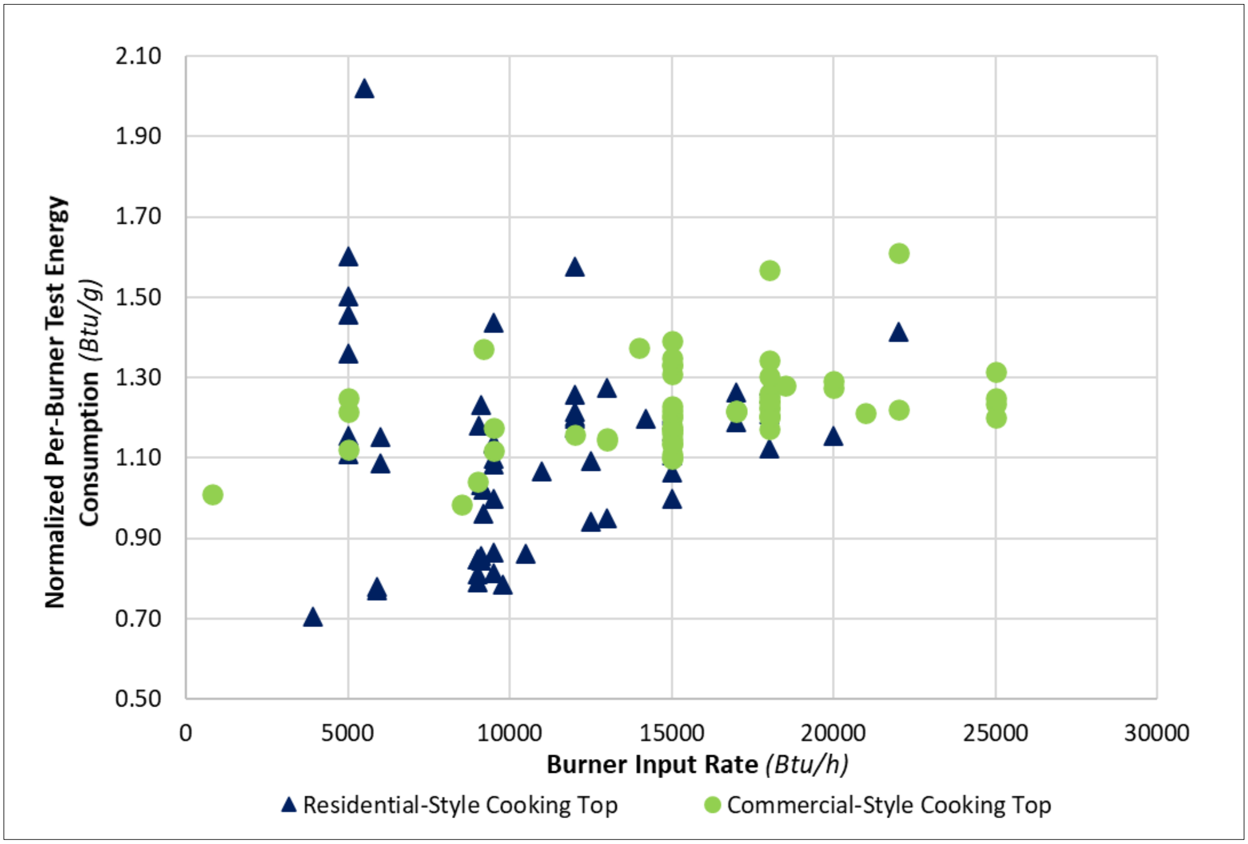

Figure 3.3.1 Gas Cooking Top Normalized Per-Burner Test Energy Consumption versus Burner Input Rate

As shown in Figure 3.3.1, there is no statistically significant difference that DOE testing found in the relationship of burner input rate to normalized per-burner energy consumption between cooking tops marketed as either residential-style or commercial-style. DOE's testing, as presented in chapter 5 of this SNOPR TSD, showed that energy consumption for gas cooking tops is more closely related to burner and grate design rather than input rate.

As discussed in the TSD accompanying the December 2020 NOPD, manufacturers stated in comments that several key customer-driven design features enhance the cooking performance of commercial-style cooking tops (quick speed-to-boil, precision simmering, and even heat distribution), as compared to residential-style cooking tops, but negatively impact efficiency. These design features include:

- HIR burners with large diameters provide faster heat up times and allow consumers to use larger cooking vessels while maintaining even heat distribution;
- HIR burners with high levels of flame controllability, specifically high turndown ratios, allow for simmering of foods such as chocolates and sauces while also providing faster heat up times;
- Spacing between the gas flame, grate, and cooking vessel must be greater for HIR burners than low input rate burners to meet performance and safety requirements, specifically even heat distribution and reduction of carbon monoxide. Reducing the

spacing between the gas flame and the cooking vessel can increase efficiency, but flame quenching due to flame impingement and contact with the grate/cooking vessel can lead to increased carbon monoxide emissions and combustion by-products. Designing high performance products with safe combustion gases provides an inherent constraint to the efficiency level that can be attained;
- Heavy cast-iron grates allow for better heat distribution to cooking vessels while also providing the strength required to support large load and increased product longevity. Heavier cast-iron grates also retain more heat once the burner is turned down during simmer or shut off.

Manufacturers stated that the features listed above deliver superior performance by allowing consumers to use a wider range of cooking methods that differ significantly from how the average consumer uses a conventional cooking product, for example sautéing at very high burner outputs, manipulating pans to mix ingredients, flaming the contents, and keeping most of the burners on the cooking top firing together when cooking. Manufacturers also stated that commercial-style cooking tops typically employ a range of burner inputs to allow the ability to cook foods that require searing on one burner and foods that require melting temperatures on another burner.

Based on review of the market, including product literature and marketing materials, DOE recognizes that the presence of certain features, such as heavy continuous cast-iron grates and multiple HIR burners, may result in consumers perceiving a difference between commercial-style and residential-style gas cooking top performance. However, DOE is not aware of a clear design delineation and corresponding utility provided by commercial-style gas cooking tops as compared to residential-style gas cooking tops. Although DOE's testing indicates there is a difference in total energy consumption between products marketed as residential-style and commercial-style gas cooking tops, this difference could not be correlated to any specific utility provided to consumers. Notably, there are many residential-style cooking tops on the market with one to two HIR burners and continuous cast-iron grates that provide consumers with the ability to sear food at high temperatures and simmer at low temperatures. For these reasons, along with the lack of correlation between cooking top style and normalized per-burner energy consumption (in essence, a measure of burner efficiency) as discussed above, DOE is not evaluating a separate product class for commercial-style gas cooking tops.

3.3.3 Electric and Gas Ovens

3.3.3.1 Oven Cleaning System

For conventional 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 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 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 this SNOPR 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 standard ovens with a catalytic line that provide continuous cleaning during normal baking, still have a separate self-cleaning mode that is user-selectable. 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.

3.3.3.2 Installation Configuration

As discussed in section 3.4 of this chapter, DOE amended its test procedure for consumer conventional cooking products in a final rule published on October 31, 2012 ("October 2012 TP Final Rule") 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. DOE maintained the methods for measuring fan-only mode in a test procedure final rule published on July 2, 2015 ("July 2015 TP Final Rule"). 80 FR 37954. Although the testing provisions for conventional ovens were later withdrawn, as discussed in section 3.4 of this chapter, DOE used the test procedure established in the July 2015 TP Final Rule for evaluating conventional oven energy consumption.

Table 3.3.1 and Table 3.3.2 list the fan-only mode duration and energy consumption, in kilowatt-hours per cycle (kWh/cycle), measured for the electric and gas ovens in the DOE test sample described in chapter 5 of this SNOPR TSD. The tables also specify the installation configuration of the oven and provide an estimate of the percentage of oven integrated annual energy consumption (IE_{AO})[c] due to fan-only mode operation alone.

[c] In this SNOPR, DOE refers to the integrated annual oven energy consumption using the abbreviation IE_{AO}, rather than IAEC, as was used in previous documents in this rulemaking. This change is being made to emphasize the difference between the IAEC values used for conventional cooking tops which were measured according to the new Appendix I1 and the energy use values used for conventional ovens which were measured according to the test procedure as finalized in the July 2015 TP Final Rule.

Table 3.3.1 Electric Oven Fan-Only Mode Energy Consumption

Unit	Source	Type	Installation	Fan-Only Mode Duration (*min*)	Fan-Only Mode Energy Consumption (*kWh/cycle)*	% of IE_{AO}
1	Electric	Self-Clean	Freestanding	0	0	-
2	Electric	Standard	Freestanding	0	0	-
3	Electric	Self-Clean	Built-in	6.7	0.002	0.2%
4	Electric	Standard	Built-in	69.0	0.032	2.4%
5	Electric	Self-Clean	Built-in	69.0	0.032	2.1%
6	Electric	Self-Clean	Built-in	66.8	0.031	1.8%
7	Electric	Self-Clean	Built-in	41.3	0.030	1.6%

Table 3.3.2 Gas Oven Fan-Only Mode Energy Consumption

Unit	Source	Type	Installation	Fan-Only Mode Duration (*min*)	Fan-Only Mode Energy Consumption (*kWh/cycle*)	% of IE_{AO}
1	Gas	Standard	Freestanding	0	0	-
2	Gas	Standard	Freestanding	0	0	-
3	Gas	Self-Clean	Freestanding	0	0	-
4	Gas	Standard	Freestanding	0	0	-
5	Gas	Self-Clean	Built-in	4.5	0.001	0.1%
6	Gas	Standard	Freestanding	0	0	-
7	Gas	Standard	Slide-in	30.8	0.016	0.5%
8	Gas	Standard	Freestanding	0	0	-

In DOE's testing of freestanding, built-in, and slide-in installation configurations for conventional gas and electric ovens, all of the built-in and slide-in ovens consumed energy in fan-only mode, whereas none of the freestanding ovens did. 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 kilowatt-hours per year (kWh/year)) and fan-only mode durations ranged from 4.5 to 69 minutes. The percentage of IE_{AO} attributable to fan-only mode was less than 1 percent for gas ovens and less than 3 percent for electric ovens.

DOE's reverse engineering analyses, discussed in chapter 5 of this SNOPR TSD, identified that built-in and slide-in products have an additional exhaust fan and vent assembly that is 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 included separate product classes for built-in/slide-in ovens and freestanding ovens in its analysis.

3.3.3.3 Commercial-Style Ovens

As part of the 2009 standards rulemaking for consumer conventional cooking products, DOE decided to exclude 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, 64444–64445 (Nov. 15, 2007). DOE also stated that the DOE cooking products test procedures at that time may not adequately measure performance of commercial-style gas ovens with higher burner input rates. 72 FR 64432, 64444–64445 (Nov. 15, 2007).

Based on DOE's review of the conventional gas ovens available on the market, residential-style gas ovens typically have a burner 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.[d] 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 cavity volumes range from 2.5 to 5.6 cubic feet (ft^3) 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 have cavity volumes between 4.0 and 5.0 ft^3 while 50 percent of the residential-style models had cavity volumes between 4.0 and 5.0 ft^3. The primary differentiating factor between the two oven types is burner input rate, which is greater than 22,500 Btu/h for commercial-style gas ovens.

DOE conducted testing according to the test procedure adopted in the July 2015 TP Final Rule to determine whether commercial-style ovens warrant establishing a separate product class. DOE evaluated the active mode metric included in the July 2015 TP Final Rule test procedure, cooking efficiency, of the eight conventional gas ovens listed in Table 3.3.3. DOE used cooking efficiency as the basis of comparison to isolate the impacts of the HIR (*i.e.*, greater than 22,500 Btu/h) burners, since the test sample comprised different installation configurations and types (standard versus self-clean) as well as marketed style. 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.

[d] Certain gas ranges, while marketed as "commercial-style" or "professional-style" and having multiple HIR burners, do not have a gas oven with a burner input rate above 22,500 Btu/h.

Table 3.3.3 Gas Oven Cooking Efficiencies

Test Unit #	Type	Installation Configuration	Burner Input Rate *(Btu/h)*	Cavity Volume *(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%

* Test units 6, 7, and 8 are marketed as commercial-style ovens.
** Measured cooking efficiency normalized to a fixed cavity volume of 4.3 ft^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 (see further explanation in chapter 5 of this SNOPR TSD). However, the commercial-style gas ovens in DOE's test sample also had greater total thermal mass and used heavier gauge construction materials, including heavier racks and thicker cavity walls, even after normalizing for cavity volume, than the residential-style test units, in addition to having HIR burners. To determine whether the lower measured efficiency of these ovens was due to the HIR 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 using the conditions specified in the DOE test procedure adopted in the July 2015 TP Final Rule. 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 (residential-style) and Test Unit 8 (commercial-style) in Table 3.3.3 for comparative testing because of their similarity in cavity volume, their difference in efficiency, and their differing burner input rate (18,000 Btu/h and 30,000 Btu/h, respectively). Figure 3.3.2 displays the resulting test block temperature increase as a function of test time, measured with and without insulation lining the interior oven cavity walls.

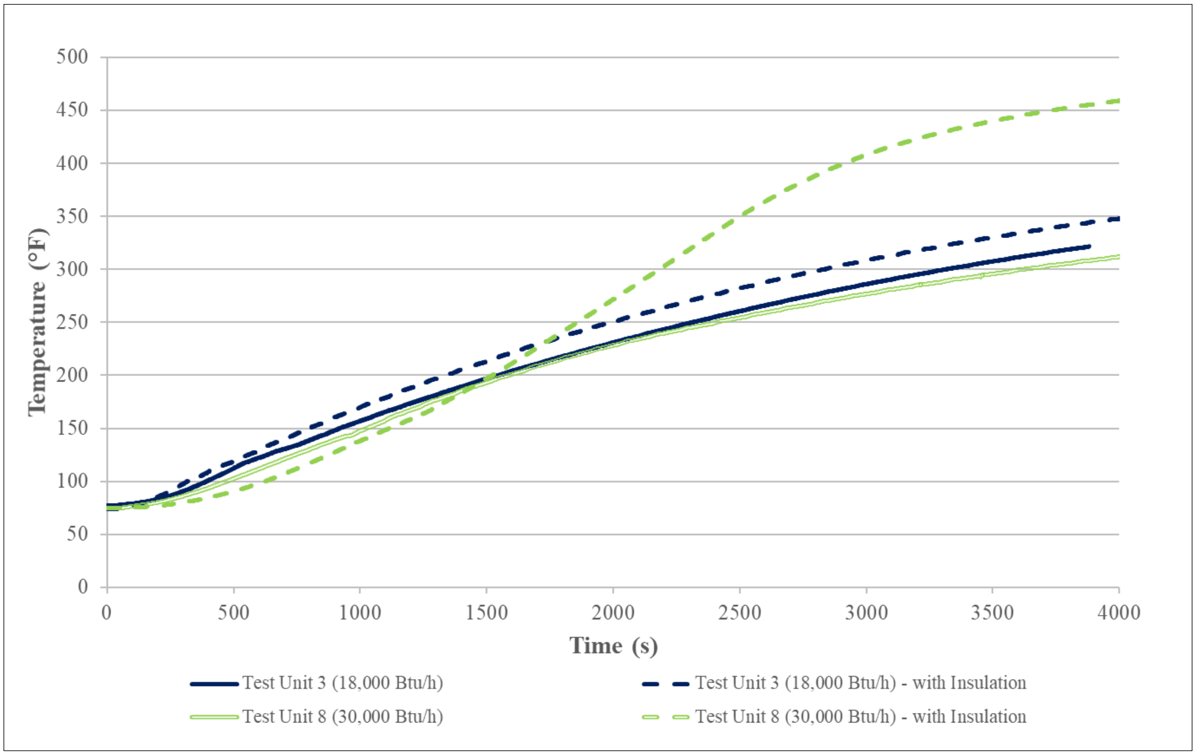

Figure 3.3.2 Gas Oven Test Load Temperature With and Without Inclusion of Cavity Thermal Mass

Without the added insulation inside the oven cavity, the temperature rise in the test block was nearly identical for both ovens, despite the large difference in burner input rate. In contrast, by adding insulation inside the cavity and thus eliminating the effects of the cavity thermal mass, the test block temperature in the commercial-style, 30,000 Btu/h oven increased at a substantially faster rate after approximately 20 minutes than in the residential-style, 18,000 Btu/h oven. This suggests that much of the energy input to the commercial-style oven goes to heating the added mass of the cavity, rather than the test load, resulting in relatively lower measured efficiency when measured according to the test procedure adopted in the July 2015 TP Final Rule.

DOE also investigated the time it took each oven in the test sample in its as-shipped configuration to heat the standardized test load to a final test temperature of 234 degrees Fahrenheit (°F) above its initial temperature, as specified in the test procedure adopted in the July 2015 TP Final Rule. As shown in Table 3.3.4, commercial-style gas ovens with HIR burners do not heat the test load significantly faster than the residential-style gas ovens with lower burner input rates. To the contrary, two out of the three commercial-style units took longer than the average time to heat the test load, and three of the residential-style units were able to heat the load faster than any of the commercial-style units.

Table 3.3.4 Gas Oven Test Times

Unit	Type	Burner Input Rate (*Btu/h*)	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.

In comments responding to a notice of proposed rulemaking (NOPR) for conventional oven energy conservation standards that DOE published on June 10, 2015 ("June 2015 NOPR"), manufacturers stated that several key customer-driven design features enhance the cooking performance of commercial-style gas ovens (professional quality baking, broiling, roasting, slow bake, proofing, and other functions), as compared to residential-style ovens, but negatively impact oven efficiency. 81 FR 60784, 60805. As discussed in the TSD accompanying the December 2020 NOPD, these design features include:

- Heavier gauge materials which may extend product life and enhance perceived product quality, cooking functionality and durability;
- Configurations that allow for up to six-rack baking capability with full extension, heavy-gauge oven racks to support large loads and provide enhanced safety and ergonomic benefit;
- Full oven-height dual convection blowers to optimize cooking air flow;
- Hidden bake elements that enhance customer safety, cleanability and heat distribution for better cooking performance;
- Controls and software to maximize the long-term reliability of oven cavity porcelain when employing a hidden bake element;
- Cooling fans for the electronic printed circuit boards that provide precise oven control and touch-screen user interface for cooking modes and other features;
- Soft-close hinges to handle constant loading and unloading of the oven to eliminate the noise of slamming doors;
- A variety of modes and options not typically found in residential-style products (*e.g.*, rapid steam generator, additional convection heating element, high power combination modes such as convection broil and steam convection);
- Powerful heating elements to maintain set temperatures during sessions of loading and unloading food (*e.g.*, caterers and entertainers at large house parties); and
- Very large usable baking space (*e.g.*, two ovens in a 60-inch range that operate independently to provide more versatility in cooking with each cavity capable of cooking one to three racks of food). In addition, commercial-style ovens can

accommodate commercial baking pans that are more than twice the size of standard residential baking pans.

To further address whether commercial-style ovens with the features described above provide a unique utility that would warrant establishing a separate product class, DOE conducted interviews with manufacturers of commercial-style cooking products and reviewed proprietary commercial-style oven test data. While these data generally indicated a difference in total energy consumption between residential-style and commercial-style ovens when measured according to the test procedure adopted in the July 2015 TP Final Rule, this difference could not be correlated to any specific utility provided to consumers, even when normalized for different cavity volumes. Moreover, DOE is not aware of an industry test standard that evaluates consumer oven cooking performance and energy consumption to allow a comparison of utility provided by these products. DOE also notes that all conventional ovens, regardless of whether or not the product is marketed as commercial-style, must meet the same safety standards for the construction of the oven. American National Standards Institute (ANSI) Z21.1 "Household Cooking Gas Appliances" ("ANSI Z21.1"), Section 1.21.1, requires that the oven structure, and specifically the baking racks, have sufficient strength to sustain a load of up to 25 pounds depending on the width of the rack. A similar standard (Underwriters Laboratories (UL) 858 "Household Electric Ranges" ("UL 858")) exists for electric ovens.

Furthermore, DOE has observed that many of the design features identified by manufacturers as associated with commercial-style ovens and that may impact the energy consumption, such as extension racks, convection fans, cooling fans, touch controls, and hidden bake elements, exist in residential-style products. DOE recognizes that the presence of these features, along with thicker oven cavity walls and higher burner input rates, may result in consumers perceiving a difference between commercial-style and residential-style oven performance. However, as with cooking tops, DOE is not aware of a clear design delineation and corresponding utility provided by commercial-style ovens as compared to residential-style ovens. Therefore, DOE is not evaluating a separate product class for commercial-style ovens.

3.3.4 Evaluated Product Classes

The product classes evaluated for this SNOPR are listed in Table 3.3.5.

Table 3.3.5 Product Classes for Conventional Cooking Products

Product Class	Product Type	Sub-Category	Installation Type
1	Electric cooking top	Open (coil) elements	-
2		Smooth elements	-
3	Gas cooking top	-	-
4	Electric oven	Standard with or without a catalytic line	Freestanding
5			Built-in/Slide-in
6		Self-clean	Freestanding
7			Built-in/Slide-in
8	Gas oven	Standard with or without a catalytic line	Freestanding
9			Built-in/Slide-in
10		Self-clean	Freestanding
11			Built-in/Slide-in

3.4 PRODUCT TEST PROCEDURES

DOE's test procedures for consumer cooking products are codified at 10 CFR part 430, subpart B, appendix I1.

DOE initially established test procedures at 10 CFR part 430, subpart B, appendix I ("Appendix I") in a final rule published in the *Federal Register* on May 10, 1978. 43 FR 20108, 20120–20128. Pursuant to the amendments contained in the Energy Independence and Security Act of 2007 ("EISA 2007"), Public Law 110-140, any final rule for new or amended energy conservation standards promulgated after July 1, 2010, is required to address standby mode and off mode energy use. (42 U.S.C. 6295(gg)(3)) Specifically, when DOE adopts a standard for a covered product after that date, it must, if justified by the criteria for adoption of standards under the Energy Policy and Conservation Act (EPCA) (42 U.S.C. 6295(o)), incorporate standby mode and off mode energy use into a single standard, or, if that is not feasible, adopt a separate standard for such energy use for that product. (42 U.S.C. 6295(gg)(3)(A)–(B)) The amendments direct DOE to take into consideration the most current version of the International Electrotechnical Commission (IEC) Standard 62301 *Household electrical appliances – Measurement of standby power* ("IEC 62301") and IEC Standard 62087 *Methods of measurement for the power consumption of audio, video and related equipment*.[e] (42 U.S.C. 6295(gg)(2)(A))

In the October 2012 TP Final Rule, DOE addressed standby and off mode energy consumption of conventional ovens, as well as certain active mode (*i.e.*, fan-only mode) testing provisions. In addition, DOE amended the test procedures to include methodology for the measurement of fan-only mode energy use. The inclusion of methods to measure these additional modes allows for the calculation of IE_{AO}. 77 FR 65942.

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

In the July 2015 TP Final Rule, DOE incorporated methods for measuring conventional oven cavity volume, clarified that the existing oven test block must be used to test all ovens regardless of input rate, and included provisions for measuring the energy consumption and efficiency of conventional ovens equipped with an oven separator. 80 FR 37954.

In a test procedure final rule published on December 16, 2016 ("December 2016 TP Final Rule"), DOE repealed the test procedures for conventional ovens. DOE determined that the test procedure did not accurately represent consumer use as it favored conventional ovens with low thermal mass and did not capture cooking performance-related benefits due to increased thermal mass of the oven cavity. DOE further stated that further investigation would be required to develop test methods that appropriately account for the effects of certain commercial-style oven design features (*e.g.*, heavier-gauge cavity construction, HIR burners, extension racks). 81 FR 91418.

For conventional ovens, as explained in chapter 5 of this SNOPR TSD, DOE developed annual energy use values based on the earlier version of the test procedure adopted in the July 2015 TP Final Rule.

In the October 2012 TP Final Rule, DOE also established a test procedure for measuring the energy consumption of conventional cooking tops using aluminum test blocks. Because aluminum is not a ferromagnetic material, the aluminum test blocks could not be used with induction cooking tops. 77 FR 65942. Therefore, the test procedure established in the October 2012 TP Final Rule did not provide a method for measuring the energy consumption of induction cooking tops.

In the December 2016 Final Rule, DOE amended its test procedure to incorporate by reference the relevant sections of European Standard EN 60350-2:2013 "Household electric cooking appliances Part 2: Hobs – Methods for measuring performance"[f] ("EN 60350-2:2013"), which provide a water-heating test method to measure the energy consumption of electric cooking tops. The test method specifies the quantity of water to be heated in a standardized test vessel whose size is selected based on the diameter of the heating element under test. DOE also extended the test methods provided in EN 60530-2:2013 to gas cooking tops by correlating the burner input rate to the test vessel diameters and water loads specified in EN 60350-2:2013. 81 FR 91418.

On August 18, 2020, DOE published a final rule ("August 2020 TP Final Rule") withdrawing the test procedure for conventional cooking tops. 85 FR 50757. DOE initiated the rulemaking for the August 2020 Final Rule in response to a petition for rulemaking submitted by the Association of Home Appliance Manufacturers (AHAM) in which AHAM asserted that the then-current test procedure for gas cooking tops was not representative, and, for both gas and electric cooking tops, had such a high level of variation that it did not produce accurate results for certification and enforcement purposes and did not assist consumers in making purchasing decisions based on energy efficiency ("AHAM petition"). 85 FR 50757, 50760; see also 80 FR 17944 (Apr. 25, 2018). DOE withdrew the test procedure for conventional cooking tops based on

[f] Hob is the British English term for cooking top.

test data submitted by outside parties indicating that the test procedure for conventional cooking tops yielded inconsistent results.[g] 85 FR 50757, 50760. DOE's test data for electric cooking tops from testing conducted as a single laboratory showed small variations. *Id*. Lab-to-lab test results submitted by AHAM showed high levels of variation for gas and electric cooking tops. *Id*. at 85 FR 50763. DOE determined that the inconsistency in results of such testing showed the results to be unreliable, and at that time DOE determined it unduly burdensome to leave that test procedure in place and require conventional cooking top tests be conducted using that test method without further study to resolve those inconsistencies. *Id*. at 85 FR 50760.

On August 22, 2022, DOE published a final rule ("August 2022 TP Final Rule") establishing a new test procedure for conventional cooking tops at Appendix I1. 87 FR 51492. DOE generally adopted the current version of the applicable industry standard, IEC 60350-2 (Edition 2.1 2021-05), "Household electric cooking appliances–Part 2: Hobs – Methods for measuring performance" ("IEC 60350-2"), which provides a water-heating test method to measure the energy consumption of electric cooking tops. *Id.* at 87 FR 51501–51504. Appendix I1 includes burden-reducing modifications to IEC 60350-2, further clarifies certain provisions, and extends the test procedure to gas cooking tops. *Id.* at 87 FR 51504–51523. In addition, Appendix I1 incorporates by reference IEC 62301 for the measurement of standby power. *Id.* at 87 FR 51524–51525.

In the IEC 60350–2 test method, each heating element on an electric cooking top is tested individually by heating a specified water load in a standardized test vessel (determined using a multi-step procedure based on the diameter of the heating element) at the maximum power setting of the cooking zone under test. The water is heated at this setting until the temperature of the water, including any overshoot after reducing the input power, reaches 90 degrees Celsius (°C). At that time, the power is reduced to a lower setting (*i.e.,* the "minimum-above-threshold setting") such that the water temperature remains as close to 90 °C as possible, without dropping below that temperature threshold, for a 20-minute period. Energy consumption is measured over the entire duration of the initial heat-up period and 20-minute simmering period (*i.e.,* the "Energy Test Cycle"). The measured energy consumption for each heating element is normalized by the weight of the tested water load and averaged for all tested heating elements to obtain an average energy consumption value for the conventional cooking top.

DOE determined that Appendix I1 would improve the repeatability and reproducibility of IEC 60350–2 by normalizing the per-cycle energy use for each heating element tested to account for the water temperature the end of the simmering period. 87 FR 51492, 51495. DOE also improved repeatability and reproducibility of the test procedure for gas cooking tops by implementing a 2-percent tolerance on the gas burner heat input rate measured prior to the start of testing. *Id*. DOE further reduced test burden by simplifying the test vessel selection process for electric cooking tops and by aligning the ambient room temperature requirement and the initial water temperature requirement with existing industry safety test procedures. *Id.*

Following a similar methodology to IEC 60350–2, Appendix I1 calculates the per-cycle energy consumption of the conventional cooking top by averaging the per-cooking zone energy

[g] DOE later stated in a NOPR published November 4, 2021, that not all of the test results submitted by outside parties were from testing that completely followed the DOE test procedure. 86 FR 60974, 60976.

use (normalized by the weight of the tested water load annual and to account for the water temperature at the end of the simmering period) across all cooking zones and multiplying by a representative water load. Appendix I1 defines the annual active-mode energy consumption of the cooking top as the per-cycle energy use multiplied by a representative 418 cooking cycles per year. The cooking top integrated annual energy consumption (IAEC), which estimates the amount of total energy used by the cooking top annually, is calculated by adding the annual active-mode energy consumption and the annual combined low-power mode energy consumption.

For this analysis, DOE evaluated the energy conservation standard levels for conventional cooking tops based on the current conventional cooking tops test procedure, as adopted in the August 2022 TP Final Rule. There were several differences between the procedures in the December 2016 TP Final Rule and the August 2022 TP Final Rule that impact the calculated IAEC value. The two changes with the most impact on IAEC were:

1. The increased number of annual cooking cycles: from 207.5 and 214.5 for electric and gas cooking tops, respectively in the December 2016 TP Final Rule (as determined using data from the 2009 Residential Energy Consumption Survey (RECS)) to 418 for all cooking tops in the August 2022 TP Final Rule (as determined using data from the 2015 RECS); and
2. The change in starting water temperature: from 15 ºC in the December 2016 TP Final Rule to 25 ºC in the August 2022 TP Final Rule, to align with the ambient room temperature.

These differences between the two test procedures resulted in an increase in IAEC for the units analyzed in this SNOPR as compared to previous analyses.

3.5 MANUFACTURER TRADE GROUPS

To gain additional information regarding 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, AHAM. DOE also identified one trade group that supports the suppliers of gas controls and ignition systems used in most residential gas cooking products, the Air-conditioning, Heating, and Refrigeration Institute (AHRI).

3.5.1 Association of Home Appliance Manufacturers

AHAM, formed in 1967, has the stated aim of enhancing the value of the home appliance industry through leadership, public education, and advocacy.[h] AHAM provides services to its members including government relations; a certification program for room air cleaners; an active communications program; and technical services and research. In addition, AHAM conducts

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

other market and consumer research studies and has published 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.

3.5.2 Air-Conditioning, Heating, and Refrigeration Institute

AHRI represents more than 300 heating, water heating, ventilation, air conditioning and commercial refrigeration manufacturers within the global HVACR industry.[i] AHRI develops and publishes technical standards, which use rating criteria and procedures for measuring and certifying performance for residential and commercial air conditioning, heating, and refrigeration equipment. Although manufacturers of conventional cooking products are not included in AHRI's membership, AHRI's members do include the suppliers of gas controls and ignition systems used in most residential and commercial gas-fired equipment sold in the United States, including ignition systems used in conventional gas ovens.

3.6 MANUFACTURER INFORMATION

The following section details information regarding domestic manufacturers of conventional 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

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 34 manufacturers of consumer conventional cooking products supplying the domestic market. Three major manufacturers, AB Electrolux[j] ("Electrolux"); Haier Smart Home Co., Ltd.[k] ("Haier"); and Whirlpool Corporation ("Whirlpool"), represent roughly 85 percent of the electric and gas cooking products market.

In addition to these three major manufacturers, manufacturers of consumer conventional cooking products also include Bilancia Holdings SPA ("Bertazzoni"); Controladora Mabe, S.A. de CV. ("Mabe"); Fagor Industrial S. Coop. ("Fagor"); Greenfield World Trade, Inc. ("Avanti"); ILVE SPA ("ILVE"); Koc Holdings A.S. ("Arcelik"); LG Corp ("LG"); Meneghetti Groupe SA ("Fulgor-Milano"); MGM SRL ("EuroChef Italia"); Miele & Cie. KG ("Miele"); Robert Bosch

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[i] For more information see: www.ahrinet.org/About-Us.aspx.
[j] Electrolux also owns Frigidaire.
[k] Haier owns GE Appliances and Fisher & Paykel

Stiftung Gesellschaft mit beschrankter Haftung[l] ("Bosch"); Samsung Electronics Co., Ltd.[m] ("Samsung"); SMEG SPA ("SMEG"); Sub-Zero, Inc. ("Wolf"); Tecnosuperiore Beyaz Esya Anonim Sirketi ("Technogas"); and The Middleby Corporation[n] ("Middleby").

DOE also identified 15 small businesses, including Acme Kitchenettes Corp. ("Acme"); American Range Corporation ("American Range"); Brown Stove Works, Inc. ("Brown Stove"); Capital Cooking Equipment, Inc. ("Capital"); Cosmo Products, LLC ("Cosmo"); Felix Storch, Inc. ("Summit"); Danby Product Limited ("Danby"); Duro Corporation ("NXR"); Hallman Industries LLC ("Hallman"); Kenyon International, Inc. ("Kenyon"); Kucht LLC ("Kucht"); Peerless-Premier Appliance Co. ("Peerless-Premier"); Prizer-Painter Stove Works, Inc ("BlueStar"); Signature Kitchen Designs, Inc. ("Signature"); Thor Group ("Thor"). Table 3.6.1 lists these manufacturers.

Table 3.6.1 Major and Other Consumer Conventional Cooking Product Manufacturers

Major Manufacturers	Other Manufacturers	Small Manufacturers
Electrolux	Arcelik	Acme
Haier	Avanti	American Range
Whirlpool	Bertazzoni	BlueStar
	Bosch	Brown Stove
	Eurochef Italia	Capital
	Fagor	Cosmo
	Fulgor-Milano	Danby
	ILVE	Hallman
	LG	Kenyon
	Mabe	Kucht
	Middleby	NXR
	Miele	Peerless-Premier
	Samsung	Signature
	SMEG	Summit
	Technogas	Thor
	Wolf	

3.6.2 Mergers and Acquisitions

On November 5, 2012, Haier acquired a controlling interest in Fisher & Paykel, which had previously acquired Dynamic Cooking Systems, Inc. in 2004.[1]

On December 31, 2016 Viking Range announced it had been acquired by Middleby.[2]

On June 6, 2016, Haier confirmed its acquisition of GE's appliance division from GE for $5.6 billion. Haier stated that "[i]nvesting and growing in the U.S. is a key part of Haier's strategy, and the acquisition of GE Appliances will help us accelerate that expansion." Haier

[l] Bosch also owns Thermador.
[m] Samsung also owns Dacor.
[n] The Middleby Corporation owns Evo, Imperial Range, and Viking.

Group, Qingdao Haier's parent company, claims to be the world's leading home appliance manufacturer, with global revenues exceeding $30 billion in 2015.[3] GE Appliances retained its headquarters in Louisville, Kentucky, and Haier has the rights to use the GE brand name until 2056.[4]

On January 2, 2019, Middleby announced the acquisition of EVO America, Inc.[5]

On September, 2021, Middleby announced the acquisition of Imperial Commercial Cooking Equipment.[6]

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.

3.6.3 Small Business Impacts

DOE considers the possibility of small businesses being impacted by the promulgation of energy conservation standards for consumer conventional cooking products. At this time, DOE is aware of 15 small conventional cooking product manufacturers, defined by the Small Business Association (SBA) as having 1,500 employees or fewer, who produce products that fall under this rulemaking and who, therefore, would be impacted by energy conservation standards. These small business manufacturers are listed in Table 3.6.1. DOE evaluated the potential impacts on these small businesses as part of the MIA, which it conducted as a part of the rulemaking analysis. For further information on the conventional cooking products small businesses, see chapter 12 of this SNOPR 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 2011 Top 100 Major Appliance Retailers Report states that home improvement stores account for almost 40 percent of appliance sales.[7]

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.[8]

3.7 REGULATORY PROGRAMS

The following section details current regulatory programs mandating energy conservation standards for conventional cooking products. Section 3.7.1 discusses current U.S. Federal energy conservation standards, section 3.7.2 reviews standards in Canada that may impact the companies servicing the North American market, and section 3.7.3 reviews regulations in the European Union.

3.7.1 Federal Energy Conservation Standards

The current Federal energy conservation standards for consumer conventional cooking products require that all gas cooking tops and gas ovens (with or without an electrical supply cord) manufactured on or after April 9, 2012, not to be equipped with constant burning pilots.

3.7.2 Canadian Energy Conservation Standards

Canada's Energy Efficiency Regulations ("Canadian Regulations") mandate minimum energy conservation standards for certain conventional cooking products, including electric and gas ranges, cooking tops, and ovens.[o] The current Canadian test method for household electric ranges is, "Energy Consumption Test Methods for Household Electric Ranges," originally published in February 2003 and reaffirmed most recently in 2018 ("CAN/CSA 358-03"). CAN/CSA 358-03 uses similar test procedures for conventional cooking tops as the pre-2012 DOE test procedure in Appendix I that used an aluminum block test load. For conventional ovens, CAN/CSA 358-03 uses similar testing methods as the DOE test procedure adopted in the July 2015 TP Final Rule, except that it does not include the active mode fan-only mode, standby mode, and off mode testing provisions.

For gas cooking products, the Canadian Regulations require that gas cooking products, including ranges, ovens, and cooking tops, with an electrical supply cord not be equipped with constant burning pilots, which is similar to the current U.S. standards except that the U.S. requirement also applies to gas cooking products without an electrical supply cord. For electric cooking products, the Canadian Regulations specify a maximum allowable energy consumption, as listed in Table 3.7.1.

Table 3.7.1 Canadian Energy Conservation Standards for Conventional Electric Cooking Products

Cooking Product Classification	Maximum Allowable Energy Consumption *(kWh/year)* *
Freestanding 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

[o] For more information, visit https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/guide-canadas-energy-efficiency-regulations/electric-ranges/6937.

3.7.3 European Union Energy Conservation Standards

The European Union (EU) 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 conventional ovens and cooking tops.[p]

The energy consumption of conventional electric and gas ovens, including the oven component of conventional ranges, is measured according to the European Committee for Electrotechnical Standardization (CENELEC)'s test procedure EN 60350-1:2016 "Household electric cooking appliances – Part 1: Ranges, ovens, steam ovens and grills – Methods for measuring performance" for electric ovens, and EN 15181:2017 "Measuring method of the energy consumption of gas fired ovens" for gas ovens. Both test procedures measure the energy used during one heating cycle which increases the temperature of a wet brick by 55 Kelvin. The Energy Efficiency Index (EEI) is the ratio (multiplied by 100) of the energy consumption of a specific oven to the standard energy consumption of an average 2012 oven with the same cavity volume.[q] The EU regulations established three tiers of requirements with compliance dates in 2015, 2016, and 2019. As of February 3, 2019,[r] the maximum allowable EEI for a conventional oven is 96. For multi-cavity conventional ovens, at least one cavity is required to have an EEI of less than 96, and the other cavities are required to have an EEI of less than 121.

The energy consumption of conventional cooking tops is measured according to CENELEC's test procedure EN 60350-2:2013/A11:2014 "Household electric cooking appliances - Part 2: Hobs - Methods for measuring performance" for electric cooking tops, and EN 30-2-1:2015 "Domestic cooking appliances burning gas – Part 2-1: Rational use of energy – General" for gas cooking tops. The test procedure for electric cooking tops is similar to Appendix I1, with the energy use calculated differently.[s] The test procedure for gas cooking tops uses different test vessels than Appendix I1, does not include a simmering period, and outputs theoretical efficiency for each burner rather than the energy consumption of a water heating test. The EU regulations established three tiers of requirements with compliance dates in 2015, 2016, and 2019. The maximum energy consumption for conventional electric cooking tops and the minimum efficiency for conventional gas cooking tops as of February 3, 2019, are indicated in Table 3.7.2.

[p] For more information, visit https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014R0066.

[q] The Standard Energy Consumption for an electric oven is 0.0042V + 0.55 kWh. The Standard Energy Consumption for a gas oven is 0.044V + 3.53 MJ, or 0.0417V + 3.346 kBtu.

[r] February 3, 2019, is 5 years after the entry into force of the directive which was February 3,2014, 20 days after its publication in the *Official Journal of the European Union*.

[s] The reported energy use corresponds to the average energy use of each heating element, normalized by the weight of the water load, but not normalized to correspond to a nominal final water temperature. The energy use is reported on a per-cycle basis, and is not multiplied by a representative water load mass nor by a number of annual usage cycles. Some other changes exist where Appendix I1 deviated from the industry test procedure incorporated by reference such as test vessel selection and starting water temperature.

Table 3.7.2 European Union Energy Conservation Standards: Energy Efficiency Performance Limits for Conventional Cooking Tops

Maximum Allowable Average Hob Energy Consumption for Electric Cooking Tops	195 *Wh/kilogram of water*
Minimum Allowable Average Hob Energy Efficiency for Gas Cooking Tops	55%

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.[t]

The EU 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.[u]

The EU regulations established two tiers of requirements with compliance dates in 2009 and 2013. As of January 6, 2013,[v] the regulations require:

(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.

[t] For more information, visit www.iea.org/.
[u] For more information, visit https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32008R1275.
[v] January 6, 2013, is 4 years after the entry into force of the directive which was January 6, 2009, 20 days after its publication in the *Official Journal of the European Union*.

(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.

This EU standard provides maximum power requirements for standby mode. The energy conservation standard proposed by DOE in this SNOPR for conventional cooking tops specifies maximum IAEC values. The IAEC value includes the energy consumption of the cooking top in standby mode. Both the EU standard and the DOE test procedure require measurement using the relevant sections of IEC Standard 62301.

3.8 OTHER PROGRAMS

DOE reviewed other labeling programs promoting energy-efficient consumer appliances (see section 3.8.1) and safety guidelines (see section 3.8.2) in the United States.

3.8.1 ENERGY STAR

ENERGY STAR®, a voluntary labeling program jointly administered by the U.S. Environmental Protection Agency (EPA) and DOE, identifies energy efficient products through a qualification process.[w] To qualify, a product must exceed Federal minimum standards by a specified amount, or if no Federal standard exists, exhibit specified energy-saving features. The ENERGY STAR program works to recognize the top quartile of products on the market, meaning that approximately 25 percent of the models on the market at the time the qualifying criteria are specified meet or exceed the ENERGY STAR criteria. ENERGY STAR guidelines have been established for numerous consumer products, including electric cooking tops.

The ENERGY STAR Emerging Technology Award (ETA) recognizes innovative technologies that reduce energy use and lower greenhouse gas emissions. For the first time in March 2021, ENERGY STAR published ENERGY STAR ETA criteria for residential induction cooking tops.[x] The ENERGY STAR ETA is awarded to conventional cooking tops available for sale in the U.S. market in 2021–2022 that:

[w] For more information on the ENERGY STAR program, please visit www.energystar.gov.
[x] For more information on the ENERGY STAR Emerging Technology Award, please visit www.energystar.gov/about/2021_residential_induction_cooking_tops.

1. meet the DOE definition for a built-in, drop-in or freestanding cooking top and are intended for residential use;
2. only include induction heating technology for all surface units on the cooking top; and
3. are tested according to the test procedure finalized in the December 2016 Final Rule with an Integrated Annual Energy Consumption less than or equal to 125 kWh/year.

3.8.2 Building Codes

As discussed, ANSI Z21.1 is the industry safety standard for newly produced household cooking gas appliances. ANSI Z21.1 includes specifications that cover construction requirements, burner operating conditions, ignition systems, gas valve performance, regulator performance, safety testing, wall temperature limits, flue gases, vent hoods, self-cleaning ovens, and safety circuitry of gas cooking appliances. In addition to these, section 5.4 of ANSI Z21.1 specifies that an appliance shall not produce a concentration of carbon monoxide in excess of 800 parts per million (ppm) when the appliance is tested in a room having approximately a normal oxygen supply.

ANSI Z21.1 is not a mandatory standard for conventional cooking product manufacturers. However, because it is included in many local building and safety codes,[y] the provisions in ANSI Z21.1 are widely followed by conventional cooking product manufacturers.

3.9 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 and AHAM to evaluate consumer appliance product shipment trends and the value of these shipments, which were used during the shipments analysis (see chapter 9 of this SNOPR TSD).

3.9.1 New Home Starts

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

Table 3.9.1 presents the number of new single-family and multi-family housing units started in the United States from 2005–2021. Between 2005 and 2010, single-family home starts decreased 73 percent, from over 1.7 million to 471,000 units annually. During the same time period, multi-family unit starts decreased 67 percent, from 353,000 to 116,000 units annually.

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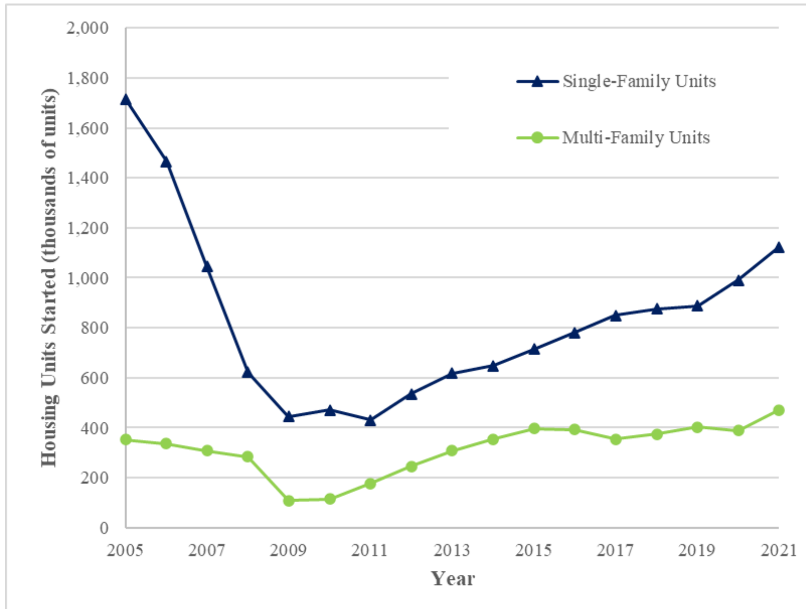
[y] See, for example, the New York City Fuel Gas Code (“NYCFGC”) of the 2022 Construction Codes, Chapter 6, Section 623.1 *Cooking Appliances*. This section requires that “[c]ooking appliances that are designed for permanent installation, including ranges, ovens, stoves, broilers, grills, fryers, griddles, hot plates and barbecues, shall be tested in accordance with ANSI Z21.1/CSA 6.5, ANSI Z21.58/CSA 1.6 or ANSI Z83.11/CSA 1.8 and shall be installed in accordance with the manufacturer’s instructions.” For more information, see: https://www1.nyc.gov/assets/buildings/apps/pdf_viewer/viewer.html?file=2022FGC_Chapter6_SpecAppliancesWB.pdf&section=conscode_2022.

While single-family unit starts have increased by 138 percent from 2010–2021, they still remain below their pre-2005 levels. Over the same time period, multi-family unit starts have rebounded to above their pre-2005 levels to 472,000 annually.

Table 3.9.1 New Privately Owned Single-Family and Multi-Family Housing Unit Starts in the United States from 2005-2021 (Thousands)[9]

Year	Single-Family	Multi-Family
2021	1123	472
2020	991	389
2019	888	402
2018	876	374
2017	849	354
2016	782	392
2015	715	397
2014	648	355
2013	618	307
2012	535	245
2011	431	178
2010	471	116
2009	445	109
2008	622	284
2007	1,046	309
2006	1,465	336
2005	1,716	353



3.9.2 Unit Shipments and Value

Shipments of conventional cooking products for 2006 through 2009 were obtained from the July 2010 *Appliance Market Research Report*'s "U.S. Appliance Industry Statistical Review: 2000 to YTD 2010." Data for 2010 was taken from the January 2011 *Appliance Market Research Report*'s "U.S. Appliance Shipment Statistics Monthly: January 2011." Shipments for 2011 to 2017 were obtained from *Appliance Design's* "Major Appliance Shipments" found in the March issue of each year. Table 3.9.2 presents the annual shipments of conventional cooking products for the period from 2006 to 2017, the most recent year of data from these sources.

Table 3.9.2 Industry Shipments of Conventional Cooking Products (Domestic and Import in Thousands of Units)[10,11,12,13,14,15]

Year	Cooking Products							
	Electric Cooking				Gas Cooking			
	Electric Ranges	Electric Ovens	Surface Cooking Units	Total	Gas Ranges	Gas Ovens	Surface Cooking Units	Total
2017*	4,638		376	5,014	3,105		502	3,607
2016*	4,528		356	4,884	3,042		458	3,500
2015*	4,246		357	4,603	2,813		435	3,248
2014	4,078	718	335	5,131	2,628	30	403	3,061
2013	3,791	677	326	4,794	2,478	33	369	2,880
2012	3,439	589	304	4,332	2,275	31	304	2,610
2011	3,424	574	320	4,318	2,286	39	300	2,625
2010	3,509	604	335	4,448	2,432	44	314	2,790
2009	3,448	549	336	4,333	2,264	44	291	2,598
2008	3,973	700	433	5,106	2,408	47	387	2,843
2007	4,612	867	512	5,991	2,781	56	497	3,334
2006*	5,684		544	6,228	3,023		563	3,586

* Disaggregated shipments data for electric and gas ranges was unavailable for 2006 and 2015–2017.

Table 3.9.3 provides the value of shipments for the household cooking appliance industry from 2002–2016 based upon data from the U.S. Census Bureau's *Annual Survey of Manufactures* (ASM).[z] The ASM expresses all dollar values in nominal dollars; *i.e.*, 2016 data are expressed in 2016 dollars, and 2014 data are expressed in 2014 dollars. The value of shipments decreased by nearly 19 percent between 2007 and 2008, but then increased to once again reach pre-2008 levels in 2014–2016 (the most recent year the ASM provided this level of disaggregation).

[z] Available online at https://www.census.gov/programs-surveys/asm/data.html.

Table 3.9.3 Household Cooking Appliance Manufacturing Statistics by Year[16]

Year	Value of Shipments in Nominal Dollars *($1,000)*
2016	4,864,516
2015	4,767,931
2014	5,160,766
2013	4,398,139
2012	4,359,383
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

There was an overall decrease in both shipment volume and values from 2006–2010, followed by an overall increase in both from 2011–2017.

3.9.3 Imports and Exports

DOE obtained import and export data from the U.S. International Trade Commission's DataWeb database.[17] Figure 3.9.1 shows the number of conventional cooking product imports for the period 2005–2021. Imports of electric cooking stoves, ranges, and ovens have generally decreased over this time period, from 4.1 million in 2005 to 3.3 million in 2021. Imports of non-portable cooking appliances for gas and other fuels have generally increased over this time period, especially from 2014 to 2021, where imports increased from 1.5 million units to 3.8 million units, exceeding imports of electric units for the first time in 2020.

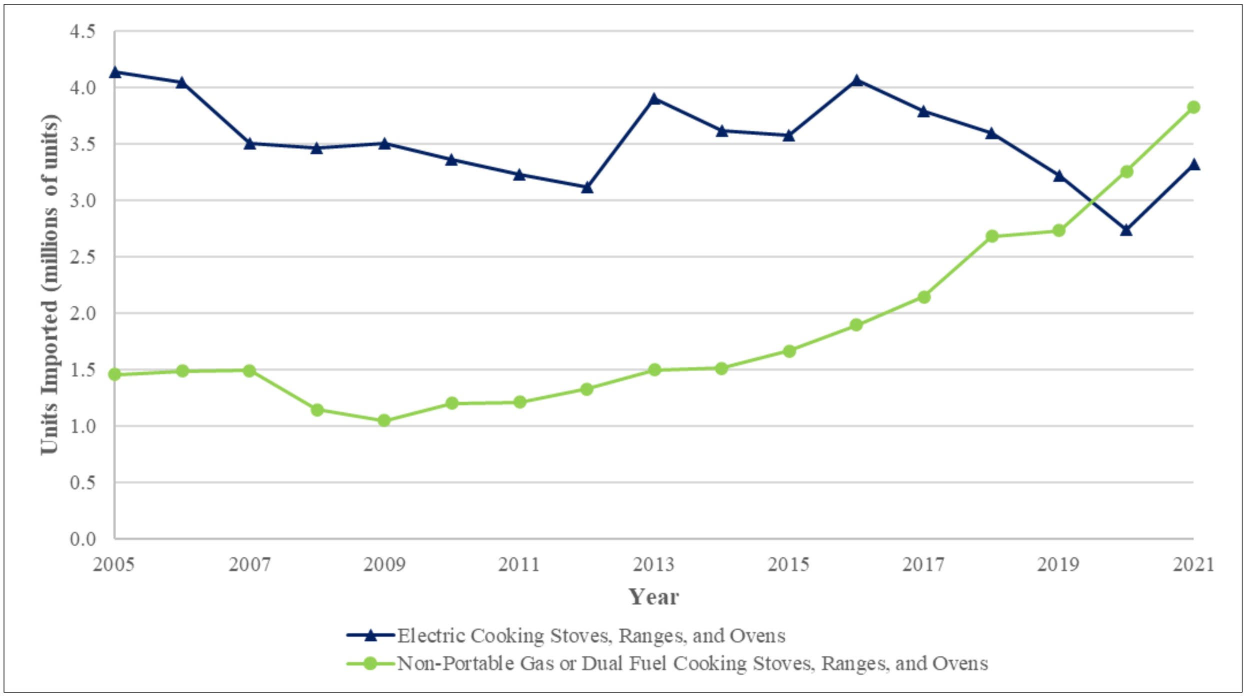


Figure 3.9.1 Annual Imports of Conventional Cooking Products[18]

Figure 3.9.2 shows the number of conventional gas cooking product exports for the period 2005–2021.[aa] The number of exports remained relatively constant for 2005–2013. From 2013 to 2021, the number of exported units changed with more volatility, yielding an overall increase from 117 thousand to 315 thousand (peaking at 414 thousand in 2018).

[aa] Figure 3.9.2 only includes the number of gas conventional cooking products exported because the U.S. International Trade Commission's DataWeb database did not have any data available for electric conventional cooking product exports.

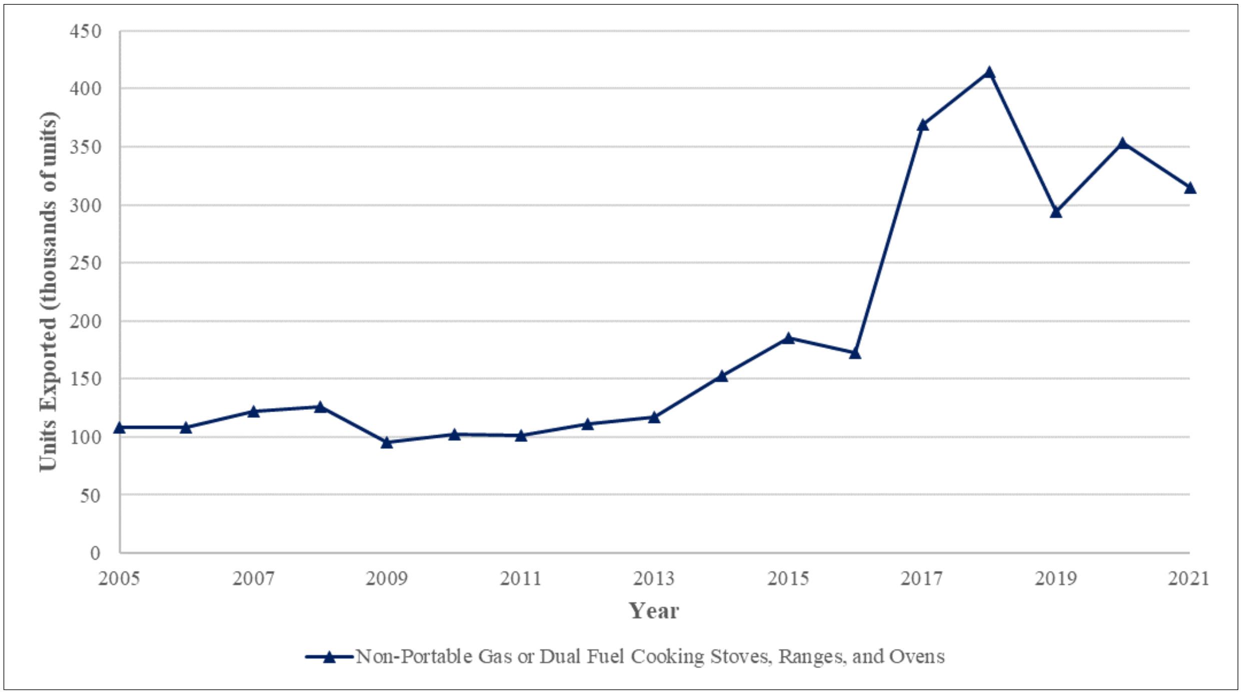


Figure 3.9.2 Annual Exports of Gas Conventional Cooking Products[19]

3.10 MARKET SATURATION

AHAM's *Fact Book 2005* and Appliance Magazine's *2007–2010 U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels* and *2011–2014 U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture* 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 3.10.1 presents the percentage of U.S. households with each product for the period of 1999–2014, the most recent year of such data from these sources.

Table 3.10.1 Percentage of U.S. Households with Conventional Cooking Products[20,21,22]

Year	Electric Ranges / Cooking Tops	Gas Ranges / Cooking Tops
2014	61.0	39.0
2013	61.0	40.0
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
2000	60.0	10.0
1999	60.0	40.0

3.11 INDUSTRY COST STRUCTURE

DOE developed the consumer conventional cooking product industry cost structure from publicly available information from the ASM, (Table 3.11.1 and Table 3.11.2) and the U.S. Securities and Exchange Commission (SEC) 10-K reports filed by publicly owned manufacturers (summarized in Table 3.11.3). For ASM data, DOE used NAICS code 335220 “Major Household Appliance Manufacturing” to represent the consumer conventional cooking product industry. Table 3.11.1 presents the major household appliance manufacturing industry employment levels and earnings from 2018–2020. The statistics illustrate an increase in the number of production and non-production workers in the industry from 2018–2020. Consequently, the annual payroll for all employees also increases from 2018–2020.

Table 3.11.1 Major Household Appliance Manufacturing Industry Employment and Earnings[23]

Year	Production Workers	All Employees	Payroll for All Employees *($1,000)*
2020	38,681	43,925	2,301
2019	38,171	43,847	2,140
2018	36,956	42,395	2,034

Table 3.11.2 presents the costs of materials and industry payroll as a percentage of value of shipments from 2018–2020. The cost of materials as a percentage of value of shipments has decreased over this time period. The cost of payroll for production workers as a percentage of value of shipments has fluctuated over this time period. Similarly, the cost of total payroll as a percentage of value of shipments has also fluctuated over this time period.

Table 3.11.2 Major Household Appliance Manufacturing Industry Census Data[24]

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 *(%)*
2020	50.0	8.2	10.7
2019	52.6	7.8	10.2
2018	53.5	8.0	10.4

Table 3.11.3 presents the industry cost structure derived from SEC 10-K reports of publicly owned consumer appliance manufacturers. Each financial statement entry is presented as a percentage of total revenues.

Table 3.11.3 Industry Cost Structure Using SEC Data

Financial Statement Entry	Percent of Revenues
Tax Rate	21.0%
Selling, general and administrative	11.2%
Capital expenditure	3.3%
Research and development	2.4%
Depreciation and amortization	3.4%
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 SNOPR TSD.) This analysis identifies key financial inputs including cost of capital, working capital, depreciation, and capital expenditures.

3.12 INVENTORY LEVELS

Table 3.12.1 shows the year-end inventory for the consumer cooking appliance industry as a percentage of annual value of shipments, according to the most recent ASM that provided this level of disaggregation (2016). The end-of-year inventory for the industry varied from 2005 to 2014, ranging from 7.8 percent to 11.6 percent. End-of-year inventories increased in 2015 to 14.8 percent and remained relatively high in 2016 at 13.9 percent.

Table 3.12.1 Consumer Cooking Appliance Industry Census Data[25]

Year	End-of-Year Inventory as a Percentage of Value of Shipments *(%)*
2016	13.9%
2015	14.8%
2014	9.3%
2013	9.0%
2012	7.8%
2011	-
2010	8.8%
2009	7.8%
2008	9.1%
2007	11.6%
2006	7.9%
2005	8.3%

3.13 TECHNOLOGY ASSESSMENT

This section provides a technology assessment for conventional cooking products. Contained in this technology assessment are details about product characteristics and operation (section 3.13.1), an examination of possible technological improvements for each product (section 3.13.2), and a characterization of the product efficiency levels currently commercially available (section 3.13.3).

3.13.1 Product Operations and Components

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

Conventional 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. Cooking tops consist of a horizontal surface comprising one or more heating elements. A cooking vessel is placed on the top surface of the cooking top over the element to facilitate heat transfer to the food load. In conventional ovens, the cooking vessel is placed inside a cavity within which the energy transfer to the food load takes place. Combined cooking products may incorporate both an oven(s) and a cooking top in a single unit.

In a gas cooking top, pressurized natural gas or propane is supplied to each burner by means of an orifice and venturi on the underside of the cooking top surface. A sheet metal box encloses the array of burner supply lines as well as the controls for gas delivery and ignition, if provided. Primary air drawn from within the enclosure mixes with the gas at the venturis and is delivered to the ports typically arrayed radially on the burners above the cooking top surface. Gas flow and thus burner turndown is controlled by individual (typically rotary) valves connected to the burner supply lines. Upon ignition of the gas-air mixture, secondary air is entrained near the burner ports to produce a substantially radial distribution of flames. For sealed burners in which the cooking top surface interfaces directly with the base of each burner, all secondary air is introduced above the cooking top surface. Open burners can derive some secondary air from the box as well. Grates positioned above the burners allow a cooking vessel to be placed at the proper spacing to ensure adequate secondary air for complete combustion, minimization of carbon monoxide emissions, and adequate convective heat transfer for cooking efficiency.

As discussed, gas cooking tops cannot have a constant burning pilot (10 CFR 430.32(j)(1)–(2)) and instead use some form of electrically powered ignition, typically an intermittently activated spark igniter. An electronic control module may automatically energize the spark electrode whenever flame extinction is detected; otherwise the spark igniter must be manually reactivated by means of switches on the burner valve controls in the event of flame loss. Controls for the burners typically consist of manual burner adjustment as dictated by the rotary valve position. In order to achieve very low firing rates associated with such cooking processes as simmering, melting chocolate, or heating delicate sauces, some conventional cooking tops incorporate electronic controls that cycle burners on and off.

An electric cooking top consists of a horizontal surface with one or more electrically powered heating elements located either above or below the cooking top surface. When the elements are located above the cooking top surface, the cooking vessel is placed directly on an element to heat the vessel and contents through conductive heat transfer. The elements are resistively heated by means of the current supplied to them. An open (coil) element cooking top uses a spiral-wound sheathed heating element. Removable drip bowls beneath each element serve as catch basins for spills.

Heating elements may also be located under a glass-ceramic cooking top surface. A baseline smooth element cooking top uses solid disk elements to heat the glass-ceramic surface, which provides heat to the cooking vessel through conductive heat transfer. Electronic control systems are provided to energize the desired heating elements. These controls may incorporate algorithms for modulation of the element according to cooking top and cooking process parameters.

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 pyrolyzed, 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.

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

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 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.

3.13.2 Technology Options

In order to gain a deeper understanding of the technological improvements used to increase the efficiency of conventional cooking products, 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) the 2009 TSD from the most recent energy conservation standards rulemaking for 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;[bb] (3) information provided by trade publications; and (4) design data identified in manufacturer product offerings.

3.13.2.1 Electric Cooking Tops

For electric open (coil) element cooking tops, DOE did not identify any technology options for improving efficiency.

For electric smooth element cooking tops, DOE considered the technologies listed in Table 3.13.1.

Table 3.13.1 Technology Options for Electric Smooth Element Cooking Tops

1. Halogen elements
2. Induction elements
3. Low-standby-loss electronic controls
4. Reduced air gap

Halogen Elements

Halogen elements transfer energy to the cooking vessel by direct infrared radiation from high-powered tungsten-halogen lamps. The halogen element lies underneath the same type of glass-ceramic panel used in a baseline electric smooth element cooking top and consists of one or more lamps installed horizontally within a corrosion-protected metal dish. The bottom of the metal dish is insulated with microtherm insulation.

Radiant heating coils are commonly fitted around the halogen element to provide heat around the element's edge. This results in a highly responsive element that provides an even temperature distribution. Halogen elements can be configured to operate across a wide range of capacities. Parallel or series lamp arrangements can yield power outputs from 1200–2500 W. Halogen lamp technology reported in the 1996 TSD consisted of a circular lamp that can provide a more optimum temperature distribution than traditional straight lamps. This circular lamp has the trademark name of Haloring.

The TSDs from previous rulemakings reported that with the continued development of halogen elements, efficiencies had increased. The circular halogen-lamp elements that had

[bb] Available online at https://www.regulations.gov/document/EERE-2006-STD-0070-0053.

recently been developed at the time of the previous analysis could exceed the efficiency of solid disk elements as measured according to the DOE test procedure at that time. Data provided for the previous rulemakings by a cooking top manufacturer were used to establish the efficiency gain of a circular halogen lamp element over that of a solid disk element. An efficiency increase of approximately 1.5 percent was measured. It is important to reiterate that this efficiency increase was only for the circular halogen lamp element. Other halogen lamp elements might not yield the same efficiency increase. The same cooking top manufacturer mentioned above also provided efficiency data based on boiling water tests. These tests indicated that circular halogen lamp elements can yield even higher efficiency increases over that of solid disk elements. European manufacturers had also conducted boiling water tests indicating that halogen lamp elements (the configuration of halogen lamp tested was not specified) are more efficient than solid disk elements.[26]

DOE is not aware of any conventional cooking tops currently on the market using halogen technologies.

Induction Elements

Induction elements use a solid-state power supply to convert 60 hertz alternating line current into a high-frequency (approximately 25 kilohertz) alternating current. This high-frequency current is supplied to an inductor. The inductor is a flat spiral winding located just underneath the same type of glass-ceramic panel used in a baseline electric smooth element cooking top. The high-frequency current, which is supplied to the inductor, causes it to generate a magnetic field which passes through the glass-ceramic panel unaffected and produces eddy currents in the bottom of the cooking vessel. The vessel must be made of ferromagnetic material, and the eddy currents that are generated within it cause it to heat up. Thus, the vessel essentially becomes the heating element.

A sensor is placed between the inductor and the glass-ceramic panel, providing a continuous temperature measurement of the vessel bottom. Sensors also enable the inductor to only heat objects of at least 4 inches in diameter. This prevents any small metal objects, such as forks or spoons, from accidentally being heated. In addition, since the glass-ceramic panel is unaffected by the magnetic field, it remains relatively cool, reducing the potential for accidental burns.

The primary advantages of induction elements are their fast response and control of the heat source, their ease of cleaning, and their ability to heat vessels that are not flat. Because these features have usually been associated with gas burners, induction elements are being marketed in competition to them. DOE’s testing, discussed in detail in chapter 5 of this SNOPR TSD, showed that induction heating resulted in up to a 14 percent relative decrease in active mode energy use compared to smooth element cooking tops with electric resistance heating elements.

Low-standby-loss Electronic Controls

Electronic controls may consume power even when the electric cooking top 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 IAEC of the electric cooking top but would not impact the energy consumption of the electric cooking top during active mode operation.

A potential area for standby power improvements is the power supplies on the control board. Baseline efficiency cooking tops use less efficient power supply designs, such as conventional linear power supplies. A linear power supply typically produces unregulated as well as regulated power. The main characteristic of an unregulated power supply is that its output may contain significant voltage ripple and that the output voltage will usually vary with the current drawn. The voltages produced by regulated power supplies are typically more stable; exhibiting less ripple than the output from an unregulated power supply and maintaining a relatively constant voltage within the specified current limits of the device(s) regulating the power. The unregulated portion of a linear power supply typically consists of a transformer that steps alternating current (AC) line voltage down, a voltage rectifier circuit for AC to direct current (DC) conversion, and a capacitor to produce unregulated, direct current output. However, there are many means of producing and implementing an unregulated power supply such as a transformerless capacitive and/or resistive rectification circuits.

Within a linear power supply, the unregulated output serves as an input into a single or multiple voltage-regulating devices. Such regulating devices include Zener diodes, linear voltage regulators, or similar components which produce a lower-potential, regulated power output from a higher-potential direct current input. This approach results in a rugged power supply which is reliable, but typically has an efficiency of about 40 percent.

Switch-mode power supplies (SMPSs) switch the current at high frequencies, adjusting the proportion of on time during each switching cycle to maintain the regulated output voltage proportional to a fixed voltage reference. SMPSs offer the highest conversion efficiencies (up to 75 percent in designs for appliance applications with power supply sizes similar to those of conventional cooking products[cc]) and the lowest no-load standby losses (0.2 W or less), though at higher part count and greater complexity. SMPSs' greater complexity may also result in lower overall reliability and take greater care to implement. For example, among other issues, a SMPS can be prone to causing electromagnetic interference.

Manufacturers could also meet very low (*i.e.*, less than 1 W) standby power levels according to the definition of "standby mode" in the DOE test procedure by incorporating an automatic function that turns off most power-consuming components once a period of inactivity has elapsed. Such a low-consumption state could be user-selectable on demand. DOE noted that at least one product in its test sample already incorporates such a design to achieve very low standby power levels (around 0.25 W). The automatic power-down module would feature a SMPS and a microprocessor that can respond to a simple capacitive-touch or switch signal to power up and enable product operation via a triac.

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

Reduced Air Gap

Typical radiant element cooking tops have an air gap between the heating element and the ceramic-glass cooking top surface. Energy is expended to heat the air between the heating element and the glass, with that heated air providing minimal to the cooking vessel. One approach for increasing the efficiency of a radiant element is to reduce the air gap, to reduce the amount of wasted heat.

3.13.2.2 Gas Cooking Tops

For gas cooking tops, DOE considered the technologies listed below.

Table 3.13.2 Technology Options for Gas Cooking Tops

1. Catalytic burners
2. Optimized burner and grate design
3. Radiant gas burners
4. Reduced excess air at burner
5. Reflective surfaces

Catalytic Burners

Catalytic burners consist of a porous ceramic or refractory material such as glass or ceramic wool, impregnated with a catalyst. The gas-air mixture or gas alone is fed to the catalytic matrix, whereupon additional ambient air diffuses into it. The catalyst, typically palladium or platinum, lowers the activation energy required for combustion such that the gas-air mixture subsequently oxidizes at temperatures below those normally required for combustion. This produces a uniform, low-intensity infrared radiation with no visible flame. The burners include an electric heating element to preheat the catalyst prior to initiating operation. Catalytic burners in consumer appliances have been investigated primarily as a means of reducing nitrogen oxides (NO_X) emissions, since NO_X formation is highly temperature dependent. Several organizations have investigated catalytic burners that could be applied to consumer conventional cooking tops. Precision Combustion, Inc. is developing several small-scale low-NO_X catalytic burners that are suitable for consumer conventional cooking tops.[27] Hybrid catalytic burners have been shown to improve cooking efficiency by 3 to 9 percent, in laboratory conditions.[28]

Optimized Burner and Grate Design

As discussed in chapter 5 of this SNOPR TSD, DOE testing 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, heavier grates result in more input energy being absorbed by the grate instead of the pan. Because designs of burner system components are interdependent and must also consider combustion efficiency to maintain approved levels of carbon monoxide emissions,[dd] DOE considered optimized gas cooking top burner designs for

[dd] The 800-ppm limit specified in ANSI Z21.1 is the most commonly referenced carbon monoxide limit. See section 3.8.2 of this chapter.

increasing efficiency only as consistent with products available on the market, which meet the relevant safety and emissions standards.

Radiant Gas Burners

Radiant gas burners transfer heat through infrared radiation from the burner surface. The burner consists of a porous matrix through which a premixed gas-air mixture is fed. Upon ignition, the flames sit on the surface of the matrix, heating the surface and causing it to emit radiation at infrared wavelengths. The burner is located under a glass-ceramic cooking top surface.

One form of radiant gas burners is termed the powered Infrared Jet-Impingement ("IR-Jet") burner. In an IR-Jet gas burner, both radiant and convective energy are transmitted to the cooking vessel. A forced-draft combustion fan is used to deliver the fully premixed gas-air mixture to the cooking top burners. At each burner, combustion occurs at the surface of a perforated ceramic tile. As the tile heats, it emits radiant energy, principally in the far infrared regime. Combustion products are jetted through perforations in the glass-ceramic cooking top, delivering convective energy to the cooking vessel as well.

As reported in the 2009 TSD, the Gas Research Institute (GRI, now known as the Gas Technology Institute) sponsored the development of the IR-Jet gas burner. With GRI's sponsorship, the American Gas Association Laboratories (AGAL) worked with a range manufacturer to produce a working IR-Jet burner. However, the IR-Jet burner is not currently being marketed. Data collected from a boiling water test indicated that the AGAL-developed IR-Jet radiant burner is more efficient than a comparable conventional open burner. The boiling water test indicated a 16-percent increase in efficiency.

Another type of radiant gas burner uses a silicon carbide-fiber burner which emits radiation in the near-infrared spectrum. A prototype developed jointly by Tokyo Gas and Rinnai Corporation used such material in a glass-ceramic cooking top that did not incorporate jet impingement. Instead, combustion products were vented from underneath a solid, non-perforated cooking top. Such a radiant burner relied entirely on radiant heat transfer and conduction from the glass-ceramic after it heated up. In tests conducted according to the Japanese Industrial Standard (JIS) S 2103:1996, *Gas burning cooking appliances for domestic use*, which is a water heating procedure, the efficiency was reported as 43.5 percent compared with an estimated 30 percent for traditional gas burners.[29]

Reduced Excess Air at Burner

The excess-air ratio is defined as the amount of air used in the combustion process of the gas burner divided by the amount of air necessary for stoichiometric combustion. Excess air is provided to ensure high-quality flame characteristics and to create a safety margin to ensure complete combustion is reached under all conditions. Reducing the excess-air ratio at the burner through redesign and shrouding can improve its efficiency. This information was provided by the 1980 engineering analysis performed by DOE[30] in support of developing energy efficiency standards for a variety of consumer products, including conventional cooking tops and conventional ovens. This document did not specify how the burner should be redesigned and shrouded.

Reflective Surfaces

Reflective surfaces for gas cooking tops use highly polished or chromed drip pans underneath the burner. By reflecting some of the radiant heat of the burner back up to the cooking vessel, the efficiency of the burner is increased. The consumer must maintain the reflective finish by cleaning the drip pans regularly.

Efficiency gains resulting from using reflective pans are extremely small because gas flames and burners have minimal infrared emissions. The primary mechanism for heat transfer to the cooking vessel is convection. The efficiency increase was obtained from using manufacturers' data provided by AHAM and reported in the 1996 TSD. The data indicate that an efficiency increase of only 0.1 percent is realized due to the incorporation of reflective surfaces. As reported in the 1996 TSD, manufacturers stated that any increase in efficiency due to a reflective surface could easily be negated if the consumer fails to regularly clean the surface or uses an abrasive pad to clean the surface.

3.13.2.3 Electric and Gas Ovens

For gas and electric ovens, DOE considered the technologies listed in Table 3.13.3.

Table 3.13.3 Technology Options for Electric and Gas Ovens

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

Bi-Radiant Oven (Electric Ovens Only)

A bi-radiant electric oven system was developed by Purdue University for Oak Ridge National Laboratory in the late 1970s.[31] 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 temperatures; (2) the heating elements, similar in construction to those in typical consumer 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 at that time) 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 typical 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

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. 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.[32] As a result, forced convection is widely used in electric ovens.

Additionally, conventional ovens can use convection heating elements in addition to resistance and other types of elements to speed up the cooking process. By using 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,[33, 34] and interested parties[35] 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 Wh would result from operation of the convection fan motor.

As described further in chapter 5 of this SNOPR TSD, DOE performed testing on conventional ovens in support of this rulemaking to determine the improvement in cooking efficiency 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 finalized in the July 2015 TP Final Rule. The relative decrease in active mode energy consumption resulting from the use of forced convection in conventional ovens ranged from 4 to 7 percent depending on the product class.

Halogen Lamp Oven (Electric Ovens Only)

Halogen elements, similar to those used in electric cooking tops, can also be used in electric ovens. Far less common than radiant elements, halogen elements are used to promote faster cooking. 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 typical 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 using 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 typical conventional ovens.

Improved and Added Insulation (Standard Ovens Only)

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 (around 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 (around 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 earlier DOE test procedure for conventional ovens did not require maintaining heat in the oven over an extended period of time, manufacturers stated in previous rulemakings that increasing the thickness or density of the oven's insulation would 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 adopted in the July 2015 TP Final Rule.

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;[36] (3) the energy efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association;[37] and (4) the 1980 DOE engineering analysis for residential appliances.[38] 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.[39] 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.[40]

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[41] 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[42] show efficiency increases much less than the 7-percent value previously reported. 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 IE_{AO} of the conventional oven but would not impact the energy consumption of the conventional oven during active mode operation.

A potential area for standby power improvements is the power supplies on the control board. As described for conventional cooking tops, baseline efficiency conventional ovens incorporate linear power supplies with efficiencies of about 40 percent. SMPS designs are also available for conventional ovens offering conversion efficiencies of up to 75 percent and the lowest no-load standby losses. Based on DOE's reverse engineering analyses, discussed in detail in chapter 5 of this SNOPR TSD, DOE observed that more than 90 percent of the conventional ovens on the U.S. market incorporated SMPSs.

No Oven-door Window

Most conventional ovens 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.

Optimized Burner and Cavity Design (Gas Ovens Only)

DOE testing and reverse engineering analyses revealed that gas oven cooking efficiency was correlated to burner and cavity design. Specifically, 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 only as consistent with products available on the market rather than considering the reduced thermal mass technology option included in the previous rulemaking.

Oven Separator (Electric Ovens Only)

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" could 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 consumer conventional electric oven that incorporates an oven separator. Based on DOE's testing of this unit, DOE observed a 19 percent relative increase in cooking efficiency associated with an oven separator in a standard electric oven. Oven separators are not used in conventional gas ovens because they would interfere with the combustion air flow and venting requirements for the separate gas burners on the top and bottom of the oven cavity.

Reduced Vent Rate (Electric Standard Ovens Only)

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. 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.

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.[43] 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 12.6-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.[44]

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.

3.13.3 Energy Efficiency

In preparation for the screening and engineering analyses, DOE gathered data on the energy efficiency of conventional cooking products 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 CAN/CSA 358-03.[ee] 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 3.13.1 displays the distribution of annual energy consumption of electric smooth element cooking tops listed in the NRCan database. The NRCan database did not include any electric open (coil) element cooking tops at the time of this analysis.

[ee] See section 3.7.2 of this chapter.

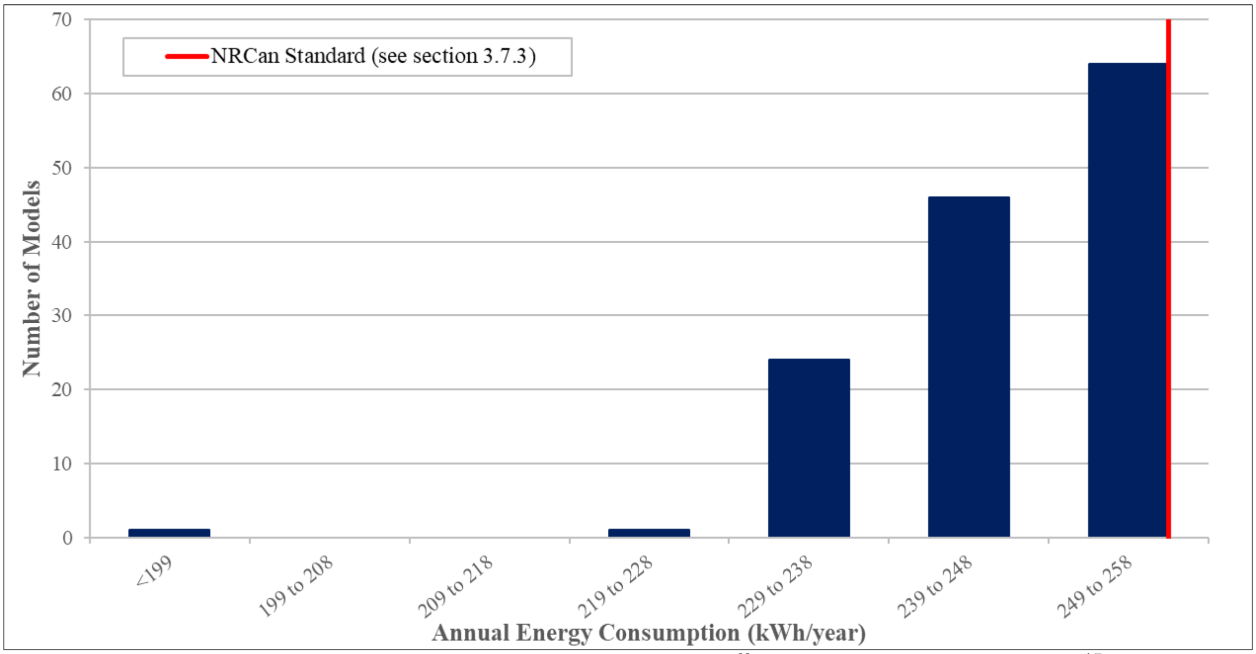


Figure 3.13.1 Electric Smooth Element Cooking Tops[ff] in the NRCan Database[45]

Because annual energy consumption is a function of cavity volume, DOE presented the annual energy consumption of electric ovens listed in the NRCan database related to their cavity volume in Figure 3.13.2.

[ff] DOE has preliminarily determined that the highest-efficiency electric smooth element cooking top listed in the NRCan database, is not available in the U.S. market.

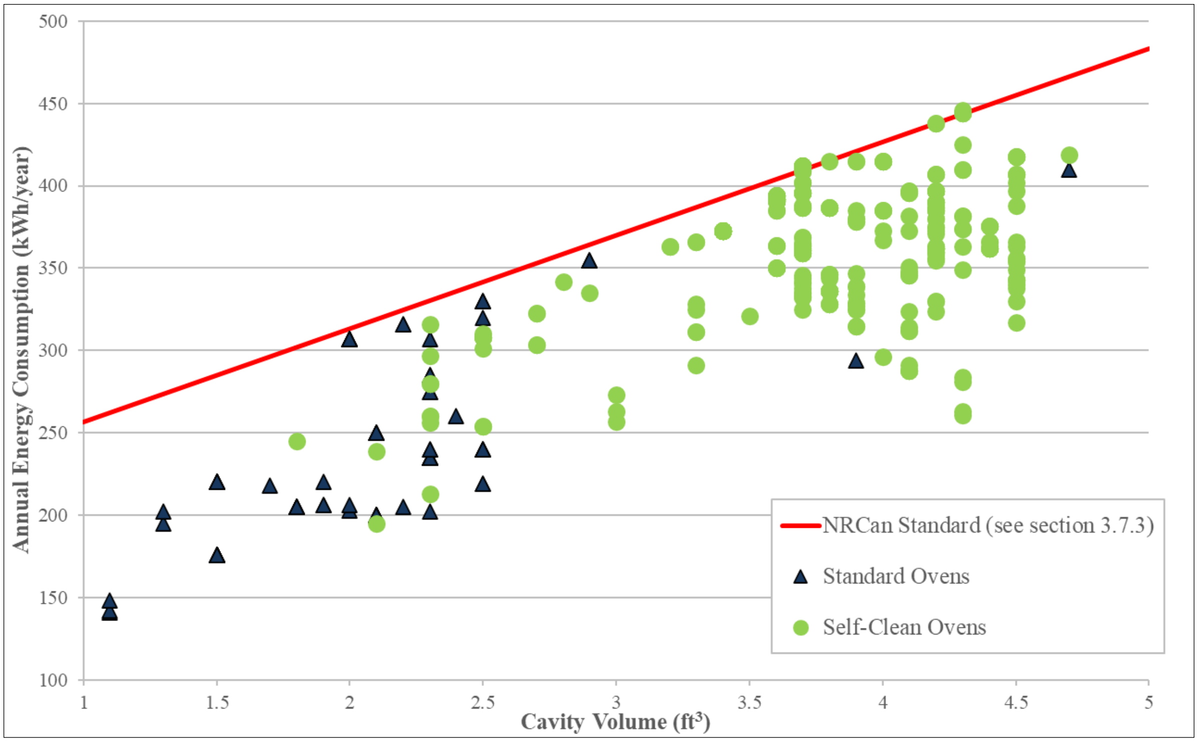


Figure 3.13.2 Electric Ovens in the NRCan Database – Annual Energy Consumption versus Cavity Volume[46]

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CHAPTER 4. SCREENING ANALYSIS

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CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter discusses the screening analysis conducted by the U.S. Department of Energy (DOE) of the technology options identified in the market and technology assessment for consumer conventional cooking tops and ovens[a] (see chapter 3 of this supplemental notice of proposed rulemaking (SNOPR) 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.

DOE must follow specific statutory criteria for prescribing new or amended standards for covered products. The Energy Policy and Conservation Act (EPCA) requires that any new or amended energy conservation standard prescribed by the Secretary of Energy ("Secretary") be designed to achieve the maximum improvement in energy or water efficiency that is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A)) The Secretary may not prescribe an amended or new standard that will not result in significant conservation of energy, or is not technologically feasible or economically justified. (42 U.S.C. 6295(o)(3)) As stated, DOE determines whether to eliminate certain technology options from further consideration based on the following criteria:

(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 or product availability. 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) Adverse impacts on health or safety. If it is determined that a technology will have significant adverse impacts on health or safety, it will not be considered further.

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[a] The term "conventional ovens" refers to residential electric and gas ovens or the oven component of a combined cooking product, but not microwave ovens.

(5) Unique-Pathway Proprietary Technologies. If a technology option uses proprietary technology that represents a unique pathway to achieving a given efficiency level, that technology will not be considered further.

10 CFR part 430, subpart C, appendix A, 6(b)(3) and 7(b).

The 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."

4.2 DISCUSSION OF TECHNOLOGY OPTIONS

For consumer conventional cooking products, the screening criteria specified in section 4.1 of this TSD were applied to the technology options to either retain or eliminate each technology from the engineering analysis. The rationale for either screening out or retaining each technology option is detailed in the following sections for each product class.

4.2.1 Screened-Out Technology Options

4.2.1.1 Electric Cooking Tops

For electric open (coil) element cooking tops, DOE did not identify any technology options for improving efficiency.

For electric smooth element cooking tops, DOE screened out halogen elements and automatic power-down for the reasons that follow.

Halogen Elements

DOE is not aware of any commercialized halogen heating elements for electric smooth element cooking tops, so DOE believes that it would not be practicable to manufacture, install and service this technology on the scale necessary to serve the relevant market at the time of the effective date of an amended standard.

Low-standby-loss Electronic Controls: Automatic Power-down

DOE is aware that the use of automatic power-down low-standby-loss electronic controls may negatively impact product utility. In particular, the use of automatic power-down low-standby-loss electric controls may result in a loss in the utility of the continuous clock display for combined cooking products, such as ranges.

However, it should be noted that the *other* low-standby-loss electronic controls such as switch-mode power supplies were still analyzed.

Reduced Air Gap

DOE is aware that the air gaps in commercialized radiant heating elements are currently as small as is practicable to manufacture on the scale necessary to serve the cooking products market. Furthermore, DOE is not aware of the magnitude of potential energy savings from this technology. Therefore, DOE screened out this technology from further analysis.

4.2.1.2 Gas Cooking Tops

For gas cooking tops, DOE screened out catalytic burners, radiant gas burners, reduced excess air at burner, and reflective surfaces for the reasons that follow.

Catalytic Burners

DOE is not aware of any commercialized catalytic burners for gas cooking tops, so DOE believes that it would not be practicable to manufacture, install and service this technology on the scale necessary to serve the relevant market at the time of the effective date of an amended standard. Also, because this technology is in the research stage, it is not possible to assess whether it will have any adverse impacts on utility to consumers or product availability, or any adverse impacts on consumers' health or safety.

Optimized Burner and Grate Design

As discussed in chapter 5 of this SNOPR TSD, DOE testing 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). Because designs of burner system components are interdependent and must also consider combustion efficiency to maintain approved levels of carbon monoxide emissions, DOE considered optimized gas cooking top burner designs for increasing efficiency only as consistent with products available on the market, which meet the relevant safety and emissions standards.

Based on market surveys and manufacturer interviews, DOE has determined that some level of optimization of the burner and grate design can affect product utility and may have adverse safety impacts. In particular, the use of wire tines as opposed to continuous cast-iron grates could lead to safety issues related to tipping hazard when placing a small pot on the cooking top if the pot is not fully centered on the wire tines or when moving a large, heavy pot off a burner. Additionally, market research has shown that consumers expect the utility of at least one high input rate burner ("HIR burner").[b] In this SNOPR, DOE is screening out any optimized burner and grate design that would result in the lack of continuous cast-iron grates or the lack of at least one HIR burner.

Radiant Gas Burners

In the previous rulemaking, manufacturers asserted that the operating characteristics of an infrared (IR)-jet radiant burner are such that it is difficult to maintain a low burner input rate for

[b] DOE defines a cooking top HIR burner as a burner with an input rate greater than or equal to 14,000 British thermal units per hour (Btu/h).

many cooking top functions. They stated that field testing for residential ranges was discontinued because test users were unable to turn down the burner satisfactorily.[1] Without an adequate "turn down" capability, the burner would not be able to be tested to the DOE test procedure at 10 CFR 430, subpart B, appendix I1 or to pass the American National Standards Institute (ANSI) Standard Z21.1-2016, *Household Cooking Gas Appliances*.

Although a silicon carbide radiant burner has been tested to the Japanese Industrial Standard (JIS) S 2103:1996, *Gas burning cooking appliances for domestic use*, it is also not known how either type of radiant burner would perform under DOE test conditions. Since DOE lacks relevant test data to evaluate potential impacts on consumers' health and safety, this technology option was not analyzed for gas cooking tops.

Reduced Excess Air at Burner

For the 1996 *Technical Support Document for Residential Cooking Products* that DOE published in support of the September 8, 1998 final rule ("1996 TSD" [c]), the Gas Research Institute (GRI, now known as the Gas Technology Institute) submitted a report that analyzed this technology option and was submitted as a comment in the previous rulemaking.[2] GRI concluded that the efficiency increase of this technology option was not measurable at that time. They pointed out that the burner described by DOE did not exist on the market and thus there were no designs that could be evaluated. DOE is unaware of any changes to that situation. GRI also noted that use of this technology option may cause a safety issue due to the possibility of increased carbon monoxide production.

Reduced excess air at the burner has not been commercialized, and DOE believes that it would not be practicable to manufacture, install and service this technology on the scale necessary to serve the relevant market at the time of the effective date of an amended standard. Also, because this technology is undeveloped, it is not possible to assess whether it will have any adverse impacts on utility to consumers or product availability, or any adverse impacts on consumers' health or safety.

Reflective Surfaces

Reflective surfaces for gas cooking tops use highly polished or chromed drip pans underneath the burner. The primary mechanism for heat transfer to the cooking vessel for gas cooking tops is convection. As a result, the efficiency gains resulting from using reflective pans are extremely small because gas flames and burners have minimal infrared emissions. Based on data provided by manufacturers through the Association of Home Appliance Manufacturers (AHAM), DOE estimated in the 2009 *Final Rule Technical Support Document: Residential Dishwashers, Dehumidifiers, and Cooking Products and Commercial Clothes Washers* ("2009 TSD")[d] that an efficiency increase of only 0.1 percent was possible. As reported in the 1996 TSD, manufacturers stated that any increase in efficiency due to a reflective surface could easily be negated if the consumer fails to regularly clean the surface or uses an abrasive pad to clean the surface. DOE is not aware of any data on prototypes or commercialized designs that have shown

[c] Available online at www.regulations.gov/document/EERE-2006-STD-0070-0053.
[d] Available online at www.regulations.gov/document/EERE-2006-STD-0127-0097.

a measurable increase in efficiency due to reflective surfaces for gas cooking tops. As a result, DOE screened out this technology option from further analysis.

4.2.1.3 Electric and Gas Ovens

For electric and gas ovens, DOE screened out bi-radiant oven, halogen lamp oven, improved and added insulation, improved door seals, low-standby-loss electronic controls resulting in automatic power-down, no oven-door window, optimized burner and cavity design, reduced vent rate, and reflective surfaces, for the reasons that follow.

Bi-radiant Oven (Electric Ovens 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, the 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 Ovens Only)

DOE is not aware of any ovens that use 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 conventional ovens on the scale necessary to serve the relevant market at the time of the standard's effective date.

Improved and Added Insulation (Standard Ovens Only)

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.

DOE recognizes that the performance associated with *improved* insulation may vary depending on the test procedure. Without a DOE test procedure to determine such performance, DOE believes it would not be practicable to manufacture, install, and service this technology on the scale necessary to serve the market at the time of the effective date of an amended standard. Furthermore, the absence of a DOE test procedure to determine performance produces uncertainty as to whether this technology option would impact product utility or product availability. For these reasons, this technology option was screened out from further analysis.

Improved Door Seals

DOE recognizes that the performance associated with improved door seals may vary depending on the test procedure. Without a DOE test procedure to determine such performance, DOE believes it would not be practicable to manufacture, install, and service this technology on the scale necessary to serve the market at the time of the effective date of an amended standard. Furthermore, the absence of a DOE test procedure to determine performance produces uncertainty as to whether this technology option would impact product utility or product availability. For these reasons, this technology option was screened out from further analysis.

Low-standby-loss Electronic Controls: Automatic Power-Down

DOE is aware that the use of automatic power-down low-standby-loss electronic controls may negatively impact product utility. In particular, the use of automatic power-down low-standby-loss electric controls may result in a loss in the utility of the continuous clock display for ovens and ranges.

However, it should be noted that the *other* low-standby-loss electronic controls such as switch-mode power supplies were still analyzed.

No Oven-Door Window

GRI issued a topical report[3] 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.

Optimized Burner and Cavity Design (Gas Ovens Only)

DOE recognizes that the performance associated with optimized burner and cavity design in gas ovens may vary depending on the test procedure. Without a DOE test procedure to determine such performance, DOE believes it would not be practicable to manufacture, install, and service this technology on the scale necessary to serve the market at the time of the effective date of an amended standard. Furthermore, the absence of a DOE test procedure to determine performance produces uncertainty as to whether this technology option would impact product utility or product availability, in particular the availability of commercial-style ovens. For these reasons, this technology option was screened out from further analysis.

Reduced Vent Rate (Electric Standard Ovens Only)

DOE recognizes that the performance associated with reduced vent rate may vary depending on the test procedure. Without a DOE test procedure to determine such performance, DOE believes it would not be practicable to manufacture, install, and service this technology on the scale necessary to serve the market at the time of the effective date of an amended standard. Furthermore, the absence of a DOE test procedure to determine performance produces uncertainty as to whether this technology option would impact product utility or product availability. For these reasons, this technology option was screened out from further analysis.

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.[4]

GRI[5] 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 12.6 percent decrease in energy efficiency. Arthur D. Little Inc. (ADL)[6] 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 consumer conventional cooking tops and ovens that were retained by DOE and subsequently designated as design options. Each of these technologies were evaluated further in the subsequent engineering analysis.

4.2.2.1 Conventional Cooking Tops

For conventional cooking tops, DOE retained the technologies listed in Table 4.2.1 for further analysis.

Table 4.2.1 Retained Design Options for Conventional Electric and Gas Cooking Tops

Electric Open (Coil) Element Cooking Tops
None
Electric Smooth Element Cooking Tops
1. Induction elements
2. Switch-mode power supply
Gas Cooking Tops
Optimized burner and grate design

4.2.2.2 Conventional Ovens

For conventional ovens, DOE retained the technologies listed in Table 4.2.2 for further analysis.

Table 4.2.2 Retained Design Options for Conventional Electric and Gas Ovens

1. Forced convection
2. Switch-mode power supply
3. Oven separator (electric ovens only)

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3. *Ibid*.

4. *Ibid*.

5. *Ibid*.

6. Arthur D. Little. 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.

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CHAPTER 5. ENGINEERING ANALYSIS

This chapter 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).

5.1 INTRODUCTION

After conducting the screening analysis, the U.S. Department of Energy (DOE) performed an engineering analysis. The purpose of the engineering analysis is to determine the incremental manufacturing cost associated with producing products at higher efficiency levels. The primary considerations in the engineering analysis are the selection of efficiency levels to analyze (*i.e.*, the "efficiency analysis") and the determination of product cost at each efficiency level (i.e., the "cost analysis").

DOE conducts the efficiency analysis using either an efficiency-level approach, a design-option approach, or a combination of both. Under the efficiency-level approach, the efficiency levels to be considered in the analysis are determined based on the market distribution of existing products (in other words, observing the range of efficiency and efficiency level "clusters" that already exist on the market). This approach typically starts with compiling a comprehensive list of products available on the market, such as from DOE's product certification database. Next, the list of models is ranked by efficiency level from lowest to highest, and DOE typically creates a scatter plot to visualize the distribution of efficiency levels. From these rankings and visual plots, efficiency levels can be identified by examining clusters of models around common efficiency levels. The maximum efficiency level currently available on the market can also be identified.

Under the design option approach, the efficiency levels to be considered in the analysis are determined through detailed engineering calculations and/or computer simulations of the efficiency improvements from implementing specific design options that have been identified in the technology assessment. In an iterative fashion, design options can also be identified during product teardowns, described below. The design option approach is typically used when a comprehensive database of certified models is unavailable (for example, if a product is not yet regulated) and therefore the efficiency-level approach cannot be used.

In certain rulemakings, the efficiency-level approach (based on actual products on the market) will be extended using the design option approach to interpolate to define "gap fill" levels (to bridge large gaps between other identified efficiency levels) and/or to extrapolate to the "max tech" level (the level that DOE determines is the maximum achievable efficiency level), particularly in cases where the "max tech" level exceeds the maximum efficiency level currently available on the market.

In this SNOPR, DOE used a design-option approach, supplemented by testing, for the efficiency analysis. The design-option approach is appropriate for consumer conventional cooking products, given the lack of certification data to determine the market distribution of existing products and to identify efficiency level "clusters" that already exist on the market.

The cost analysis portion of the engineering analysis is conducted using one or a combination of cost approaches. The selection of the cost approach depends on a variety of factors such as the availability and reliability of public information on product features and pricing, the physical characteristics of the regulated product, and the practicability of purchasing the product on the market. DOE generally uses the following cost approaches:

- Physical teardown: Under this approach, DOE physically dismantles a commercially available product, component-by-component, to develop a detailed bill of materials (BOM) for the product.

- Catalog teardown: In lieu of physically deconstructing a product, DOE identifies each component using parts diagrams (available from manufacturer websites or appliance repair websites, for example) to develop the BOM for the product.

- Price surveys: If neither a physical nor catalog teardown is feasible (for example, for tightly integrated products that are infeasible to disassemble and for which parts diagrams are unavailable), DOE conducts retail price surveys by scanning retailer websites and other marketing materials. This approach must be coupled with assumptions regarding distributor markups and retailer markups in order to estimate the actual manufacturing cost of the product.

The primary inputs to the engineering analysis are baseline information from the market and technology assessment (chapter 3 of this supplemental notice of proposed rulemaking (SNOPR) technical support document (TSD)) and design options from the screening analysis (chapter 4). Additional inputs were determined through teardown analysis and manufacturer interviews.

In this SNOPR, DOE used the physical teardown approach, supplemented by catalog teardowns specifically for printed circuit boards (PCBs), to develop the cost-efficiency data. In addition, DOE considered 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 final rule.[a]

The primary output of the engineering analysis is a set of tables identifying the incremental manufacturing cost, in relation to the manufacturing cost of the minimum-efficiency baseline product, required to produce products at each of the higher efficiency levels considered in the analysis (visualized as "cost-efficiency curves"). In the subsequent markups analysis (chapter 6 of this SNOPR TSD), DOE determined customer (*i.e.*, product purchaser) prices by applying manufacturer markups (determined in the manufacturer impact analysis (chapter 12 of this SNOPR TSD)), distribution markups, and sales tax. After applying these markups, the cost-

[a] Available online at www.regulations.gov/document/EERE-2006-STD-0127-0097.

efficiency curves serve as the input to the building energy-use and end-use load characterization (chapter 7 of this SNOPR TSD), and the life-cycle cost (LCC) and payback period (PBP) analyses (chapter 8 of this SNOPR TSD).

5.2 PRODUCT CLASSES ANALYZED

When evaluating energy conservation standards, DOE may establish separate standards for a group of covered products (*i.e.*, establish a separate product class) if DOE determines that separate standards are justified based on the type of energy used, or if DOE determines that a product's capacity or other performance-related feature justifies a different standard. (42 U.S.C. 6295(q)(1)(A) and (B)) In making a determination whether a performance-related feature justifies a different standard, DOE must consider factors such as the utility to the consumer of the feature and other factors DOE determines are appropriate. (42 U.S.C. 6295(q)(1))

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

For electric cooking tops, DOE analyzed the following product classes:

- Open (coil) elements; and
- Smooth elements.

As discussed in chapter 3 of this SNOPR TSD, DOE has initially determined that induction cooking provides the same basic function of cooking or heating food as electric resistance heating. Therefore, DOE did not define it as a separate product class.

For gas cooking tops, DOE analyzed a single product class.

As discussed in chapter 3 of this SNOPR TSD, there was no statistically significant correlation between burner input rate and the ratio of cooking zone[b] energy consumption to test load mass for cooking products marketed either as residential-style or commercial-style. DOE's testing, as presented in section 5.5.3 shows that cooking efficiency for gas cooking tops was more closely related to burner and grate design rather than input rate. In addition, DOE is not aware of clearly defined, consistent design differences and corresponding utility provided by commercial-style gas cooking tops as compared to residential-style gas cooking tops. Thus, DOE did not evaluate a separate product class for consumer conventional gas cooking tops with higher burner input rates or for those marketed as commercial-style.

DOE published a test procedure final rule on August 22, 2022 ("August 2022 TP Final Rule"), establishing the DOE test procedure at title 10 of the Code of Federal Regulations (CFR) part 430, subpart B, appendix I1 ("Appendix I1"). 87 FR 51492. DOE conducted the analysis for

[b] The term cooking zone refers to burners for gas cooking tops and electric resistance heating elements or inductive heating elements for electric cooking tops.

electric and gas cooking top standards for this SNOPR using the test procedure at Appendix I1 that was adopted in the August 2022 TP Final Rule.

For electric ovens, as discussed in previous rulemakings, DOE determined that the type of oven-cleaning system is a utility feature that affects performance. 73 FR 62034, 62048. DOE also considered separately for the purpose of this rulemaking, built-in and slide-in ovens based on the presence of 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 of this SNOPR TSD. DOE analyzed the following potential 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-clean oven; and
- Built-in/slide-in self-clean oven.

For gas ovens, DOE analyzed the following potential 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-clean oven; and
- Built-in/slide-in self-clean oven.

As discussed in chapter 3 of this SNOPR TSD, DOE recognizes that commercial-style conventional ovens typically incorporate certain features that may be expected by purchasers of such products (*e.g.*, heavier-gauge cavity construction, high input rate burners, and extension racks). DOE also recognizes that these features result in inherently lower efficiencies for commercial-style ovens than for residential-style ovens with comparable cavities sizes, due to the greater thermal mass of the cavity and racks. However, DOE is not aware of an industry test standard that evaluates cooking performance and that would quantify the utility provided by these products. In addition, DOE is not aware of a clearly defined and consistent design difference and corresponding utility provided by commercial-style ovens as compared to residential-style ovens. For these reasons, DOE did not evaluate a separate product class for commercial-style ovens.

DOE conducted the analysis for electric and gas oven standards for this SNOPR using the test procedure finalized in a test procedure final rule published July 2, 2015 ("July 2015 TP Final Rule").[c] 80 FR 37954.

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

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[c] DOE subsequently withdrew the conventional oven testing provisions in the final rule published on December 16, 2016. 81 FR 91418.

Table 5.2.1 Product Classes for Consumer Conventional Cooking Products

Product Class	Product Type	Sub-Category	Installation Type
1	Electric cooking top	Open (coil) elements	-
2		Smooth elements	-
3	Gas cooking top	-	-
4	Electric oven	Standard with or without a catalytic line	Freestanding
5			Built-in/Slide-in
6		Self-clean	Freestanding
7			Built-in/Slide-in
8	Gas oven	Standard with or without a catalytic line	Freestanding
9			Built-in/Slide-in
10		Self-clean	Freestanding
11			Built-in/Slide-in

5.3 EFFICIENCY LEVELS

5.3.1 Conventional Cooking Tops

5.3.1.1 Baseline Efficiency Levels

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

There are no current Federal energy conservation standards for electric cooking tops. For gas cooking tops, the current Federal energy conservation standards are prescriptive standards that require gas cooking tops not to be equipped with constant burning pilots. For this SNOPR, DOE developed performance-based baseline efficiency levels for conventional cooking tops using the measured cooking top integrated annual energy consumption (IAEC) of units in the DOE test sample, based on the water heating test procedure adopted in the August 2022 TP Final Rule (see section 5.5.3.1).

The baseline cooking top efficiency levels for this SNOPR differ from those presented in previous documents in this rulemaking. As discussed, the conventional cooking top efficiency levels for this SNOPR were determined using the test procedure finalized in the August 2022 TP Final Rule, whereas the analysis published in the notification of proposed determination published on December 14, 2020 ("December 2020 NOPD") was based on the test method adopted in the test procedure final rule published on December 16, 2016 ("December 2016 TP Final Rule"). Significantly, as part of the August 2022 TP Final Rule, DOE defined IAEC using an average of 418 cooking top cycles per year to represent consumer cooking frequency, as determined using data from the 2015 Residential Energy Consumption Survey (RECS). By comparison, the December 2016 TP Final Rule used values of 207.5 and 214.5 cooking top cycles per year for electric and gas cooking tops, respectively, based on the 2009 RECS. Primarily due to the updated number of cooking top cycles per year (along with some other minor changes to the test procedure), the baseline IAEC values calculated using the test method finalized in the August 2022 TP Final Rule are higher than the baseline IAEC values presented in the December 2020 NOPD.[d]

To establish the new baseline IAEC for conventional cooking tops, DOE set the baseline cooking top IAEC equal to the sum of the maximum cooking top annual active mode energy consumption (AEC) observed in the dataset for the analyzed product class and the maximum annual combined low-power mode energy consumption (E_{TLP}) observed in the dataset for the analyzed product class. This approach is consistent with the design-option approach used to determine the incremental efficiency levels, as discussed further in section 5.3.1.1. The conventional cooking top baseline efficiency levels for this SNOPR, expressed in kilowatt-hours (kWh) per year (kWh/year) for electric cooking tops and thousand British thermal units (kBtu) per year (kBtu/year), are presented in Table 5.3.1.

Table 5.3.1 Conventional Cooking Top Baseline Efficiency Levels

Product Class	IAEC
Electric Cooking Tops – Open (Coil) Elements	199 kWh/year
Electric Cooking Tops – Smooth Elements	250 kWh/year
Gas Cooking Tops	1,775 kBtu/year

DOE notes that the efficiency levels for gas cooking tops evaluated in this SNOPR would replace the current prescriptive standards for gas cooking tops, which prohibit the use of a constant burning pilot light. As such, DOE's proposed standards for gas cooking tops would be only performance standards. DOE further notes that constant burning pilot lights consume approximately 2,000 kBtu/year and even the baseline analyzed efficiency level of 1,775 kBtu per year for gas cooking tops would not be achievable by products if they were to incorporate a constant burning pilot.

5.3.1.2 Incremental Efficiency Levels

As part of its analysis, DOE establishes incremental efficiency levels (ELs) to evaluate the range of efficiencies available on the market. DOE must also determine the maximum improvement in energy efficiency that is technologically feasible ("max-tech") for each product class. (42 U.S.C. 6295(p)(1)) DOE typically determines max-tech levels based on technologies that are either commercially available or have been demonstrated as working prototypes. DOE also considers consumer utility and availability of features, which may be met by a niche product. If the max-tech design meets DOE's screening criteria, DOE considers the design in further analysis. For this SNOPR analysis, DOE identified design options and determined corresponding incremental efficiency levels during the testing and reverse engineering performed in support of this rulemaking.

[d] See chapter 3 of this SNOPR TSD for a more complete discussion of the differences between the two test procedures.

Electric Cooking Tops

For the electric open (coil) element cooking top product class, DOE did not identify any design options for reducing IAEC and as a result, DOE did not consider any higher efficiency levels above the baseline.

For electric smooth element cooking tops, DOE measured the AEC of each cooking top in its test sample. Figure 5.3.1 shows the measured AEC of all electric smooth element cooking tops in the test sample.

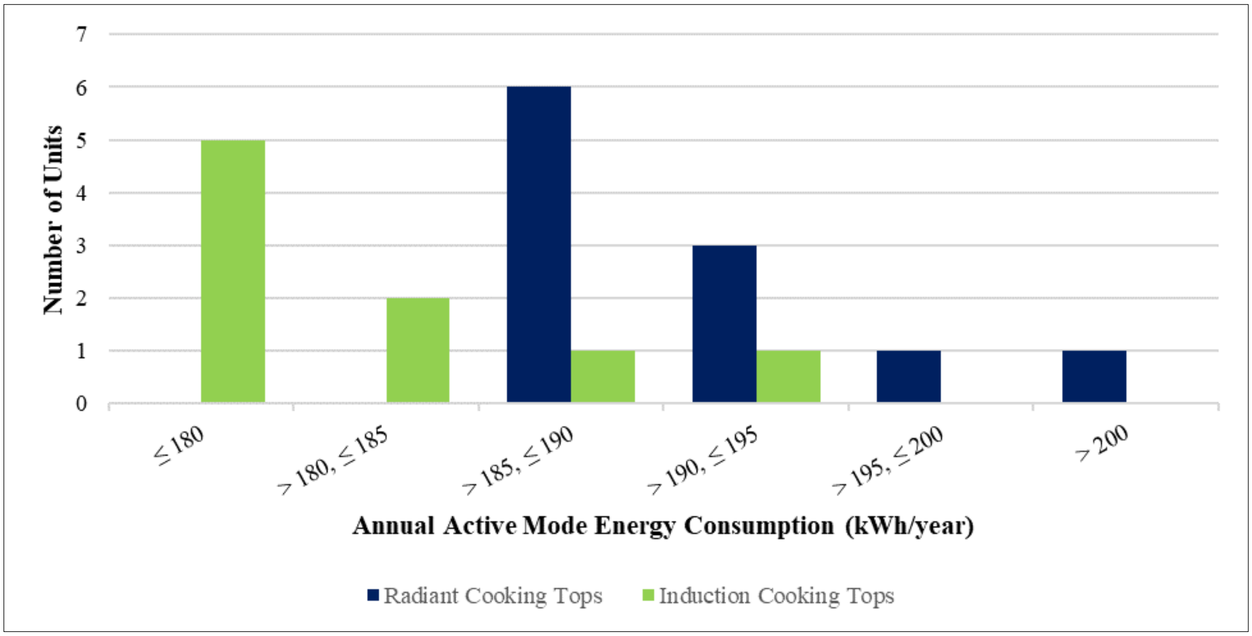

Figure 5.3.1 Annual Active Mode Energy Consumption Distribution of Electric Smooth Element Cooking Tops in DOE's Test Sample

DOE also measured the E_{TLP} of the electric smooth element cooking tops in its test sample and evaluated the efficiency levels associated with standby power improvements based on product testing. The results of this testing are presented in section 5.5.3.2.

DOE reviewed the AEC and E_{TLP} values for the electric smooth element cooking tops in its test sample and identified three higher efficiency levels as discussed further in the following paragraphs.

DOE defined EL 1 for electric smooth element cooking tops based on the low-standby-loss electronic controls design option. As discussed in section 5.3.1.1, DOE defined the baseline efficiency assuming the highest AEC would be paired with the highest E_{TLP} observed in its test sample. DOE is aware of many methods employed by manufacturers to achieve lower E_{TLP}, including by changing from a linear power supply to a switch-mode power supply (SMPS), by dimming the control screen's default brightness, by allowing the clock functionality to turn off after a period of inactivity, and by removing the clock from the cooking top altogether. DOE defined EL 1 using the lowest measured E_{TLP} among the units in its test sample with clock functionality, paired with the baseline AEC.

DOE defined EL 2 for electric smooth element cooking tops using the lowest measured AEC (highest efficiency) among radiant cooking tops in its sample and the same E_{TLP} as EL 1. As shown in Figure 5.3.1, this AEC value can also be reached by units using induction technology.

To determine the highest measured efficiency for electric smooth element cooking tops (EL 3), DOE calculated the sum of the lowest measured AEC in its test sample of electric smooth element cooking tops, which represented induction technology, and the same E_{TLP} as EL 1.

Gas Cooking Tops

For gas cooking tops, DOE measured the AEC of each cooking top in its test sample. Figure 5.3.2 shows the measured AEC of all gas cooking tops in the test sample.

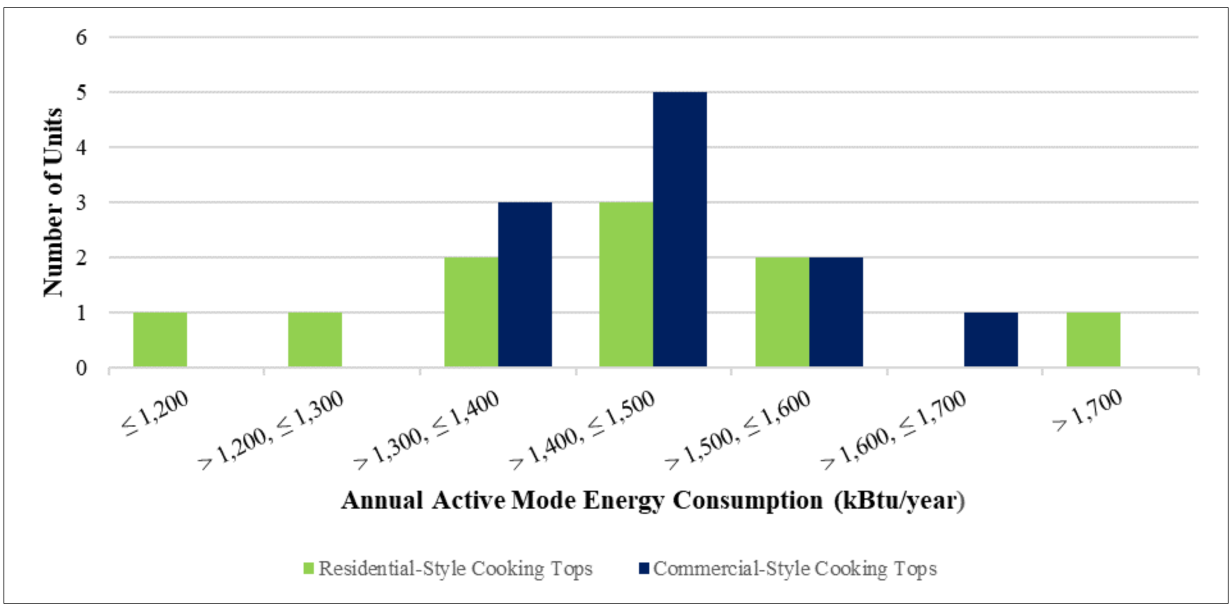

Figure 5.3.2 Annual Active Mode Energy Consumption Distribution of Gas Cooking Tops in DOE's Test Sample

For gas cooking tops, DOE's analysis for the 2009 standards rulemaking considered sealed burner as a design option for improving efficiency. Based on DOE's testing of both sealed and open burners conducted for this rulemaking, presented in section 5.5.3.2, DOE observed that neither burner type clearly performed better or worse than the other. As a result, DOE did not consider an efficiency level associated with sealed burners for conventional gas cooking tops for this SNOPR.

For this SNOPR, DOE considered efficiency levels associated with optimized burner and grate design. DOE only considered optimized burner and grate design insofar as the technology option was not screened out in chapter 4 of this SNOPR TSD. DOE's testing, as presented in section 5.5.3, showed that energy use was correlated to burner design and cooking top configuration (*e.g.*, grate weight, flame angle, distance from burner ports to the cooking surface) and could be reduced by optimizing the design of the burner and grate system. DOE reviewed the test data for the gas cooking tops in its test sample and identified two efficiency levels associated with improving the burner and grate design that corresponded to different design criteria, as detailed in Table 5.3.4. DOE defined EL 1 and EL 2 for gas cooking tops using the same E_{TLP} as used for the baseline efficiency level.

DOE is aware that some methods used by gas cooking top manufacturers to achieve lower AEC can result in a smaller number of high input rate burners ("HIR burners").[e] HIR burners provide unique consumer utility and allow consumers to perform high heat cooking activities such as searing and stir-frying. DOE is also aware that some consumers derive utility from continuous cast-iron grates, such as the ability to use heavy pans, or to shift cookware between burners without needing to lift them. As discussed in chapter 4 of this SNOPR TSD, DOE has screened out any efficiency levels that would result in the lack of continuous cast-iron grates or no HIR burners and has defined the efficiency levels for gas cooking tops such that all efficiency levels are achievable with continuous cast-iron grates and at least one HIR burner.

Analyzed Efficiency Levels

As discussed, DOE established efficiency levels for electric smooth element cooking tops and gas cooking tops based on combining an AEC value and an E_{TLP} value associated with specific design options. However, DOE notes that different combinations of AEC and E_{TLP} could be used to meet the IAEC of a given efficiency level.

Table 5.3.2 through Table 5.3.4 show the efficiency levels for each conventional cooking top product class that DOE evaluated for this SNOPR.

Table 5.3.2 Electric Open (Coil) Element Cooking Top Efficiency Levels

Level	**IAEC** (*kWh/year*)
Baseline	199

Table 5.3.3 Electric Smooth Element Cooking Top Efficiency Levels

Level	**Design Options**	**IAEC** (*kWh/year*)
Baseline	Baseline	250
1	Baseline + Low-Standby-Loss Electronic Controls	207
2	1 + Improved Resistance Heating Elements	189
3	1 + Highest Active-mode Efficiency (Induction)	179

[e] DOE defines a cooking top HIR burner as a burner with an input rate greater than or equal to 14,000 British thermal units per hour ("Btu/h").

Table 5.3.4 Gas Cooking Top Efficiency Levels

Level	Design Options	IAEC (*kBtu/year*)
Baseline	Baseline	1,775
1	Baseline + Optimized Burner/Improved Grates (Achievable with 4 or more HIR burners and continuous cast-iron grates)	1,440
2	Highest Measured Efficiency	1,204

5.3.2 Conventional Ovens

5.3.2.1 Potential Prescriptive Standards

There are currently no Federal energy conservation standards for electric ovens. For gas ovens, the current Federal energy conservation standards are prescriptive standards that require gas ovens not to be equipped with constant burning pilots. For this SNOPR, DOE considered only efficiency levels corresponding to prescriptive design requirements as defined by the design options developed as part of the screening analysis (see chapter 4 of this SNOPR TSD): forced convection, the use of a switch-mode power supply, and (for electric ovens) an oven separator.

DOE ordered the design options by ease of implementation. Table 5.3.5 and Table 5.3.6 define the efficiency levels analyzed in this SNOPR for conventional electric and gas ovens, respectively.

Table 5.3.5 Conventional Electric Oven Efficiency Levels

Level	Design Option
Baseline	Baseline
1	Baseline + SMPS
2	1 + Forced Convection
3	2 + Oven Separator

Table 5.3.6 Conventional Gas Oven Efficiency Levels

Level	Design Option
Baseline	Baseline
1	Baseline + SMPS
2	1 + Forced Convection

Note: All efficiency levels for conventional gas ovens include the current prescriptive requirement prohibiting the use of a constant burning pilot light.

5.3.2.2 Energy Consumption of Baseline Efficiency Level

For this SNOPR, DOE compared the minimum cooking efficiency measured in its test sample to the baseline cooking efficiency levels presented in the 2009 standards rulemaking analysis. DOE also conducted testing for conventional ovens according to the version of the test procedure adopted in the July 2015 TP Final Rule. 80 FR 33030, 33048–33049. Although DOE repealed the conventional oven test procedure in Appendix I as part of the December 2016 TP Final Rule, DOE based its analyses for this SNOPR on the data measured using the previous version of the test procedure. For each conventional oven in its test sample, DOE calculated the oven annual active cooking mode energy consumption (E_{AO})[f] and the oven integrated annual energy consumption (IE_{AO})[g] using the test procedure finalized in the July 2015 TP Final Rule. The IE_{AO} metric combines the energy use of active cooking mode (including any self-cleaning operation), any fan-only mode, and combined low-power mode (including standby mode and off mode). DOE set the baseline IE_{AO} for conventional ovens equal to the sum of:

- the maximum E_{AO} measured in the test sample for each conventional oven product class,
- the maximum E_{TLP} measured in the entire test sample among conventional ranges equipped with baseline (linear) power supplies, and,
- for the built-in/slide-in product classes, the maximum fan-only mode annual energy consumption measured in the entire test sample.

DOE notes that the energy consumption of a conventional oven depends on the oven cavity volume (see section 5.5.1.4 and section 5.5.4). In the 2009 rulemaking analysis, DOE determined that there was a linear relationship between energy factor (EF) and cavity volume. To correlate IE_{AO}, which combines active mode and combined low-power mode energy consumption, with cavity volume, DOE translated EF to IE_{AO} using the slopes from the 2009 rulemaking and the baseline E_{TLP} in DOE's current test sample.

To expand the number of electric standard oven data points in its analysis of baseline efficiency levels, DOE "augmented" its test sample by subtracting the self-cleaning energy consumption from these electric self-clean ovens' IE_{AO}.

[f] The test procedure finalized in the July 2015 TP Final Rule referred to the annual active cooking mode energy consumption of an electric oven using the abbreviation E_{AO}. However, this test procedure did not provide a single abbreviation for the annual active cooking mode energy consumption of a gas oven: the primary (gas) energy was designated as E_{AOG} and the secondary (electric) energy was designated as E_{AOE}. This SNOPR analysis defines E_{AO} for gas ovens as the sum of E_{AOG} and E_{AOE}, which is comparable to E_{AO} for electric ovens.

[g] Similar to above, the test procedure finalized in the July 2015 TP Final Rule referred to the integrated annual energy consumption of an electric oven using the abbreviation IE_{AO}. However, this test procedure did not provide a single abbreviation for the integrated annual energy consumption of a gas oven: the primary (gas) energy was designated as E_{AOG} (there is no difference between the primary active cooking mode energy consumption and primary integrated energy consumption of a gas cooking top because fan-only mode and combined-low-power mode do not consume any gas) and the secondary (electric) energy was designated as IE_{AOE}. This SNOPR analysis defines IE_{AO} for gas ovens as the sum of E_{AOG} and IE_{AOE}, which is comparable to the value IE_{AO} for electric ovens.

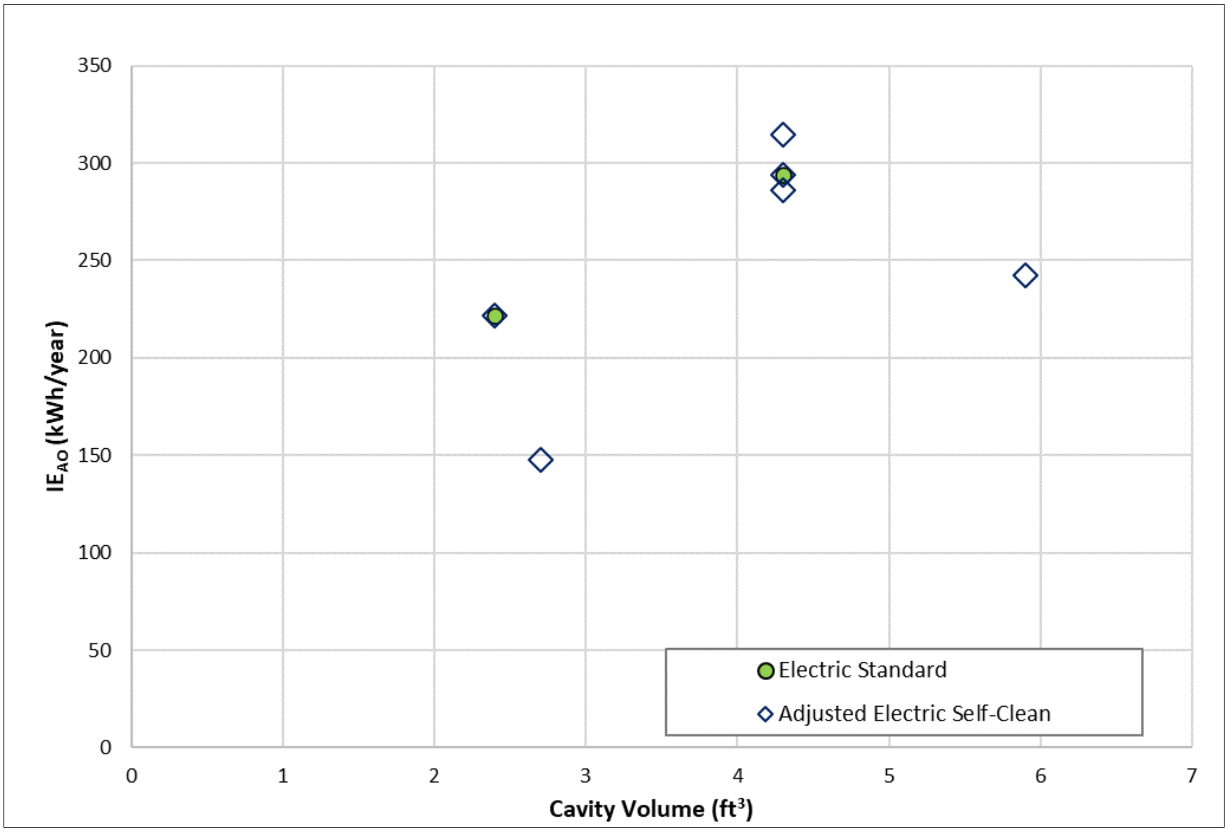

Figure 5.3.3 Augmented Electric Standard Oven Data from the DOE Test Sample

Augmenting the electric standard oven dataset with self-clean models in the DOE test sample allowed DOE to include a wider range of cavity volumes in its baseline efficiency analysis, as shown in Figure 5.3.3.

For each product class, DOE compared its augmented test sample baseline to the baseline values from the 2009 TSD. For multiple product classes, the lowest measured conventional oven efficiency in DOE's test sample was lower (less efficient) than the values for the previous rulemaking. In those cases, DOE selected y-intercepts for the baseline efficiency levels corresponding to the conventional ovens in the current test sample with the highest measured IE_{AO}, so that no conventional ovens in the test sample were cut off by the baseline curve. For self-clean gas ovens, DOE selected the y-intercept of the best fit line corresponding to the baseline evaluated in the 2009 TSD.

Compared to the values used in the December 2020 NOPD, for this SNOPR, DOE expanded its sample size of conventional ovens and ranges which were used to determine the baseline E_{TLP} value. DOE also rectified a formula error which was incorrectly allocating the number of hours in fan-only mode. These small changes resulted in slightly updated estimated energy consumption representing the baseline efficiency levels.

The estimated energy use of the baseline efficiency levels for conventional ovens are presented in Table 5.3.7. After receiving manufacturer feedback and reviewing products currently on the market, DOE determined the energy consumption of the baseline efficiency levels based on a conventional oven with a cavity volume of 4.3 ft^3 to represent the market-average cavity volume.

Table 5.3.7 Estimated Energy Consumption of Baseline Conventional Ovens

Product Class	Sub Type	IE_{AO}*
Electric Oven – Standard Oven with or without a Catalytic Line	Freestanding	314.7 kWh/year
	Built-in/Slide-in	321.2 kWh/year
Electric Oven – Self-Clean Oven	Freestanding	354.4 kWh/year
	Built-in/Slide-in	360.5 kWh/year
Gas Oven – Standard Oven with or without a Catalytic Line	Freestanding	2,085 kBtu/year
	Built-in/Slide-in	2,104 kBtu/year
Gas Oven – Self-Clean Oven	Freestanding	1,958 kBtu/year
	Built-in/Slide-in	1,979 kBtu/year

* IE_{AO} values are normalized based on a 4.3 ft^3 cavity volume.

5.3.2.3 Energy Consumption of Incremental Efficiency Levels

DOE developed incremental efficiency levels for each conventional oven product class based on test data collected according to the earlier version of the conventional oven test procedure established in the July 2015 TP Final Rule. DOE developed the incremental efficiency levels in cases where DOE identified design options during testing and reverse engineering performed in support of this analysis.

Specifically, DOE evaluated EL 1, the efficiency level associated with combined low-power mode power improvements for conventional ovens based on product testing and reverse engineering. To determine standby mode and off mode power levels, DOE measured the standby mode and off mode power consumption of the standalone ovens and combined cooking products in its test sample. The results are presented in section 5.5.3. As discussed in section 5.3.2.2, DOE selected the baseline E_{TLP} for conventional ovens based on the highest measured combined low-power mode power consumption in DOE's test sample among conventional ranges equipped with a linear power supply. DOE determined the reduction in combined low-power mode power associated with changing from a linear power supply to an SMPS using the lowest measured combined low-power mode power consumption among conventional convection ranges, to maintain the full functionality of controls.

DOE included in its analysis EL 2, an efficiency level for both electric and gas ovens based on test data from units in the test sample equipped with forced convection. For each conventional oven equipped with forced convection, DOE averaged the energy consumption both with and without the convection mode enabled as required by the test procedure finalized in the July 2015 TP Final Rule. In the TSD accompanying the December 2020 NOPD, DOE had determined the efficiency improvement for a forced-convection design option to be an adder to EF (which includes any self-cleaning operations). In this SNOPR TSD, DOE updated its analysis with the understanding that the use of forced convection would impact only active cooking mode energy, excluding self-clean mode. The resulting relative decrease in E_{AO} was 4.4% for electric standard ovens and 6.6% for gas standard ovens at the representative cavity volume of 4.3 ft^3. These percentages of E_{AO} at that representative volume correspond to incremental E_{AO} values of 13.0 kWh/year for electric standard ovens and 133 kBtu/year for gas standard ovens. In this

SNOPR TSD, DOE used these values to calculate the energy savings of the forced convection design option at the IE_{AO} level for each product class, assuming the same incremental E_{AO} between EL 1 and EL 2 for both standard and self-clean product classes.

Using a similar analysis, DOE developed an efficiency level, EL 3, 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 energy consumption of the conventional oven when measured without the separator and then measured with the separator according to the earlier version of the conventional oven test procedure established in the July 2015 TP Final Rule. Noting that the existence of an oven separator would affect only the E_{AO} of a standard oven, DOE calculated the percent decrease in E_{AO} as a result of using the oven separator. DOE calculated the efficiency level for an oven separator in electric standard ovens by first applying this percent decrease to the E_{AO} of EL 2, and then adding the E_{TLP} to determine the IE_{AO} of a freestanding oven. To develop the energy savings estimates for the self-clean product classes, DOE assumed the same incremental E_{AO} energy use between EL 2 and EL 3 for both standard and self-clean product classes at 4.3 ft^3.

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 have a fan that consumes energy in fan-only mode, whereas freestanding ovens do not have such a fan. The energy consumption in fan-only mode for built-in and slide-in ovens ranges from 1 watt-hour (Wh) to 32 Wh per fan-only cycle, which can extend from 4.5 to 69 minutes after the cooking cycle ends. For this SNOPR, DOE estimated the maximum fan-only mode energy using 32 Wh and 69 minutes. As discussed in section 5.3.2.2, DOE developed separate baseline IE_{AO} values for each installation configuration. DOE estimated the relative decrease in IE_{AO} for each incremental efficiency level to be constant across installation configuration since fan-only mode energy consumption is independent of the design options retained for this analysis.

Table 5.3.8 and Table 5.3.9 show the efficiency levels for each conventional oven product class analyzed in this SNOPR. The IE_{AO} values for each efficiency level are normalized based on an oven cavity volume of 4.3 ft^3.

Table 5.3.8 Estimated Energy Consumption of Electric Oven Efficiency Levels

Level	Design Option	IE_{AO} (*kWh/year*)			
		Standard Freestanding	Standard Built-in / Slide-in	Self-Clean Freestanding	Self-Clean Built-in / Slide-in
Baseline	Baseline	314.7	321.2	354.4	360.5
1	Baseline + SMPS	302.0	308.9	341.7	348.1
2	1 + Forced Convection	289.0	295.9	328.7	335.1
3	2 + Oven Separator	235.3	242.1	275.0	281.4

Table 5.3.9 Estimated Energy Consumption of Gas Oven Efficiency Levels

Level	Design Option	IE_{AO} (*kBtu/year*)			
		Standard Freestanding	Standard Built-in / Slide-in	Self-Clean Freestanding	Self-Clean Built-in / Slide-in
Baseline	Baseline	2,085	2,104	1,958	1,979
1	Baseline + SMPS	2,041	2,062	1,915	1,937
2	1 + Forced Convection	1,908	1,929	1,781	1,804

5.4 METHODOLOGY OVERVIEW

DOE relied on multiple sources of information for this engineering analysis, including 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 consumer conventional cooking products. These previous rulemaking TSDs served as a source for design options and energy consumption analysis, in addition to other sources. For consumer conventional cooking products, 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 consumer conventional cooking product efficiency, and their associated manufacturing costs. DOE conducted interviews throughout this rulemaking, most recently after the publication of the December 2020 NOPD and the August 2022 TP Final Rule.

During the interviews, DOE also gathered information about the capital expenditures required to implement different design options at different efficiency levels. 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 this SNOPR TSD includes a discussion of this information obtained during manufacturer interviews.

5.4.3 Selection of Units

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

- The selected products should span the full range of efficiency levels for each product class under consideration;
- 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.

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.

5.4.4 Product Testing

DOE conducted testing using the conventional cooking top test procedure adopted in the August 2022 TP Final Rule to develop a better understanding of the design options and product features currently available on the market. The testing also allowed DOE to characterize the distribution of product energy consumption in the marketplace.

Because there is currently no test procedure in place for conventional ovens, most manufacturers of conventional ovens do not have energy consumption data to share with DOE. Therefore, DOE conducted its own investigative using the earlier version of the conventional oven test procedure adopted in the July 2015 TP Final Rule to develop a better understanding of the impact of the design options available on the market.

5.4.5 Product Teardowns

As noted, DOE used the physical teardown approach, supplemented by catalog teardown of PCBs for this SNOPR.

The teardown method provides key information that is difficult to obtain from the other cost analysis approaches and that can be critical to the quality of the engineering analysis. In conducting a teardown, DOE physically disassembles a commercially available product, component-by-component, to develop a structured BOM that estimates the costs of raw materials, machining processes, purchased parts, capital depreciation, and factory overhead costs at an assumed production volume. The teardown approach allows for the unbundling of non-efficiency related features that are often bundled with higher efficiency technologies and subsequently contribute to the higher retail price of higher-efficiency models. The teardown approach also reveals different design paths used by different manufacturers, and enables DOE to estimate manufacturer investments required to achieve each higher efficiency level. The teardown approach is time-intensive, and unit selection is critical to ensure an industry-representative cost curve. Periodically, DOE invites manufacturers to review the results in detail and verifies the manufacturing parameters/processes via site visits to production facilities.

A supplementary method to a physical teardown, called a catalog teardown or virtual 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. In a catalog teardown, DOE references public information to estimate manufacturing costs. Usually, these estimates leverage prior product teardowns, allowing the analysis to capture a broader range of capacities and other features within a product family. Using product teardown data as a foundation, DOE can model the costs associated with higher-efficiency models through parametric scaling, part substitutions, *etc.*, to capture relevant product parameters. In some instances, the incremental cost of well-defined equipment may also be characterized with a catalog teardown alone. This method is best suited for product categories where features are well-documented, with "mature" or commoditized designs, and where efficiency-related design are physically scalable. This approach allows a wide variety of capacities and features to be covered.

The teardown methodology is further explained in the following sections.

5.4.5.1 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—which require conversion steps to be made ready for assembly—and purchased parts, which 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 past 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.*, 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 past discussions with manufacturers, quotes from suppliers, and secondary research. DOE regularly updates historical data to present-day prices using indices from resources such as MEPS Intl.,[h] PolymerUpdate,[i] the U.S. geologic survey (USGS),[j] and the Bureau of Labor Statistics (BLS).[k]

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[h] For more information on MEPS Intl, please visit: www.meps.co.uk/.
[i] For more information on PolymerUpdate, please visit: www.polymerupdate.com.
[j] For more information on the USGS metal price statistics, please visit: www.usgs.gov/centers/nmic/commodity-statistics-and-information.
[k] For more information on the BLS producer price indices, please visit: www.bls.gov/ppi/.

5.4.5.2 Cost Structure of the Spreadsheet Models

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

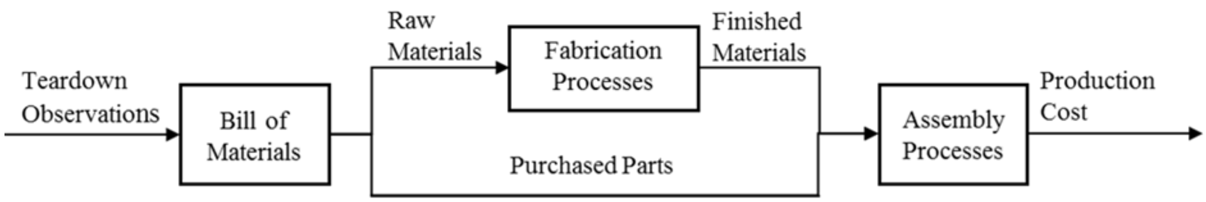

Figure 5.4.1 Manufacturing Cost Assessment Stages

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 are dismantled, and each part is 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 are based on industry experience and past discussions with manufacturers.

Following the development of a detailed BOM, the major manufacturing processes are 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 are estimated and entered into the BOM. Based on estimated assembly and fabrication time requirements, the labor content of each teardown unit are estimated based on typical annual wages and benefits of industry employees.

Cycle requirements for fabrication steps are similarly aggregated by fabrication machine type while accounting for dedicated versus non-dedicated machinery and/or change-over times (*e.g.*, die swaps in a press). Once the cost estimate for each teardown unit is finalized, a detailed summary is 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.

5.4.5.3 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, supervisor, and indirect 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. The equipment, tooling, and building depreciation costs are modeled as a "green-field" site; *i.e.*, a new manufacturing plant with all new equipment.

DOE defines the above terms as follows:

- Direct material: Purchased parts (outsourced) plus manufactured parts (made in-house from raw materials).
- Indirect material: Material used during manufacturing (*e.g.*, welding rods, adhesives).
- Fabrication labor: Labor associated with in-house piece manufacturing.
- Assembly labor: Labor associated with final assembly.
- Supervisory labor: Labor associated with fabrication and assembly basis. Assigned on a span basis (× 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.

5.4.5.4 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 reconstructs manufacturing processes for each component using internal expertise and knowledge of the methods used by the industry. DOE regularly confirms its cost model assumptions through various sources such as manufacturer interviews and reviews of current BLS data.

5.5 ANALYSIS AND RESULTS

5.5.1 Manufacturer Interviews

DOE conducted interviews with conventional oven manufacturers to develop a better understanding of current product features and the technologies used to improve energy efficiency. The interviewed manufacturers 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
- Incremental efficiency levels and design options
- Oven energy consumption as a function of cavity volume
- Impacts on consumer utility
- Installation and repair costs as a function of efficiency

Following the December 2020 NOPD and the August 2022 TP Final Rule, DOE conducted further conversations with manufacturers, during which the following topics related to the engineering analysis were discussed:

- Product classes
- Power supplies
- Variability of test procedure results
- Carbon monoxide emission limits

The discussions helped DOE understand what design options have already been implemented and what additional design options DOE should consider. The following sections summarize the manufacturer responses.

5.5.1.1 Product Classes

DOE asked manufacturers if there are additional product classes that should be considered. Some manufacturers commented that induction cooking tops should be analyzed in a separate product class because the method of cooking differs from electric resistance and because induction requires the use of ferromagnetic cookware.

DOE also discussed with manufacturers during both the initial round of interviews and the interviews following the August 2022 TP Final Rule whether separate product classes are warranted for gas cooking products with higher burner input rates, including products marketed as commercial-style. Some manufacturers indicated that the major difference between commercial-style and residential-style cooking products is consumer-driven aesthetics and not performance. However, other manufacturers stated that commercial-style cooking products offer consumers improved cooking performance. Specifically, manufacturers stated that commercial-style cooking products can cook larger loads faster and more evenly than residential-style cooking products. Manufacturers also stated that commercial-style cooking products have consumer-driven features such as heavy-duty construction that differentiate the products in the marketplace and that consumers have come to associate with product quality. Manufacturers also asserted the safety benefits of continuous cast-iron grates, which are present on all commercial-style cooking tops and many residential-style cooking tops, stating that this type of grate mitigates the tipping risk of small cooking vessels placed off-center from burners or large cooking vessels that are slid to different locations on the cooking top.

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 and during the previous stages of the current 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 did not test their conventional cooking products according to the current DOE test procedure and thus had limited or no data to help support a baseline estimate.

5.5.1.3 Incremental Efficiency Levels and Design Options

DOE asked manufacturers to comment on the incremental efficiency levels presented in previous stages of the current rulemaking, including the December 2020 NOPD. In general, manufacturers were not able to provide feedback on the 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. Some manufacturers indicated that improved contact conductance as a design option for electric open (coil) element cooking tops may not be feasible because manufacturers do not have control over whether or not the cookware used by the consumer is flat. The base of the cookware may undergo warping with use over time. Manufacturers also commented that electric open (coil) element cooking tops have already been optimized to reduce time-to-boil, which is correlated with increased efficiency, indicating that no additional levels are available beyond the baseline. Manufacturers also commented that for electric smooth element cooking tops, halogen lamp elements did not offer an improvement because they could not reach high enough temperatures to heat certain types of food.

Regarding gas cooking tops, manufacturers stated that sealed burners already represent the majority of the U.S. market. Additionally, manufacturers stated that sealed burners are not necessarily more efficient than open burners and should not be considered for the max-tech efficiency level.

Manufacturers generally commented that there is little improvement available for insulation in most conventional 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 conventional 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 conventional oven energy consumption may scale with cavity volume. Manufacturers stated that conventional ovens with smaller cavities are generally more efficient but did not supply data to support this statement.

5.5.1.5 Impacts on Consumer Utility

DOE asked manufacturers how the design option changes identified in previous stages of the current rulemaking may impact consumer utility. As discussed in detail in section 3.3 of chapter 3 of this SNOPR TSD, manufacturers indicated that several customer-driven design features enhance the cooking performance of commercial-style cooking products, including:

- HIR burners with large diameters and precise flame controllability
- Heavy cast iron grates
- Heavier gauge extension racks and thick oven cavity walls
- Configurations that allow for up to six-rack baking
- Full oven-height dual convection
- Hidden bake elements

Manufacturers have stated that these and other commercial-style features result in faster heat up times for large loads, allow consumers to use larger cooking vessels while maintaining even heat distribution, increase product longevity, enhance customer safety, and improve performance overall. Manufacturers indicated that if an energy conservation standard resulted in reduced burner input rates for both conventional cooking tops and conventional ovens, pre-heat and overall cooking times may be affected.

5.5.1.6 Installation and Repair Costs as a Function of Efficiency

Manufacturers commented on the installation and repair costs associated primarily with induction cooking tops. Most manufacturers indicated that while installation costs may not increase for induction cooking tops, consumers would have to purchase ferromagnetic cookware. Manufacturers also said that due to the complexity of the electronics and controls required for induction, the cost of repair is higher than for electric resistance or electric open (coil) element cooking tops.

5.5.1.7 Power Supplies

DOE asked manufacturers about the market uptake of SMPSs in conventional ovens, and any impact that a requirement to use an SMPS could have on MPC, consumer utility, or conversion costs. Multiple manufacturers commented that they already use SMPSs in all their conventional ovens that use line power. Manufacturers noted the engineering complexity of a control system with an SMPS as compared to a linear power supply.

5.5.1.8 Design Implications of the Test Procedure

Several manufacturers expressed concerns about the variability of the test procedure for conventional cooking tops finalized in the August 2022 TP Final Rule. Specifically, these manufacturers expressed concerns that their designs would need to account for a wide margin relative to any standard level that might be set, to avoid any potential non-compliance.

DOE asked manufacturers whether the efficiency levels in its analysis should be adjusted to account for this variability. Manufacturers did not provide any suggested approaches for DOE to consider. DOE did not incorporate any margin or tolerance for the potential variability of the test procedure.

5.5.1.9 Carbon Monoxide Emission Limits

DOE is aware that for gas cooking tops many of the strategies that yield higher efficiency (*e.g.*, reduced space between the burner and the grate) also tend to increase emissions of carbon monoxide. As discussed in chapter 3 of this SNOPR TSD, American National Standards Institute (ANSI) Z21.1 "Household Cooking Gas Appliances" ("ANSI Z21.1"), Section 5.4 requires that gas appliances not produce a concentration of carbon monoxide exceeding 800 ppm. In this SNOPR, DOE only considered potential standards corresponding to the efficiency of cooking products available on the market that already meet the ANSI Z21.1 requirements.

5.5.2 Product Selection

5.5.2.1 Conventional Cooking Tops

DOE conducted a market survey of conventional cooking top 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 cooking tops, DOE selected test units based on performance-related features and technologies advertised in product literature. These features included, among other things: 1) cooking top fuel type; 2) product configuration (*i.e.*, whether the cooking top is a component of a conventional range); 3) cooking zone input rate in British thermal units per hour (Btu/h) or Watts (W); 4) heating element type (*i.e.*, electric resistance versus induction and sealed versus open burners); 5) grate material type; and 6) whether the product was marketed as commercial-style (or professional-style). DOE's test sample for this SNOPR includes 14 standalone electric cooking tops, the cooking top portion of 8 electric ranges, 13 standalone gas cooking tops, and the cooking top portion of 8 gas ranges for a total of 43 conventional cooking tops covering all of the product classes considered in this analysis. The key parameters for each of the conventional cooking top test units are presented in Table 5.5.1 and Table 5.5.2.

Table 5.5.1 Conventional Electric Cooking Tops in DOE's Test Sample

Test Unit #	Product Configuration	Heating Element Type	Heating Element Input Ratings (*W*)
1	Standalone Cooking Top	Open (Coil)	3×1,300; 1×2,100
2	Conventional Range	Open (Coil)	2×1,250; 2×2,400
3	Standalone Cooking Top	Smooth–Electric Resistance	2×1,200; 1×1,800; 1×2,500
4	Standalone Cooking Top	Smooth–Electric Resistance	1×1,200; 2×1,500; 1×2,200; 1×3,100
5	Standalone Cooking Top	Smooth–Electric Resistance	1,200; 2×1,800; 1,900; 3,600
6	Standalone Cooking Top	Smooth–Electric Resistance	2×1,200; 1,500; 2,400; 3,000
7	Standalone Cooking Top	Smooth–Electric Resistance	1,200; 2×1,500; 3,000; 3,300
8	Standalone Cooking Top	Smooth–Electric Resistance	2×1,200; 2,500; 3,000
9	Standalone Cooking Top	Smooth–Electric Resistance	2×1,200; 1,800; 2,200
10	Conventional Range	Smooth–Electric Resistance	2×1,200; 3,000; 3,200
11	Conventional Range	Smooth–Electric Resistance	2×1,200; 3,000; 3,100
12	Conventional Range	Smooth–Electric Resistance	1,200; 2×1,800; 3,000
13	Conventional Range	Smooth–Electric Resistance	1,200; 3×3,000
14	Standalone Cooking Top	Smooth–Induction	1,900; 2,600; 3,200; 3,400
15	Standalone Cooking Top	Smooth–Induction	2×1,800; 3,600; 3,700
16	Standalone Cooking Top	Smooth–Induction	6×3,700
17	Standalone Cooking Top	Smooth–Induction	1,800; 2×2,600; 4,800
18	Standalone Cooking Top	Smooth–Induction	1,400; 2,100; 2×3,700
19	Standalone Cooking Top	Smooth–Induction	2×2,200; 2×3,700
20	Conventional Range	Smooth–Induction	1,800; 2×2,500; 3,700
21	Conventional Range	Smooth–Induction	1,800; 2×2,500; 3,700
22	Conventional Range	Smooth–Induction	1,800; 2×2,500; 3,600

Table 5.5.2 Conventional Gas Cooking Tops in DOE's Test Sample

Test Unit #	Product Configuration	Burner Input Ratings (*Btu/h*)	Burner Type	Grate Material	Marketed Style
1	Standalone Cooking Top	5,500; 3×12,000; 18,000	Sealed	Cast Iron	Residential
2	Standalone Cooking Top	2×9,500; 2×12,500; 18,000	Sealed	Cast Iron	Residential
3	Standalone Cooking Top	6,000; 9,100; 11,000; 15,000	Sealed	Cast Iron	Residential
4	Standalone Cooking Top	5,000; 2×9,500; 13,000; 22,000	Sealed	Cast Iron	Residential
5	Standalone Cooking Top	6,000; 9,050; 3×15,000; 18,000	Sealed	Cast Iron	Residential
6	Standalone Cooking Top	2×9,200; 2×12,000; 20,000	Sealed	Cast Iron	Residential
7	Conventional Range	5,000; 9,500; 2×15,000	Sealed	Cast Iron	Residential
8	Conventional Range	5,000; 9,100; 12,000; 17,000	Sealed	Cast Iron	Residential
9	Conventional Range	5,000; 9,500; 14,200; 18,000	Sealed	Cast Iron	Residential
10	Conventional Range	5,000; 2×9,500; 15,000; 17,000	Sealed	Cast Iron	Residential
11	Standalone Cooking Top	4×18,000	Sealed	Cast Iron	Commercial
12	Standalone Cooking Top	4×18,000	Sealed	Cast Iron	Commercial
13	Standalone Cooking Top	9,200; 5×15,000	Sealed	Cast Iron	Commercial
14	Standalone Cooking Top	5×15,000; 18,500	Sealed	Cast Iron	Commercial
15	Standalone Cooking Top	4×15,000; 2×18,000	Sealed	Cast Iron	Commercial
16	Standalone Cooking Top	8,500; 15,000; 18,000; 2×22,000; 25,000	Open	Cast Iron	Commercial
17	Standalone Cooking Top	5,000; 3×15,000; 2×20,000	Sealed	Cast Iron	Commercial
18	Conventional Range	5,000; 14,000; 2×18,000	Sealed	Cast Iron	Commercial
19	Conventional Range	8,000; 3×25,000	Open	Cast Iron	Commercial
20	Conventional Range	9,000; 2×13,000; 3×17,000	Sealed	Cast Iron	Commercial
21	Conventional Range	5,000; 2×9,500; 12,000; 15,000; 21,000	Sealed	Cast Iron	Commercial

DOE's sample of conventional gas cooking tops included 43 individual gas burners rated below 14,000 Btu/h and 62 HIR burners rated at or above 14,000 Btu/h. DOE notes that not all cooking tops with HIR burners above 14,000 Btu/h were marketed as commercial-style. As discussed, all units in DOE's test sample include at least one HIR burner and continuous cast-iron grates.

5.5.2.2 Conventional Ovens

DOE also conducted a market survey of conventional oven models and their associated features to identify the primary differentiators among commercially available units. DOE selected test units based on performance-related features and technologies advertised in product literature. These features included, among other things: 1) oven fuel type; 2) product configuration (*i.e.*, whether the oven is a component of a conventional range); 3) whether the oven offers a self-clean cycle; 4) installation configuration (*i.e.*, built-in/slide-in versus freestanding); 5) heating element rating in W or burner rating in Btu/h; 6) oven cavity volume in ft^3; 7) the presence of a forced convection cooking function; and 8) whether the product was marketed as commercial-style (or professional-style). DOE's test sample included 5 standalone electric ovens, the oven portion of 2 electric ranges, 1 standalone gas oven, and the oven portion of 7 gas ranges, for a total of 15 conventional ovens covering all of the product classes considered in this SNOPR. The key parameters for each of the test units are presented in Table 5.5.3 and Table 5.5.4.

Table 5.5.3 Conventional Electric Ovens in DOE's Test Sample

Test Unit #	Product Configuration	Type	Installation Configuration	Heating Element Wattage (*W*)	Cavity Volume (ft^3)	Convection (Y/N)
1	Conventional range	Self-Clean	Freestanding	3,000	5.9*	Y
2	Conventional range	Standard	Freestanding	2,000	2.4	N
3	Standalone oven	Self-Clean	Built-in	3,400	2.7	N
4	Standalone oven	Standard	Built-in	2,600	4.3	N
5	Standalone oven	Self-Clean	Built-in	2,600	4.3	N
6	Standalone oven	Self-Clean	Built-in	2,600	4.3	Y
7	Standalone oven	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 of 4.3 ft^3. In accordance with the test procedure adopted in the July 2015 TP Final Rule, the measured energy consumption for these two cavities were averaged together to determine the energy consumption for the unit.

Table 5.5.4 Conventional Gas Ovens in DOE's Test Sample

Test Unit #	Product Configuration	Type	Installation Configuration	Burner Input Rate (*Btu/h*)	Cavity Volume (*ft³*)	Convection (Y/N)	Marketed Style
1	Conventional range	Standard	Freestanding	18,000	4.8	N	Residential
2	Conventional range	Standard	Freestanding	18,000	4.8	N	Residential
3	Conventional range	Self-Clean	Freestanding	18,000	5.0	Y	Residential
4	Conventional range	Standard	Freestanding	16,500	4.4	N	Residential
5	Standalone oven	Self-Clean	Built-in	13,000	2.8	N	Residential
6	Conventional range	Standard	Freestanding	28,000	5.3	Y	Commercial
7	Conventional range	Standard	Slide-in	27,000	4.4	Y	Commercial
8	Conventional range	Standard	Freestanding	30,000	5.4	Y	Commercial

The range of input rates and cavity volumes were determined on the basis of manufacturer specifications. Gas products marketed as commercial-style or professional-style typically had oven burner input rates above 18,000 Btu/h. 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 the product was equipped with self-clean and whether the product offered forced convection.

5.5.3 Product Testing

5.5.3.1 Test Procedure

Conventional Cooking Tops

As discussed in chapter 3 of this SNOPR TSD, in the August 2022 TP Final Rule, DOE generally adopted the current version of the applicable industry standard, IEC 60350-2 (Edition 2.1 2021-05), "Household electric cooking appliances–Part 2: Hobs – Methods for measuring performance" [1] ("IEC 60350-2"), which provides a water-heating test method to measure the energy consumption of electric cooking tops. 87 FR 51492, 51495. Appendix I1 includes burden-reducing modifications to IEC 60350-2, further clarifies certain provisions, and also extends these test methods to gas cooking tops by correlating the burner input rate to specific test load diameters. *Id.*

[1] Hob is the British English term for cooking top.

The water-heating energy test for both electric and gas cooking tops requires heating a test load to a calculated "turndown temperature"[m] at the maximum energy input setting. When the water temperature reaches the turndown temperature, the energy input rate is reduced to a lower energy input setting, and the test is run for a 20-minute "simmering period" after the smoothened[n] water temperature reaches 90 degrees Celsius (°C) (194 degrees Fahrenheit (°F)), without additional adjustment of the energy input setting. The test load is made up of a quantity of water which is heated in a standardized, stainless-steel test vessel and covered with a vented aluminum lid. There are eight standardized cooking vessel sizes, ranging from 120 to 300 millimeters (4.7 to 13 inches) in diameter, one of which is selected to test each cooking zone based on the electric heating element dimension or the gas burner input rate. The amount of water varies with test vessel diameter. The full energy test is run for two consecutive energy input settings where the higher setting is one that can maintain the smoothened water temperature above 90 °C for the entire 20-minute simmering period and the lower setting cannot.

The per-cycle energy use for each cooking zone is then interpolated between the two energy tests, to represent the energy use of a test run with a final water temperature of 90 °C. The total conventional cooking top energy consumption is determined as the average of the energy consumed during each independent test divided by the mass of the water load used for that test. This average energy consumption is then normalized to a standard water load size (2,853 grams (g)) to determine the average per-cycle energy consumption of the conventional cooking top. To determine the AEC, the average per-cycle cooking top energy consumption is multiplied by the number of cooking cycles per year, 418.

The E_{TLP} is calculated by multiplying the average of the standby-mode power and the off-mode power by the number of annual low-power mode hours. The number of annual low-power hours is 8,544 for a standalone cooking top and 8,392 for a conventional range. The annual low-power mode energy consumption of a conventional range is apportioned between the cooking top component and the oven component such that 60% of the energy is included in the cooking top IAEC. The IAEC is calculated by adding the AEC and the E_{TLP}.

Conventional Ovens

As discussed in section 5.5.2, DOE conducted testing on a sample of conventional ovens representing each product class for this rulemaking using the earlier version of the conventional oven test procedure adopted in the July 2015 TP Final Rule. DOE used this data to help determine product classes (as discussed in chapter 3 of this SNOPR TSD) and efficiency levels, and to determine whether certain design changes resulted in reduced product energy consumption.

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[m] The turndown temperature is determined during a preliminary test (the "overshoot test") performed for each cooking zone to account for the continued temperature rise of the water (due to residual heat on the cooking top surface and in the test vessel) that occurs after the cooking top control is adjusted. The turndown temperature is calculated so that after the cooking top control is turned down from the maximum power setting to a low-power setting, the steady-state temperature of the water reaches a temperature slightly above 90 °C.

[n] The smoothened water temperature is the 40-second moving average temperature, used to reduce the impact of measurement noise of the water temperature on the final result.

The conventional oven test procedure adopted in the July 2015 TP Final Rule involved setting the oven controls to achieve an average internal cavity temperature that was 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 included the energy input during the time the load was being heated plus the energy consumed during fan-only mode.

The annual primary energy consumption for cooking, E_{CO}, in kWh/year for electric ovens and in kBtu/year for gas ovens, was 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 = the test energy consumption, in Wh;
K_e = 3.412 Btu/Wh, the conversion factor of Wh to Btu;
O_O = 29.3 kWh/year, the annual useful cooking energy output of a conventional electric oven;
W_1 = the measured weight of test block, in pounds (lb);
C_p = 0.23 Btu/lb·°F, the specific heat of test block; and
T_S = 234 °F, the 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 = the test energy consumption, in Btu;
O_O = 88.8 kBtu/year, the annual useful cooking energy output of a conventional gas oven;
and W_1, C_p and T_S were the same as defined above.

In the test procedure adopted in the July 2015 TP Final Rule, the annual secondary energy consumption for gas ovens (*i.e.*, the electrical energy consumption due to the ignition system and the display) was incorrectly calculated using the annual useful cooking energy output intended for conventional electric ovens, 29.3 kWh/year, instead of the constant specified for gas ovens, 26.0 kWh/year (88.8 kBtu/year). Because the purpose of the constant was to represent the typical field usage of the conventional oven during the cooking cycle, the factor used to calculate the annual secondary energy consumption should have corresponded to the same usage factor used to calculate the annual primary energy consumption for gas ovens. Thus, for all gas oven energy consumption values presented in this analysis, DOE included the secondary annual energy consumption of gas ovens, E_{SO}, in kWh/year, calculated using the following equation:

$E_{SO} = \frac{E_{IO} \times K_e \times O_O}{W_1 \times C_p \times T_S}$ for gas ovens, where,

E_{IO} = the electrical test energy consumption, as measured, in Wh;
O_O = 26.0 kWh/year (88.8 kBtu/year), the annual useful cooking energy output of a conventional gas oven;
and K_e, W_1, C_p and T_S were the same as defined above.

The test procedure adopted in the July 2015 TP Final Rule also included a method for measuring the annual primary and secondary energy consumption for conventional oven self-cleaning operations, E_{SC} and E_{SS}, respectively.

The annual active cooking mode energy consumption, E_{AO}, in kWh/year for electric ovens and in kBtu/year for gas ovens, was defined as:

$E_{AO} = E_{CO} + E_{SC}$ for electric ovens, where,

E_{CO} = the annual primary (electrical) cooking energy consumption for the electric oven, in kWh/year; and
E_{SC} = the annual self-cleaning energy consumption, in kWh/year.

$E_{AO} = E_{CO} + E_{SC} + [(E_{SO} + E_{SS}) \times K_e]$ for gas ovens, where,

E_{CO} = the annual primary (gas) cooking energy consumption for the gas oven, in kBtu/year;
E_{SO} = the annual secondary (electrical) cooking energy consumption for gas ovens only, in kWh/year;
E_{SC} = the annual primary (gas) self-cleaning energy consumption, in kBtu/year;
E_{SS} = the annual secondary (electrical) self-cleaning energy consumption, in kWh/year;
and K_e is the same as defined above.

In the test procedure adopted in the July 2015 TP Final Rule, the number of combined low-power mode hours for built-in/slide-in ovens was incorrectly calculated using the annual number of non-active hours (8540.1 and 8329.2, for conventional ovens and conventional ranges respectively) minus the duration in hours of the fan-only mode portion of the cooking cycle, instead of subtracting the number of annual hours spent in fan-only mode. Because the purpose of the subtraction was to represent the annual hours not spent in combined low-power mode, the subtraction should have corresponded to the annual hours spent in fan-only mode. Thus, for all oven energy consumption values presented in this analysis, DOE defined the number of combined low-power mode hours, S_{TOT}, in hours, calculated using the following equation:

$S_{TOT} = S - \frac{t_{OF} \times N_O}{60}$, where,

S = the annual number of non-active hours, 8540.1 for conventional ovens, and 8329.2 for conventional ranges;
t_{OF} = the fan-only mode duration in minutes;
N_O = the representative number of annual conventional oven cooking cycles per year;[o] and
60 = the conversion factor for minutes to hours.

The test procedure finalized in the July 2015 TP Final Rule further specified that the number of combined low-power mode hours for freestanding conventional ovens and

[o] N_O is equal to 219 for electric standard ovens, 204 for electric self-clean ovens, 183 for gas standard ovens, and 197 for gas self-clean ovens.

conventional ranges are equal to these same values (8540.1 and 8329.2, respectively) because freestanding ovens do not typically have a fan-only mode.

DOE measured standby-mode and off-mode power for the standalone ovens and for the oven components of combined cooking products, E_{TLP}, in kWh/year, was defined as:

$E_{TLP} = [(P_{IA} \times S_{IA}) + (P_{OM} \times S_{OM})] \times K$ where,

P_{IA} = the inactive mode power, in W;
P_{OM} = the off mode power, in W;
S_{IA} = the annual hours in inactive mode;
S_{OM} = the annual hours in off mode;
If the oven has both standby-mode and off-mode, $S_{IA} = S_{OM} = S_{TOT}/2$. If the oven has a standby mode but no off mode, $S_{IA} = S_{TOT}$ and $S_{OM} = 0$. If the oven has an off mode but no standby mode, $S_{IA} = 0$ and $S_{OM} = S_{TOT}$;
S_{TOT} is the number of combined low-power mode hours, as defined above; and
K = 0.001 kWh/Wh, the conversion factor for Wh to kWh.

The total integrated annual energy consumption, IE_{AO}, in kWh/year for electric ovens and in kBtu/year for gas ovens, was defined as:

$IE_{AO} = E_{CO} + E_{SC} + E_{TLP} + (E_{OF} \times N_{OE})$ for electric ovens, where,

E_{CO} = the annual primary (electrical) cooking energy consumption for the electric oven, in kWh/year;
E_{SC} = the annual self-cleaning energy consumption, in kWh/year;
E_{TLP} = the annual combined low-power mode energy consumption, in kWh/year;
E_{OF} = the fan-only mode energy consumption, in kWh/cycle; and
N_{OE} = the representative number of annual conventional electric oven cooking cycles per year.

$IE_{AO} = E_{CO} + E_{SC} + \{[E_{SO} + E_{SS} + E_{TLP} + (E_{OF} \times N_{OG})] \times K_e\}$ for gas ovens, where,

E_{CO} = the annual primary (gas) cooking energy consumption for the gas oven, in kBtu/year;
E_{SO} = the annual secondary (electrical) cooking energy consumption for gas ovens only, in kWh/year;
E_{SC} = the annual primary (gas) self-cleaning energy consumption, in kBtu/year;
E_{SS} = the annual secondary (electrical) self-cleaning energy consumption, in kWh/year;
N_{OG} = the representative number of annual conventional gas oven cooking cycles per year;
and E_{TLP}, E_{OF}, and K_e are the same as defined above.

5.5.3.2 Test Results

Conventional Cooking Tops

Electric Cooking Tops

Table 5.5.5 lists the test results for each electric cooking top in the DOE test sample.

Table 5.5.5 Annual Energy Consumption of Electric Cooking Tops in the DOE Test Sample

Test Unit #	Heating Element Type	Does Cooking Top Display Include a Clock (Y/N)	AEC (*kWh/year*)	E_{TLP}* (*kWh/year*)	IAEC** (k*Wh/year*)
1	Open (Coil)	N	196	0	196
2	Open (Coil)	Y	182	3	185
3	Smooth–Electric Resistance	N	186	0	186
4	Smooth–Electric Resistance	N	189	7	196
5	Smooth–Electric Resistance	N	193	1	193
6	Smooth–Electric Resistance	N	193	8	200
7	Smooth–Electric Resistance	N	188	9	197
8	Smooth–Electric Resistance	N	190	0	190
9	Smooth–Electric Resistance	N	186	4	190
10	Smooth–Electric Resistance	Y	189	10	200
11	Smooth–Electric Resistance	Y	191	3	195
12	Smooth–Electric Resistance	Y	199	25	224
13	Smooth–Electric Resistance	Y	204	14	218
14	Smooth–Induction	N	176	25	201
15	Smooth–Induction	N	179	5	184
16	Smooth–Induction	N	177	6	183
17	Smooth–Induction	N	191	22	213
18	Smooth–Induction	N	186	4	189
19	Smooth–Induction	N	176	2	177
20	Smooth–Induction	Y	183	6	189
21	Smooth–Induction	Y	180	10	191
22	Smooth–Induction	Y	180	47	226

* For conventional ranges, the E_{TLP} presented here represents the portion of the combined low-power mode energy apportioned to the cooking top component of the combined cooking product, as finalized in the August 2022 TP Final Rule.
** IAEC may not equal the sum of AEC and E_{TLP} presented in this table, due to rounding.

The AEC for electric cooking tops in the test sample varied from 182 to 196 kWh/year for electric open (coil) element cooking tops and from 176 to 204 kWh/year for electric smooth element cooking tops. The E_{TLP} for electric cooking tops in the test sample varied from 0 to 3 kWh/year for electric open (coil) element cooking tops and from 0 to 47 kWh/year for electric smooth element cooking tops. The IAEC for electric cooking tops in the test sample varied from 185 to 196 kWh/year for electric open (coil) element cooking tops and from 177 to 226 kWh/year for electric smooth element cooking tops.

As discussed, for electric open (coil) and electric smooth element cooking tops, DOE set the baseline efficiency levels based on the cooking top in the dataset with the highest AEC (Unit 1 for open element and Unit 13 for smooth element) and the cooking top with the highest combined low-power mode energy consumption (Unit 2 for open element and Unit 22 for smooth element). The electric smooth element cooking top with the lowest AEC and IAEC in the DOE sample, Unit 19, is a standalone cooking top equipped with induction heating elements and a cooking top display that does not include a clock.

Gas Cooking Tops

Table 5.5.6 presents the test results for each gas cooking top unit in the DOE test sample.

Table 5.5.6 Annual Energy Consumption of Gas Cooking Tops in the DOE Test Sample

Test Unit #	Burner Type	Grate Material	Marketed Style	Does Cooking Top Display Include a Clock (Y/N)	AEC (*kBtu/year*)	E_{TLP}* (*kWh/year)*	IAEC** (*kBtu/year*)
1	Sealed	Cast Iron	Residential	N	1,745	3	1,756
2	Sealed	Cast Iron	Residential	N	1,175	4	1,187
3	Sealed	Cast Iron	Residential	N	1,267	0	1,267
4	Sealed	Cast Iron	Residential	N	1,509	3	1,517
5	Sealed	Cast Iron	Residential	N	1,437	0	1,437
6	Sealed	Cast Iron	Residential	N	1,328	0	1,328
7	Sealed	Cast Iron	Residential	Y	1,321	10	1,356
8	Sealed	Cast Iron	Residential	Y	1,507	3	1,519
9	Sealed	Cast Iron	Residential	Y	1,465	11	1,501
10	Sealed	Cast Iron	Residential	Y	1,410	7	1,434
11	Sealed	Cast Iron	Commercial	N	1,436	30	1,537
12	Sealed	Cast Iron	Commercial	N	1,487	17	1,543
13	Sealed	Cast Iron	Commercial	N	1,607	0	1,607
14	Sealed	Cast Iron	Commercial	N	1,454	0	1,454
15	Sealed	Cast Iron	Commercial	N	1,410	4	1,422
16	Open	Cast Iron	Commercial	N	1,552	0	1,552
17	Sealed	Cast Iron	Commercial	N	1,415	5	1,430
18	Sealed	Cast Iron	Commercial	N	1,572	10	1,607
19	Open	Cast Iron	Commercial	N	1,398	0	1,398
20	Sealed	Cast Iron	Commercial	N	1,387	2	1,393
21	Sealed	Cast Iron	Commercial	Y	1,380	6	1,400

* For conventional ranges, the E_{TLP} presented here represents the portion of the combined low-power mode energy apportioned to the cooking top component of the combined cooking product, as finalized in the August 2022 TP Final Rule.
** IAEC may not equal the sum of AEC and E_{TLP} presented in this table, due to rounding.

The AEC for gas cooking tops in the dataset varied from 1,175 to 1,745 kBtu/year. The E_{TLP} for gas cooking tops in the dataset varied from 0 to 30 kWh/year. The IAEC for gas cooking tops in the dataset varied from 1,187 to 1,756 kBtu/year.

As discussed, DOE set the baseline efficiency level based on the gas cooking top in the dataset with the highest AEC (Unit 1) and the gas cooking top with the highest E_{TLP} (Unit 11). The cooking top with the lowest AEC and IAEC in the DOE sample, Unit 2, is equipped with sealed burners, continuous cast-iron grates, and includes one HIR burner.

The test procedure adopted in the August 2022 TP Final Rule specifies that gas cooking top burners with input rates above 14,300 Btu/h, including commercial-style cooking tops, be tested with a larger test load size than for burners with input rates below 14,300 Btu/h. As discussed in section 3.3 of chapter 3 of this SNOPR TSD, DOE considered whether a separate product class for commercial-style gas cooking tops with higher burner input rates was warranted. However, DOE did not identify any clearly defined, consistent design differences and corresponding utility provided by commercial-style gas cooking tops as compared to residential-style gas cooking tops.

Figure 5.5.1 presents individual per-burner normalized test energy consumption, as a function of input rate for all gas burners in the DOE test sample. DOE compared the test energy consumption of the generally higher input rate gas burners on commercial-style cooking tops to the generally lower input rate gas burners on residential-style cooking tops, and found that the test energy consumption for an individual burner, after normalizing for the mass of the test load, was not correlated to either burner input rate or style of cooking top. Therefore, DOE maintained a single product class for all gas cooking tops.

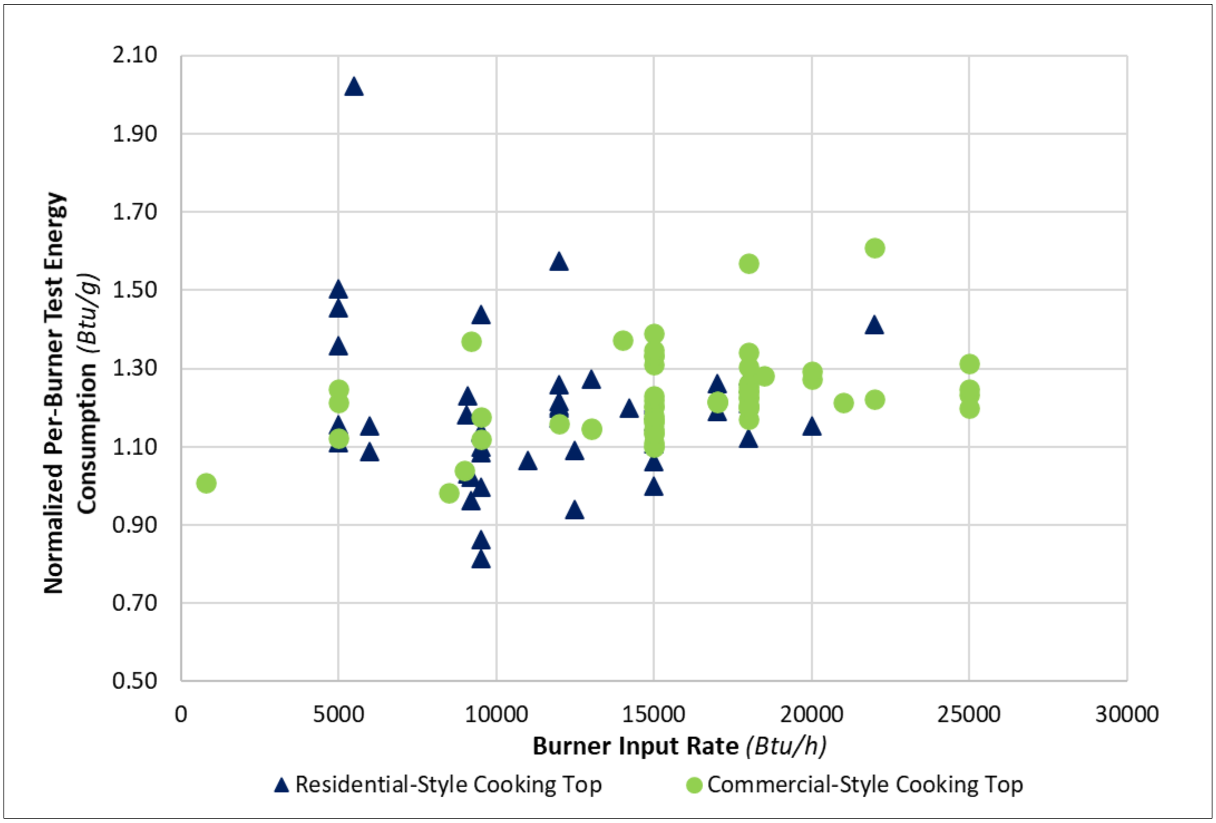

Figure 5.5.1 Normalized Per-Burner Gas Energy Consumption vs. Input Rate by Cooking Top Type

In previous rulemakings, DOE considered sealed gas burners as a design option, but the test data in Table 5.5.6 indicate that neither sealed burners nor open burners are inherently more efficient than the other. The range of measured energy consumption for both burner types overlap as shown in Figure 5.5.2.

Figure 5.5.2 Normalized Per-Burner Gas Energy Consumption vs. Input Rate by Burner Type

The range of burner energy consumption values further suggests that, because DOE evaluated standards in terms of cooking top IAEC, which is the average of the energy consumption measured for each burner, the specific combination of burner types of a given cooking top will have an impact on overall cooking top energy consumption.

Conventional Ovens

Each conventional oven in DOE's test sample was evaluated according to the earlier version of the test procedure adopted in the July 2015 TP Final Rule. The IE_{AO} for conventional ovens included the energy of active cooking mode, E_{AO} (including any self-cleaning operation); fan-only mode, for built-in/slide-in ovens as applicable; and combined low-power mode, E_{TLP} (including standby mode and off mode).

Combined Low-Power Mode

Although DOE based its analysis of conventional ovens on the test procedure adopted in the July 2015 TP Final Rule, the test procedure adopted in the December 2016 TP Final Rule specifies how to apportion the combined low-power mode energy of a conventional cooking product. Specifically, the total E_{TLP} consumption measured for a combined cooking product is apportioned to each component of the combined cooking product: 51% to the conventional oven component and 49% to the conventional cooking top component.[p] In this SNOPR, DOE used this apportioning methodology for determining the E_{TLP} of the conventional oven component of conventional ranges.

Table 5.5.7 and Table 5.5.8 list the measured and apportioned E_{TLP} consumption and the power supply type for the conventional ovens in DOE's test sample for which DOE was able to ascertain the power supply type.

Table 5.5.7 Combined Low-Power Mode Annual Energy of Standalone Ovens in the DOE Test Sample

Test Unit #*	Product Class	Low-Power Mode Power (*W*)	Combined Low-Power Mode Annual Energy (*kWh/year*)	Power Supply Type
E3	Electric Self-Clean Built-in/Slide-in	1.72	14.7	Linear
E4	Electric Standard Built-in/Slide-in	0.53	4.5	SMPS
E5	Electric Self-Clean Built-in/Slide-in	0.66	5.6	SMPS
E6	Electric Self-Clean Built-in/Slide-in	0.84	7.2	SMPS
E7	Electric Self-Clean Built-in/Slide-in**	1.61	13.7	SMPS
G5	Gas Self-Clean Built-in/Slide-in	1.67	14.3	Linear

* Test unit numbers can be read as the first letter of the energy source of the oven, E for electric or G for gas followed by the unit number as listed in Table 5.5.3 or Table 5.5.4, as applicable.
** This unit was a double oven having two separate cavities with equal volumes. The measured low-power mode energy consumption for this product was apportioned evenly between these two cavities for comparison to single ovens.

[p] The percentage allocation to the conventional oven component of a conventional range is calculated as 219.9 ÷ (219.9+213.1) = 51%.

Table 5.5.8 Combined Low-Power Mode Annual Energy of Combined Cooking Products in the DOE Test Sample

Test Unit #*	Oven Product Class	Standby Power (*W*)	Combined Low-Power Mode Energy *(kWh/year)*		Power Supply Type
			Apportioned to Cooking Top Component	Apportioned to Oven Component	
Ov-E1	Electric Self-Clean – Freestanding	1.2	4.9	5.0	SMPS
Ov-E2	Electric Standard – Freestanding	1.2	5.0	5.2	Linear
Ckt-E2	Electric Standard – Freestanding	0.6	2.5	2.5	SMPS
Ckt-E10	Electric Self-Clean – Freestanding	2.0	8.4	8.6	SMPS
Ckt-E11	Electric Self-Clean – Freestanding	0.7	2.7	2.8	SMPS
Ckt-E12	Electric Self-Clean – Built-in/Slide-in	5.0	20.7	21.4	SMPS
Ckt-E13	Electric Self-Clean – Built-in/Slide-in	2.7	11.2	11.6	SMPS
Ckt-E20	Electric Self-Clean – Built-in/Slide-in	1.2	5.0	5.2	SMPS
Ckt-E21	Electric Self-Clean – Freestanding	2.1	8.4	8.7	SMPS
Ckt-E22	Electric Self-Clean – Built-in/Slide-in	9.3	37.9	39.1	SMPS
Ov-G3	Gas Self-Clean – Freestanding	1.6	6.6	6.8	Linear
Ov-G4	Gas Standard – Freestanding	2.1	8.8	9.1	Linear
Ov-G8	Gas Standard – Freestanding	0.8	3.2	3.3	Linear
Ckt-G11	Gas Self-Clean – Freestanding	0.7	2.8	2.9	SMPS
Ckt-G12	Gas Self-Clean – Freestanding	2.1	8.6	8.8	SMPS
Ckt-G13	Gas Self-Clean – Built-in/Slide-in	1.4	5.6	5.7	SMPS
Ckt-G21	Gas Self-Clean – Built-in/Slide-in	2.0	8.2	8.5	Linear
Ckt-G24	Gas Self-Clean – Built-in/Slide-in	1.2	4.7	4.9	SMPS

* Test unit numbers starting with Ov were tested as part of the oven test sample and can be read as the first letter of the energy source of the oven, E for electric or G for gas followed by the unit number as listed in Table 5.5.3 or Table 5.5.4, as applicable. Test unit numbers starting with Ckt were tested as part of the cooking top test sample and can be read as the first letter of the energy source of the oven, E for electric or G for gas followed by the unit number as listed in Table 5.5.1 or Table 5.5.2, as applicable.

For conventional ovens, as noted in section 5.3.2.2, DOE set baseline E_{TLP} consumption for conventional ovens equal to that of the range equipped with a linear power supply with the highest E_{TLP} consumption in the test sample in order to maintain the full functionality of controls for consumer utility.

Fan-only Mode

Table 5.5.9 presents the fan-only mode testing results for built-in/slide-in ovens in DOE's test sample. DOE separated freestanding ovens and built-in/slide-in ovens into different product classes, as noted in section 5.2, because built-in/slide-in ovens consume energy during fan-only mode to exhaust air from the oven cavity to meet safety-related temperature requirements, since the oven is enclosed in cabinetry.

Table 5.5.9 Fan-only Mode Energy of Conventional Ovens in the DOE Test Sample

Test Unit #*	Oven Product Class	Fan-Only Mode Energy Use (*Wh/cycle*)	Fan-Only Mode Duration *(minutes)*
E3	Electric Self-Clean – Built-in/Slide-in	2	6.7
E4	Electric Standard – Built-in/Slide-in	32	69
E5	Electric Self-Clean – Built-in/Slide-in	32	69
E6	Electric Self-Clean – Built-in/Slide-in	31	67
E7	Electric Self-Clean – Built-in/Slide-in	30	41
G5	Gas Self-Clean – Built-in/Slide-in	1	4.5
G7	Gas Standard – Built-in/Slide-in	16	31

* Test unit numbers can be read as the first letter of the energy source of the oven, E for electric or G for gas followed by the unit number as listed in Table 5.5.3 or Table 5.5.4, as applicable.

The fan-only mode energy ranged from 1 to 32 Wh/cycle and the fan was on for a duration between 4.5 and 69 minutes.

For conventional ovens, as noted in section 5.3.2.2, DOE set fan-only mode energy consumption for conventional slide-in/built-in ovens equal to the maximum fan energy per cycle measured in DOE's test sample. For the purposes of calculating annual combined low-power mode hours, DOE set fan-only mode duration for conventional slide-in/built-in ovens equal to the maximum duration measured in DOE's test sample.

Active Cooking Mode

Table 5.5.10 presents the active cooking mode testing results for conventional electric ovens in DOE's test sample. Because conventional oven cooking efficiency and energy consumption depend on cavity volume, DOE also normalized IE_{AO} using the relationship between energy consumption and cavity volume discussed in section 5.5.4 to allow for more direct comparison between units in the test sample.

Table 5.5.10 Annual Energy Consumption of Electric Ovens in the DOE Test Sample

Test Unit #	Oven Product Class	Cavity Volume (ft^3)	E_{AO} (*kWh/year*)	Measured IE_{AO}† (*kWh/year*)	Normalized IE_{AO}†† (*kWh/year*)
1	Electric Self-Clean – Freestanding	5.9*	256.3	266.2	200.7
2	Electric Standard – Freestanding	2.4	203.4	213.6	309.6
3	Electric Self-Clean – Built-in/Slide-in	2.7	143.7	158.7	241.6
4	Electric Standard – Built-in/Slide-in	4.3	276.2	287.7	300.5
5	Electric Self-Clean – Built-in/Slide-in	4.3	296.7	308.8	320.5
6	Electric Self-Clean – Built-in/Slide-in	4.3	328.3	341.8	352.1
7	Electric Self-Clean – Built-in/Slide-in	4.3**	336.6	370.0	360.5

* 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 of 4.3 ft^3. In accordance with the test procedure adopted in the July 2015 TP Final Rule, the measured energy consumption for these two cavities were averaged together to determine the energy consumption for the unit.
† Measured IE_{AO} includes measured E_{AO} plus measured E_{TLP} plus any measured fan-only mode energy.
†† Measured IE_{AO} includes measured E_{AO} plus baseline E_{TLP} plus, for built-in/slide-in ovens the maximum fan-only mode energy from the test sample. This sum is then normalized to a fixed cavity volume of 4.3 ft^3.

The normalized IE_{AO} for conventional electric ovens ranged from 301 to 310 kWh/year for standard ovens and 201 to 361 kWh/year for self-clean ovens.

Table 5.5.11 presents the testing results for conventional gas ovens in DOE's test sample. As with electric ovens, DOE normalized IE_{AO} using the energy consumption versus cavity volume relationship discussed in section 5.5.4 for comparison between units of differing cavity volumes.

Table 5.5.11 Annual Energy Consumption of Gas Ovens in the DOE Test Sample

Test Unit #*	Oven Product Class	Cavity Volume (ft^3)	E_{AO} (*kBtu/year*)	Measured IE_{AO}** (*kBtu/year*)	Normalized IE_{AO}† (*kBtu/year*)
1	Gas Standard – Freestanding	4.8	1,341	1,341	1,289
2	Gas Standard – Freestanding	4.8	1,489	1,489	1,437
3	Gas Self-Clean - Freestanding	5.0	1,358	1,403	1,260
4	Gas Standard – Freestanding	4.4	1,440	1,501	1,480
5	Gas Self-Clean – Built-in/Slide-in	2.8	1,110	1,160	1,536
6	Gas Standard – Freestanding	5.3	2,050	2,061	1,883
7	Gas Standard – Built-in/Slide-in	4.4	1,720	1,923	1,778
8	Gas Standard – Freestanding	5.4	2,274	2,297	2,085

* Units 6, 7, and 8 have oven burner input rates greater than 18,000 Btu/h and were marketed as commercial-style.
** Measured IE_{AO} includes measured E_{AO} plus measured E_{TLP} plus any measured fan-only mode energy.
† Measured IE_{AO} includes measured E_{AO} plus baseline E_{TLP} plus, for built-in/slide-in ovens the maximum fan-only mode energy from the test sample. This sum is then normalized to a fixed cavity volume of 4.3 ft^3.

The normalized IE_{AO} for conventional gas ovens ranged from 1,260 to 2,085 kBtu/year.

5.5.4 Conventional Oven Energy Use versus Cavity Volume

The conventional oven efficiency levels detailed in the previous sections are predicated upon 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, IE_{AO} 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 test procedure adopted in the July 2015 TP Final Rule used a fixed test load size to measure IE_{AO}, larger ovens with higher thermal mass will have a higher measured IE_{AO}. As a result, DOE characterized the relationship between IE_{AO} and oven cavity volume for each product class, using available data.

DOE determined the slope of the baseline curves by first reviewing data from the previous rulemaking analysis as presented in the 2009 TSD, which presented a relationship between measured EF and cavity volume for each product class. These relationships continue to be relevant based on DOE's testing described in the previous sections. Because DOE is using IE_{AO} to determine incremental efficiency levels in this SNOPR, DOE translated the baseline EF determined using the 2009 TSD relationship to baseline IE_{AO} by assuming a baseline E_{TLP}. DOE plotted baseline IE_{AO} versus cavity volume for each product class and compared it to the measured test data discussed in section 5.5.3.2, as shown in Figure 5.5.3 through Figure 5.5.6.

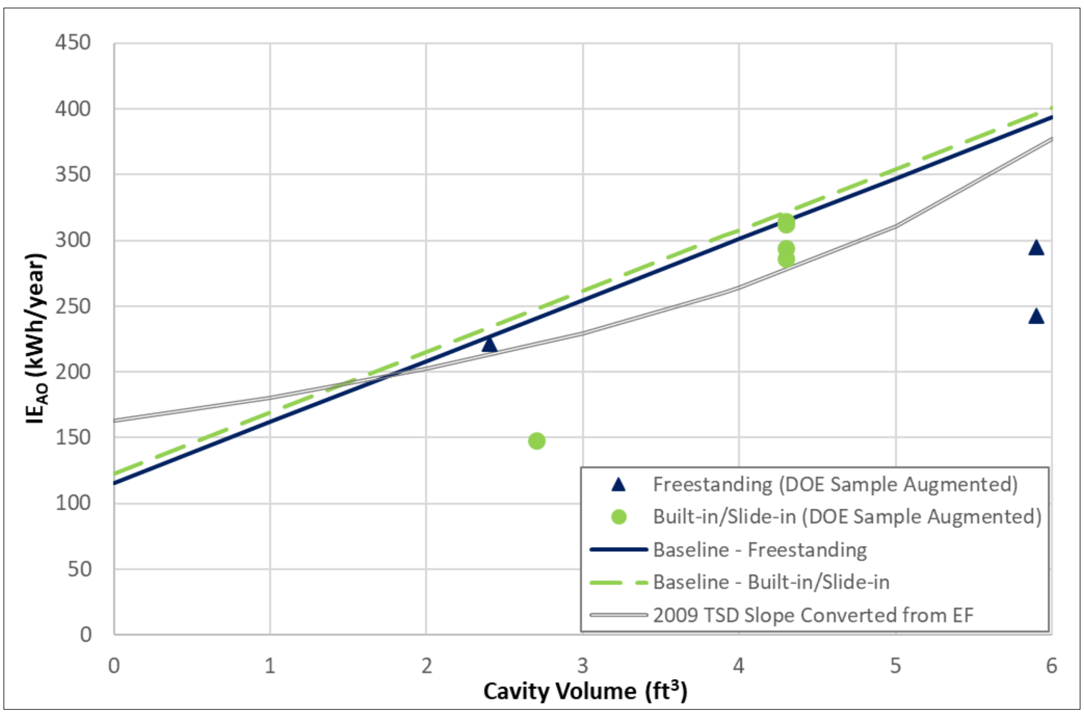

Figure 5.5.3 Electric Standard Oven IE_{AO} vs. Cavity Volume Slope

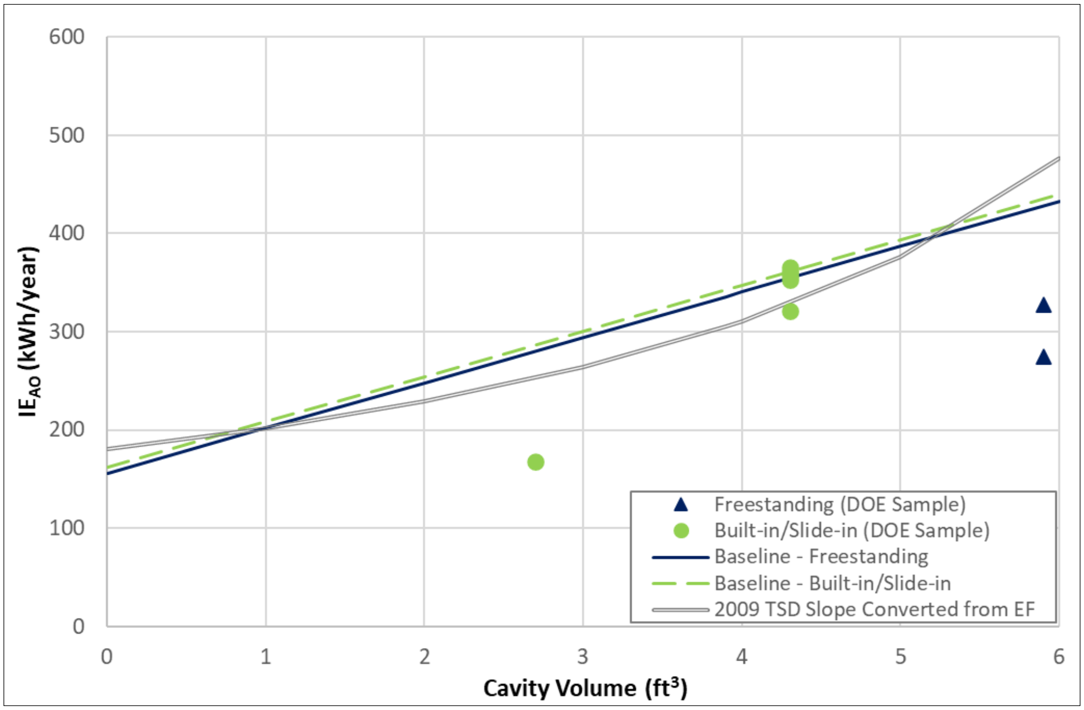

Figure 5.5.4 Electric Self-Clean Oven IE_{AO} vs. Cavity Volume Slope

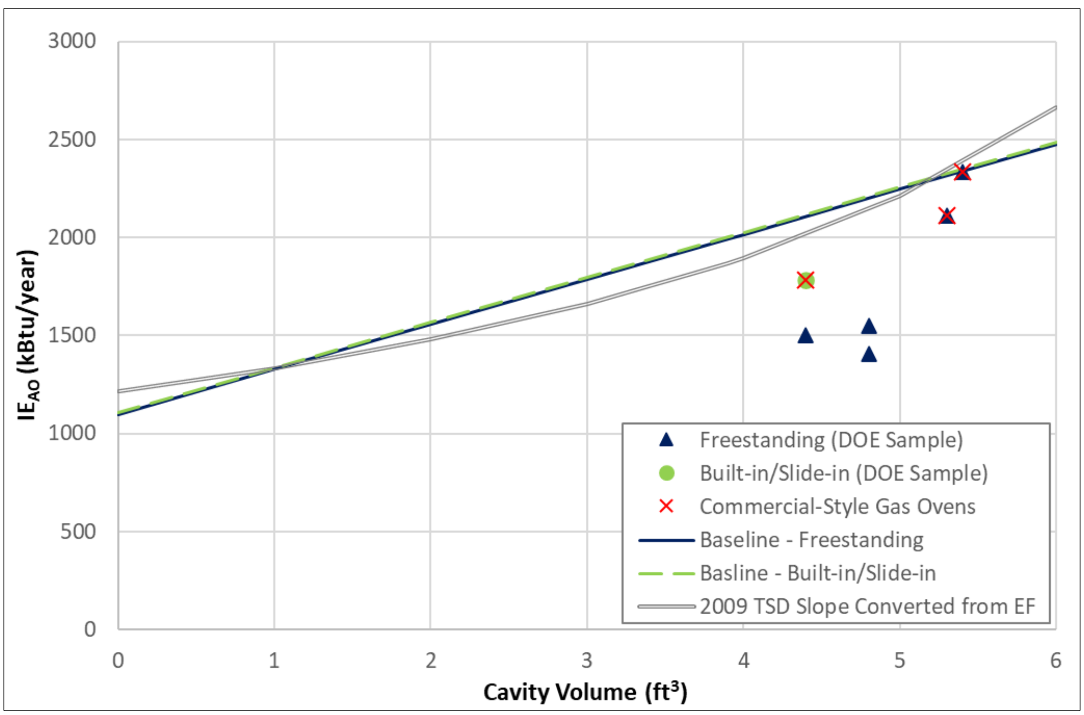

Figure 5.5.5 Gas Standard Oven IE_{AO} vs. Cavity Volume Slope

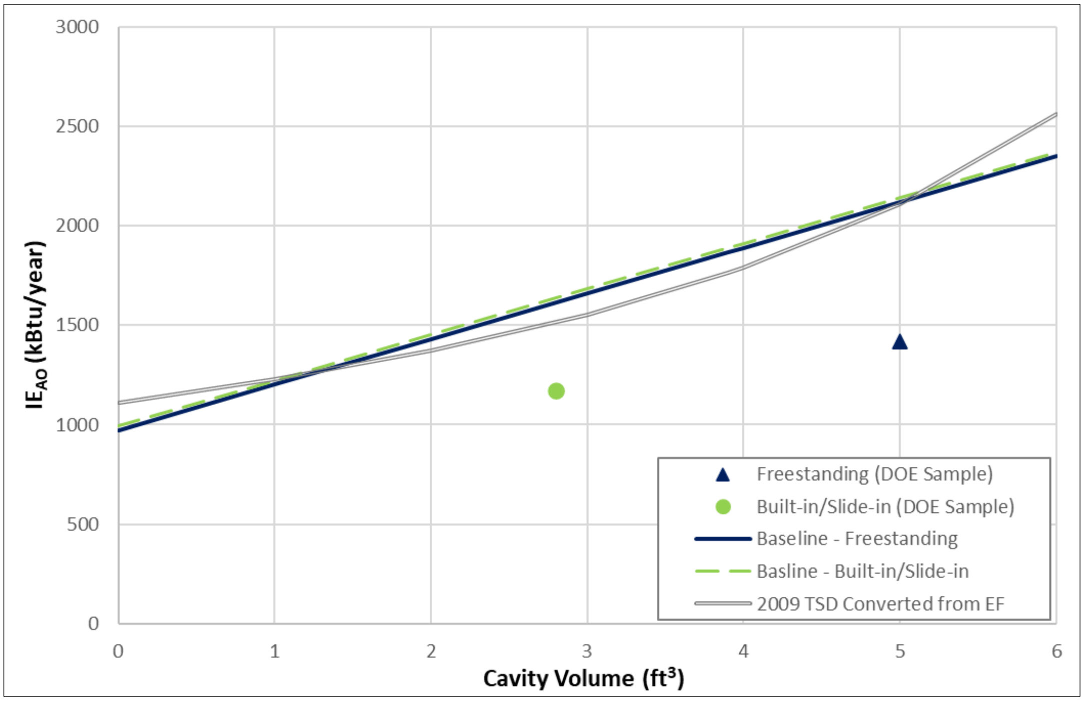

Figure 5.5.6 Gas Self-Clean Oven IE_{AO} vs. Cavity Volume Slope

Although the relationship between IE_{AO} 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 SNOPR TSD) use a linear relationship between energy consumption and cavity volume, indicating that a linear fit is appropriate. DOE performed a linear curve fit on the IE_{AO} data evaluated for discrete cavity volumes that were considered to represent the range of cavity volumes available on the market. The resulting IE_{AO} versus cavity volume equations were used to establish the baseline slope for each product class. DOE notes that for the electric oven product classes, the conversion to IE_{AO} initially resulted in different slopes for the standard and self-clean product class. After expanding the dataset used to establish baseline energy consumption for electric standard ovens, as described in section 5.3.2.2, to include a wider range of cavity volumes, DOE modified the slope for electric standard ovens so that it was representative of the augmented dataset and was consistent with the slope used for electric self-clean ovens. If necessary, the baseline intercepts were adjusted so that none of the conventional ovens in the DOE test sample were cut off by the baseline curve, as discussed in section 5.3.2.2.

As noted above, baseline built-in/slide-in conventional ovens consume more energy than freestanding ovens. DOE offset the baseline intercepts for each built-in oven product class by adding the maximum fan-only mode energy consumption measured in the test sample to the baseline intercept for the corresponding freestanding oven product class. DOE then shifted the intercept for the built-in product classes so that none of the resulting data were cut off by the built-in curve.

Table 5.5.12 and Table 5.5.13 present the slopes and intercepts of the IE_{AO} versus cavity volume relationship for electric and gas ovens respectively, at each efficiency level.

Table 5.5.12 Slopes and Intercepts of Electric Oven IE_{AO} versus Cavity Volume Relationship

Level	Standard Electric Ovens		Self-Clean Electric Ovens	
	Slope = 46.3		Slope = 46.3	
	Freestanding Intercepts	Built-in / Slide-in Intercepts	Freestanding Intercepts	Built-in / Slide-in Intercepts
Baseline	115.8	122.3	155.5	161.5
1	103.1	109.9	142.8	149.2
2	90.1	97.0	129.8	136.2
3	36.3	43.2	76.1	82.5

Table 5.5.13 Slopes and Intercepts of Gas Oven IE_{AO} versus Cavity Volume Relationship

Level	Standard Gas Ovens		Self-Clean Gas Ovens	
	Slope = 229.5		Slope = 229.5	
	Freestanding Intercepts	Built-in / Slide-in Intercepts	Freestanding Intercepts	Built-in / Slide-in Intercepts
Baseline	1,098	1,117	971	993
1	1,054	1,075	928	950
2	921	942	795	817

5.5.5 Product Teardowns

In addition to conducting the investigative testing described in the previous section, DOE conducted teardowns on a subset 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 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.

DOE also conducted catalog teardowns of PCBs to determine the controls design approaches (specifically the types of power supplies) used by the products in its test sample.

5.5.5.1 Baseline Construction

Baseline Electric Cooking Tops – Open (Coil) Elements

Baseline electric open (coil) element cooking tops were enclosed on the bottom and sides by a single sheet metal box. If the cooking top was part of a range, this assembly typically sat directly above the oven insulation. The top of the enclosure was a separate stamped metal piece with cutouts for each coil heating element. Under each coil heating element was a reflective drip pan.

Baseline electric open (coil) element cooking tops typically had four cooking zones of two different sizes in order to serve a range of pot diameters. Each element was connected to a central switch box and had associated electromechanical controls. DOE observed that many of the components, specifically those associated with the heating element and controls, were purchased parts, and that components manufactured in-house were limited to large metallic pieces, like the enclosure to house the coil assemblies.

Baseline Electric Cooking Tops – Smooth Elements

Electric smooth element cooking tops had a glass ceramic cooking top surface that shields the heating elements. Electric smooth element cooking tops were also equipped with more complex electronic controls and used a layer of insulation in the cooking top enclosure to help protect against overheating. Each electric resistance heating element consisted of a metallic ribbon encased in a dense insulation material located flush against the glass ceramic surface. The heating elements in DOE's sample had a variety of diameters. A temperature sensor was also located in the center of each heating element to protect from overheating and to provide temperature feedback to the controls. The cooking zone would cycle on and off based on the desired temperature and input power of the heating element. The heating element assemblies were determined to be a purchased component.

Baseline Gas Cooking Tops

Baseline gas cooking tops in the DOE teardown sample had cast-iron grates. Each baseline cooking top was enclosed on the bottom and sides by a single sheet metal box, like conventional electric open (coil) element cooking tops. The top of the cooking top enclosure was a separate stamped piece of sheet metal with cutouts for each burner.

The number of burners for each conventional cooking top in DOE's sample ranged from four to six, and were of either open or sealed types, although only a single type was used per cooking top. The open burner assemblies observed in the DOE's sample of conventional cooking tops consisted of a steel cylinder with openings arranged for adequate gas flow and combustion. Aluminum tubes extended from each burner and connected to the main gas tube to deliver gas to the burners. For every pair of open burners on the cooking top, a single electronic spark electrode was used to ignite gas flowing to each burner.

Sealed burner assemblies in the DOE sample had removable ceramic burner caps to protect against spills, and a main burner body consisting of one or two cast aluminum pieces. The burner body was fixed mechanically to the top of the cooking top enclosure. A brass orifice fitted in the center of the burner body connected to an aluminum tube leading to the main gas tube. Cooking tops with sealed burners had one electronic spark electrode mounted on the body of each burner.

The electronic spark electrodes for both burner types were controlled by a spark module that connects to the mechanically controlled rotary spark switches and gas valves attached to the main gas tube. The main gas tube extends outside of the cooking top enclosure and is fitted with a gas pressure regulator which can be connected to a natural gas or propane hookup. As with conventional electric cooking tops, DOE observed that many of the key components in each gas cooking top, including the burner assemblies, were purchased parts.

Baseline Electric Ovens

The interior surface of the oven cavity for the electric ovens in DOE's teardown sample had a porcelain enamel coating for durability and cleanability. Accessories such as a 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 making up 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. As discussed in previous sections, built-in/slide-in ovens had an added fan, motor, and vent assembly to provide cooling.

The radiant heating elements performing the bake function were situated at the bottom of the oven cavity and were made up of a composite metal rod.

All of the electric 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 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 electric ovens featured electronic controls in which the user interface and clock display comprised a push-button control panel with a Liquid Crystal Display (LCD) or Light-Emitting Diode (LED) display.

Baseline Gas Ovens

The baseline gas oven cavities examined by DOE were similar in construction to electric ovens. Accessories, insulation, and door seals were also made of the same materials. The primary difference in construction between electric and gas ovens observed by DOE was that the bake and broil heating elements were gas burners. The bake element was shielded by a baffle to help distribute heat evenly but was also shielded by the cavity base, which partially concealed 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 increased, allowing gas to flow as long as the hot surface igniter was energized by the burner controller.

DOE 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.

DOE also noted that combustion products from the burner and gases released in the interior cavity during the cooking process were vented from the top of the cavity through a sheet metal air channel using natural convection.

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.

5.5.5.2 Cost Estimates

DOE developed manufacturer cost estimates based on the method outlined in section 5.4.5 for the models considered in this teardown sample.

Baseline Cost Estimates

DOE developed baseline manufacturer production costs (MPCs) for each of the consumer conventional cooking product classes that are outlined in Table 5.5.14 and Table 5.5.15. All costs presented are in 2021 dollars.

Table 5.5.14 Baseline Manufacturer Production Costs for all Conventional Cooking Top Product Classes

Product Class	Product Type	Sub-Category	Baseline MPC *(2021$)*
1	Electric cooking top	Open (coil) elements	$98.84
2		Smooth elements	$222.32
3	Gas cooking top	-	$127.92

Table 5.5.15 Baseline Manufacturer Production Costs for all Conventional Oven Product Classes

Product Class	Product Type	Sub-Category	Installation Type	Baseline MPC *(2021$)*
4	Electric oven	Standard with or without a catalytic line	Freestanding	$287.72
5			Built-in/Slide-in	$304.20
6		Self-clean	Freestanding	$313.44
7			Built-in/Slide-in	$329.92
8	Gas oven	Standard with or without a catalytic line	Freestanding	$306.60
9			Built-in/Slide-in	$323.07
10		Self-clean	Freestanding	$400.84
11			Built-in/Slide-in	$417.32

Incremental Cost Estimates

Based on the analyses discussed above, DOE developed the cost-efficiency results for each product class shown in Table 5.5.16 through Table 5.5.19. Where available, DOE developed incremental MPCs based on manufacturing cost modeling of units in its sample featuring the design options. DOE notes that the estimated incremental MPCs are equivalent for the freestanding and built-in/slide-in oven product classes and for the standard and self-clean oven product classes because none of the considered design options would be implemented differently as a function of installation configuration or self-clean functionality.

This SNOPR TSD does not include a table of incremental MPCs for the electric open (coil) element cooking top product class, because as discussed in section 5.3.1.2, DOE did not consider any higher efficiency levels above the baseline.

Table 5.5.16 Electric Smooth Element Cooking Top Incremental Manufacturer Production Costs

Level	Design Option	Incremental MPC (*2021$*)
1	Baseline + Low-Standby-Loss Electronic Controls	$2.17
2	1 + Improved Resistance Heating Elements	$11.05
3	1 + Highest Active-mode Efficiency (Induction)	$263.19

Table 5.5.17 Gas Cooking Top Incremental Manufacturer Production Costs

Level	Design Option	Incremental MPC (*2021$*)
1	Baseline + Optimized Burner/Improved Grates (Achievable with 4 or more HIR burners and continuous cast-iron grates)	$12.41
2	Maximum Measured Efficiency	$12.41

Table 5.5.18 Electric Oven Incremental Manufacturer Production Costs

Level	Design Option	Incremental MPC (*2021$*)
1	Baseline + SMPS	$2.03
2	1 + Forced Convection	$34.11
3	2 + Oven Separator	$67.77

Table 5.5.19 Gas Oven Incremental Manufacturer Production Costs

Level	Design Option	Incremental MPC (*2021$*)
1	Baseline + SMPS	$2.17
2	1 + Forced Convection	$24.96

CHAPTER 6. MARKUPS ANALYSIS

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CHAPTER 6. MARKUPS ANALYSIS

6.1 INTRODUCTION

To carry out its analyses, the U.S. Department of Energy (DOE) needed to determine the cost to the consumer of both baseline products (*i.e.*, products not subject to newly amended energy conservation standards) and more efficient products. DOE calculated such costs based on engineering estimates of manufacturing production costs, a manufacturer markup to calculate the manufacturer sales price (*i.e.,* the price to the manufacturer's first customer), and appropriate additional markups for the various distribution channels to move the product to consumers.

The total markups applied to all product classes differ by their corresponding distribution channel, as discussed below. DOE adopts a total firm approach to markups, consistent with economic theory, rather than a product level cost accounting approach. In the economics based approach, the firm is assumed to produce a single product, so marginal costs include total costs for the firm rather than cost of goods inventoried and produced. The markup in this treatment depends on marginal cost, not average cost as is the case in cost accounting. These distinctions should be kept in mind when considering the results presented. At each point in a distribution channel, companies mark up the price of a product to cover costs. In financial statements, gross margin in dollar value (GM) is the difference between the company revenue and the company cost of sales, or CGS. The GM takes account of the expenses of companies, including various operating costs; research and development (R&D); interest expenses; depreciation; and taxes—and company profits. To cover costs and to contribute positively to company cash flow, the price of products must include a markup. Products command lower or higher markups depending on company expenses associated with the product and the degree of market competition.

DOE estimates a baseline markup and an incremental markup for each market participant besides manufacturers. DOE defines a baseline markup as a multiplier that converts the manufacturer selling price (MSP) of equipment with baseline efficiency to the consumer purchase price. An incremental markup is defined as the multiplier to convert the incremental increase in manufacturer selling price of higher efficiency equipment to the consumer purchase price. Because companies mark up the price at each point in the distribution channel, both overall baseline and incremental markups are dependent on the distribution channel, as described in section 6.1.1.

6.1.1 Distribution Channels

The appropriate markups for determining consumer product prices depend on the type of distribution channels through which products move from manufacturers to consumers. At each point in the distribution channel, companies mark up the price of the product to cover costs.

DOE based the distribution channel on data from the Association of Home Appliance Manufacturers (AHAM).[1] AHAM estimates that 93 percent of consumer conventional cooking 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 Consumer Conventional Cooking Products

6.2 MANUFACTURER MARKUP

DOE uses the manufacturer markups to convert manufacturer production costs to manufacturer selling prices. The manufacturer markup covers all manufacturer non-production costs (*e.g.,* SG&A, R&D, and interest) and profit.

DOE relied on publicly available financial data to estimate an industry-average manufacturer markup. See chapter 12 for more information on the manufacturer markup.

6.3 RETAILER MARKUPS

A change in energy efficiency standards usually increases the manufacturer selling price that retailers pay. In the past, DOE used the same markups as for baseline products to estimate the product price of more efficient products. Applying a fixed markup on higher manufacturer selling price would imply an increase in the dollar margin earned by retailers, and an increase in per-unit profit.

Based on microeconomic theory, the degree to which firms can pass along a cost increase depends on the level of market competition, as well as the market structure on both the supply and demand sides (e.g., supply and demand elasticity). DOE examined industry data from IBISWorld and the results suggest that the industry groups involved in appliance retail exhibit a fair degree of competition (see Table 6.3.1).[2] In addition, consumer demand for household appliances is relatively inelastic (*i.e.,* demand is not expected to decrease substantially with an increase in the price of product). Under relatively competitive markets, it may be tenable for retailers to maintain a fixed markup for a short period of time after an input price increase, but the market competition should eventually force them to readjust their markups to reach a medium-term equilibrium in which per-unit profit is relatively unchanged before and after standards are implemented.

Table 6.3.1 Competitive Environment of Appliance Retailers

Sector	Industry Concentration	Competition	Barriers to Entry
TV & appliance retailers	low	high and steady	medium and steady
Consumer electronics stores	medium	medium and increasing	medium and steady
Department stores	high	high and increasing	medium and steady
Home improvement clubs	high	medium and steady	medium and steady

Thus, DOE concluded that applying fixed markups for both baseline products and higher-priced products meeting a standard is not viable in the medium to long term considering the competitive nature of the appliance retail industry. DOE developed the incremental markup approach based on the widely accepted economic view that firms are not able to sustain a persistently higher dollar margin in a competitive market in the medium term. If the price of the product increases under standards, the only way to maintain the same dollar margin as before is for the markup (and percent gross margin) to decline.

To estimate the markup under standards, DOE derived an incremental markup that is applied to the incremental product costs of higher efficiency products. The overall markup on the products meeting standards is an average of the markup on the component of the cost that is equal to the baseline product and the markup on the incremental cost, weighted by the share of each in the total cost of the standards-compliant product.

DOE's incremental markup approach allows the part of the cost that is thought to be affected by the standard to scale with the change in manufacturer price. The income statements DOE used to develop retailer markups itemize firm costs into a number of expense categories, including direct costs to purchase or install the product, labor and occupancy costs, and other operating costs and profit. Although retailers tend to handle multiple commodity lines, DOE contends that these aggregated data provide the most accurate available indication of the cost structure of distribution channel participants.

DOE uses these income statements to divide firm costs between those that are not likely to scale with the manufacturer price of product (labor and occupancy expenses, or "invariant" costs) and those that are (operating expenses and profit, or "variant" costs). For example, when the manufacturer selling price of product increases, only a fraction of a wholesaler's expenses increase (operating expenses and profit), while the remainder can be expected to stay relatively constant (labor and occupancy expenses). If the unit price of a cooking product increases by 20 percent under standards, it is unlikely that the cost of secretarial support in an administrative office or office rental expenses will increase proportionally.

6.3.1 Approach for Retailer Markups

DOE based the retailer markups for consumer conventional cooking products on financial data for electronics and appliance stores from the 2017 U.S. Census *Annual Retail Trade Survey* (ARTS)[3], which is the most recent survey that includes industry-wide detailed operating expenses for that economic sector. 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 consumer conventional 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.

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

Eq. 6.1

Where:

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

To estimate incremental retailer markups, DOE divides retailers' operating expenses into two categories: (1) those that do not change when CGS increases due to amended efficiency standards ("fixed"), and (2) those that increase proportionately with CGS ("variable"). DOE defines labor and occupancy expenses as fixed costs, because these costs are not likely to increase as a result of a rise in CGS due to amended efficiency standards. All other expenses, as well as the net profit, are assumed to vary in proportion to CGS. Although it is possible that some of the other expenses may not scale with CGS, DOE is inclined to take a more conservative position and include these as variable costs. (Note: Under DOE's approach, a high fixed cost component yields a low incremental markup.)

DOE calculated the incremental markup (MU_{INCR}) for retailers using the following equation:

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

Eq. 6.2

where:

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

6.3.2 Derivation of Retailer Markups

The 2017 ARTS data for electronics and appliance stores provide total sales data and detailed operating expenses that are most relevant to consumer conventional cooking product retailers. To construct a complete data set for estimating markups, DOE needed to estimate CGS and GM. The most recent 2017 ARTS publishes a separate document containing historical sales and gross margin for household appliance stores. DOE took the GM as a percent of sales reported for 2017 and combined that percent with detailed operating expenses data from 2017 ARTS to construct a complete income statement for electronics and appliance stores to estimate both baseline and incremental markups. Table 6.3.2 shows the calculation of the baseline retailer markup.

Table 6.3.2 Data for Baseline Markup Calculation: Electronics and Appliance Stores

Kind of business item	Amount ($1,000,000)
Sales	99,401
Cost of Goods Sold (CGS)	66,897
Gross Margin (GM)	32,504
Baseline Markup = (CGS+GM)/CGS	**1.49**

Source: U.S. Census, 2017 Annual Retail Trade Survey

Table 6.3.3 shows the breakdown of operating expenses using the 2017 ARTS data. The incremental markup is calculated as 1.24.

Table 6.3.3 Data for Incremental Markup Calculation: Electronics and Appliance Stores

	Amount ($1,000,000)
Sales	99,401
Cost of Goods Sold (CGS)	*66,897*
Gross Margin (GM)	*32,504*
Labor & Occupancy Expenses ("Fixed")	
Annual payroll	10,226
employer costs for fringe benefit	1,574
Contract labor costs including temporary help	157
Purchased utilities, total	459
Purchased Repairs and Maintenance to Buildings, Structures, and Offices	266
Cost of purchased professional and technical services	743
Purchased communication services	290
Lease and Rental Payments for Land, Buildings, Structures, Store Space, and Offices	2,686
Subtotal:	16,401
Other Operating Expenses & Profit ("Variable")	
Expensed equipment	87
Cost of purchased packaging and containers	51
Other materials and supplies not for resale	387
Cost of purchased transportation, shipping and warehousing services	471
Cost of purchased advertising and promotional services	1,392
Cost of purchased software	93
Purchased Repairs and Maintenance to Machinery and Equipment	118
Lease and Rental Payments for Machinery, Equipment, and Other Tangible Items	89
Cost of data processing and other purchased computer services	66
Commission expenses	235
Depreciation and amortization charges	1,019
Taxes and license fees (mostly income taxes)	382
Other operating expenses	2,312
Net profit before tax (Operating profit)	*9,401*
Subtotal:	16,103
Incremental Markup = (CGS+Total Other Operating Expenses and Profit)/CGS	**1.24**

Source: U.S. Census, 2017 Annual Retail Trade Survey

6.4 SALES TAXES

The sales tax represents state and local sales taxes that are applied to the consumer product price. The sales tax is a multiplicative factor that increases the consumer product price. DOE used state and local tax data provided by the Sales Tax Clearinghouse.[4] DOE then derived population-weighted average tax values for each RECS region, as shown in Table 6.4.1. Detailed state-level sales taxes can be found in Appendix 6A.

Table 6.4.1 Average Sales Tax Rates by RECS Region

RECS Region	State(s)	Tax Rate (%)
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	5.60
2	Massachusetts	7.38
3	New York	7.07
4	New Jersey	7.19
5	Pennsylvania	6.63
6	Illinois	8.12
7	Indiana, Ohio	8.29
8	Michigan	5.98
9	Wisconsin	7.51
10	Iowa, Minnesota, North Dakota, South Dakota	7.98
Population-weighted average		7.30

6.5 SUMMARY OF MARKUPS

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

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

where:

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

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

where:

EQP_{STD} = Consumer product price for models meeting new efficiency standards,
EQP_{BASE} = Consumer product 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).

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

Table 6.5.1 Summary of Markups

Markup	Baseline	Incremental
Manufacturer	1.20	
Retailer	1.49	1.24
Sales Tax	1.073	
Overall	1.92	1.60

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CHAPTER 7. ENERGY USE ANALYSIS

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CHAPTER 7. ENERGY USE ANALYSIS

7.1 INTRODUCTION

The purpose of the energy use analysis is to determine the annual energy consumption of conventional electric and gas cooking products in representative U.S. homes and to assess the potential savings in energy use and costs that consumers would experience from more-efficient products. The U.S. Department of Energy (DOE) uses annual energy use, along with energy prices, to establish energy costs at various energy efficiency levels and to carry out the life-cycle cost (LCC) and payback period (PBP) analysis described in chapter 8. This chapter describes how DOE determined the annual energy use of consumer conventional cooking products at various efficiency levels for each product class considered in this Supplemental Notice of Proposed Rulemaking (SNOPR).

The engineering analysis, described in chapter 5 of this technical support document (TSD), reports energy use based on the DOE test procedure, which uses typical operating conditions in a laboratory setting. This test serves as the basis for comparing the performance of appliances under uniform conditions. Actual energy usage in the field varies depending on the conditions under which an appliance is operated. The energy use analysis seeks to estimate the range of energy consumption of the products in the field across diverse climate types and household characteristics.

7.2 AVERAGE ANNUAL ENERGY CONSUMPTION

DOE's 2009 (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], Florida Solar Energy Center (FSEC)[3], the 2019 California Residential Appliance Saturation Study (CA RASS 2019), and 2021 field metered data from the Pecan Street Project[4] on electric ranges show that the decline has somewhat levelled off in the annual energy consumption. 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. Red squares indicate energy consumption values estimated using a conditional demand analysis (CDA) and blue diamonds indicated field metered values.

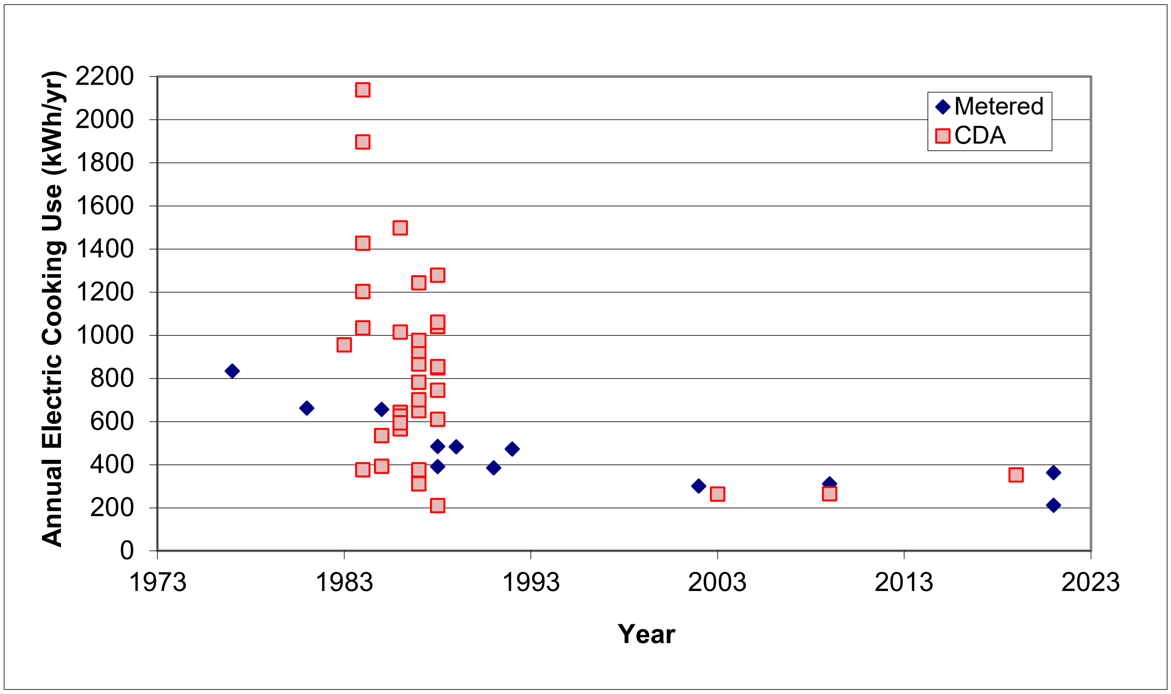

Figure 7.2.1 Historical Estimates of Annual Electric Range Energy Use

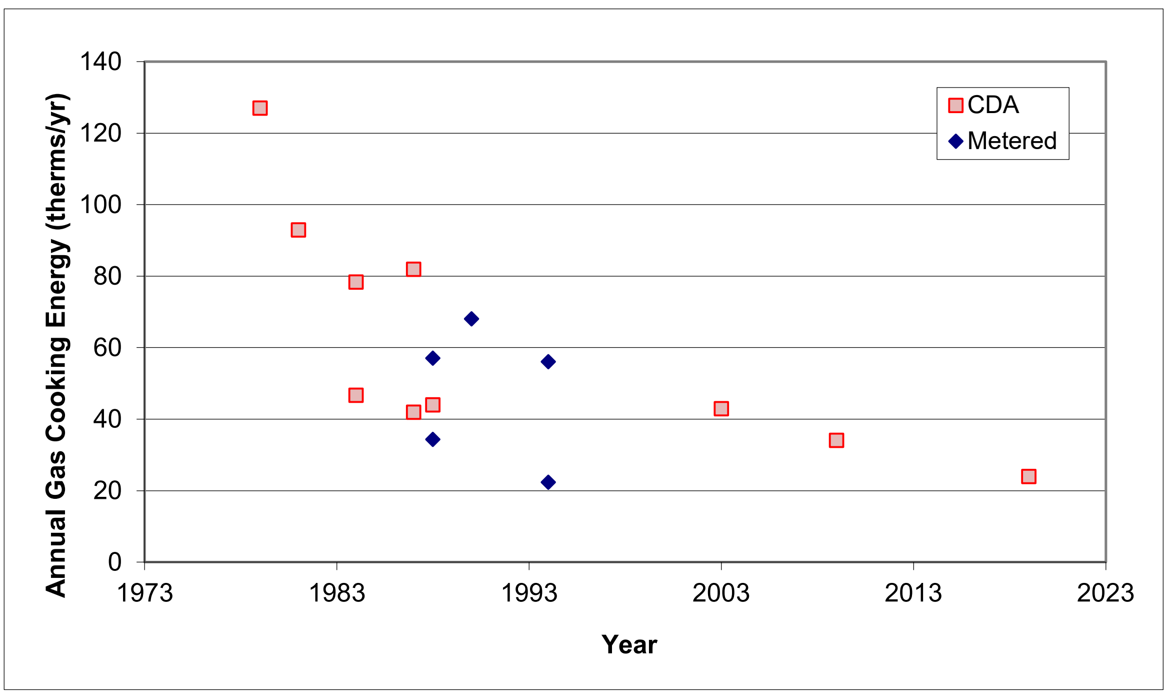

Figure 7.2.2 Historical Estimates of Annual Gas Range Energy Use

For this SNOPR analysis, DOE bases its estimates for cooking product energy use analysis on the two most recent datasets available: CA RASS 2019 and 2021 field-metered data from the Pecan Street Project.[5] Both data-sets provide estimates for the annual electricity usage of electric ranges. Pecan Street measures circuit-level electricity use at 1-minute resolution from volunteer households across multiple states. From the Pecan Street data, DOE performed an analysis of 39 households in Texas and 28 households in New York to derive develop average annual energy consumption values for each State. The CA RASS 2019 reported an average electric range annual energy consumption of 352 kWh per year while the Pecan Street data reported an average electric range annual energy consumption of 211kWh and 363 kWh per year for Texas and New York, respectively. DOE then calculated a household-weighted National value of 308.7 kWh using the average values from Texas, New York, and California (from CA RASS 2019) and estimates for the number of households in each State from the U.S. Census.

7.2.1 Annual Energy Consumption of Energy-Using Components

The CA RASS 2019 and Pecan street annual energy consumption values represent the consumption of electric and gas ranges which combine cooktop and ovens into a single unit. DOE performed several calculation steps to disaggregate the representative baseline average annual energy consumption value for an electric range, 308.7 kWh per year, into appropriate energy use values for the various energy-using components of electric and gas cooking tops. The detailed calculations are presented in Appendix 7A. Table 7.2.1 and Table 7.2.2 show the results of these calculations for cooking tops and ovens, respectively. In the tables, DOE presents the energy use values for electric and gas cooking tops, standard ovens, and self-clean ovens with their disaggregated energy use components (i.e., cooking, self-clean, and combined low power mode energy) that correspond to the baseline efficiency levels. For comparison, Table 7.2.1 includes the integrated annual energy consumption (IAEC) as measured by the DOE cooktop test procedure and Table 7.2.2 shows the integrated annual oven energy consumption (IE_{AO}) as measured using data gathered in the engineering analysis (see chapter 5 for details) for the baseline efficiency level.

Table 7.2.1 Component Annual Energy Use of Baseline Cooking Tops

Energy Use Components	Cooking Tops		
	Electric Coil	**Electric Smooth**	**Gas**
Cooking			
Electric (kWh/yr)	93.5	93.5	
Gas (kBtu/yr)*			810.1
Standby (kWh/yr)			
Electric (kWh/yr)	3.0	47	
Gas (kBtu/yr)*			30
Total	96.5 kWh	140.5 kWh	840.1 kBtu
IAEC	199.0 kWh	250.0 kWh	1,775.0 kBtu

* kBtu/yr for gas cooking tops.

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								
Electric (kWh/yr)	137.6	137.6	140.1	140.1				
Gas (kBtu/yr)					938.7	938.7	761.4	761.4
Self-clean								
Electric (kWh/yr)			34.4	34.4			6.0	6.0
Gas (kBtu/yr)							234.0	234.0
Fan								
Electric (kWh/yr)		7.0		6.6		5.9		6.3
Gas (kBtu/yr)								
Combined Low Power Mode Energy(kWh/yr)	18.3	17.8	18.3	17.8	18.3	17.9	18.3	17.9
Total	155.9 kWh	162.4 kWh	192.8 kWh	198.9 kWh	1001.2 kBtu	1020.0 kBtu	1,078.3 kBtu	1,098.5 kBtu
IE_{AO}	314.7 kWh	321.2 kWh	354.4 kWh	360.5 kWh	2,085.0 kBtu	2,104.0 kBtu	1,958.0 kBtu	1,979.0 kBtu

*The ratio of component energy consumption to overall annual energy consumption used to disaggregate the baseline energy consumption for conventional ovens was based on the product testing and analysis described in chapter 5 of this TSD.

Table 7.2.3 summarizes the estimated average baseline energy consumption for each product class based on the energy component analysis applied to the average range energy consumption estimated from CA RASS 2019 and Pecan Street data. Table 7.2.3 also shows the IAEC for cooktops and IE_{AO} for ovens. While similar in magnitude, DOE considers the annual energy consumption values from CA RASS 2019 and Pecan Street to be representative of electric and gas cooking energy usage in the field.

Table 7.2.3 Annual Energy Consumption of Baseline Electric and Gas Cooking Tops Based on DOE Test Procedure Energy Use Calculations

Product Type	Baseline Efficiency Level ($IAEC/IE_{AO}$)**	Annual Energy Consumption
Electric Cooking Tops - Open (Coil) Elements	199.0 kWh	96.5 kWh
Electric Cooking Tops - Smooth Elements	250.0 kWh	140.5 kWh
Gas Cooking Tops	1,775.0 kBtu	810.6 kBtu
Electric Standard Ovens, Free-Standing	314.7 kWh	155.9 kWh
Electric Standard Ovens, Built-In/Slide-In	321.2 kWh	162.5 kWh
Electric Self-Clean Ovens, Free-Standing	354.4 kWh	192.8 kWh
Electric Self-Clean Ovens, Built-In/Slide-In	360.5 kWh	198.9 kWh
Gas Standard Ovens, Free-Standing	2,085.0 kBtu	928.0 kBtu
Gas Standard Ovens, Built-In/Slide-In	2,104.0 kBtu	928.0 kBtu
Gas Self-Clean Ovens, Free-Standing	1,958.0 kBtu	752.7 kBtu
Gas Self-Clean Ovens, Built-In/Slide-In	1,979.0 kBtu	752.7 kBtu

** IE_{AO} baseline efficiency levels are normalized based on a 4.3 ft^3 volume for oven

7.2.2 Annual Energy Consumption by Efficiency Level

7.2.2.1 Cooktops

Table 7.2.4 and Table 7.2.5 show the electric cooking top IAEC, cooking energy consumption, non-cooking energy consumption, and total annual energy consumption. The total energy consumption includes energy for cooking and some additional energy for standby. For electric smooth cooking tops, DOE determined the annual 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 energy consumption. For electric coil cooking tops, DOE considered only the baseline efficiency in this SNOPR.

Table 7.2.4 Electric Coil Cooking Tops: Annual Energy Consumption by Efficiency Level

Level	IAEC	Cooking Energy	Non-Cooking Energy*	Annual Energy Consumption
	kWh/year			
Baseline	199	93.5	3.0	96.5

*Includes standby energy consumption

Table 7.2.5 Electric Smooth Cooking Tops: Annual Energy Consumption by Efficiency Level

Level	IAEC	Cooking Energy	Non-Cooking Energy*	Annual Energy Consumption
	kWh/year			
Baseline	250	93.5	47.0	140.5
1	207	94.0	3.0	97.0
2	189	85.7	3.0	88.7
3	179	81.1	3.0	84.1

*Includes standby energy consumption

Table 7.2.6 shows the gas cooking top integrated annual energy consumption and their corresponding annual energy consumption. For gas cooking products, DOE estimated the annual gas consumption associated directly with cooking and the non-cooking electricity consumption associated with a standby mode based on estimates from the engineering analysis.

Table 7.2.6 Electric Smooth Cooking Tops: Annual Energy Consumption by Efficiency Level

Level	IAEC	Gas	Electricity
		Annual Gas Consumption	Non-Cooking Energy*
	kBtu/year	*kBtu/year*	*kWh/year*
Baseline	1,775	811	8.8
1	1,440	655	8.8
2	1,204	545	8.8

*Includes standby energy consumption

7.2.2.2 Electric Ovens

DOE considered three efficiency levels in addition to the baseline for electric ovens. Table 7.2.7 and Table 7.2.8 show the electric standard oven IE_{AO}, the average annual cooking energy consumption, non-cooking energy consumption, and total annual energy consumption.

For product classes without self-cleaning mode, non-cooking energy is attributed to energy consumed in standby mode. The annual cooking energy consumption for efficiency levels above the baseline are estimated 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 7.2.7 Electric Standard Ovens - Freestanding: Annual Energy Consumption by Efficiency Level

Level	IE_{AO}	Cooking Energy	Non-Cooking Energy*	Annual Energy Consumption
	kWh/year			
Baseline	314.7	137.6	18.3	155.9
1	302	137.6	5.6	143.2
2	289	131.6	5.6	137.2
3	235.3	106.7	5.6	112.3

*Includes standby energy consumption

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

Level	IE_{AO}	Cooking Energy	Non-Cooking Energy*	Annual Energy Consumption
	kWh/year			
Baseline	321.2	137.6	24.8	162.5
1	308.9	137.6	12.5	150.2
2	295.9	131.6	12.5	144.1
3	242.1	106.6	12.5	119.1

*Includes standby and fan-only energy consumption

Table 7.2.9 and Table 7.2.10 show the electric self-clean oven IE_{AO}, cooking energy consumption, non-cooking energy consumption, and total annual energy consumption. For self-cleaning product classes, non-cooking energy consumption includes the electricity consumption associated with self-cleaning and standby modes. Built-in product classes also include fan-only mode in estimates for non-cooking energy consumption. The annual cooking energy consumption for efficiency levels above the baseline are estimated 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-clean remains constant with increased efficiency.

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

Level	IE_{AO}	Cooking Energy	Non-Cooking Energy*	Annual Energy Consumption
	kWh/year			
Baseline	354.4	140.1	52.7	192.8
1	341.7	140.1	40.0	180.1
2	328.7	134.1	40.0	174.1
3	275	109.1	40.0	149.1

*Includes standby and self-cleaning mode energy consumption

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

Level	IE_{AO}	Cooking Energy	Non-Cooking Energy*	Annual Energy Consumption
	kWh/year			
Baseline	360.5	140.1	58.8	198.9
1	348.1	140.1	46.5	186.6
2	335.1	134.0	46.5	180.5
3	281.4	109.1	46.5	155.6

*Includes standby, fan-only and self-clean energy consumption

7.2.2.3 Gas Ovens

DOE considered two efficiency levels in addition to the baseline for electric ovens. Table 7.2.11 and Table 7.2.12 show the gas standard oven IE_{AO}, gas cooking energy consumption, and non-cooking electricity consumption. For product classes without self-cleaning mode, non-cooking energy is attributed to energy consumed in standby mode. Built-in product classes also include standby and fan-only modes in estimates for non-cooking electricity consumption. DOE determined the annual cooking energy consumption for a more efficient level by taking the ratio of the IE_{AO} of the more efficient and baseline levels and multiplying it by the baseline annual cooking energy consumption.

Table 7.2.11 Gas Standard Ovens - Freestanding: Annual Energy Consumption by Efficiency Level

Level	IA_{EO}	Gas Cooking Energy Consumption	Electricity Non-Cooking Energy*
	kBtu/year	*kBtu/year*	*kWh/year*
Baseline	2085	928	18.3
1	2041	928	5.6
2	1908	867	5.6

*Includes standby and fan-only energy consumption

Table 7.2.12 Gas Standard Ovens – Built-in/Slide-in: Annual Energy Consumption by Efficiency Level

Level	IA_{EO}	Gas Cooking Energy Consumption	Electricity Non-Cooking Energy*
	kBtu/year	*kBtu/year*	*kWh/year*
Baseline	2104	928	18.3
1	2062	928	5.6
2	1929	867	5.6

*Includes standby and fan-only mode energy consumption

Table 7.2.13 and Table 7.2.14 show the gas self-clean oven IEAO, gas cooking energy consumption, gas non-cooking energy consumption, total annual gas consumption, and electricity non-cooking energy consumption. For self-cleaning product classes, non-cooking energy consumption includes the gas and electricity consumption associated with self-cleaning mode and the electricity consumption associated with standby mode. Built-in product classes also include fan-only mode in estimates for non-cooking electricity consumption. DOE assumed that the self-clean energy remains constant with increased efficiency.

Table 7.2.13 Gas Self-Clean Ovens - Freestanding: Annual Energy Consumption by Efficiency Level

Level	IA_{EO}	Gas			Electricity
		Cooking Energy	Non-Cooking Energy*	Annual Gas Consumption	Non-Cooking Energy**
	kBtu/year				*kWh/year*
Baseline	1958	753	234	987	24.3
1	1915	753	234	987	11.6
2	1781	691	234	925	11.6

*Includes self-cleaning mode energy consumption
**Includes standby and self-cleaning mode energy consumption.

Table 7.2.14 Gas Self-Clean Ovens – Built-in/Slide-in: Annual Energy Consumption by Efficiency Level

Level	IA_{EO}	Gas			Electricity
		Cooking Energy	Non-Cooking Energy*	Annual Gas Consumption	Non-Cooking Energy**
	kBtu/year				*kWh/year*
Baseline	1979	753	234	987	30.2
1	1937	753	234	987	17.8
2	1804	692	234	926	17.8

*Includes self-cleaning energy consumption
**Includes standby, self-cleaning, and fan-only mode energy consumption

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 2015 RECS collected data from 5,686 housing units representing almost 118.2 million households.[6] The RECS indicates which households in the survey use electric and gas cooking tops. With regard to cooking tops, 464 household records have electric cooking tops and 5,398 household records have gas cooking tops. The above totals represent cooking tops 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 top for each household record, it does provide the frequency of cooking use. For each household using a conventional cooking top, RECS provides data on the frequency of use per week for combined cooktop and oven, separated cooktop and separated oven as well as number of meals cooked per day 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 in Table 7.2.3. To determine the variability of cooking top energy consumption, DOE first equated the weighted-average cooking frequency from RECS with the average energy use values reported in Table 7.2.3. Table 7.2.15 presents the weighted-average cooking frequency values along with the corresponding annual energy use values from Table 7.2.3. For the purposes of the energy-use analysis, DOE excludes households that own a cooking product, but indicate that they never cook hot meals at home in the calculation of average cooking frequency.

Table 7.2.15 Annual Energy Use of Baseline Cooking tops and Ovens with corresponding RECS Cooking Frequency

	Cooking Tops			**Ovens**			
				Electric		**Gas**	
	Electric Coil	**Electric Smooth**	**Gas**	**Standard Freestanding /Built-In**	**Self-Clean Freestanding/ Built-In**	**Standard Freestanding /Built-In**	**Self-Clean Freestanding /Built-In**
Annual Energy Consumption	96.5 kWh	140.5 kWh	810.6 kBtu	155.9/162.5 kWh	192.8/198.9 kWh	928/928 kBtu	753/753 kBtu
RECS average cooking frequency *(usage per day)*	1.218	1.218	1.343	0.729	0.729	0.617	0.617

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 a cooking top based on the following equation:

$$E_{CA\_HH} = Freq_{C\_HH} \times \frac{E_{CA\_AVG}}{Freq_{C\_AVG}}$$

where:

E_{CA_HH} = Cooking top annual energy consumption for specific RECS household,
$Freq_{C\_HH}$ = Cooking top frequency for specific RECS household,
E_{CA_AVG} = Average cooking top annual energy consumption (from Table 7.2.4, Table 7.2.5, or Table 7.2.6), and
$Freq_{C\_AVG}$ = Average cooking top frequency (from Table 7.2.6).

DOE determined the annual cooking energy consumption for each RECS household with an oven based on the following equation:

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

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 7.2.7-Table 7.2.14), and
$Freq_{O\_AVG}$ = Average oven frequency (from Table 7.2.15).

For all RECS households, cooking frequency varies between zero to four meals per day. Figure 7.2.3 and Figure 7.2.4 show the probability distributions of annual cooking energy consumption based on correlating the average cooking energy use to the cooking frequency data from RECS. Figure 7.2.3 and Figure 7.2.4 show the distribution of electric and gas cooking top energy use, respectively.

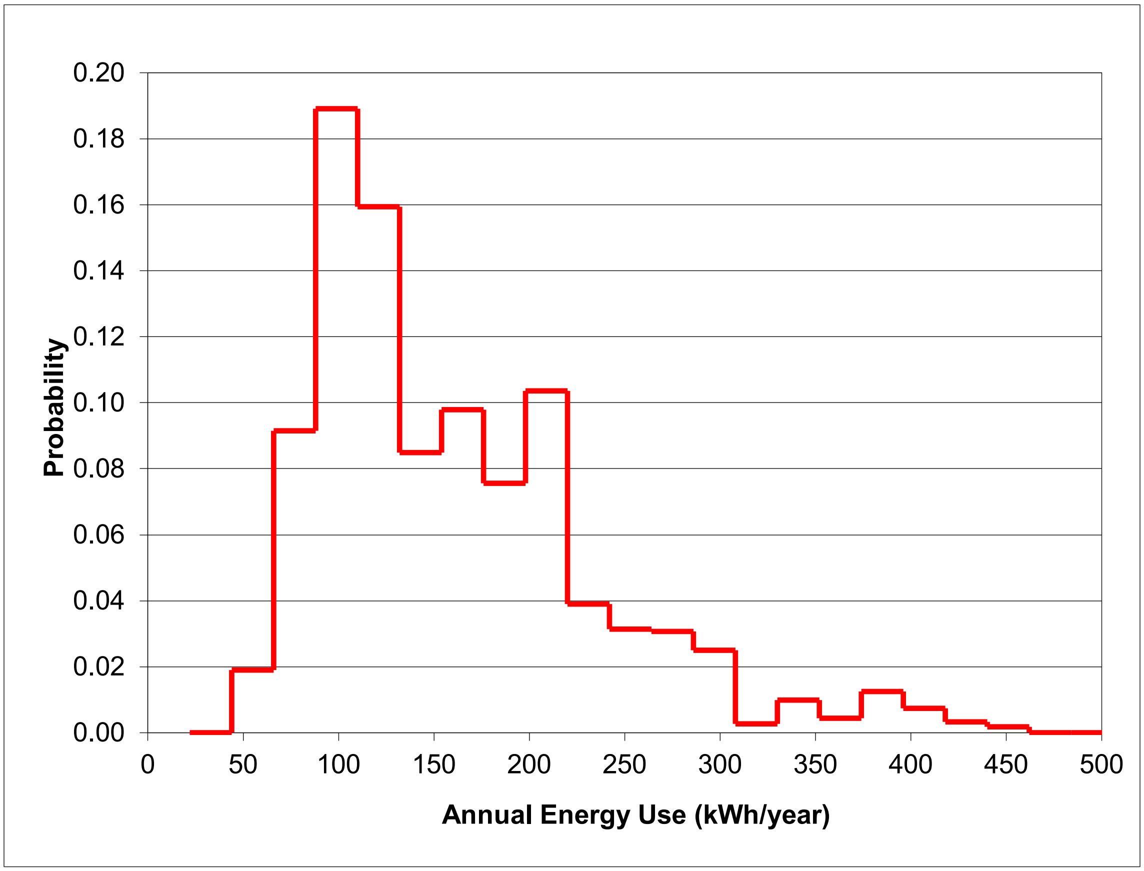

Figure 7.2.3 Distribution of Baseline Electric Cooking Top Annual Energy Use Based on 2015 RECS Cooking Frequency

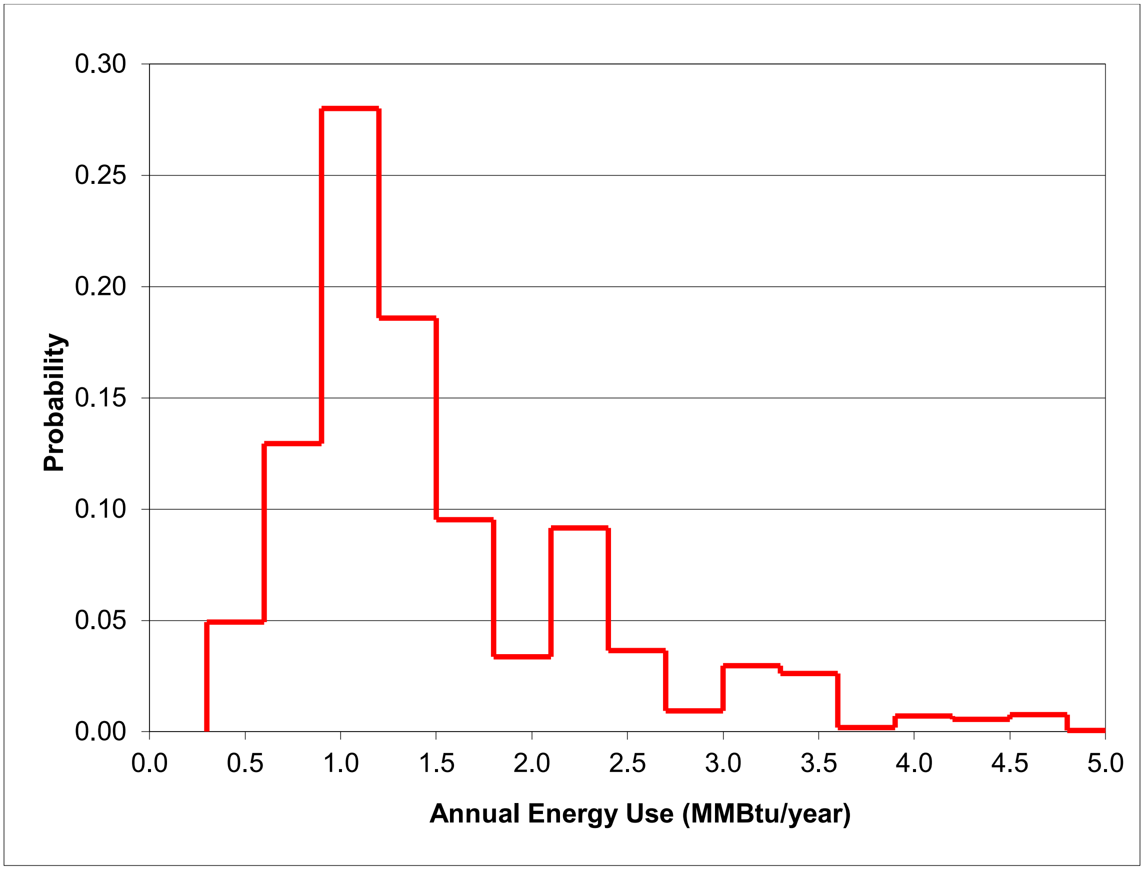

Figure 7.2.4 Distribution of Baseline Gas Cooking Top Annual Energy Use Based on 2015 RECS Cooking Frequency

Figure 7.2.5 and Figure 7.2.6 show the distribution of annual energy use for electric standard and self-clean ovens, respectively.

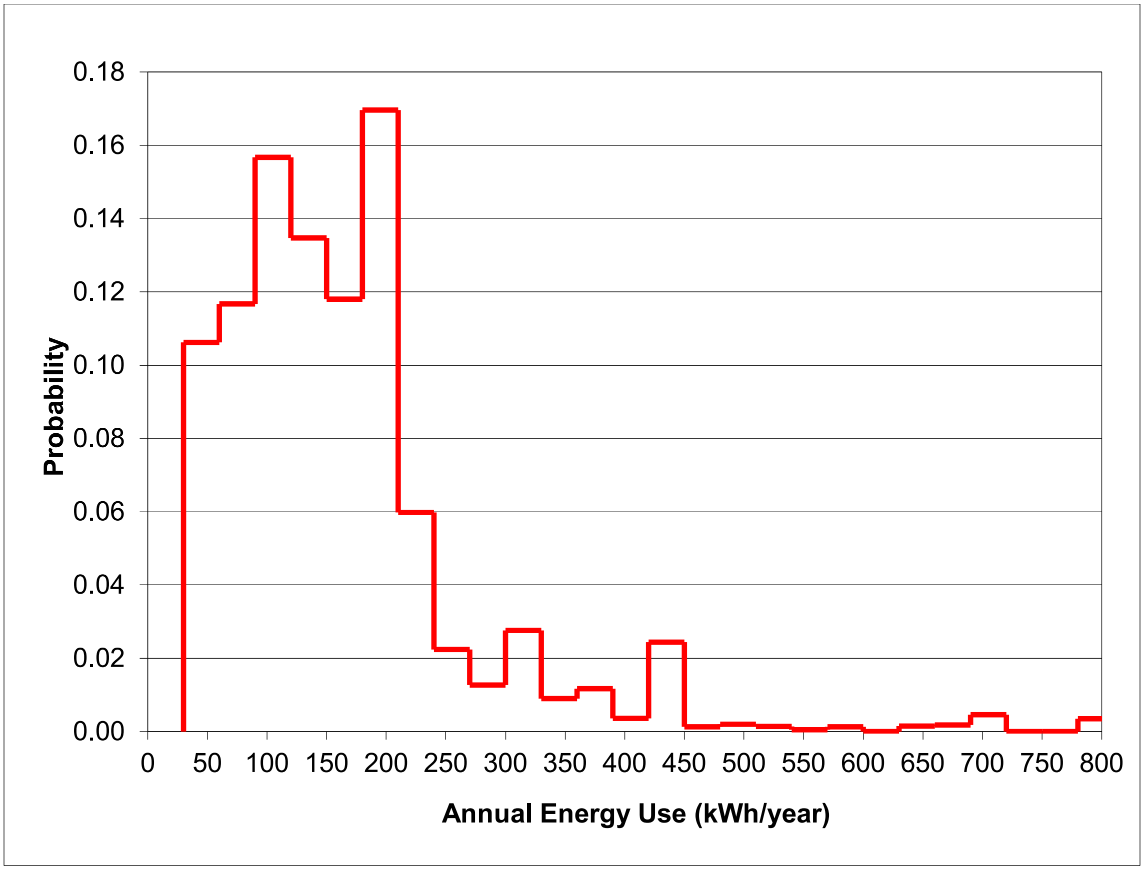

Figure 7.2.5 Distribution of Baseline Electric Standard Oven Annual Energy Use Based on 2015 RECS Cooking Frequency

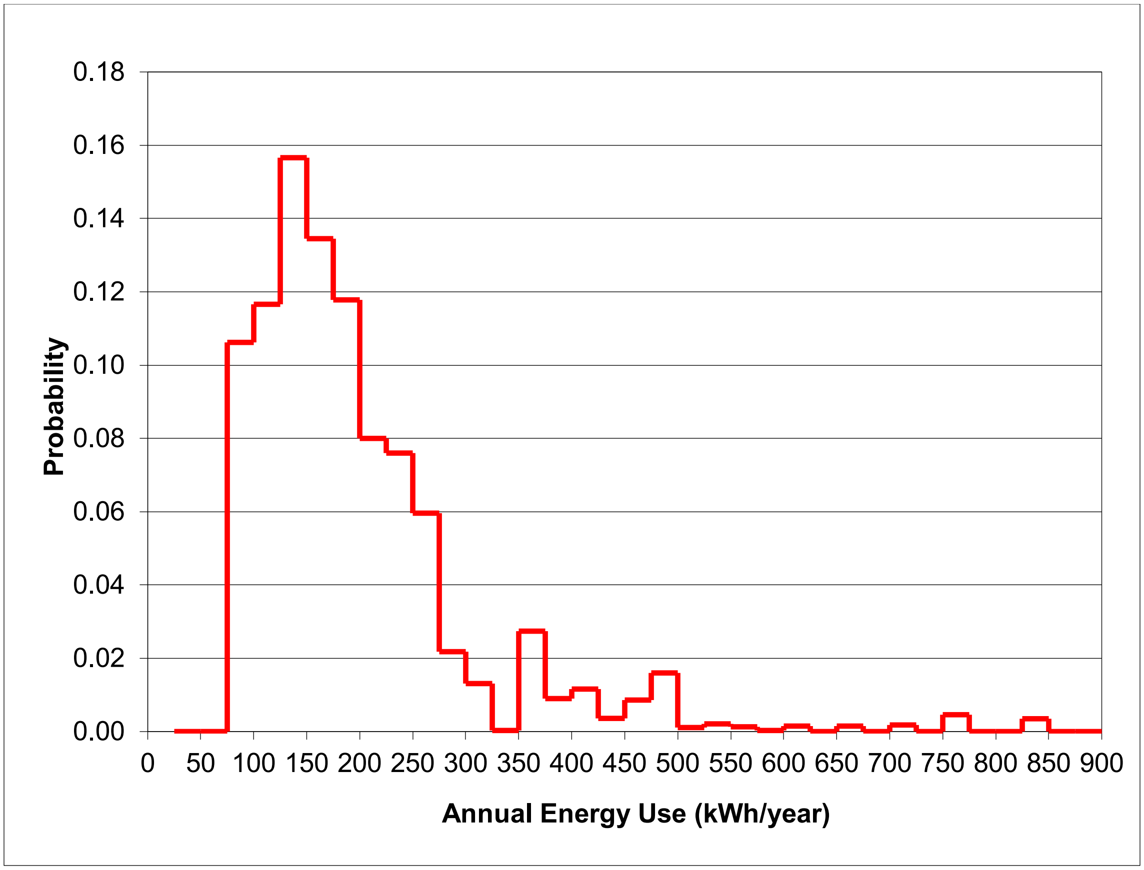

Figure 7.2.6 Distribution of Baseline Electric Self-clean Oven Annual Energy Use Based on 2015 RECS Cooking Frequency

Figure 7.2.7 and Figure 7.2.8 show the distribution of annual energy use for gas standard and self-clean ovens, respectively.

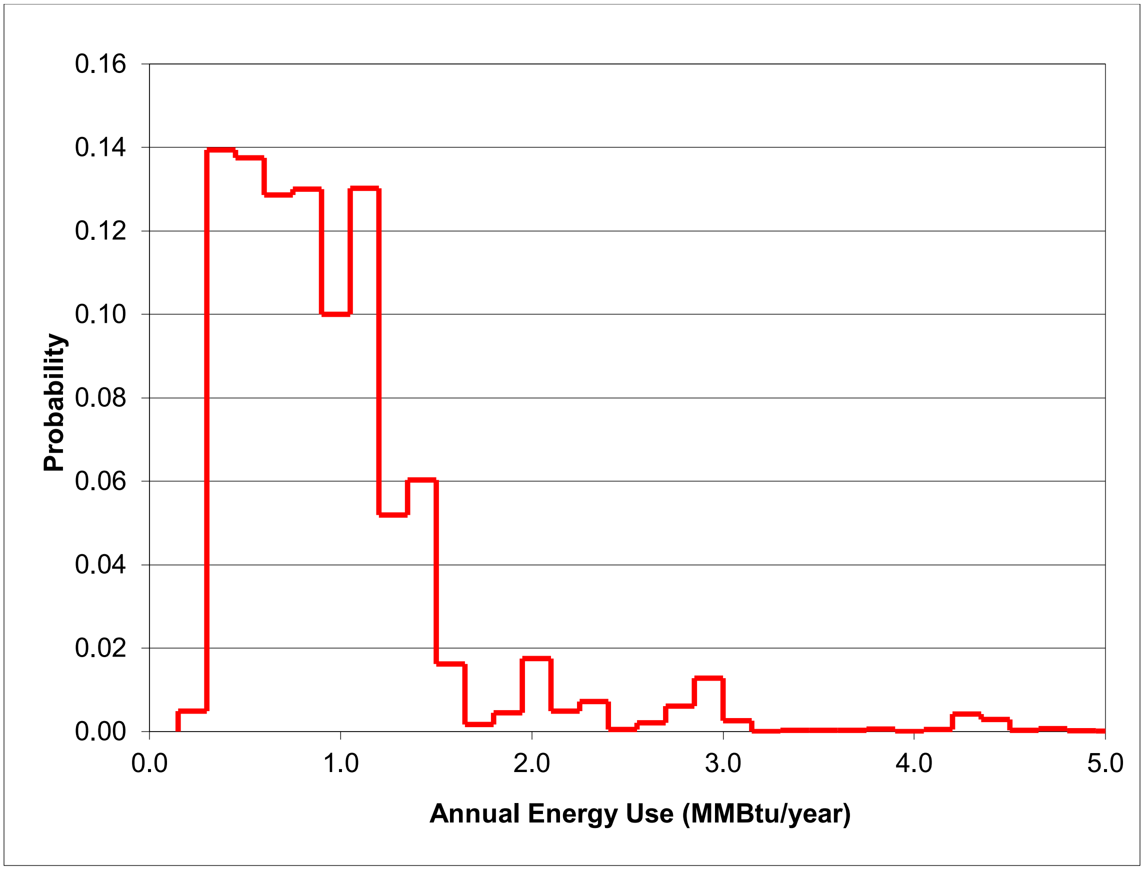

Figure 7.2.7 Distribution of Baseline Gas Standard Oven Annual Energy Use Based on 2015 RECS Cooking Frequency

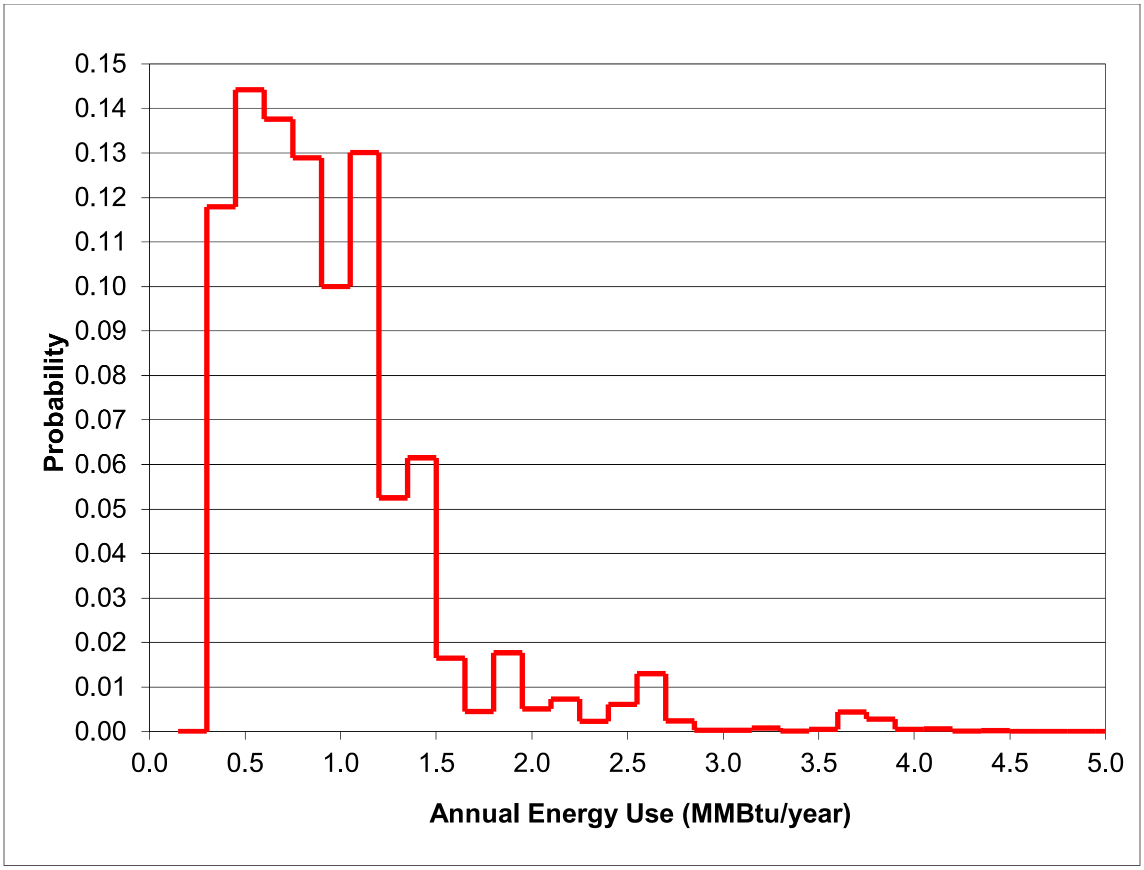

Figure 7.2.8 Distribution of Baseline Gas Self-clean Oven Annual Energy Use Based on 2015 RECS Cooking Frequency

DOE used the RECS household samples with their associated baseline annual cooking energy consumption to conduct the LCC and PBP analysis as described in chapter 8 of this SNOPR TSD.

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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 supplemental notice of proposed rulemaking (SNOPR) 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 consumer 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 = for which operating cost is being determined.

Numerically, the 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 the first-year 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. The equation for PBP is:

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

Eq. 8.2

Where:

ΔIC = difference in weighted-average total installed cost between the more energy efficient design and the baseline design for the entire sample, and
ΔOC = difference in weighted-average first-year operating costs for the entire sample.

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 costs.

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 conventional electric and gas cooking products. 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 TSD, DOE used the Energy Information Administration's (EIA's) 2015 Residential Energy Consumption Survey (RECS 2015) to develop household samples for electric and gas cooking tops and ovens[1]. The EIA designed RECS 2015, which consists of 5,686 housing units, to be a national representation of 118.2 million households in the United States. Although RECS does not provide the annual energy consumption of the consumer conventional cooking products for each household record, it does provide the frequency of cooking use (see chapter 7 of this 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 cooking tops and ovens use and/or energy pricing contributes to the range of LCCs 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.

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 2022* (*AEO 2022*) 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).

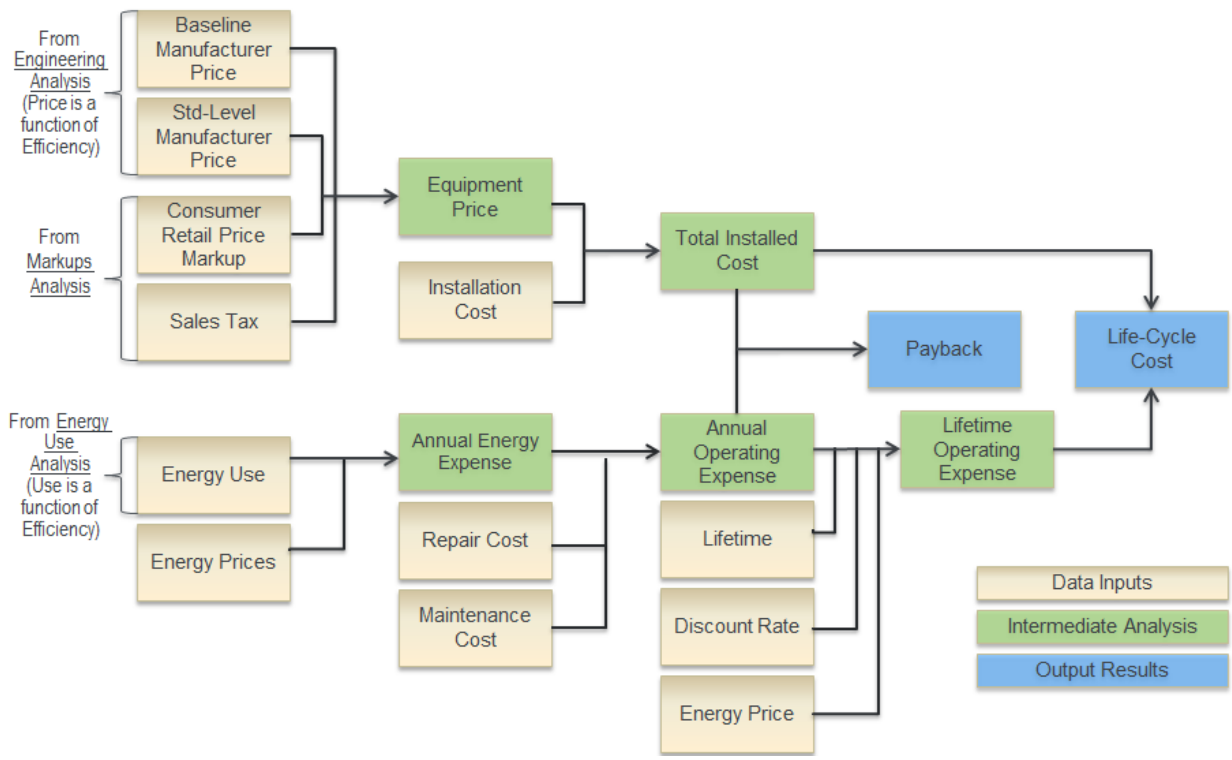

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

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 2021 and 2022. DOE expresses dollar values in 2021$.

8.2.1 Inputs to Total Installed Cost

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

$$IC = CPC + INST \qquad \textbf{Eq. 8.3}$$

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 TSD, DOE defined markups and sales taxes for converting manufacturing costs into consumer product costs. Table 8.2.1 summarizes 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.

$$\begin{aligned} IC_{BASE} &= CPC_{BASE} + INST_{BASE} \\ &= COST_{MFG} \times MU_{OVERALL\_BASE} + INST_{BASE} \end{aligned} \qquad \textbf{Eq. 8.4}$$

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 consumer conventional cooking products.

DOE assumed that the product costs would be the same in the compliance year, as at the time of this analysis.

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 conventional gas and electric cooking products, 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 1981-2021 and 1967-2021, 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 implicit price deflator for Gross Domestic Product for the same years. These inflation-adjusted price indices (shown in Figure 8.2.1 and 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: PCU33522013 for gas household ranges, ovens, surface cooking units and equipment and PCU33522011 for electric household ranges, ovens, surface cooking units and equipment. Available at: http://www.bls.gov/ppi/.

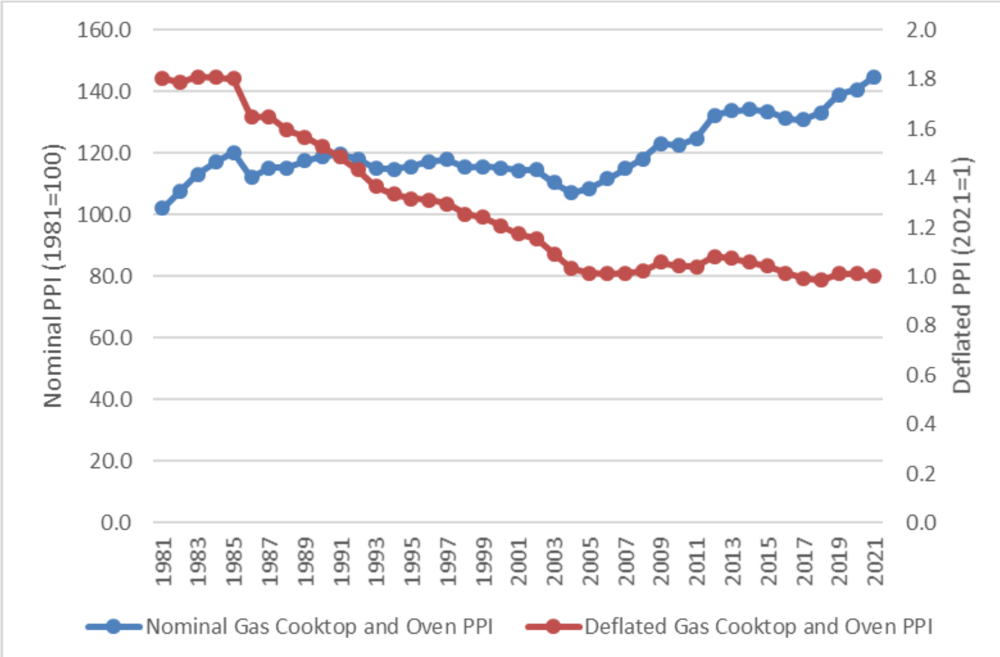

Figure 8.2.1 Nominal and Deflated Conventional Gas Cooking Products PPI from 1981 to 2021

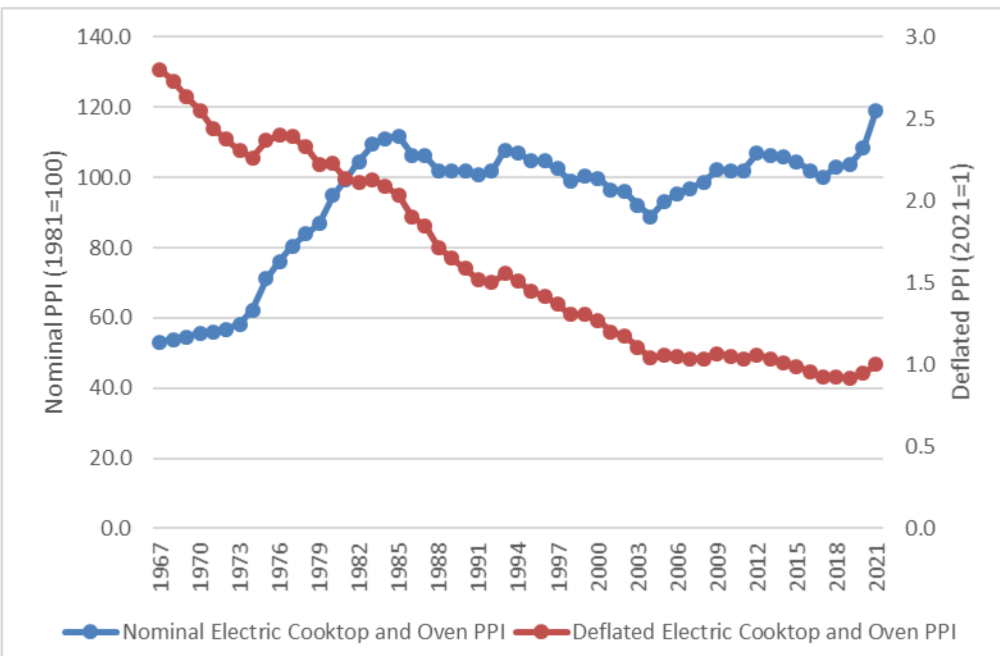

Figure 8.2.2 Nominal and Deflated Conventional Electric Cooking Products PPI from 1967 to 2021

DOE assembled a time-series of annual shipments for both consumer conventional electric and gas cooking products 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 2020 were obtained from the no-new-standards case projections made for the NIA (see chapter 9 of this TSD).

To estimate learning rate parameter, a least-squares power-law fit was performed on the deflated price index versus cumulative shipments. See Figure 8.2.3 and Figure 8.2.4.

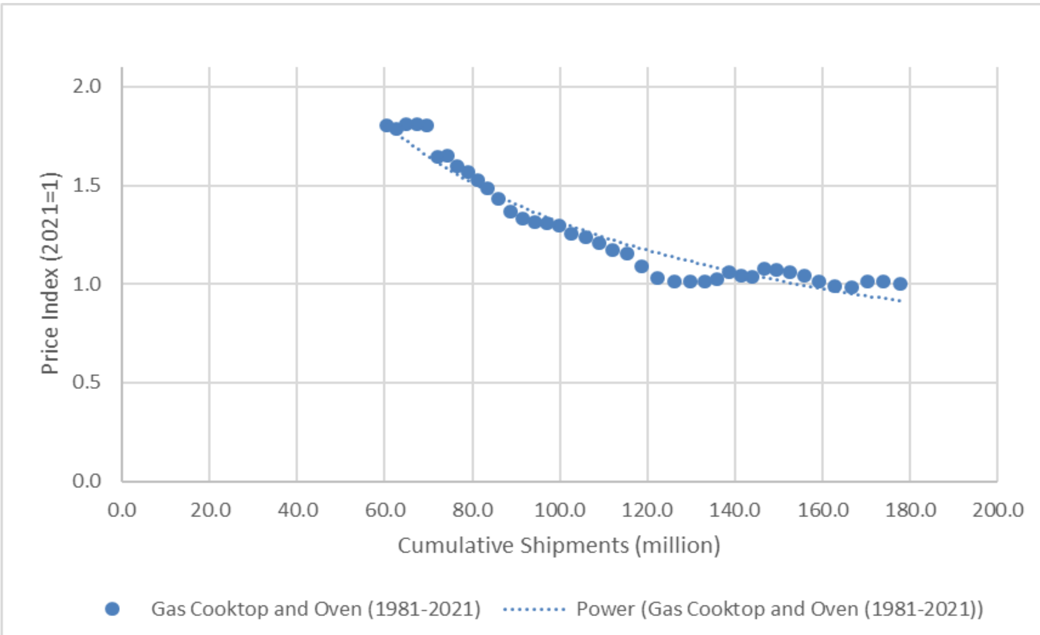

Figure 8.2.3 Relative Price versus Cumulative Shipments of Consumer Conventional Gas Cooking Products from 1981 to 2021, with Power Law Fit

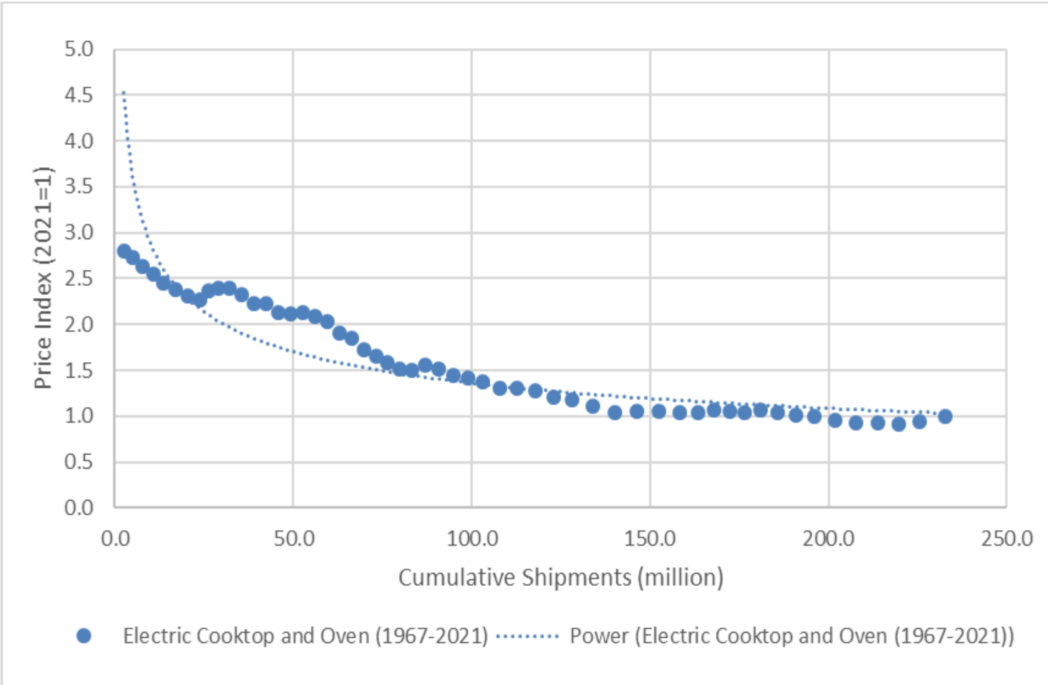

Figure 8.2.4 Relative Price versus Cumulative Shipments of Consumer Conventional Electric Cooking Products from 1967 to 2021, with Power Law Fit

The form of the fitting equation is:

$$P(X) = P_o X^{-b},$$

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 consumer conventional gas cooking products, the parameter values obtained are:

$P_o = 23.96^{+6.89}_{-5.35}$(95% confidence), and
b = 0.63±0.054 (95% confidence).

The estimated learning rate (defined as the fractional reduction in price expected from each doubling of cumulative production) is 35.4±2.4% (95% confidence).

For consumer conventional electric cooking products, the parameter values obtained are:

$$P_o = 6.09^{+1.14}_{-1.00}\text{(95\% confidence), and}$$
$$b = 0.33 \pm 0.039 \text{ (95\% confidence).}$$

The estimated learning rate (defined as the fractional reduction in price expected from each doubling of cumulative production) is 20.2±2.1% (95% confidence).

Since the production costs estimated in the engineering analysis represent the cost data in 2021, DOE derived two price factor indices, with 2021 equal to 1, to project prices for conventional gas and electric cooking products 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 each considered efficiency level. The estimated price forecast index is shown in Figure 8.2.5.

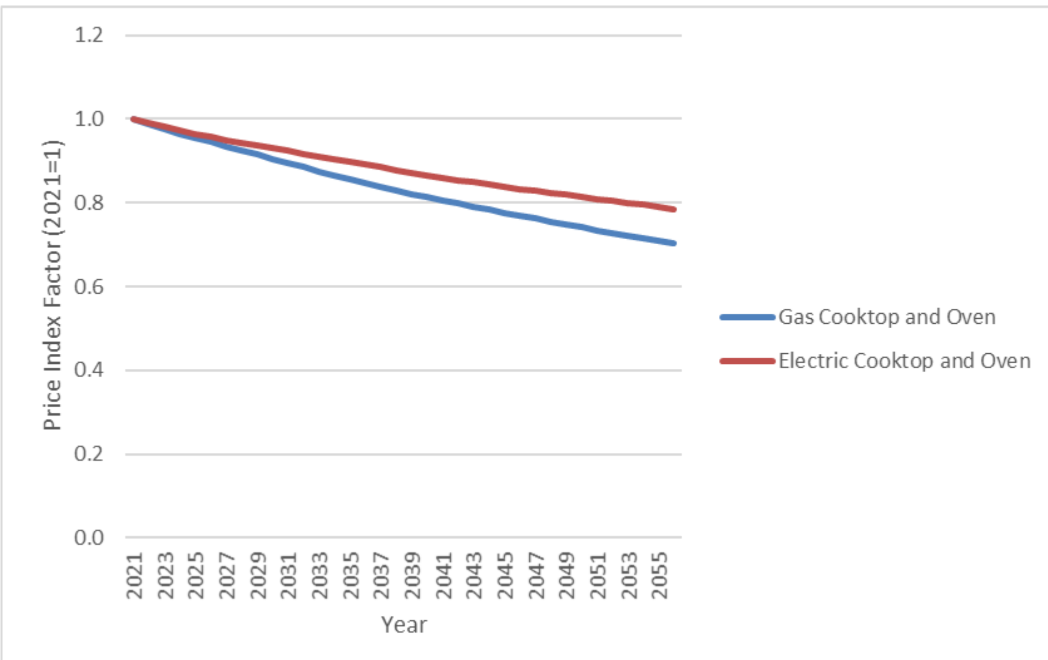

Figure 8.2.5 Price Forecast Indices for Conventional Gas and Electric Cooking Products

8.2.1.2 Baseline Manufacturer Costs

As described in detail in chapter 5 of this SNOPR TSD, DOE developed the baseline manufacturer costs for three product classes of conventional cooktops and 8 product classes of conventional ovens shown in Table 8.2.2 and Table 8.2.3, respectively. Also included in the table are the associated baseline efficiency metric for each product class, integrated annual energy consumption (IAEC) for cooktops and integrated annual oven energy consumption (IE_{AO}) for ovens.

Table 8.2.2 Baseline Manufacturer Costs for Cooktops

Product Class	IAEC		Baseline Manufacturer Cost (2021$)
	Gas *(kBtu/year)*	***Electricity*** *(kWh/year)*	
Electric Open (Coil) Element Cooking Tops	--	199	98.84
Electric Smooth Element Cooking Tops	--	250	222.32
Gas Cooking Tops	1,775	--	127.92

Table 8.2.3 Baseline Manufacturer Costs for Ovens

Product Class	IE_{AO}		Baseline Manufacturer Costs (2021$)
	Gas *(kBtu/year)*	***Electricity*** *(kWh/year)*	
Electric Standard Ovens, Freestanding	--	314.7	287.72
Electric Standard Ovens, Built-In/Slide-In	--	321.2	304.20
Electric Self-Clean Ovens, Freestanding	--	354.4	313.44
Electric Self-Clean Ovens, Built-In/Slide-in	--	360.5	329.92
Gas Standard Ovens, Freestanding	2,085	--	306.60
Gas Standard Ovens, Built-In/Slide-In	2,104	--	323.07
Gas Self-Clean Ovens, Freestanding	1,958	--	400.84

Product Class	IE_{AO}		Baseline Manufacturer Costs (2021$)
	Gas *(kBtu/year)*	***Electricity*** *(kWh/year)*	
Gas Self-Clean Ovens, Built-In/Slide-In	1,979	--	417.32

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 tops and ovens. Refer to Chapter 5, Engineering Analysis, of this TSD for details. Table 8.2.4 through Table 8.2.13 present the incremental manufacturer costs at each efficiency level for all eleven product classes of consumer conventional cooking products. Also included in each of the tables are the associated efficiency metric, IAEC for conventional cooktops and IE_{AO} for conventional ovens.

Table 8.2.4 Electric Smooth Element Cooking Tops: Incremental Manufacturer Cost by Efficiency Level

EL	IAEC	Manufacturer Cost Increase (2021$)
	kWh/year	
Baseline	250	--
1	207	$2.17
2	189	$11.05
3	179	$263.19

Table 8.2.5 Gas Cooking Tops: Incremental Manufacturer Cost by Efficiency Level

EL	IAEC	Manufacturer Cost Increase (2021$)
	kBtu/year	
Baseline	1,775	-
1	1,440	$12.41
2	1,204	$12.41

Table 8.2.6 Electric Standard Ovens, Freestanding: Incremental Manufacturer Cost by Efficiency Level

EL	IE_{AO} *kWh/year*	Manufacturer Cost Increase (2021$)
Baseline	314.7	--
1	302.0	$2.03
2	289.0	$34.11
3	235.3	$67.77

Table 8.2.7 Electric Standard Ovens, Built-In/Slide-In: Incremental Manufacturer Cost by Efficiency Level

EL	IE_{AO} *kWh/year*	Manufacturer Cost Increase (2021$)
Baseline	321.2	--
1	308.9	$2.03
2	295.9	$34.11
3	242.1	$67.77

Table 8.2.8 Electric Self-Clean Ovens, Freestanding: Incremental Manufacturer Cost by Efficiency Level

EL	IE_{AO} *kWh/year*	Manufacturer Cost Increase (2021$)
Baseline	354.4	--
1	341.7	$2.03
2	328.7	$34.11
3	275.0	$67.77

Table 8.2.9 Electric Self-Clean Ovens, Built-In/Slide-In: Incremental Manufacturer Cost by Efficiency Level

EL	IE_{AO} *kWh/year*	Manufacturer Cost Increase (2021$)
Baseline	360.5	--
1	348.1	$2.03
2	335.1	$34.11
3	281.4	$67.77

Table 8.2.10 Gas Standard Ovens, Freestanding: Incremental Manufacturer Cost by Efficiency Level

EL	IE_{AO} *kBtu/year*	Manufacturer Cost Increase (2021$)
Baseline	2,085	--
1	2,041	$2.17
2	1,908	$24.96

Table 8.2.11 Gas Standard Oven, Built-In/Slide-In: Incremental Manufacturer Cost by Efficiency Level

EL	IE_{AO} *kBtu/year*	Manufacturer Cost Increase (2021$)
Baseline	2,104	--
1	2,062	$0.83
2	1,929	$6.18

Table 8.2.12 Gas Self-Clean Ovens, Freestanding: Incremental Manufacturer Cost by Efficiency Level

EL	IE_{AO} *kBtu/year*	Manufacturer Cost Increase (2021$)
Baseline	1,958	--
1	1,915	$2.17
2	1,781	$24.96

Table 8.2.13 Gas Self-Clean Ovens, Built-In/Slide-In: Incremental Manufacturer Cost Increases by Efficiency Level

EL	IE_{AO} *kBty/year*	Manufacturer Cost Increase (2021$)
Baseline	1,979	--
1	1,937	$2.17
2	1,804	$24.96

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 TSD for details.

Table 8.2.14 Cooking Products: Overall Markup

Markup	Baseline	Incremental
Manufacturer	1.20	
Retailer	1.49	1.24
Sales Tax	1.073	
Overall	1.92	1.60

8.2.1.5 Installation Cost

DOE derived baseline installation costs for cooking tops and ovens from data in the *RS Means Residential Cost Data, 2021*.[5] The book estimates the labor required to install consumer cooking range equipment. Table 8.2.15 and Table 8.2.16 summarize the nationally representative costs associated with the installation of a 30-inch, free-standing cooking range and a 4-burner counter top cooking top, as presented in *RS Means Residential Cost Data*. DOE decided that the costs of installing a range are representative of the costs of installing an oven. As for cooking tops, in general, DOE estimated that installation costs would be the same for different efficiency levels. In the case of electric smooth cooking tops, the induction heating design option requires a change of utensils to those that are ferromagnetic to operate the cooking tops. DOE treated this as additional installation cost for this particular design option. DOE used average number of pots and pans utilized by a representative household and average retail price of induction compatible cooking utensils to estimate this portion of the installation cost.

Table 8.2.15 and Table 8.2.16 provide 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 baseline cooking tops and 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 8.2.15 Cooking Range (1 Oven): Baseline Installation Costs

	Bare Costs (2021$)			Including Overhead & Profit (2021$)		
Installation Type	**Material**	**Labor**	**Total**	**Total**	**Material***	**Labor****
Minimum	$460	$46	$506	$579	$506	$73
Maximum	$2,300	$114	$2,414	$2,710	$2,530	$180
					Average (2021$)	$127

* 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, Residential Cost Data, 2021.

Table 8.2.16 Countertop Cooking Tops (4 Burner Standard): Baseline Installation Costs

	Bare Costs (2021$)			Including Overhead & Profit (2021$)		
Installation Type	**Material**	**Labor**	**Total**	**Total**	**Material***	**Labor****
Minimum	$335	$57	$392	$462	$369	$93
Maximum	$1,850	$114	$1,964	$2,235	$2,035	$200
					Average (2018$)	$147

* 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, *Residential Cost Data, 2021.*

As for electric smooth cooking tops, to calculate the incremental installation cost required by the design option induction heating, DOE utilized the Willem et al. study[6] to determine the average number of pots and pans to be replaced. DOE used average number of pots and pans utilized by a representative household and average retail price of induction compatible cooking utensils to estimate this portion of the installation cost. DOE estimated $109 as the cost due to the change of pots and pans. With regard to those consumers who may need to upgrade the electrical wiring to accommodate for a higher amperage, DOE did not have information about the existing amperage of the electrical circuit of the consumer population. In order to be representative of the consumer population in this final rule, DOE estimated an average additional cost based on the assumption that 50% of the user population may need upgrades and 50% may not, using the wiring cost contained in 2021 RS Means Residential Cost Data. Table 8.2.17 provides the material and labor costs due to the upgrade of the electrical wiring based on the 2021 RS Means Residential Cost Data.

Table 8.2.17 Induction Cooking Tops (Range outlet, 50 amp-240 volt receptacle): Incremental Installation Costs

Residential Wiring	**Material**	**Labor**	**Total**	**Total Incl O&P**
Type NM cable	$97.66	$75.12	$171.71	$229.67
Type MC cable	$133.08	$79.42	$212.49	$275.81
EMT & Wire	$115.91	$106.25	$222.15	$301.57
			Average (2018$)	$269

8.2.1.6 Total Installed Cost

The total installed cost is the sum of the consumer product cost and installation cost. Table 8.2.18 through Table 8.2.28 present the total installed costs for each consumer conventional cooking product class at each efficiency level examined.

Table 8.2.18 Electric Open (Coil) Element Cooking Tops: Consumer Equipment Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$180.01	$146.75	$326.76

Table 8.2.19 Electric Smooth Element Cooking Tops: Consumer Equipment Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$404.89	$146.75	$551.64
1	$408.16	$146.75	$554.91
2	$421.64	$146.75	$568.39
3	$803.78	$400.06*	$1,203.85

*$400.06 for EL3 represents the installation cost for induction type cooking top. This cost includes an additional cost of $108.94 for change-out of cooking utensils and $134.50 for the upgrade of electric wiring. DOE estimated the cost of change-out of cooking utensils based on retail data for pots and pans for utensils with a ferromagnetic base.

Table 8.2.20 Gas Cooking Tops: Consumer Equipment Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$229.38	$146.75	$376.13
1	$247.89	$146.75	$394.64
2	$247.89	$146.75	$394.64

Table 8.2.21 Electric Standard Ovens, Freestanding: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$525.30	$127.00	$652.30
1	$528.38	$127.00	$655.38
2	$577.12	$127.00	$704.12
3	$628.27	$127.00	$755.27

Table 8.2.22 Electric Standard Ovens, Built-In/Slide-In: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$555.39	$127.00	$682.39
1	$558.47	$127.00	$685.47
2	$607.21	$127.00	$734.21
3	$658.36	$127.00	$785.36

Table 8.2.23 Electric Self-Clean Ovens, Freestanding: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$572.26	$127.00	$699.26
1	$575.34	$127.00	$702.34
2	$624.08	$127.00	$751.08
3	$675.23	$127.00	$802.23

Table 8.2.24 Electric Self-Clean Ovens, Built-In/Slide-In: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$602.34	$127.00	$729.34
1	$605.43	$127.00	$732.43
2	$654.17	$127.00	$781.17
3	$705.31	$127.00	$832.31

Table 8.2.25 Gas Standard Ovens, Freestanding: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$550.42	$127.00	$677.42
1	$553.65	$127.00	$680.65
2	$587.71	$127.00	$714.71

Table 8.2.26 Gas Standard Ovens, Built-In/Slide-In: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$579.99	$127.00	$706.99
1	$583.23	$127.00	$710.23
2	$617.28	$127.00	$744.28

Table 8.2.27 Gas Self-Clean Ovens, Freestanding: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$719.61	$127.00	$846.61
1	$722.85	$127.00	$849.85
2	$756.90	$127.00	$883.90

Table 8.2.28 Gas Self-Clean Ovens, Built-In/Slide-In: Consumer Product Prices, Installation Costs, and Total Installed Costs

EL	Equipment Price (2021$)	Installation Cost (2021$)	Total Installed Cost (2021$)
Baseline	$749.19	$127.00	$876.19
1	$752.44	$127.00	$879.44
2	$786.48	$127.00	$913.48

8.2.2 Inputs to Operating Cost

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

$$\boldsymbol{OC = EC + RC + MC}$$

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

Table 8.2.29 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.

$$\boldsymbol{OC_{BASE} = EC_{BASE} + RC_{BASE} + MC_{BASE} = AEC_{BASE} \times PRICE_{ENERGY} + RC_{BASE} + MC_{BASE}} \qquad \textbf{Eq. 8.10}$$

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:

$$\boldsymbol{\begin{aligned} OC_{STD} &= EC_{STD} + RC_{STD} + MC_{STD} = AEC_{STD} \times PRICE_{ENERGY} + RC_{STD} + MC_{STD} \\ &= (AEC_{BASE} - \Delta AEC_{STD}) \times PRICE_{ENERGY} + (RC_{BASE} + \Delta RC_{STD}) + (MC_{BASE} + \Delta MC_{STD}) \end{aligned}} \qquad \textbf{Eq. 8.11}$$

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 consumer conventional cooking products.

8.2.2.1 Annual Energy Consumption

As described in section 7.2.3 of chapter 7 of this TSD, DOE developed a sample of individual households that use one of the product classes of consumer 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 2015 RECS to develop the household samples and, in turn, to establish the variability in both annual energy consumption and energy pricing. Tables in chapter 7 provide the average annual energy consumption by efficiency level for each product class of consumer conventional cooking products.

8.2.2.2 Energy Prices

DOE used regional energy prices to characterize the variability in consumer operating costs. DOE's method for deriving energy prices is described here.

Recent Electricity Prices

Because marginal electricity price more accurately captures the incremental savings associated with a change in energy use from higher efficiency, it provides a better representation of incremental change in consumer costs than average electricity prices. Therefore, DOE applied average electricity prices for the energy use of the product purchased in the no-new-standards case, and marginal electricity prices for the incremental change in energy use associated with the other efficiency levels considered.

DOE derived annual electricity prices in 2021 for each census division using data from the latest EEI Typical Bills and Average Rates reports.[7] For the residential sector and for most of the major investor-owned utilities (IOUs) in the country, each report provides the total bill assuming household consumption levels of 500, 750 and 1,000 kWh for the billing period. DOE calculated electricity prices using the methodology described in Coughlin and Beraki (2018). [8]

Table 8.2.30 shows the average and Table 8.2.31 shows the marginal prices for each census division.

Table 8.2.30 Average Residential Electricity Prices in 2021

	Geographic Area	2021$/kWh
1	New England Census Division	$0.228
2	Middle Atlantic Census Division	$0.167
3	East North Central Census Division	$0.143
4	West North Central Census Division	$0.127
5	South Atlantic Census Division	$0.119
6	East South Central Census Division	$0.129
7	West South Central Census Division	$0.107
8	Mountain Census Division	$0.122
9	Pacific Census Division	$0.231

Source: EEI 2021.

Table 8.2.31 Marginal Residential Electricity Prices in 2021

	Geographic Area	2021$/kWh
1	New England Census Division	$0.215
2	Middle Atlantic Census Division	$0.152
3	East North Central Census Division	$0.130
4	West North Central Census Division	$0.110
5	South Atlantic Census Division	$0.103
6	East South Central Census Division	$0.106
7	West South Central Census Division	$0.090
8	Mountain Census Division	$0.119
9	Pacific Census Division	$0.260

Source: EEI 2021.

Recent Natural Gas Prices

DOE obtained data for calculating regional prices of natural gas from the EIA publication, *Natural Gas Navigator*.[9] This publication presents monthly volumes of natural gas deliveries and average prices by state for residential, commercial, and industrial customers. DOE used the complete annual data for 2020 to calculate an average annual price for each census division. 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 census division by its number of households.

The prices in Table 8.2.32 are in dollars per million Btu ($/MMBtu).

Table 8.2.32 Average Residential Natural Gas Prices in 2020

	Geographic Area	2020$/MMBtu
1	New England Census Division	$15.296
2	Middle Atlantic Census Division	$13.043
3	East North Central Census Division	$11.020
4	West North Central Census Division	$11.156
5	South Atlantic Census Division	$17.760
6	East South Central Census Division	$14.041
7	West South Central Census Division	$13.956
8	Mountain North Census Division	$8.247
9	Mountain South Census Division	$12.788
10	Pacific Census Division	$13.665

Source: EIA, Natural Gas Navigator for 2020.

Residential 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 natural gas consumption and expenditures by state. This data was used to determine 10-year average marginal prices factors for the RECS 2015 census divisions, which are then used to convert average monthly natural gas prices into marginal monthly natural gas prices.[10] DOE interpreted the slope of the regression line (consumption vs. expenditures) for each state as the marginal natural gas price factor for that state. Because a cooking product operates all year around, DOE determined summer and winter marginal price factors.

Table 8.2.33 shows the natural gas marginal price for each census division.

Table 8.2.33 Residential Marginal Natural Gas Price in 2020

	Geographic Area	2020$/MMBtu
1	New England Census Division	$13.13
2	Middle Atlantic Census Division	$9.00
3	East North Central Census Division	$6.69
4	West North Central Census Division	$6.94
5	South Atlantic Census Division	$10.97
6	East South Central Census Division	$8.72
7	West South Central Census Division	$7.60
8	Mountain North Census Division	$6.18
9	Mountain South Census Division	$8.34
10	Pacific Census Division	$12.26

Source: EIA, Natural Gas Navigator for 2020.

Average LPG Prices

DOE collected 2016 average LPG prices from EIA's 2020 State Energy Consumption, Price, and Expenditures Estimates (SEDS)[11]. SEDS includes annual LPG prices for residential, commercial, industrial, and transportation consumers by state.

Table 8.2.34 shows the LPG average price for each census division.

Table 8.2.34 Residential Average LPG Price in 20

	Geographic Area	2020$/MMBtu
1	New England Census Division	$32.803
2	Middle Atlantic Census Division	$29.614
3	East North Central Census Division	$19.513
4	West North Central Census Division	$15.808
5	South Atlantic Census Division	$31.897
6	East South Central Census Division	$23.108
7	West South Central Census Division	$24.051
8	Mountain North Census Division	$21.253
9	Mountain South Census Division	$26.593
10	Pacific Census Division	$26.594

Source: EIA 2020.

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 and marginal prices listed in section 8.2.2.2 by the forecast of annual average price changes based on the reference case in

EIA's *AEO 2022*. To estimate the trend after 2050, DOE used a constant value derived from the average values from 2046 through 2050.

DOE calculated LCC and PBP based on three separate projections from *AEO 2022*: reference, low economic growth, and high economic growth. These three cases reflect the uncertainty of economic growth in the projection period. The high and low growth cases show the projected effects of alternative growth assumptions on energy markets. Figure 8.2.6 and Figure 8.2.7 show the residential electricity and natural gas price trends, respectively, based on the three *AEO 2022* projections.

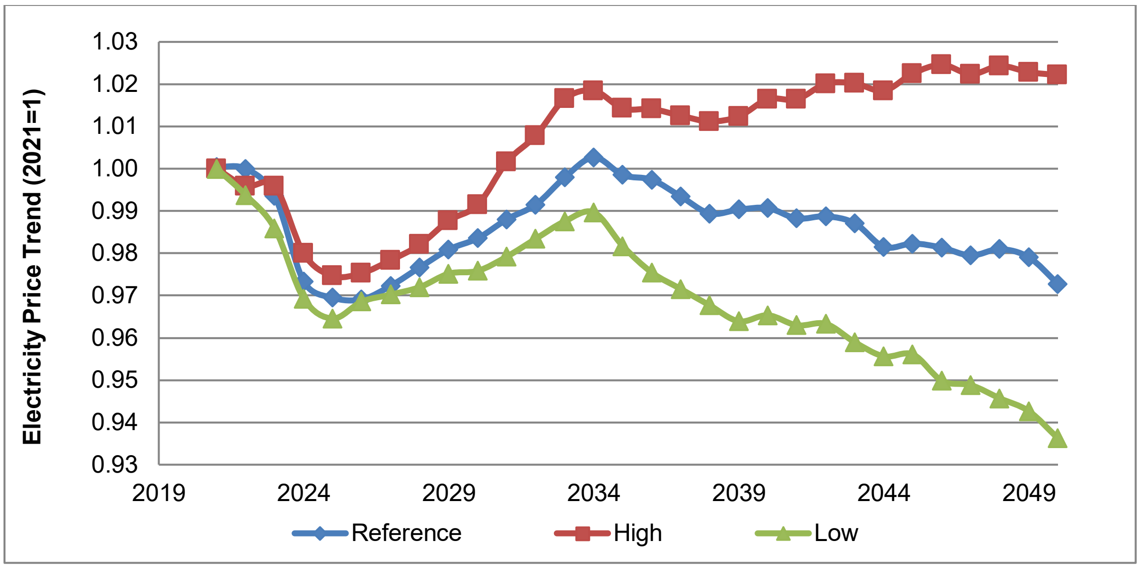

Figure 8.2.6 AEO 2022 Residential Electricity Price Trends

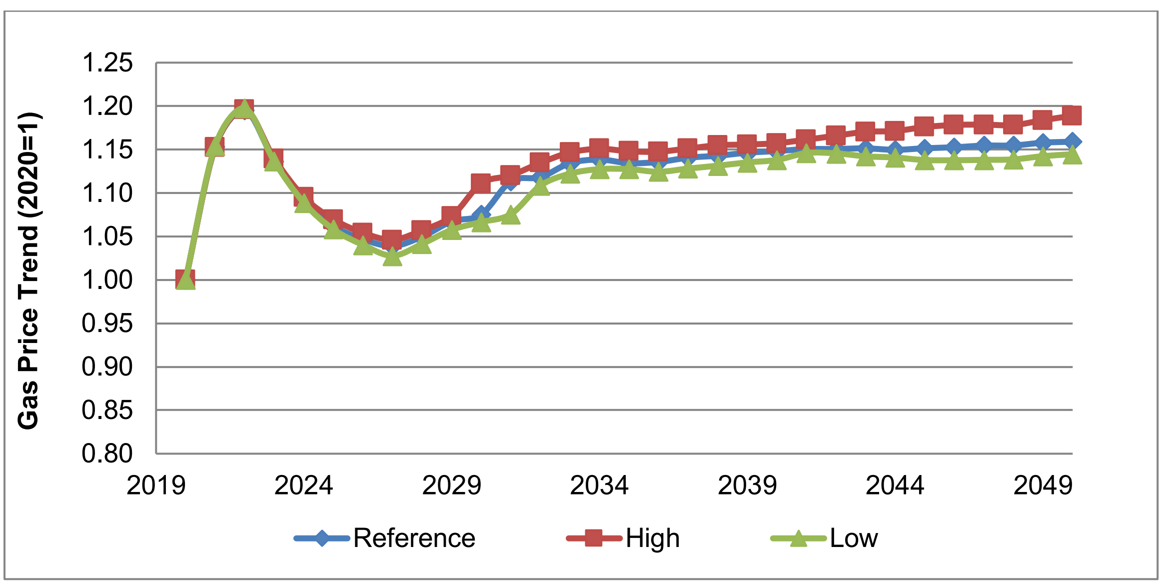

Figure 8.2.7 AEO 2022 Residential Natural Gas Price Trends

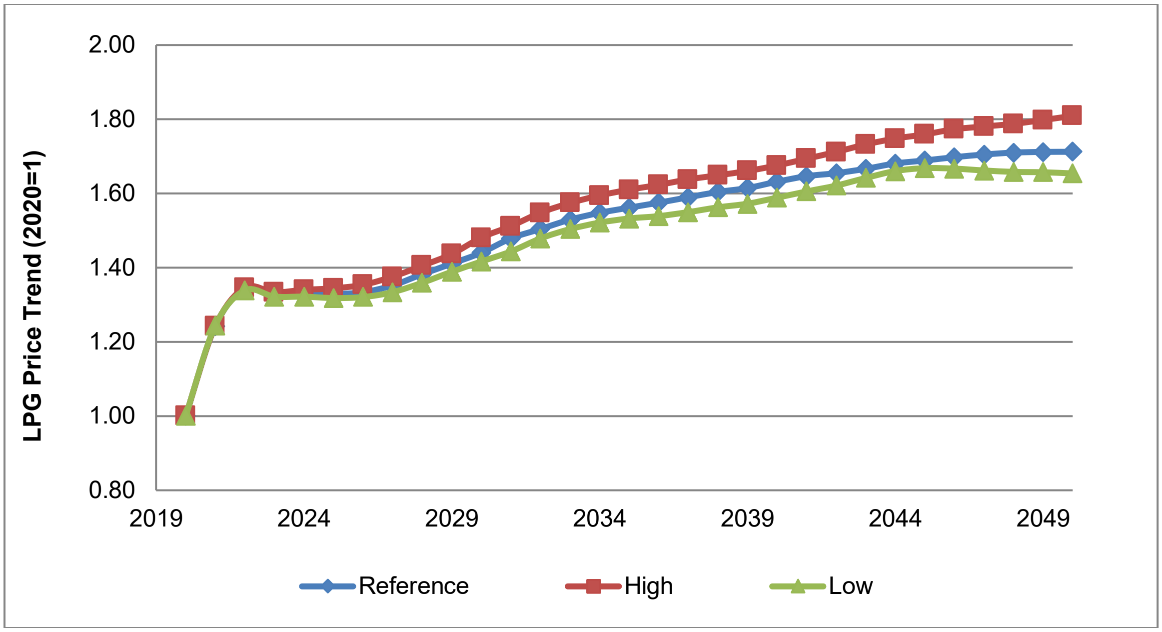

Figure 8.2.8 AEO 2022 Residential LPG Price Trends

8.2.2.4 Repair and Maintenance Costs

For cooktops, DOE determined the repair and maintenance costs associated with different types of repairs commonly found on appliance repair web sites. DOE found that the repair costs typically varied between $121 and $300 on average for a range of problems with the unit. Utilizing the data available from these sources, DOE estimated an average repair cost of $228 and $277 for cooking tops and ovens, over the product's lifetime. Typically, small incremental changes in product efficiency incur no, or only very small, changes in repair and maintenance costs over baseline products. For all cooking tops, 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 glo-bar ignition systems. DOE estimated the average repair cost attributable to glo-bar systems and annualized it over the life of the unit at $22.58 based on an analysis of available online data found on appliance repair costs.

8.2.2.5 Product Lifetime

For cooking tops, DOE assumed that average lifetime for electric cooking tops is 16.8 years and average lifetime for gas cooking tops is 14.5 years.[12]

To perform the LCC and PBP analysis, DOE had to develop survival functions for conventional cooking tops. 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:

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

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 $\beta = 1$, 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 8.2.8 and Figure 8.2.9 show the Weibull retirement and survival functions for electric and gas cooking products, respectively. The results of DOE's analysis are shown in Table 8.2.35. Details of calculations and assumptions can be found in appendix 8C.

[c] For reference on the Weibull distribution, see sections 1.3.6.6.8 and 8.4.1.3 of the National Institute of Standards and Technology (*NIST)/SEMATECH e-Handbook of Statistical Methods*. www.itl.nist.gov/div898/handbook/ (Last accessed November 18, 2016.)

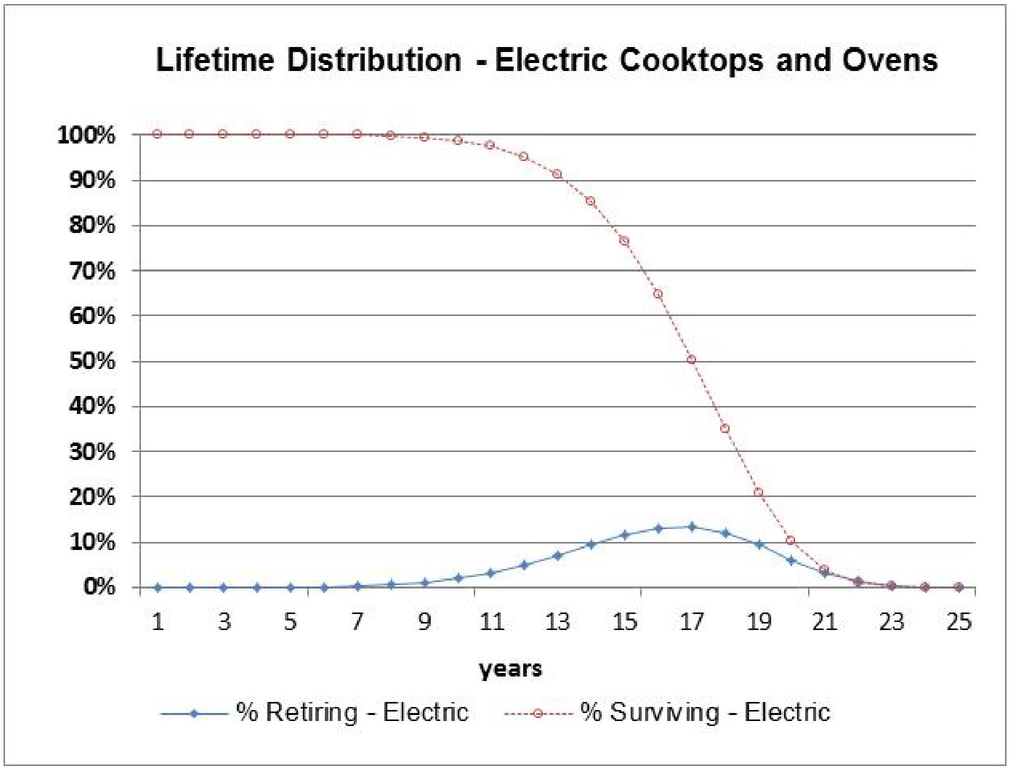

Figure 8.2.9 Weibull Function for Lifetime of Electric Cooking Products

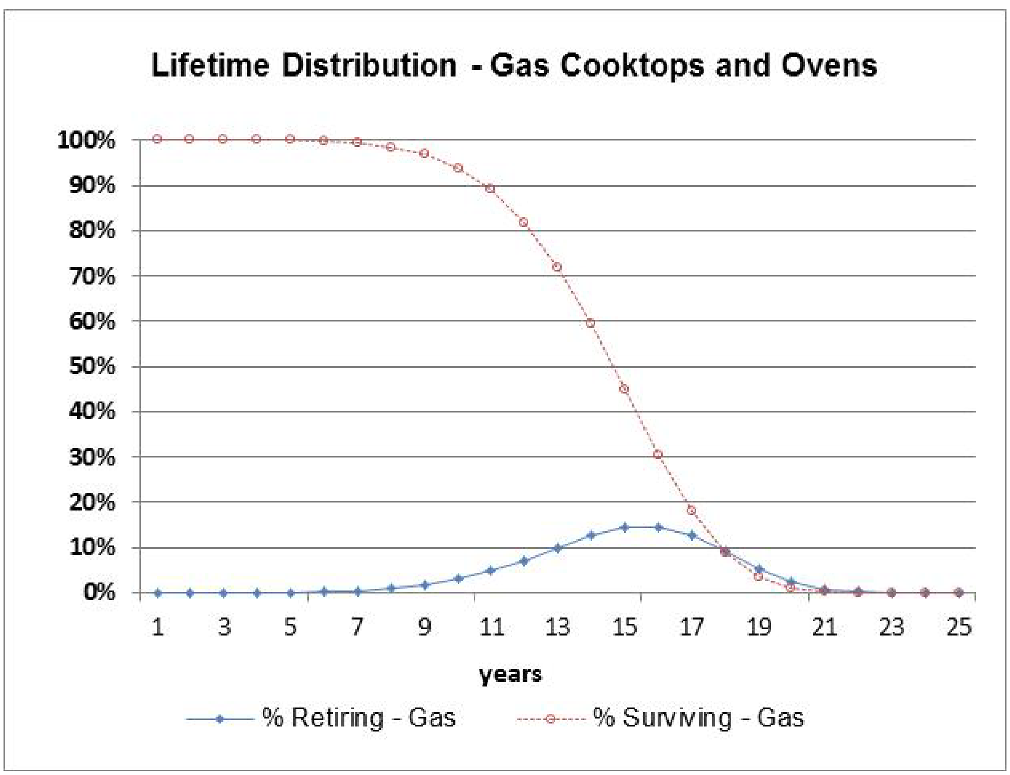

Figure 8.2.10 Weibull Function for Lifetime of Gas Cooking Products

Table 8.2.35 Lifetime Parameters

Product Fuel Type	Average (Years)	Weibull Parameters	
		Alpha (Scale)	Beta (Shape)
Electric	16.8	16.88	6.99
Gas	14.5	14.56	5.73

8.2.3 Discount Rate

The consumer discount rate is the rate at which future operating costs of residential products are discounted to establish their present value in the LCC analysis. The discount rate value is applied in the LCC to future year energy costs and non-energy operations and maintenance costs in order to calculate the estimated net life-cycle cost of products of various efficiency levels and the life-cycle cost savings of higher-efficiency models as compared to the baseline for a representative sample of consumers.

DOE calculates the consumer discount rate using publicly available data (the Federal Reserve Board's *Survey of Consumer Finance*s [SCF]) to estimate a consumer's required rate of return or opportunity cost of funds related to appliances.[13] In the economics literature, opportunity cost reflects potential foregone benefit from choosing one option over another. Opportunity cost of capital refers to the rate of return that one could earn by investing in an alternate project with similar risk; similarly, opportunity cost may be defined as the cost associated with opportunities that are foregone when resources are not put to their highest-value use.[14]

DOE's method views the purchase of a higher efficiency appliance as an investment that yields a stream of energy cost savings. The stream of savings is discounted at a rate reflecting (1) the rates of return associated with other investments available to the consumer, and (2) the observed costs of credit options available to the consumer to reflect the value of avoided debt. DOE notes that the LCC does not analyze the appliance purchase decision, so the implicit discount rate is not relevant in this model. The LCC estimates net present value over the lifetime of the product, so the appropriate discount rate will reflect the general opportunity cost of household funds, taking this time scale into account.

Given the long time horizon modeled in the LCC, the application of a marginal interest rate associated with an initial source of funds is inaccurate. Regardless of the method of purchase, consumers are expected to continue to rebalance their debt and asset holdings over the LCC analysis period, based on the restrictions consumers face in their debt payment requirements and the relative size of the interest rates available on debts and assets. DOE estimates the aggregate impact of this rebalancing using the historical distribution of debts and assets. The discount rate is the rate at which future savings and expenditures are discounted to establish their present value.

DOE estimates separate discount rate distributions for six income groups based on income percentiles as reported in the SCF. These income groups are listed in Table 8.2.36. This disaggregation reflects the fact that low and high income consumers tend to have substantially different shares of debt and asset types, as well as facing different rates on debts and assets. Summaries of shares and rates presented in this chapter are averages across the entire population.

Table 8.2.36 Definitions of Income Groups

Income Group	Percentile of Income
1	0 – 19.9
2	20 – 39.9
3	40 – 59.9
4	60 – 79.9
5	80 – 89.9
6	90 - 100

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.

8.2.3.1 Shares of Debt and Asset Classes

DOE's approach involved identifying all household debt or equity classes in order to approximate a consumer's opportunity cost of funds over the product's lifetime. This 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 now includes 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 8.2.37). The household-level discount rates are then aggregated to form discount rate distributions for each of the six income groups.[d]

DOE estimated the average percentage shares of the various types of debt and equity using data from the SCF for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.[e] DOE derived the household-weighted mean percentages of each source of across the twenty-one years covered by the eight survey versions. DOE posits that these long-term averages are most appropriate to use in its analysis.

---

[d] 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.

[e] 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 time span covered by the eight surveys included is sufficiently representative of recent debt and equity shares and interest rates.

Table 8.2.37 Average Shares of Household Debt and Asset Types by Income Group (%)

Type of Debt or Equity	Income Group						
	1	**2**	**3**	**4**	**5**	**6**	**All**
Debt:							
Mortgage	14.3	22.2	33.1	43.3	47.5	37.0	31.0
Home equity loan	1.5	1.8	2.4	3.5	4.6	7.7	3.1
Credit card	15.8	12.2	9.4	6.1	4.0	1.9	9.3
Other installment loan	31.9	28.0	23.9	16.9	11.5	5.9	21.9
Other line of credit	1.4	1.8	1.5	2.0	2.5	2.3	1.8
Other residential loan	0.7	0.4	0.5	0.4	0.3	0.2	0.5
Equity:							
Savings account	19.1	15.0	11.6	9.0	8.2	7.5	12.5
Money market account	3.5	4.3	3.8	3.6	4.4	6.7	4.1
Certificate of deposit	6.0	6.4	4.6	3.8	3.1	3.3	4.8
Savings bond	1.5	1.6	1.4	1.6	1.4	1.2	1.5
State & Local bonds	0.0	0.1	0.2	0.2	0.4	1.3	0.3
Corporate bonds	0.1	0.1	0.1	0.2	0.1	0.4	0.1
Stocks	2.3	3.2	3.8	4.8	6.0	12.2	4.6
Mutual funds	1.8	3.0	3.7	4.8	6.1	12.5	4.5
Total	**100.0**	**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, 2010, 2013, 2016, and 2019.

8.2.3.2 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 SCF for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019, which associates an interest rate with each type of debt for each household in the survey.

DOE adjusted the nominal rates to real rates for each type of debt by using the annual inflation rate for each year (using the Fisher formula).[f] In calculating effective interest rates for home equity loans and mortgages, DOE also accounted for the fact that interest on both such loans are tax deductible. This rate corresponds to the interest rate after deduction of mortgage interest for income tax purposes and after adjusting for inflation. The specific inflation rates vary by SCF year, while the marginal tax rates vary by SCF year and income bin as shown in Table 8.2.38. For example, a 6 percent nominal mortgage rate has an effective nominal rate of 5.5

[f] Fisher formula is given by: Real Interest Rate = [(1 + Nominal Interest Rate) / (1 + Inflation Rate)] – 1. Note that for this analysis DOE used a minimum real effective debt interest rate of 0 percent.

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.

Table 8.2.38 Data Used to Calculate Real Effective Household Debt Rates

Year	Inflation Rate (%)	Applicable Marginal Tax Rate by Income Group (%)					
		1	2	3	4	5	6
1995	2.81	15.0	15.0	15.0	28.0	28.0	39.6
1998	1.55	15.0	15.0	15.0	28.0	28.0	39.6
2001	2.83	10.0	15.0	15.0	27.5	27.5	39.1
2004	2.68	10.0	15.0	15.0	25.0	25.0	35.0
2007	2.85	10.0	15.0	15.0	25.0	25.0	35.0
2010	1.64	10.0	15.0	15.0	25.0	25.0	35.0
2013	1.46	10.0	15.0	15.0	25.0	25.0	37.3
2016	1.26	10.0	15.0	15.0	25.0	25.0	37.3
2019	1.81	10.0	12.0	12.0	22.0	22.0	36.0

Table 8.2.39 shows the household-weighted average effective real rates in each year and the mean rate across years. Because the interest rates for each type of household debt reflect economic conditions throughout numerous years and various phases of economic growth and recession, they are expected to be representative of rates in effect in 2025.

Table 8.2.39 Average Real Effective Interest Rates for Household Debt (%)

Type of Debt	Income Group						
	1	2	3	4	5	6	All
Mortgage	4.09	3.74	3.60	2.92	2.79	2.19	3.18
Home equity loan	4.29	4.34	3.86	3.24	3.11	2.45	3.35
Credit card	9.80	11.02	11.15	11.26	10.90	10.11	10.64
Other installment loan	6.14	7.09	5.98	5.33	4.54	4.42	6.10
Other line of credit	3.73	3.67	6.23	5.47	4.89	5.33	4.97
Other residential loan	6.53	6.41	5.22	4.96	4.33	3.99	5.32

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.

8.2.3.3 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 (1991-2020). The rates for stocks are the annual returns on the Standard and Poor's 500 for 1991–2020.[15] The interest rates associated with AAA corporate bonds were collected from Moody's time-series data for 1991–2020.[16] Rates on Certificates of Deposit (CDs) accounts came from Cost of Savings Index (COSI) data covering 1991–2020.[17,18,19,20,21,g] The interest rates associated with state and local bonds (20-bond municipal bonds) were collected from Federal Reserve Board economic data time-series for 1991–2020.[22,h] The interest rates associated with treasury bills (30-Year treasury constant maturity rate) were collected from Federal Reserve Board economic data time-series for 1991–2020.[23,24,i] Rates for money market accounts are based on three-month money market account rates reported by Organization for Economic Cooperation and Development (OECD) from 1991–2020.[25] Rates for savings accounts are assumed to be half the average real money market rate. Rates for mutual funds are a weighted average of the stock rates and the bond rates.[j] DOE adjusted the nominal rates to real rates using the annual inflation rate in each year (see appendix 8C). In addition, DOE adjusted the nominal rates to real effective rates by accounting for the fact that interest on such equity types is taxable. The capital gains marginal tax rate varies for each household based on income as shown in Table 8.2.40.

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[g] The Wells COSI is based on the interest rates that the depository subsidiaries of Wells Fargo & Company pay to individuals on certificates of deposit (CDs), also known as personal time deposits. Wells Fargo COSI started in November 2009. From July 2007 to October 2009 the index was known as Wachovia COSI and from January 1984 to July 2007 the index was known as GDW (or World Savings) COSI.

[h] This index was discontinued in 2016. To calculate the 2017 and after values, DOE compared 1981-2020 data for 30-Year Treasury Constant Maturity Rate[32] and Moody's AAA Corporate Bond Yield[24] to the 20-Bond Municipal Bond Index data.[31]

[i] From 2003-2005 there are no data. For 2003-2005, DOE used 20-Year Treasury Constant Maturity Rate.

[j] SCF reports what type of mutual funds the household has (*e.g.,* stock mutual fund, savings bond mutual fund, etc.). For mutual funds with a mixture of stocks and bonds, the mutual fund interest rate is a weighted average of the stock rates (two-thirds weight) and the savings bond rates (one-third weight).

Table 8.2.40 Average Capital Gains Marginal Tax Rate by Income Group (%)

Year	Income Group					
	1	**2**	**3**	**4**	**5**	**6**
1995	12.5	12.5	12.5	28.0	28.0	33.8
1998	12.5	12.5	12.5	24.0	24.0	29.8
2001	7.5	10.0	15.0	21.3	21.3	27.1
2004	7.5	10.0	15.0	21.3	21.3	27.1
2007	7.5	10.0	15.0	20.0	20.0	25.0
2010	5.0	7.5	15.0	20.0	20.0	25.0
2013	5.0	7.5	15.0	20.0	20.0	27.4
2016	5.0	7.5	15.0	20.0	20.0	27.4
2019	5.0	6.0	6.0	18.5	18.5	26.8

Average real effective interest rates for the classes of household assets are listed in Table 8.2.41. 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 the compliance year. The average nominal interest rates and the distribution of real interest rates by year are shown in appendix 8C of this SNOPR TSD.

Table 8.2.41 Average Real Interest Rates for Household Assets (%)

Equity Type	Income Group						
	1	2	3	4	5	6	All
Savings accounts	0.24	0.23	0.22	0.20	0.20	0.19	0.22
Money market accounts	0.48	0.47	0.45	0.41	0.41	0.37	0.43
Certificate of deposit	0.76	0.74	0.71	0.64	0.64	0.59	0.71
Treasury Bills (T-bills)	2.25	2.21	2.12	1.93	1.93	1.78	2.08
State/Local bonds	1.86	2.05	1.96	1.78	1.78	1.64	1.77
AAA Corporate Bonds	2.30	2.33	2.71	2.59	2.49	2.38	2.49
Stocks (S&P 500)	8.84	8.67	8.27	7.51	7.51	6.91	7.76
Mutual funds	7.31	7.37	7.13	6.38	6.46	5.67	6.52

8.2.3.4 Discount Rate Calculation and Summary

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

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

Where:

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

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

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

Table 8.2.42 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 8C presents the full probability distributions for each income group that DOE used in the LCC and PBP analysis.

Table 8.2.42 Average Real Effective Discount Rates

Income Group	Discount Rate (%)
1	4.76
2	4.99
3	4.54
4	3.84
5	3.47
6	3.23
Overall Average	4.29

Source: Board of Governors of the Federal Reserve System, Survey of Consumer Finances (1995 – 2019)

8.2.4 Compliance Date of Standard

DOE calculates the LCC and PBP as if all consumers purchase the consumer conventional cooking products in the expected initial year of compliance with a new or amended standard. At this time, the expected compliance date of potential energy conservation standards for consumer conventional cooking products manufactured in, or imported into, the United States is in 2027. DOE calculated the LCC for all consumers as if each would purchase a new product in 2027.

8.2.5 Product Energy Efficiency in the No-New-Standards 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 no-new-standards case (the case without new or amended energy conservation standards). DOE refers to this distribution of product efficiencies as the no-new-standards 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 cooking tops, DOE estimated the current efficiency distribution for each product class from the sample of cooking tops used to develop the engineering analysis. For ovens, DOE relied on model counts of the current market distribution. Given the lack of data on historic efficiency trends, DOE assumed that the estimated current distributions would apply in 2027. Table 8.2.43 through Table 8.2.45 show the no-new-standards case efficiency distribution in 2027 for each product class.

Table 8.2.43 No-New-Standards Case Market Share for Cooking Tops by Efficiency Level in 2027

EL	Electric Open (Coil) Element Cooking Tops	Electric Smooth Element Cooking Tops	Gas Cooking Tops
0	100.0%	20%	48%
1	--	50%	48%
2	--	25%	4%
3	--	5%	--

Table 8.2.44 No-New-Standards Case Market Share for Electric Ovens by Efficiency Level in 2027

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	5%	5%	5%	5%
1	57%	65%	18%	7%
2	38%	30%	77%	86%
3	0%	0%	0%	2%

Table 8.2.45 No-New-Standards Case Market Share for Gas Ovens by Efficiency Level in 2027

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	4%	4%	4%	4%
1	34%	58%	3%	19%
2	62%	38%	93%	77%

8.3 RESULTS OF LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

This section presents the results of the LCC and PBP for consumer 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 no-new-standards case products that it assigned to sample households. For some consumers DOE assigned a no-new-standards 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 8.3.22 show the LCC and simple PBP results by efficiency level for each cooking top product class. The average operating cost is the discounted sum.

Table 8.3.1 Average LCC and PBP Results by Efficiency Level for Electric Open (Coil) Element Cooking Tops

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
1-3	Baseline	$327	$14	$334	$661	--	$327

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 No-New-Standards Case Efficiency Distribution for PC1 Electric Open (Coil) Element Cooking Tops

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, ** 2021$
1-3	Baseline	0	0%

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 8.3.3 Average LCC and PBP Results by Efficiency Level for PC2 Electric Smooth Element Cooking Tops

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	Baseline	$552	$20	$408	$960	--	$552
1,2	1	$555	$14	$336	$891	0.6	$555
--	2	$568	$13	$321	$890	2.5	$568
3	3	$1,204	$12	$314	$1,517	87.5	$1,204

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 No-New-Standards Case Efficiency Distribution for PC2 Electric Smooth Element Cooking Tops

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, ** 2021$
1,2	1	0%	$13.29
--	2	33%	$13.77
3	3	95%	($580.31)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 8.3.5 Average LCC and PBP Results by Efficiency Level for PC3 Gas Cooking Tops

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	Baseline	$376	$15.5	$337	$713	--	$376
1	1	$395	$13.3	$310	$705	8.4	$395
2,3	2	$395	$11.8	$292	$686	5.0	$395

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 No-New-Standards Case Efficiency Distribution for PC3 Gas Cooking Tops

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, ** 2021$
1	1	27%	$3.88
2,3	2	18%	$21.89

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 8.3.7 Average LCC and PBP Results by Efficiency Level for PC4 Electric Standard Ovens, Free-Standing

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	0	$652	$23	$482	$1,134	--	$652
1,2	1	$655	$21	$459	$1,114	1.7	$655
--	2	$704	$20	$448	$1,152	19.8	$704
3	3	$755	$17	$405	$1,160	17.0	$755

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 No-New-Standards Case Efficiency Distribution for PC4 Electric Standard Ovens, Free-Standing

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, **
			2021$
1, 2	1	0%	$0.99
--	2	59%	($22.48)
3	3	80%	($29.92)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 8.3.9 Average LCC and PBP Results by Efficiency Level for PC5 Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	0	$682	$24	$494	$1,176	--	$682
1,2	1	$685	$22	$472	$1,157	1.8	$685
--	2	$734	$21	$461	$1,195	20.2	$734
3	3	$785	$18	$417	$1,203	17.2	$785

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 No-New-Standards Case Efficiency Distribution for PC5 Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, ** 2021$
1, 2	1	0%	$0.95
--	2	67%	($25.69)
3	3	81%	($33.05)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 8.3.11 Average LCC and PBP Results by Efficiency Level for PC6 Electric Self-Clean Ovens, Free-Standing

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	0	$699	$28	$552	$1,251	--	$699
1,2	1	$702	$26	$529	$1,231	1.7	$702
--	2	$751	$26	$518	$1,269	19.8	$751
3	3	$802	$22	$474	$1,277	17.0	$802

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 No-New-Standards Case Efficiency Distribution for PC6 Electric Self-Clean Ovens, Free-Standing

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, ** 2021$
1, 2	1	0%	$1.02
--	2	22%	($7.87)
3	3	75%	($15.31)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 8.3.13 Average LCC and PBP Results by Efficiency Level for PC7 Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	Baseline	$729	$29	$563	$1,292	--	$729
1,2	1	$732	$27	$540	$1,273	1.8	$732
--	2	$781	$27	$530	$1,311	20.1	$781
3	3	$832	$23	$486	$1,319	17.2	$832

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 No-New-Standards Case Efficiency Distribution for PC7 Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, **
			2021$
1, 2	1	0%	$1.01
--	2	11%	($3.50)
3	3	72%	($10.84)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 8.3.15 Average LCC and PBP Results by Efficiency Level for PC8 Gas Standard Ovens, Free-Standing

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	Baseline	$677	$43	$684	$1,361	--	$677
1, 2	1	$681	$41	$664	$1,345	1.9	$681
3	2	$715	$40	$653	$1,367	14.1	$715

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 No-New-Standards Case Efficiency Distribution for PC8 Gas Standard Ovens, Free-Standing

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, ** 2021$
1, 2	1	1%	$0.65
3	2	33%	($7.56)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 8.3.17 Average LCC and PBP Results by Efficiency Level for PC9 Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	Baseline	$707	$44	$692	$1,399	--	$707
1,2	1	$710	$42	$673	$1,384	2.0	$710
3	2	$744	$41	$662	$1,406	14.4	$744

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 8.3.18 Average LCC Savings Relative to the No-New-Standards Case Efficiency Distribution for PC9 Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, ** 2021$
1, 2	1	1%	$0.59
3	2	56%	($13.37)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 8.3.19 Average LCC and PBP Results by Efficiency Level for PC10 Gas Self-Clean Ovens, Free-Standing

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	Baseline	$847	$44	$702	$1,549	--	$847
1, 2	1	$850	$43	$683	$1,532	1.9	$850
3	2	$884	$42	$671	$1,555	14.1	$884

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 8.3.20 Average LCC Savings Relative to the No-New-Standards Case Efficiency Distribution for PC10 Gas Self-Clean Ovens, Free-Standing

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, ** 2021$
1, 2	1	1%	$0.70
3	2	6%	($0.86)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 8.3.21 Average LCC and PBP Results by Efficiency Level for PC11 Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs *2021$*				Simple Payback *years*	Average Lifetime *years*
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
--	Baseline	$876	$45	$711	$1,587	--	$876
1, 2	1	$879	$44	$692	$1,571	2.0	$879
3	2	$913	$43	$680	$1,594	14.4	$913

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 8.3.22 Average LCC Savings Relative to the No-New-Standards Case Efficiency Distribution for PC11 Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience Net Cost	Average Savings*, **
			2021$
1, 2	1	1%	$0.60
3	2	20%	($4.52)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

8.3.2 Distribution of Impacts

The figures in this section show the distribution of LCCs in the no-new-standards 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.

8.3.2.1 No-New-Standards Case LCC Distributions

Figure 8.3.1 through Figure 8.3.11 show the no-new-standards case LCC distributions for each product class of consumer conventional cooking products.

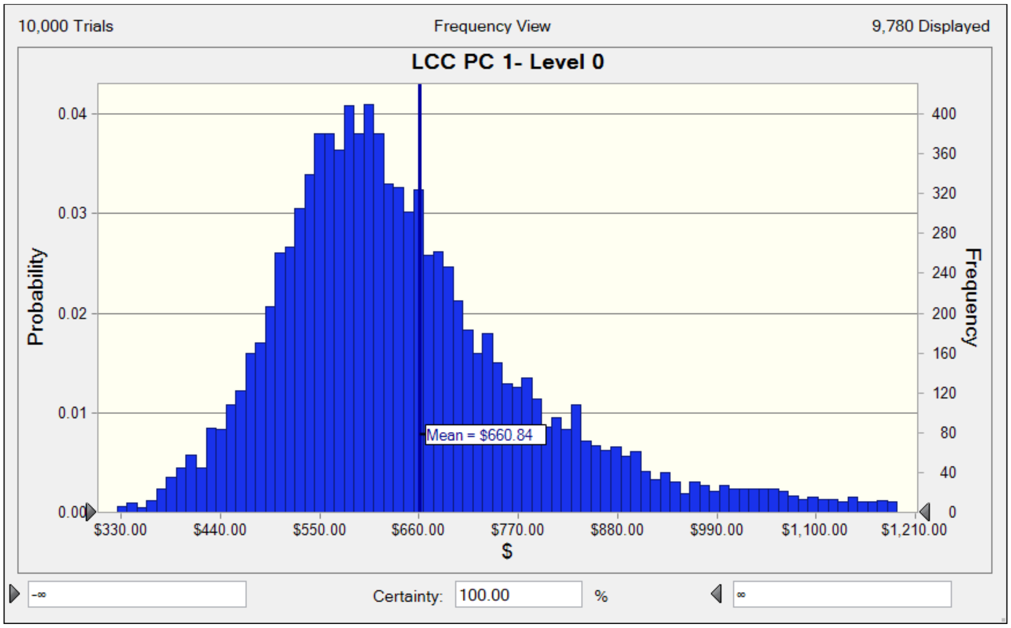

Figure 8.3.1 Electric Coil Cooking Tops: No-New-Standards Case LCC Distribution

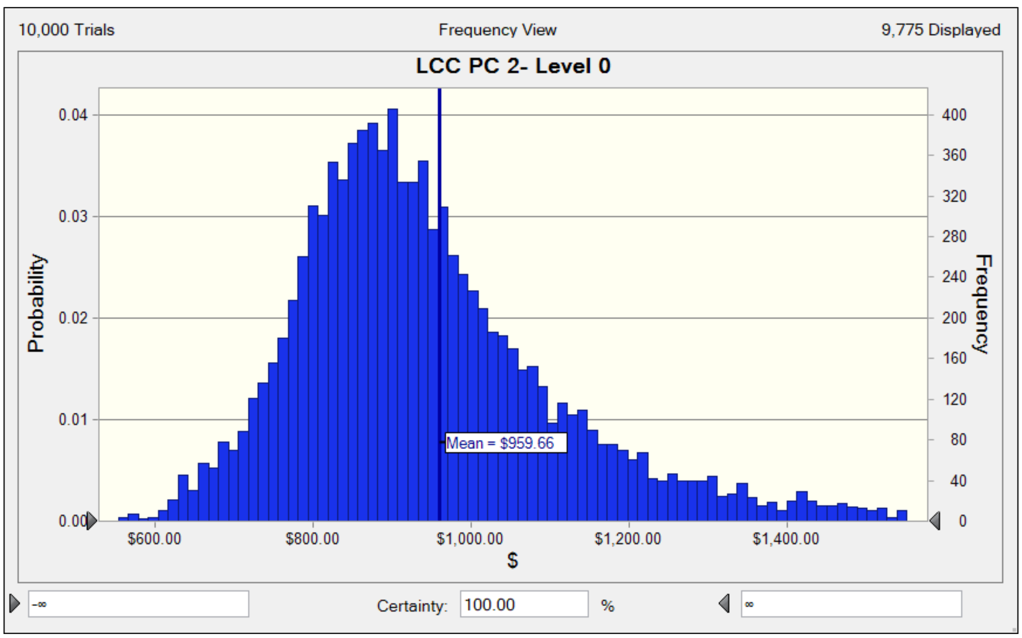

Figure 8.3.2 Electric Smooth Element Cooking Tops: No-New-Standards Case LCC Distribution

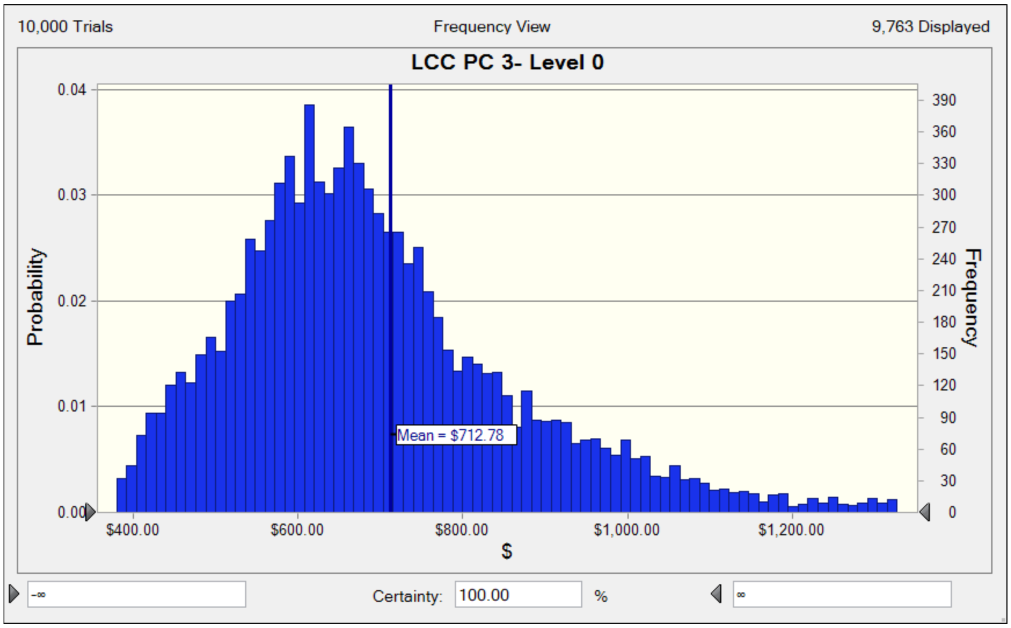

Figure 8.3.3 Gas Cooking Tops: No-New-Standards Case LCC Distribution

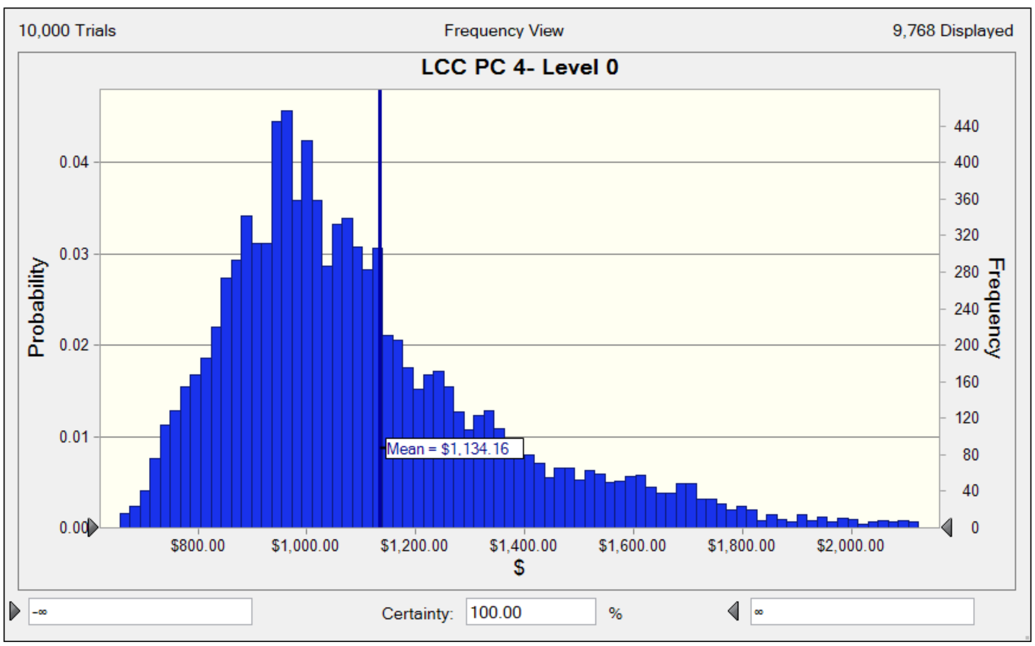

Figure 8.3.4 Electric Standard Ovens, Freestanding: No-New-Standards Case LCC Distribution

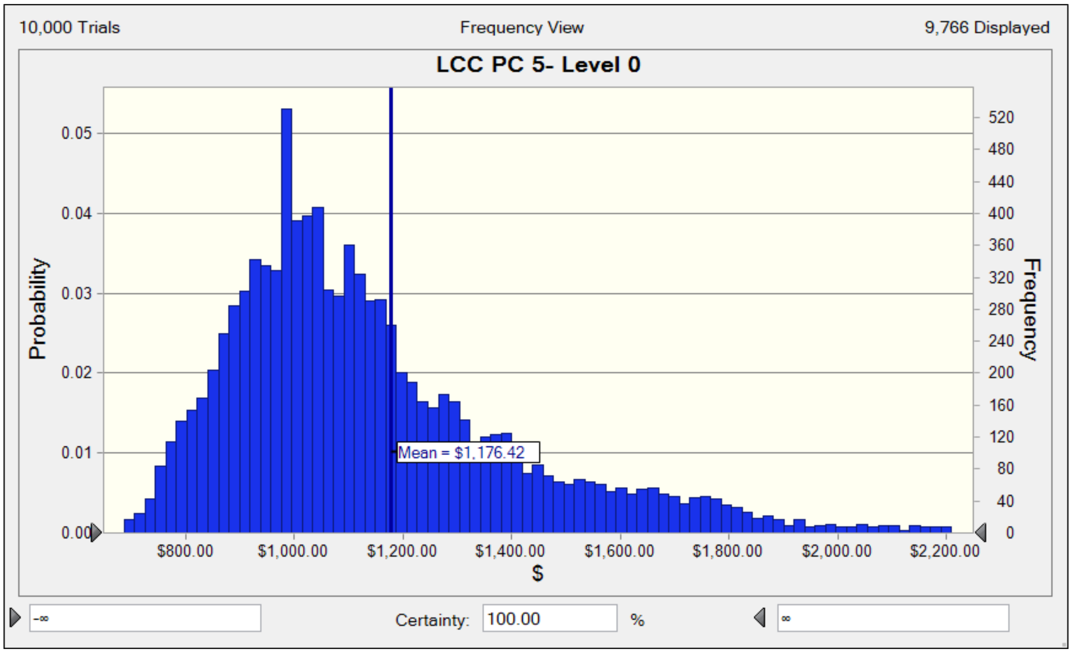

Figure 8.3.5 Electric Standard Ovens, Built-in/Slide-in: No-New-Standards Case LCC Distribution

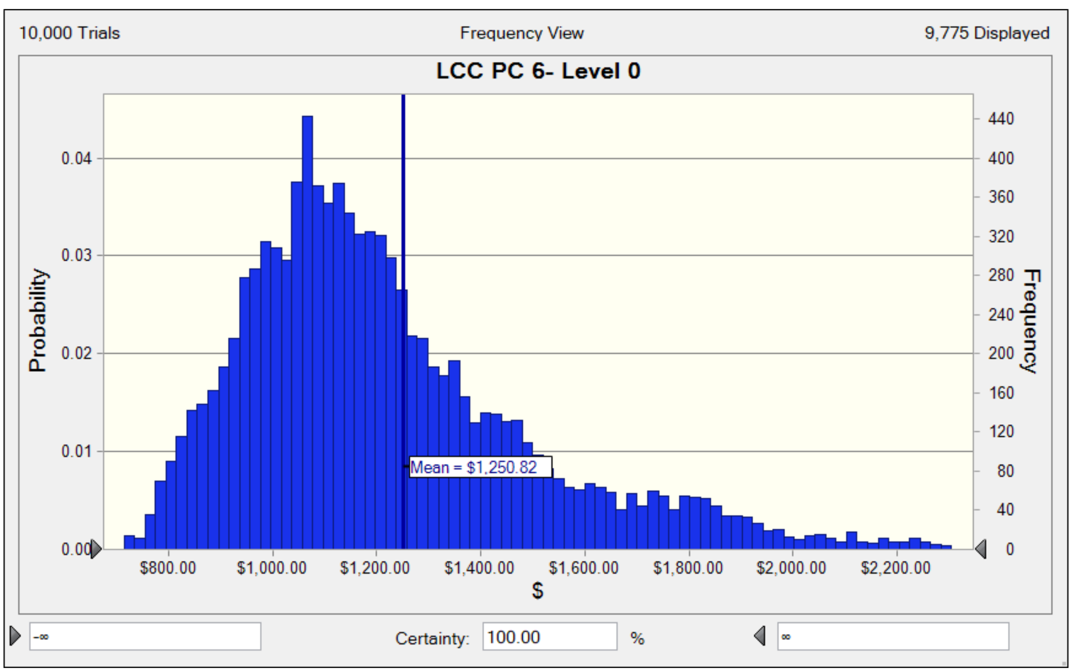

Figure 8.3.6 Electric Self-Clean Ovens, Freestanding: No-New-Standards Case LCC Distribution

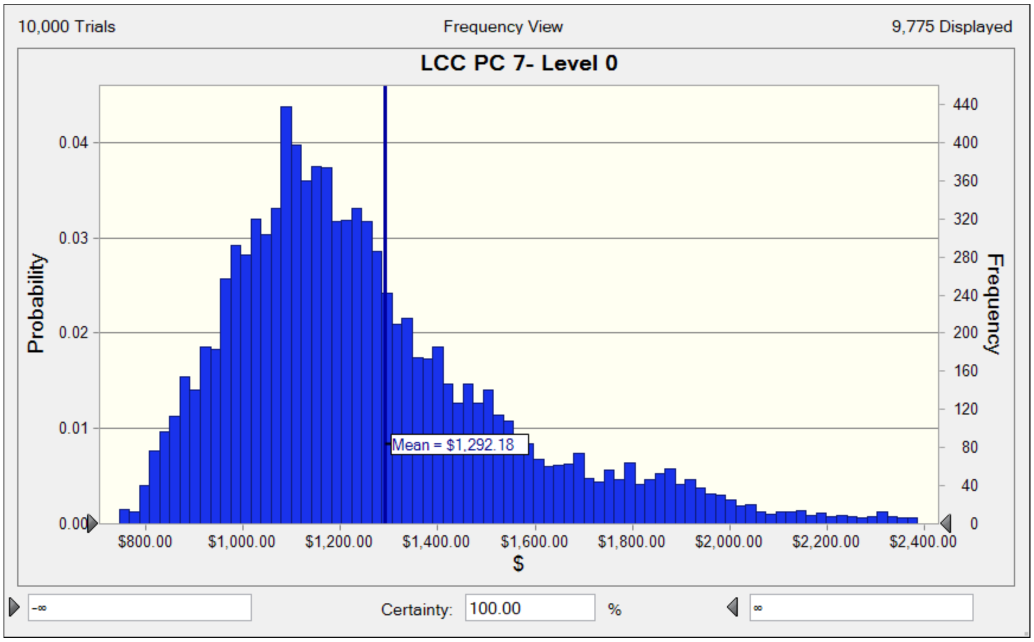

Figure 8.3.7 Electric Self-Clean Ovens, Built-in/Slide-in: No-New-Standards Case LCC Distribution

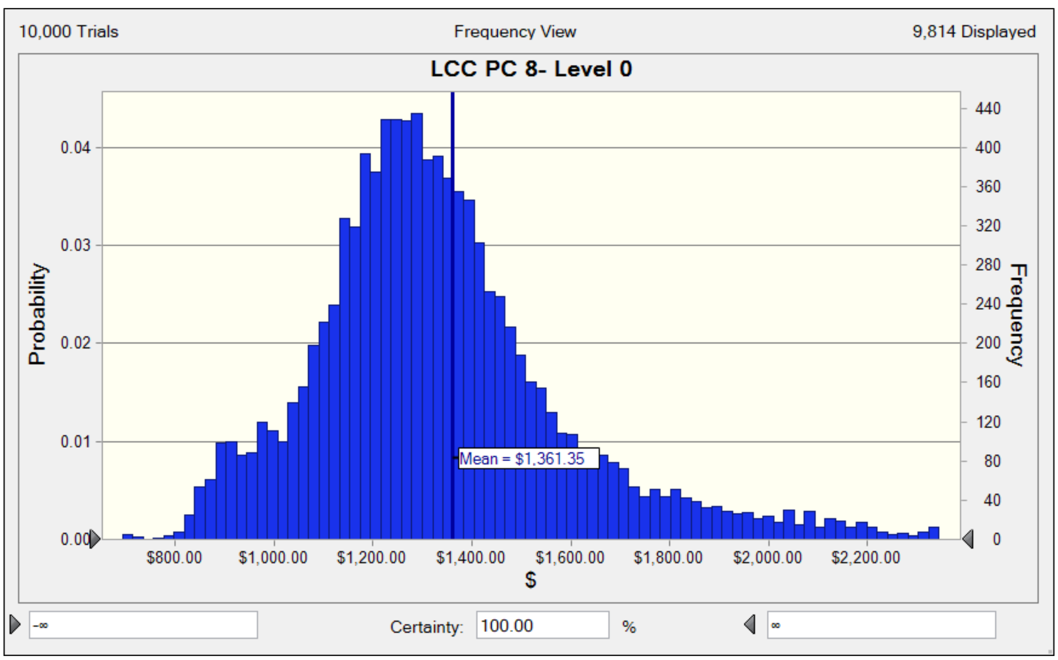

Figure 8.3.8 Gas Standard Ovens, Freestanding: No-New-Standards Case LCC Distribution

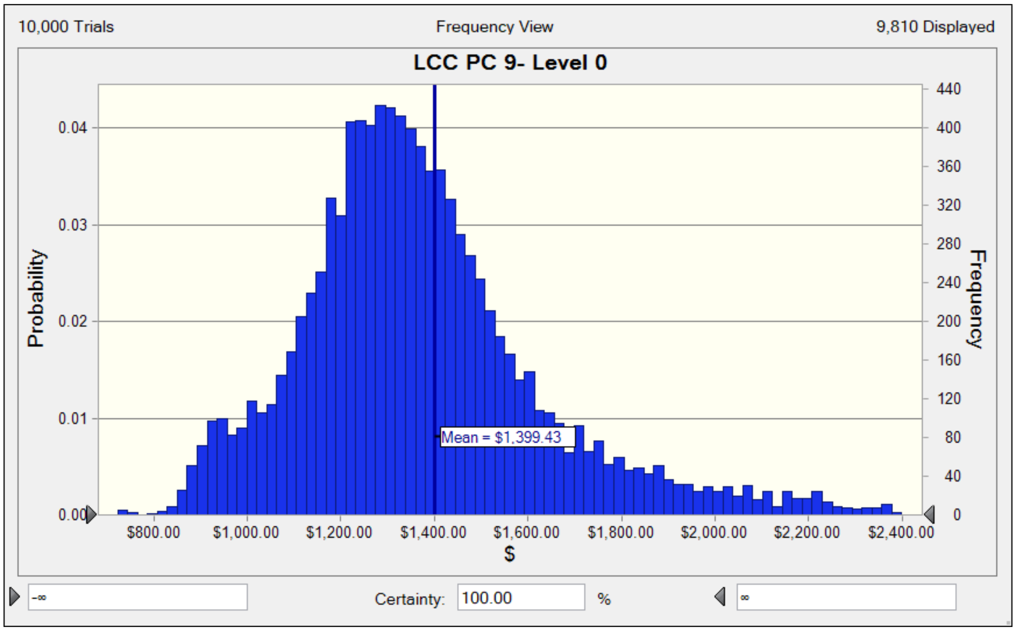

Figure 8.3.9 Gas Standard Ovens, Built-in/Slide-in: No-New-Standards Case LCC Distribution

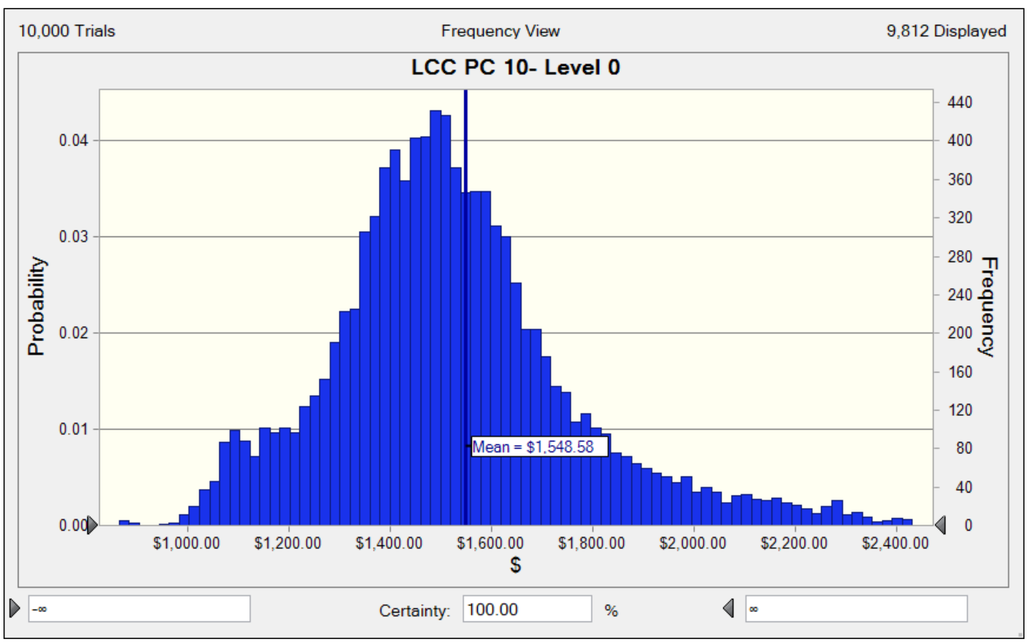

Figure 8.3.10 Gas Self-Clean Ovens, Freestanding: No-New-Standards Case LCC Distribution

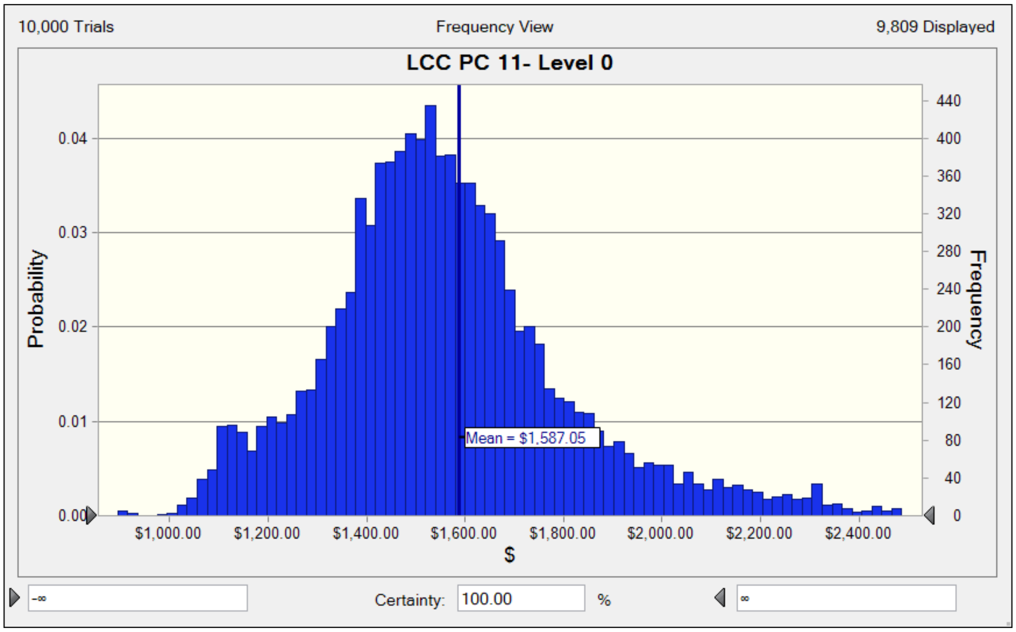

Figure 8.3.11 Gas Self-Clean Ovens, Built-in/Slide-in: No-New-Standards Case LCC Distribution

8.3.2.2 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 2 for product class 2, electric smooth element cooking tops. In the figure, a text box next to a vertical line at a given value on the x-axis shows the mean change in LCC (a savings of $13.77 in the example here). The note, "Certainty is 100.00%," means that 100 percent of owners of electric smooth element cooking tops will have LCC savings or not be affected by the efficiency level compared to the no-new-standards case. Refer to section 8.2.5 on the distribution of product efficiencies under the no-new-standards case. DOE can generate a frequency chart like the one shown in Figure 8.3.12 for each efficiency level and product class.

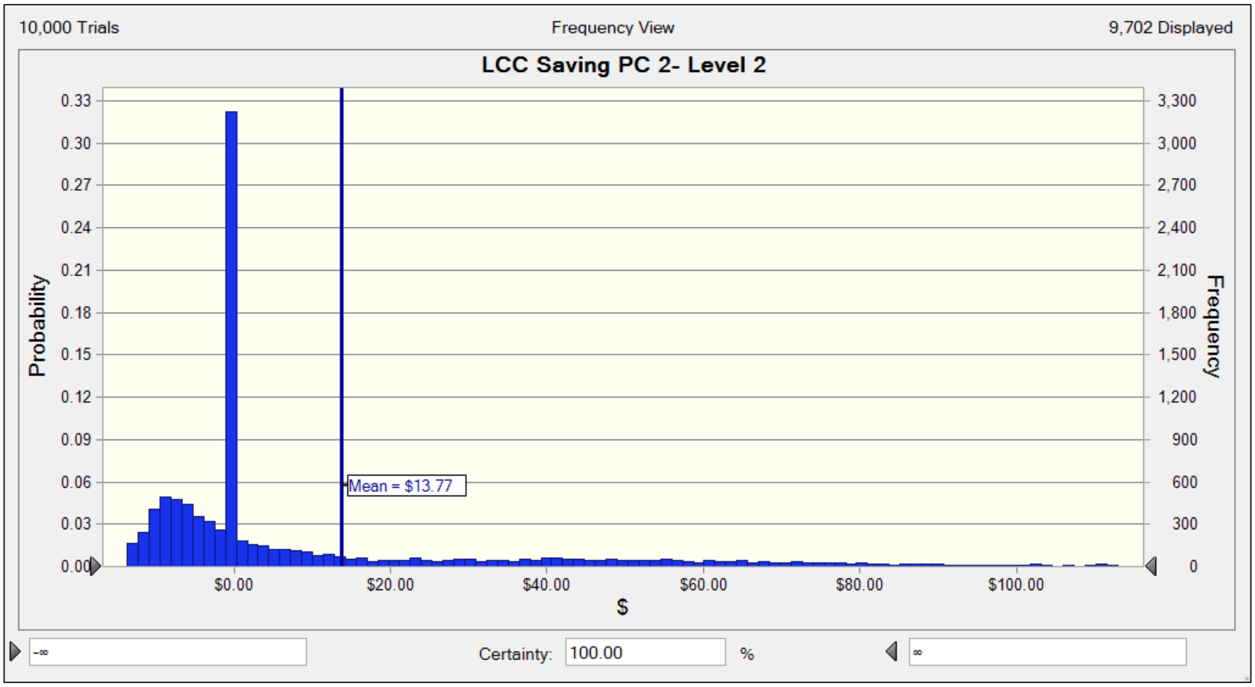

Figure 8.3.12 Electric Smooth Element Cooking Tops: Distribution of LCC Impacts for TSL 2

8.3.2.3 Range of Impacts

Figure 8.3.13 through Figure 8.3.22 show the range of LCC savings for all efficiency levels considered for all consumer conventional cooking products, except electric open element cooking tops[k]. 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.

[k] Since DOE does not consider any additional efficiency levels for improvement, there are no impacts to be shown for this product class.

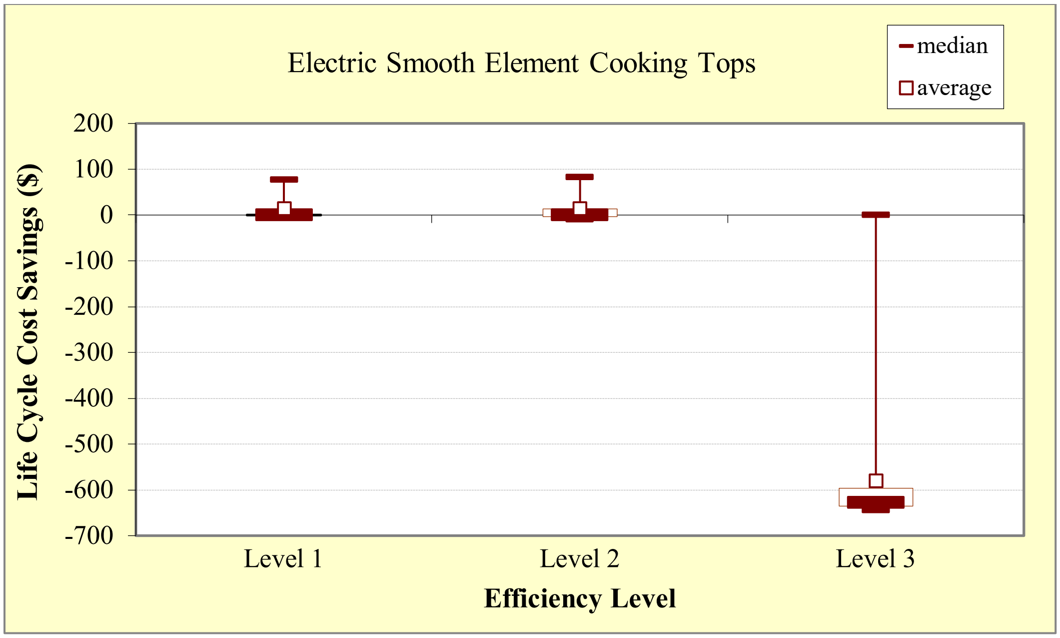

Figure 8.3.13 Electric Smooth Element Cooking Tops: Range of LCC Savings

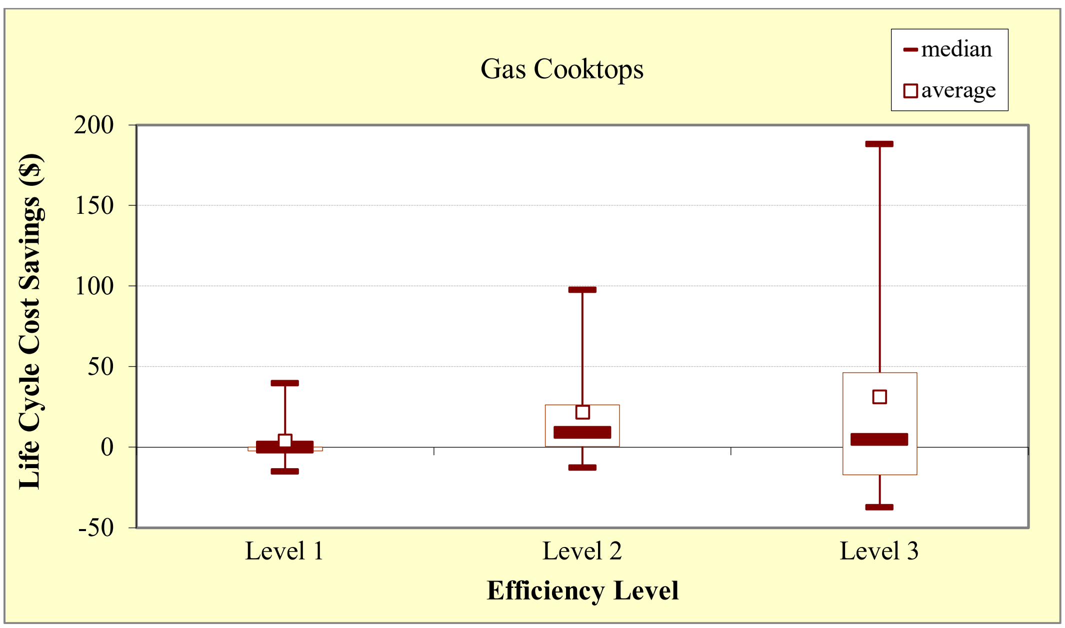

Figure 8.3.14 Gas Cooking Tops: Range of LCC Savings

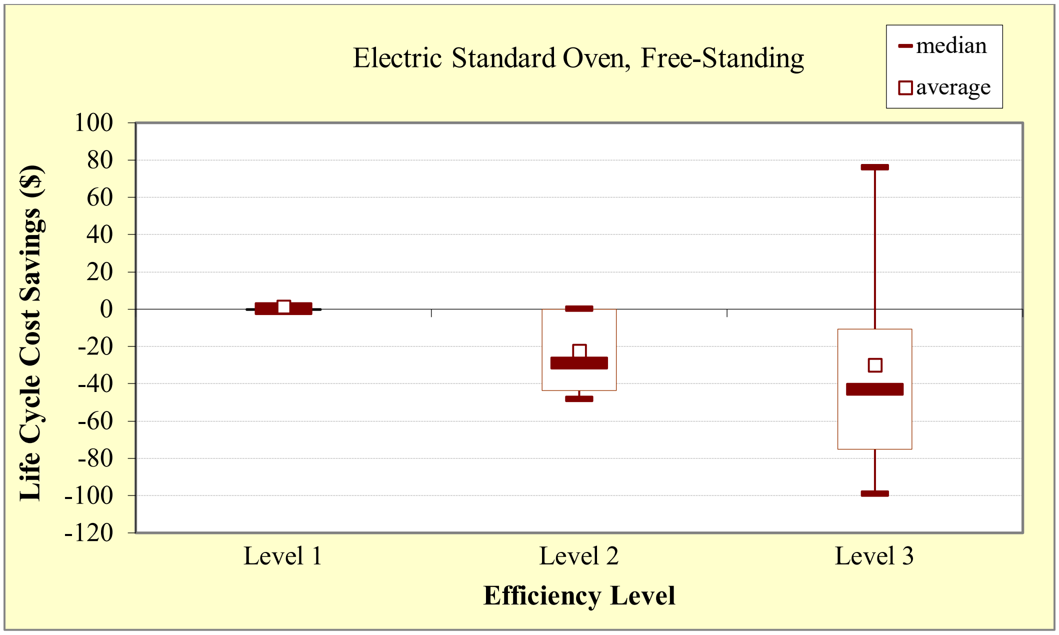

Figure 8.3.15 Electric Standard Ovens, Freestanding: Range of LCC Savings

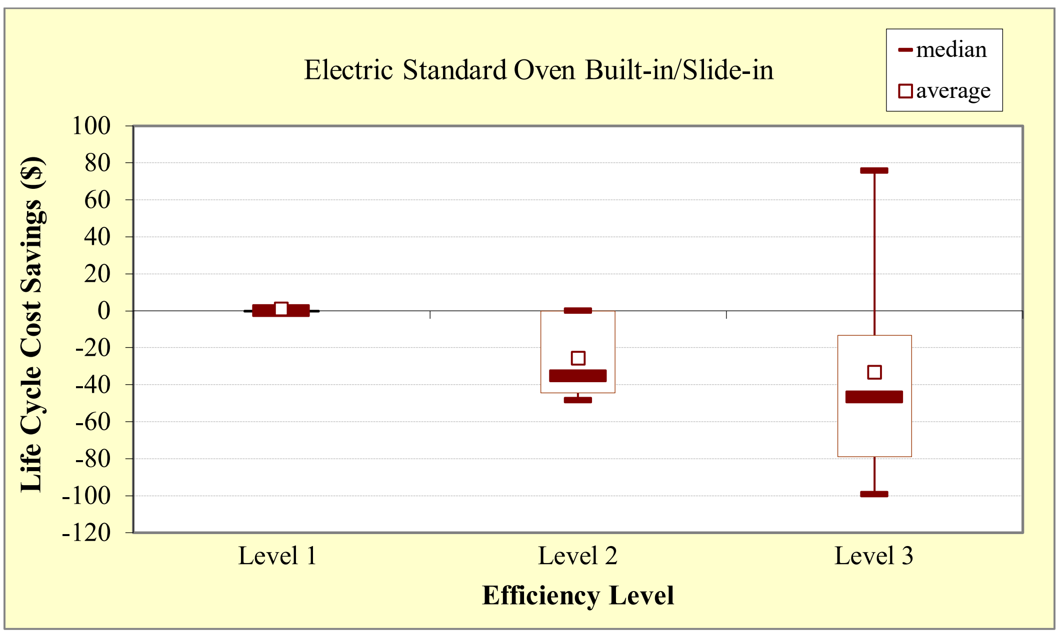

Figure 8.3.16 Electric Standard Ovens, Built-In/Slide-In: Range of LCC Savings

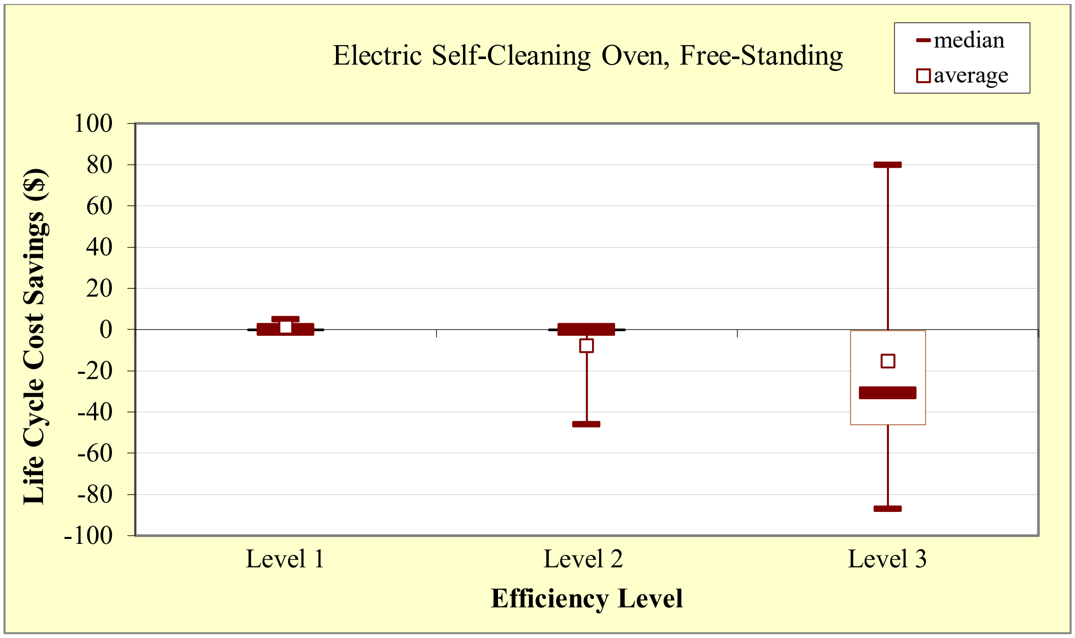

Figure 8.3.17 Electric Self-Clean Ovens, Freestanding: Range of LCC Savings

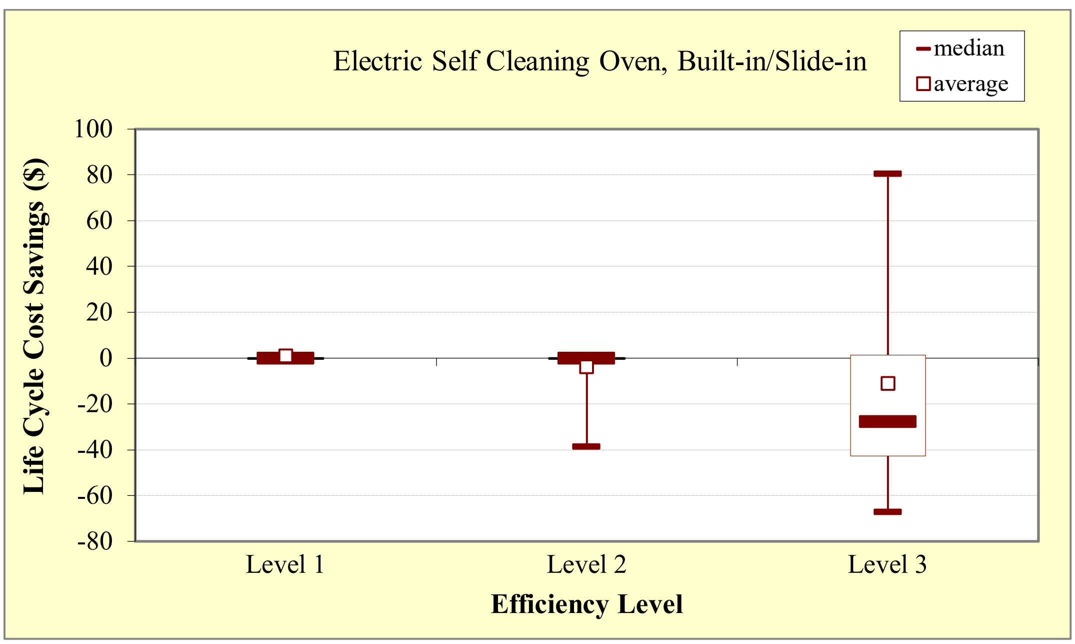

Figure 8.3.18 Electric Self-Clean Ovens, Built-In/Slide-In: Range of LCC Savings

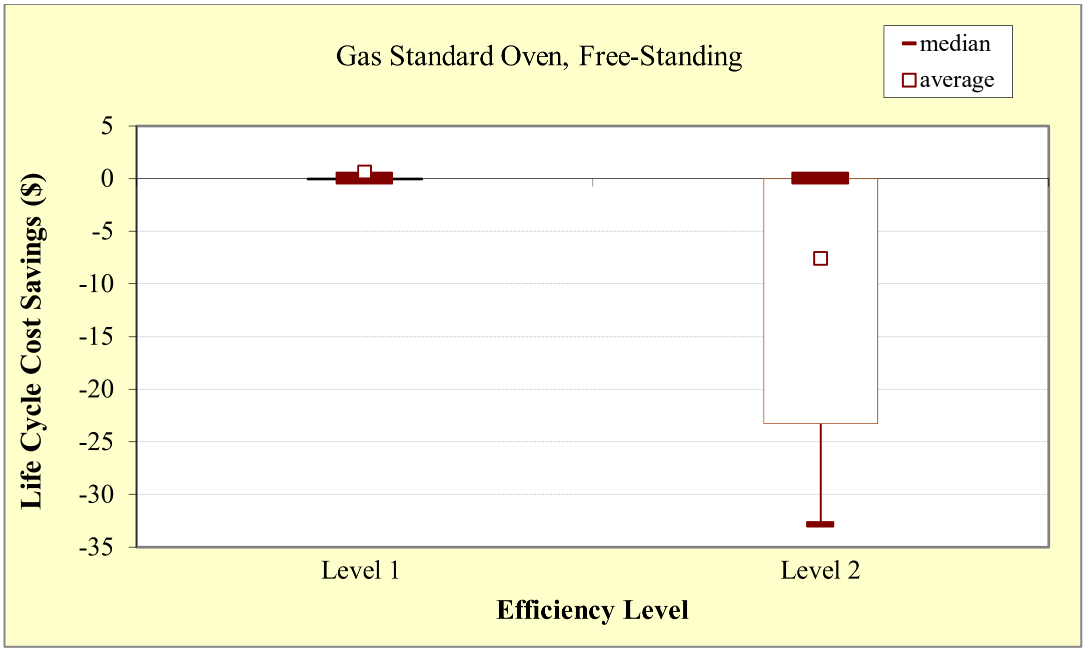

Figure 8.3.19 Gas Standard Ovens, Freestanding: Range of LCC Savings

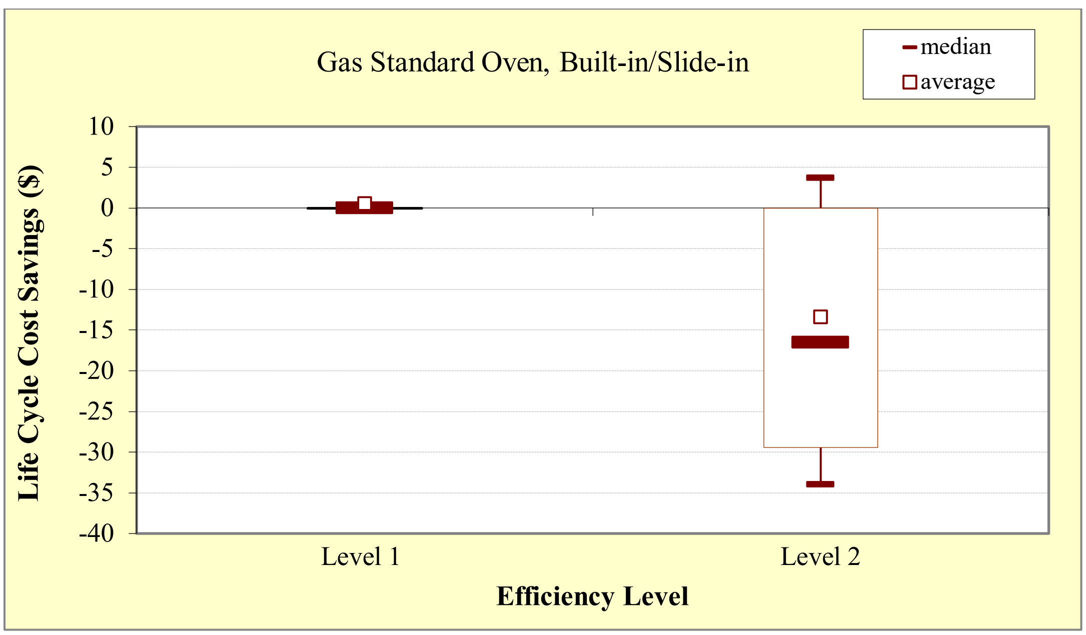

Figure 8.3.20 Gas Standard Ovens, Built-In/Slide-In: Range of LCC Savings

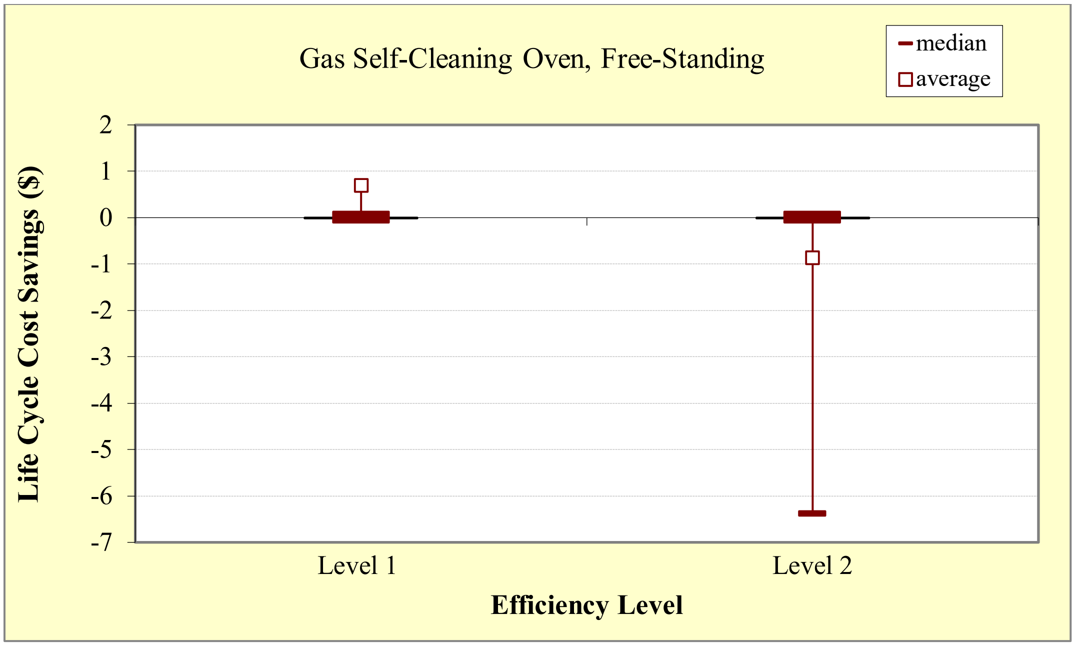

Figure 8.3.21 Gas Self-Clean Ovens, Freestanding: Range of LCC Savings

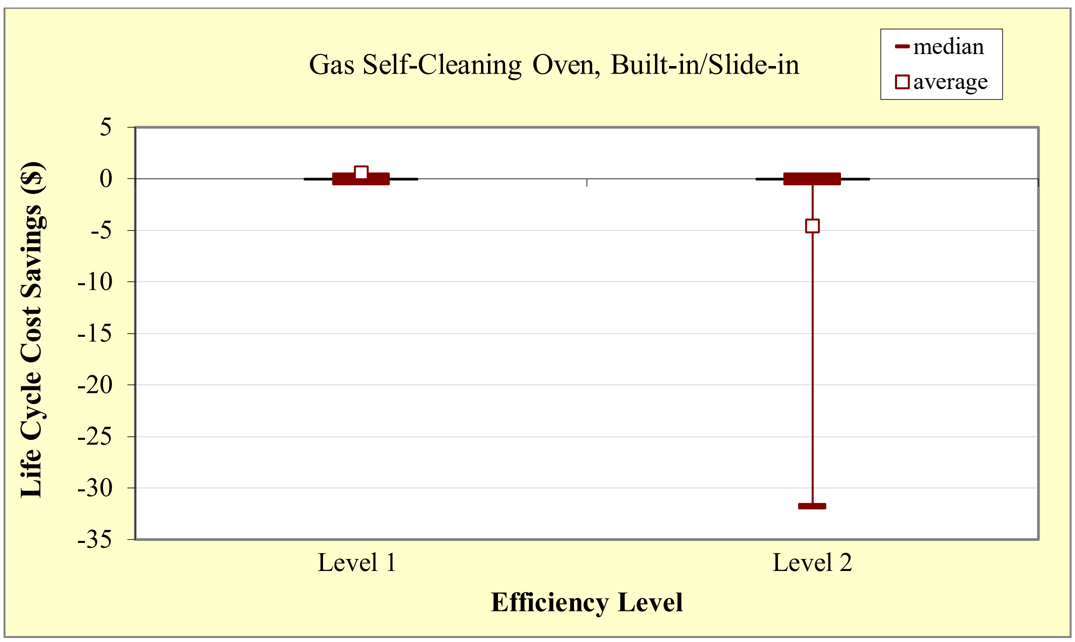

Figure 8.3.22 Gas Self-Clean Ovens, Built-In/Slide-In: Range of LCC Savings

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 8.1.1, 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 tops. 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 consumer 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 2027.

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 no-new-standards 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 through Table 8.4.3 present the rebuttable PBPs for each product class of consumer conventional cooking products.

Table 8.4.1 Conventional Cooking Tops: Rebuttable Payback Periods

EL	Electric Open (Coil) Element	Electric Smooth Element	Gas
	PBP *years*	**PBP** *years*	**PBP** *years*
Baseline	--	--	--
1	--	0.5	6.4
2	--	2.0	3.8
3	--	66.0	--

Table 8.4.2 Conventional 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	1.8	1.8	1.8	1.8
2	14.6	14.8	14.6	14.8
3	9.4	9.4	9.4	9.4

Table 8.4.3 Conventional Gas Ovens: Rebuttable Payback Periods

EL	Gas Standard, Freestanding	Gas Standard, Built-In/Slide-In	Gas Self-Clean, Freestanding	Gas Self-Clean, Built-In/Slide-In
	PBP *years*	**PBP** *years*	**PBP** *years*	**PBP** *years*
Baseline	--	--	--	--
1	8.5	8.9	8.7	8.9
2	24.4	24.7	24.4	24.7

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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 the rulemaking. This chapter describes DOE's methodology for projecting annual shipments and presents results for consumer conventional cooking products.

DOE estimated shipments for consumer conventional cooking products with a shipments model. DOE calibrated the 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 and annual operating cost on the consumer purchase decision.

The shipments model first considers specific market segments to estimate shipments by fuel category of consumer conventional cooking 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 households.

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 consumer conventional 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 no-new-standards 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 no-new-standards 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, multiplied by 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).

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.

[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 section 9.4.

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 2021 and adopted the projections from the DOE Energy Information Administration (EIA)'s *Annual Energy Outlook 2022* for the period of 2022–2050.[1] For the years after 2050, DOE used constant value from 2050. 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 (see chapter 8 of this SNOPR TSD for more details). 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.

DOE used historical shipments of conventional electric and gas cooking products as the basis for calibrating its shipments models. For both product types, shipments due to new construction and replacements were found to overestimate shipments relative to historical data. DOE developed another market segment associated with the non-replacement of retired units due to building demolitions 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 conventional electric cooking products and five product types for conventional gas cooking products. Since each product class consists of two or more product types, DOE then disaggregated 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.,* conventional electric and gas cooking products). For conventional electric cooking products there are eight product types and six product classes; for conventional 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 shipments for each product class.

Table 9.3.1 Consumer Conventional Cooking Products: Product Categories, Product Types, and Product Classes

Product Categories	Electric								Gas				
Product Types (PT): 8 electric, 5 gas	Conventional Range				Standalone Cooking Tops		Standalone Oven		Conventional Range		Standalone Cooking Tops	Standalone 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): 6 electric, 5 gas	PC 1: Electric Open (Coil) Element Cooking Tops = Product Type 1, 2, 5 PC 2: Electric Smooth Element Cooking Tops = Product Type 3, 4, 6 PC 4: Electric Standard Oven with or without a Catalytic Line – Freestanding = Product Type 1, 3 PC 5: Electric Standard Oven with or without a Catalytic Line – Built-In/Slide-In = Product Type 7 PC 6: Electric Self-Clean Oven – Freestanding = Product Type 2, 4 PC 7: Electric Self-Clean Oven – Built-In/Slide-In = Product Type 8													
	PC3: Gas Cooking Tops = Product Type 9, 10, 11 PC 8: Gas Standard Oven with or without a Catalytic Line – Freestanding = Product Type 9 PC 9: Gas Standard Oven with or without a Catalytic Line – Built-In/Slide-In = Product Type 12 PC 10: Gas Self-Clean Oven – Freestanding = Product Type 10 PC 11: Gas Self-Clean Oven – Built-In/Slide-In = Product Type 13													

Std = standard; SC = self-clean; Smth = smooth

Figure 9.3.1 shows the historical shipments data of conventional electric and gas cooking products. DOE relied on three data sources to establish historical shipments data: (1) data from the Association of Home Appliance Manufacturers (AHAM) for the period 2013 – 2020[2], (2) data from Market Research Magazine provided for the period 2006 – 2012[3], and (3) data from DOE's 2006 technical support document (TSD) on consumer conventional cooking products covering the period 1970–2005[4].

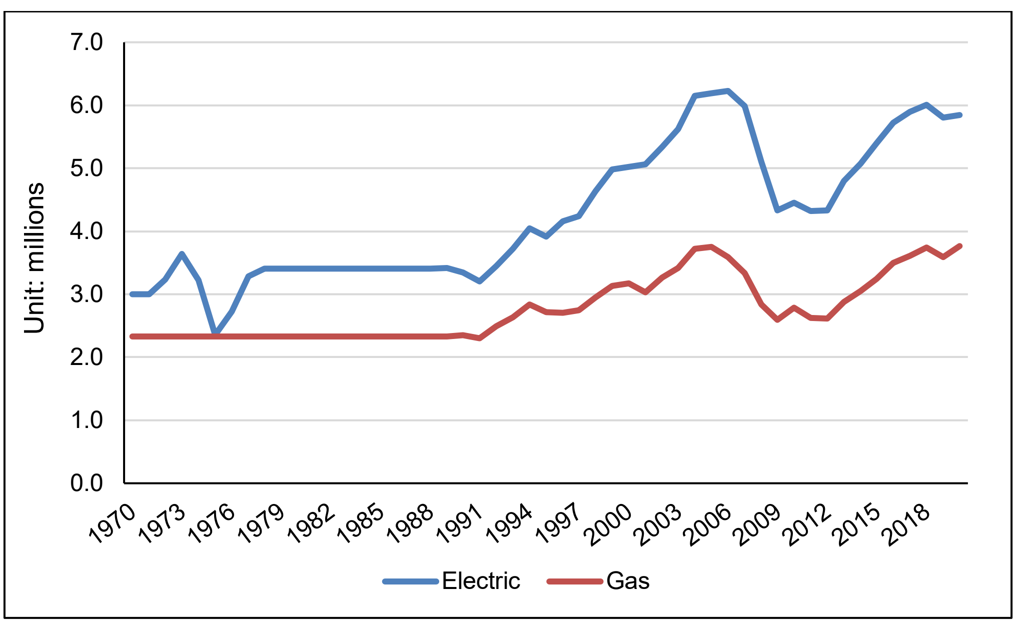

Figure 9.3.1 Historical Shipments: Conventional Electric and Gas Cooking Products

DOE then used the following sources to establish historical market shares for each product type under each fuel type: (1) data from AHAM for the period 2013 – 2020[2] and (2) data from Market Research Magazine provided for the period 2006 – 2012[3]. Table 9.3.2 shows the market share between freestanding and slide-in ranges by fuel type using average historical AHAM sales data between 1989 to 2006. This information enables DOE to reallocate historical shipments data based on the newly proposed product classes. Table 9.3.3 presents the re-grouped market shares of the six product types that comprise total electric cooking product shipments. Table 9.3.4 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 9.3.2 Market Share of Freestanding and Slide-In Ranges by Fuel Type

Range Type	Electric Conventional Ranges	Gas Conventional Ranges
Freestanding	82.4%	96.9%
Slide-In	17.6%	3.1%
Total	100.0%	100.0%

Source: AHAM data between 1986 to 2006.

Table 9.3.3 Conventional Electric Cooking Products: Historical Shipment Market Shares by Product Type

Year	Percent of Total Shipments					
	Conventional Ranges		Standalone Cooking Tops		Standalone Ovens	
	Standard	Self-Clean	Coil	Smooth	Standard	Self-Clean
1970–1989	28.7%	27.8%	4.1%	9.0%	9.7%	20.7%
1990	25.0%	31.7%	4.0%	8.8%	11.2%	19.2%
1991	28.1%	30.3%	3.8%	8.3%	6.2%	23.4%
1992	28.6%	29.6%	3.7%	8.3%	6.5%	23.3%
1993	28.7%	30.2%	3.6%	7.9%	5.8%	23.8%
1994	25.1%	35.2%	3.1%	6.9%	9.7%	20.0%
1995	27.0%	34.6%	3.1%	6.8%	5.7%	22.8%
1996	24.8%	37.1%	3.1%	6.9%	5.7%	22.4%
1997	23.1%	38.6%	3.3%	7.2%	5.3%	22.4%
1998	22.2%	39.6%	3.4%	7.5%	4.8%	22.4%
1999	21.6%	41.0%	3.1%	6.8%	4.5%	23.0%
2000	20.7%	42.0%	3.1%	6.8%	4.1%	23.4%
2001	19.8%	42.7%	3.1%	6.8%	3.7%	24.0%
2002	18.9%	43.4%	3.1%	6.8%	3.3%	24.6%
2003	15.6%	46.6%	3.3%	6.4%	3.4%	24.9%
2004	15.7%	46.2%	2.8%	6.5%	2.9%	26.0%
2005	17.1%	45.1%	2.6%	6.2%	2.7%	26.3%
2006	17.0%	44.8%	2.6%	6.2%	2.8%	26.7%

Year	Percent of Total Shipments					
	Conventional Ranges		Standalone Cooking Tops		Standalone Ovens	
	Standard	Self-Clean	Coil	Smooth	Standard	Self-Clean
2007	17.5%	46.0%	2.5%	6.0%	2.6%	25.4%
2008	17.7%	46.5%	2.5%	6.0%	2.6%	24.8%
2009	18.1%	47.5%	2.3%	5.5%	2.5%	24.2%
2010	17.9%	47.1%	2.2%	5.3%	2.6%	24.9%
2011	18.0%	47.3%	2.2%	5.2%	2.6%	24.7%
2012	18.0%	47.4%	2.1%	4.9%	2.6%	25.0%
2013	17.9%	47.2%	2.0%	4.8%	2.7%	25.4%
2014	18.0%	47.3%	1.9%	4.7%	2.7%	25.5%
2015	17.9%	47.2%	2.0%	4.7%	2.7%	25.5%
2016	18.0%	47.4%	1.8%	4.4%	2.7%	25.6%
2017	17.9%	47.2%	1.9%	4.5%	2.7%	25.8%
2018	17.8%	47.0%	1.9%	4.5%	2.7%	26.1%
2019	18.0%	47.4%	1.7%	4.1%	2.7%	26.0%
2020	18.1%	47.6%	1.8%	4.2%	2.7%	25.6%

Table 9.3.4 Conventional Gas Cooking Products: Historical Shipment Market Shares by Product Type

Year	Percent of Total Shipments				
	Conventional Ranges		Standalone Cooking Tops	Standalone Ovens	
	Standard	Self-Clean		Standard	Self-Clean
1970–1989	61.2%	21.3%	10.1%	6.5%	0.9%
1990	61.2%	20.8%	10.9%	5.9%	1.3%
1991	59.7%	22.3%	11.4%	5.4%	1.2%
1992	59.2%	22.9%	11.7%	5.2%	1.0%
1993	56.4%	25.8%	11.8%	4.4%	1.5%
1994	58.7%	24.4%	11.2%	4.8%	0.9%
1995	56.3%	29.0%	8.8%	4.4%	1.5%
1996	54.1%	30.4%	10.0%	4.3%	1.1%
1997	51.8%	32.6%	10.2%	4.0%	1.3%
1998	48.9%	34.6%	11.4%	3.8%	1.3%
1999	46.5%	36.8%	11.7%	3.7%	1.3%
2000	44.2%	39.0%	11.9%	3.6%	1.3%
2001	41.7%	40.6%	12.6%	3.7%	1.4%
2002	40.0%	42.4%	12.7%	3.5%	1.3%
2003	39.1%	42.9%	13.3%	3.1%	1.6%
2004	36.0%	45.4%	14.2%	3.3%	1.1%
2005	35.7%	45.1%	14.9%	3.2%	1.1%
2006	35.4%	44.6%	15.7%	3.2%	1.1%
2007	35.7%	45.1%	14.9%	3.2%	1.1%

Year	Percent of Total Shipments				
	Conventional Ranges		Standalone Cooking Tops	Standalone Ovens	
	Standard	Self-Clean		Standard	Self-Clean
2008	36.3%	45.8%	13.6%	3.2%	1.1%
2009	37.3%	47.1%	11.2%	3.3%	1.2%
2010	37.3%	47.1%	11.3%	3.2%	1.1%
2011	37.3%	47.0%	11.4%	3.1%	1.1%
2012	37.3%	47.1%	11.6%	2.9%	1.0%
2013	36.8%	46.5%	12.9%	2.8%	1.0%
2014	36.8%	46.4%	13.2%	2.7%	1.0%
2015	36.8%	46.5%	13.3%	2.5%	0.9%
2016	37.0%	46.6%	13.0%	2.5%	0.9%
2017	36.6%	46.2%	13.8%	2.5%	0.9%
2018	36.5%	46.0%	14.1%	2.5%	0.9%
2019	36.9%	46.6%	13.0%	2.5%	0.9%
2020	37.1%	46.8%	12.6%	2.5%	0.9%

To project future market share of each product type for the period 2021–2056, DOE conducted a regression analysis to fit the historical market share data as shown in Table 9.3.3 and Table 9.3.4. DOE then normalized the projected market share of each product type, so the sum of the total market share equals 100 percent under each fuel type for any given year. Table 9.3.5 and Table 9.3.6 present the projected market share for conventional electric and gas cooking products, respectively.

Table 9.3.5 Conventional Electric Cooking Products: Projected Shipment Market Shares by Product Type

Year	Percent of Total Shipments					
	Conventional Ranges		Standalone Cooking Tops		Standalone Ovens	
	Standard	Self-Clean	Coil	Smooth	Standard	Self-Clean
2021	18.1%	47.9%	1.7%	4.1%	2.6%	25.6%
2022	18.1%	48.0%	1.7%	4.0%	2.5%	25.7%
2023	18.1%	48.0%	1.6%	3.9%	2.5%	25.8%
2024	18.1%	48.1%	1.6%	3.8%	2.4%	26.0%
2025	18.1%	48.2%	1.6%	3.7%	2.3%	26.1%
2026	18.1%	48.2%	1.5%	3.6%	2.3%	26.2%
2027	18.1%	48.3%	1.5%	3.6%	2.2%	26.3%
2028	18.1%	48.4%	1.5%	3.5%	2.2%	26.4%
2029	18.1%	48.4%	1.4%	3.4%	2.1%	26.5%
2030	18.1%	48.5%	1.4%	3.3%	2.0%	26.6%
2031	18.1%	48.6%	1.4%	3.2%	2.0%	26.7%
2032	18.1%	48.6%	1.3%	3.2%	1.9%	26.8%
2033	18.1%	48.7%	1.3%	3.1%	1.9%	26.9%
2034	18.1%	48.7%	1.3%	3.0%	1.8%	27.0%

Year	Percent of Total Shipments					
	Conventional Ranges		Standalone Cooking Tops		Standalone Ovens	
	Standard	Self-Clean	Coil	Smooth	Standard	Self-Clean
2035	18.1%	48.8%	1.2%	2.9%	1.8%	27.1%
2036	18.2%	48.8%	1.2%	2.9%	1.7%	27.2%
2037	18.2%	48.9%	1.2%	2.8%	1.7%	27.3%
2038	18.2%	48.9%	1.1%	2.7%	1.6%	27.4%
2039	18.2%	49.0%	1.1%	2.7%	1.6%	27.5%
2040	18.2%	49.0%	1.1%	2.6%	1.6%	27.6%
2041	18.2%	49.1%	1.1%	2.5%	1.5%	27.7%
2042	18.2%	49.1%	1.0%	2.5%	1.5%	27.7%
2043	18.2%	49.2%	1.0%	2.4%	1.4%	27.8%
2044	18.2%	49.2%	1.0%	2.4%	1.4%	27.9%
2045	18.2%	49.3%	1.0%	2.3%	1.4%	28.0%
2046	18.2%	49.3%	0.9%	2.2%	1.3%	28.0%
2047	18.2%	49.3%	0.9%	2.2%	1.3%	28.1%
2048	18.2%	49.4%	0.9%	2.1%	1.2%	28.2%
2049	18.2%	49.4%	0.9%	2.1%	1.2%	28.2%
2050	18.2%	49.5%	0.9%	2.0%	1.2%	28.3%
2051	18.2%	49.5%	0.8%	2.0%	1.2%	28.4%
2052	18.2%	49.5%	0.8%	1.9%	1.1%	28.4%
2053	18.2%	49.6%	0.8%	1.9%	1.1%	28.5%
2054	18.2%	49.6%	0.8%	1.8%	1.1%	28.6%
2055	18.2%	49.6%	0.8%	1.8%	1.0%	28.6%
2056	18.2%	49.7%	0.7%	1.8%	1.0%	28.7%

Table 9.3.6 Conventional Gas Cooking Products: Projected Shipment Market Shares by Product Type

Year	Percent of Total Shipments				
	Conventional Ranges		Standalone Cooking Tops	Standalone Ovens	
	Standard	Self-Clean		Standard	Self-Clean
2021	37.1%	47.1%	12.7%	2.5%	0.6%
2022	37.1%	47.1%	12.8%	2.4%	0.6%
2023	37.1%	47.1%	12.9%	2.4%	0.5%
2024	37.1%	47.1%	13.0%	2.4%	0.5%
2025	37.1%	47.0%	13.1%	2.3%	0.5%
2026	37.0%	47.0%	13.2%	2.3%	0.4%
2027	37.0%	47.0%	13.3%	2.3%	0.4%
2028	37.0%	47.0%	13.4%	2.3%	0.4%
2029	37.0%	47.0%	13.5%	2.2%	0.3%
2030	37.0%	47.0%	13.6%	2.2%	0.3%
2031	37.0%	46.9%	13.7%	2.2%	0.3%

Year	Percent of Total Shipments				
	Conventional Ranges		Standalone Cooking Tops	Standalone Ovens	
	Standard	Self-Clean		Standard	Self-Clean
2032	36.9%	46.9%	13.8%	2.1%	0.2%
2033	36.9%	46.9%	13.9%	2.1%	0.2%
2034	36.9%	46.9%	14.0%	2.1%	0.2%
2035	36.9%	46.8%	14.1%	2.1%	0.1%
2036	36.9%	46.8%	14.2%	2.0%	0.1%
2037	36.9%	46.8%	14.3%	2.0%	0.1%
2038	36.8%	46.7%	14.4%	2.0%	0.1%
2039	36.8%	46.7%	14.5%	2.0%	0.0%
2040	36.8%	46.6%	14.6%	1.9%	0.0%
2041	36.8%	46.6%	14.7%	1.9%	0.0%
2042	36.8%	46.6%	14.8%	1.9%	0.0%
2043	36.8%	46.5%	14.9%	1.8%	0.0%
2044	36.7%	46.5%	15.0%	1.8%	0.0%
2045	36.7%	46.4%	15.1%	1.7%	0.0%
2046	36.7%	46.4%	15.2%	1.7%	0.0%
2047	36.7%	46.3%	15.4%	1.6%	0.0%
2048	36.7%	46.2%	15.5%	1.6%	0.0%
2049	36.7%	46.2%	15.6%	1.6%	0.0%
2050	36.6%	46.1%	15.7%	1.5%	0.0%
2051	36.6%	46.1%	15.8%	1.5%	0.0%
2052	36.6%	46.0%	15.9%	1.5%	0.0%
2053	36.6%	45.9%	16.0%	1.4%	0.0%
2054	36.6%	45.9%	16.2%	1.4%	0.0%
2055	36.6%	45.8%	16.3%	1.4%	0.0%
2056	36.5%	45.7%	16.4%	1.3%	0.0%

9.3.2 Markets and Model Calibration

For each general fuel category of consumer conventional 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 conventional 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 conventional 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).

9.3.2.1 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 consumer conventional cooking products for new housing units.

Figure 9.3.2 presents historical new housing starts based on the U.S. Census data for the period 1970 – 2021[5,6]. New housing is comprised of single- and multi-family units and mobile home placements. Figure 9.3.3 through Figure 9.3.5 present the projected new housing starts based on EIA's *AEO 2022* for the period 2022–2050[1]. The *AEO* typically provides three scenarios of housing starts: the Reference case, the High Economic Growth case, and the Low Economic Growth case. All three housing starts projections are presented in Figure 9.3.3 through Figure 9.3.5. DOE used the projections from the Reference case as its default to estimate its shipments to new construction.

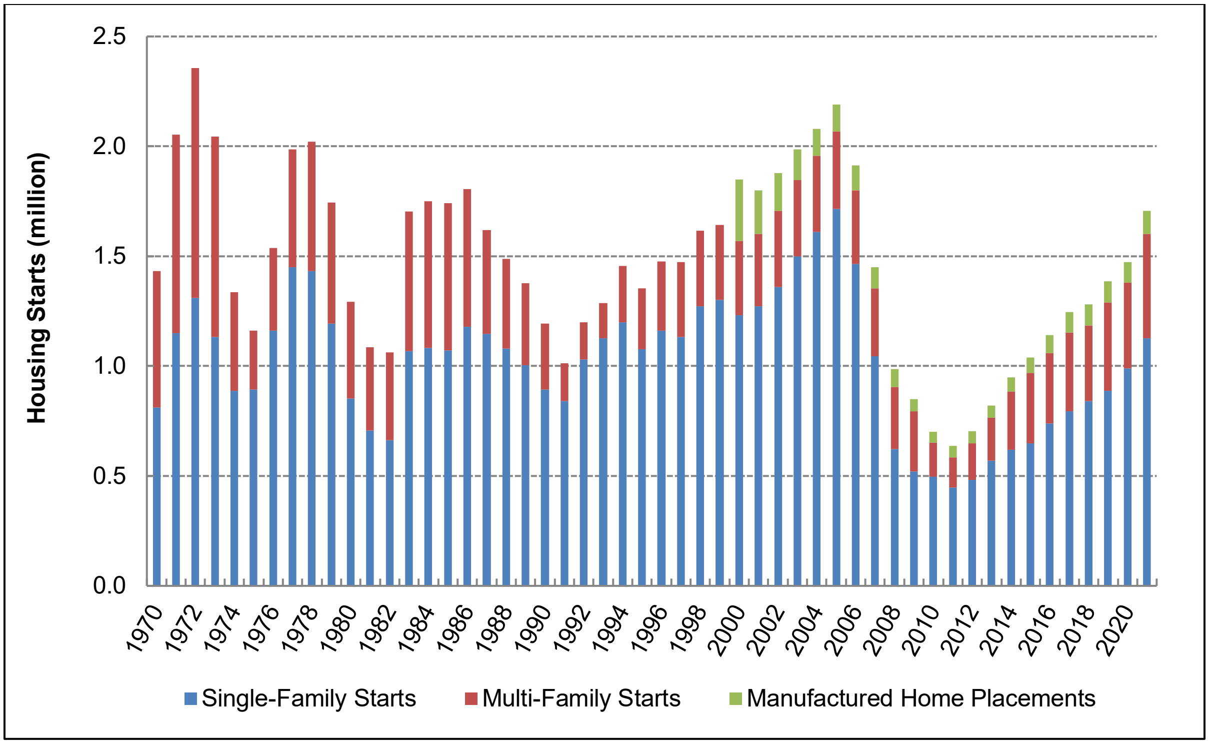

Figure 9.3.2 Historical Housing Starts by Housing Type (1970 – 2021)

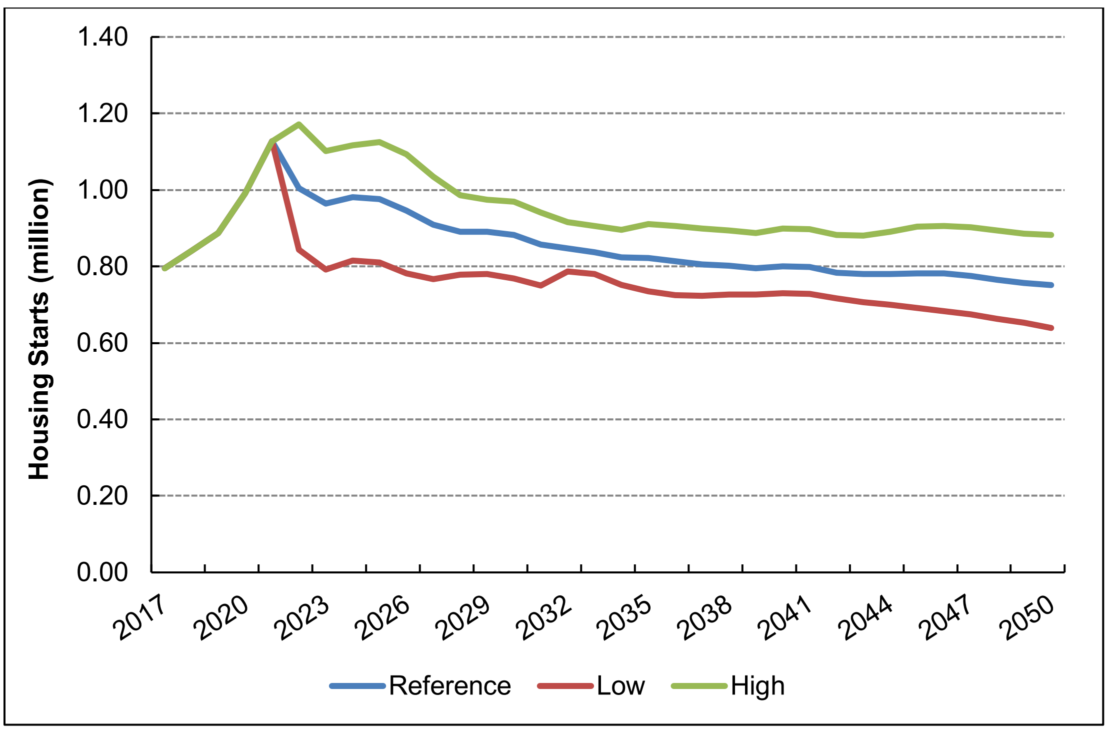

Figure 9.3.3 Projected Single-Family Starts (2021 – 2050)

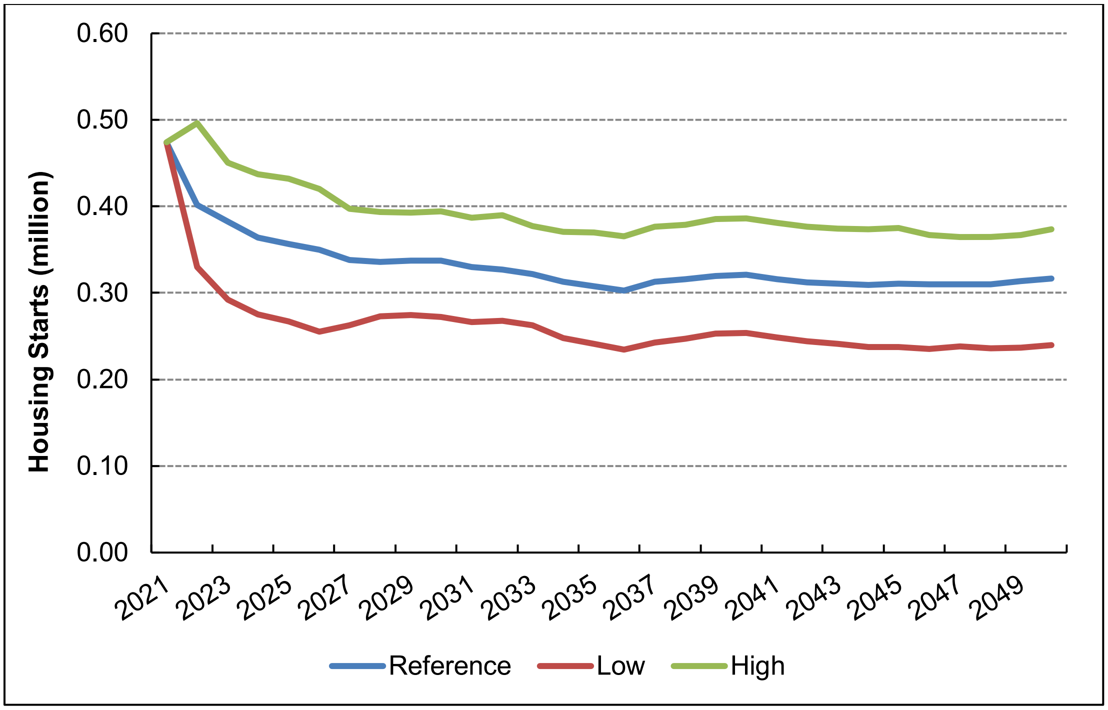

Figure 9.3.4 Projected Multi-Family Starts (2021 – 2050)

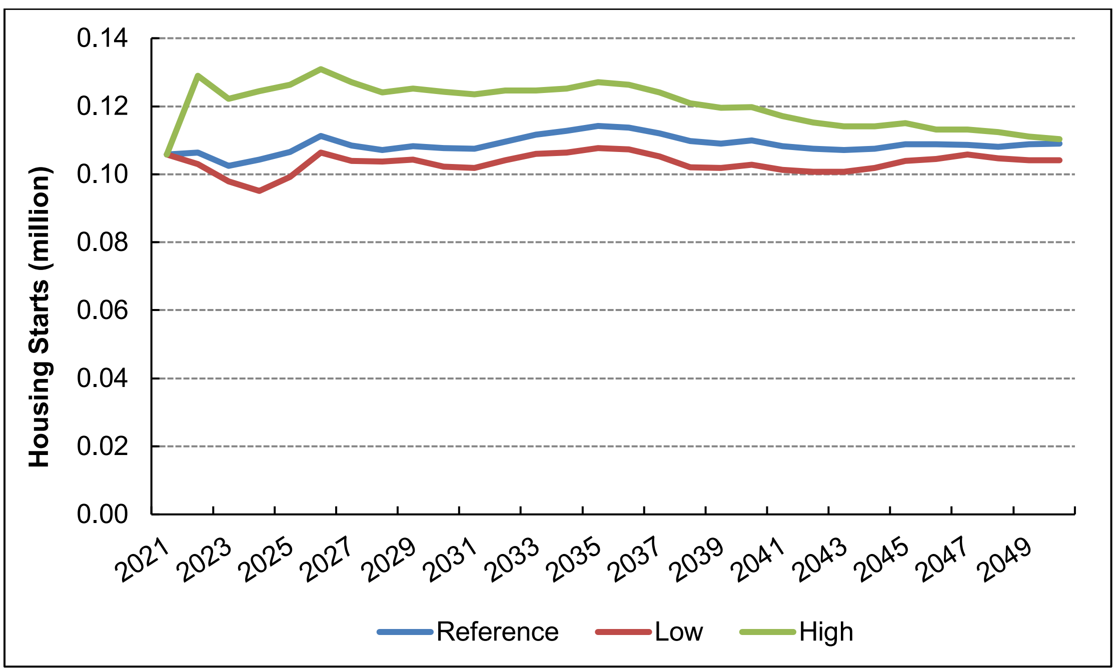

Figure 9.3.5 Projected Manufactured Home Placements (2021 – 2050)

To project saturation of consumer conventional cooking products in new housing starts, DOE reviewed data provided by the Residential Energy Consumption Survey (RECS) 1997, 2001, 2005, 2009, and 2015[7]. DOE used the saturations for the year 2015 to estimate the shipments to new construction for future years. Because DOE conducted its shipments analysis by first projecting overall cooking product shipments by fuel category and then disaggregating the total shipments into product types using the historical market share data in Table 9.3.4 and Table 9.3.5, it used the overall saturation of conventional electric and gas cooking products to estimate shipments to new construction, respectively. Table 9.3.7 summarizes the saturation rates in new housing units in RECS 2015. DOE froze saturation rates at the level in the year 2015 over the shipments analysis period.

Table 9.3.7 Saturation Rates of Consumer Conventional Cooking Products in New Housing Units in 2015

Conventional Electric Cooking Products			Conventional Gas Cooking Products		
Single-Family	**Multi-Family**	**Mobile-Home**	**Single-Family**	**Multi-Family**	**Mobile-Home**
92.6%	99.4%	75.1%	39.5%	8.9%	20.8%

Source: RECS 2015.

9.3.2.2 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 conventional 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 16.8 years. For conventional gas cooking products, DOE used a product survival function based on the same Weibull lifetime distribution with an average value of 14.5 years[8]. For a more complete discussion of cooking product lifetimes, refer back to section 8.2.3 of chapter 8. Figure 9.3.6 shows the survival functions that DOE used to estimate replacement shipments.

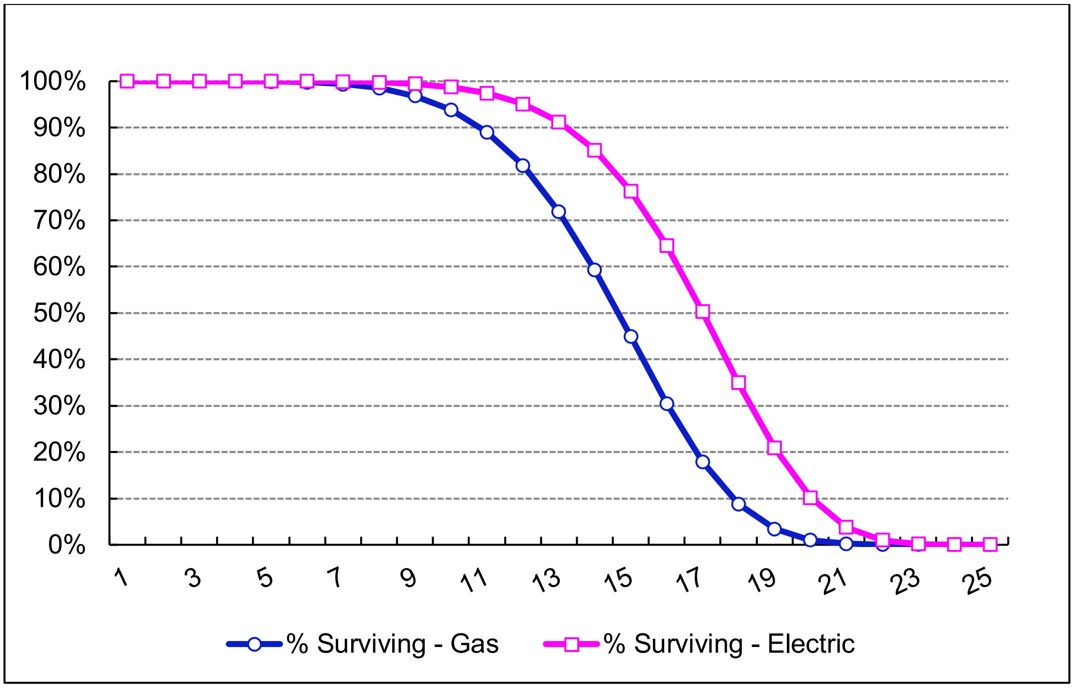

Figure 9.3.6 Consumer Conventional Electric and Gas Cooking Products: Surviving Functions

9.3.2.3 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 consumer conventional cooking products would not be replaced in this category due to building demolition occurs at the weighted average rate of 0.8 percent for consumer conventional cooking products. DOE multiplied the not-replaced rates with the annual retiring conventional electric and gas cooking products, respectively. DOE then excluded not-replaced units from the annual retiring units to estimate actual replacement of consumer conventional cooking products per annum for the period 2021–2056.

9.3.3 No-New-Standards Case Shipments

Figure 9.3.7 and Figure 9.3.8 show the projected shipments of electric and gas cooking products, respectively, in the no-new-standards case (*i.e.,* the case without new energy efficiency standards) and the historical shipments DOE used to calibrate the projection.

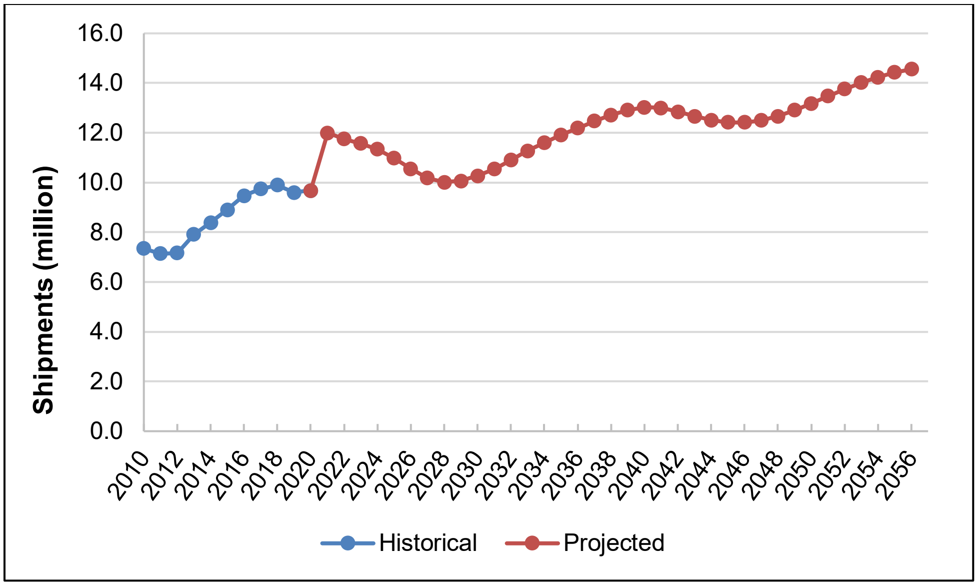

Figure 9.3.7 Electric Cooking Products: Historical and No-New-Standards Case Shipments Projection

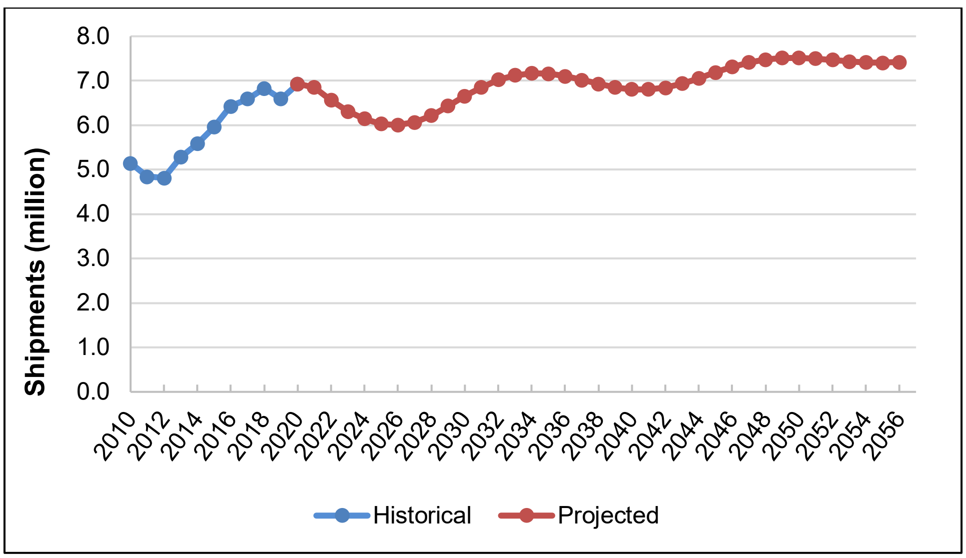

Figure 9.3.8 Gas Cooking Products: Historical and No-New-Standards Case Shipments Projection

Figure 9.3.9 presents total projected electric and gas cooking top shipments under the no-new-standards case over the analysis period (2027-2056). Note that electric cooking products shipments comprised approximately 63 percent of the percent of total cooking products shipments during the analysis period.

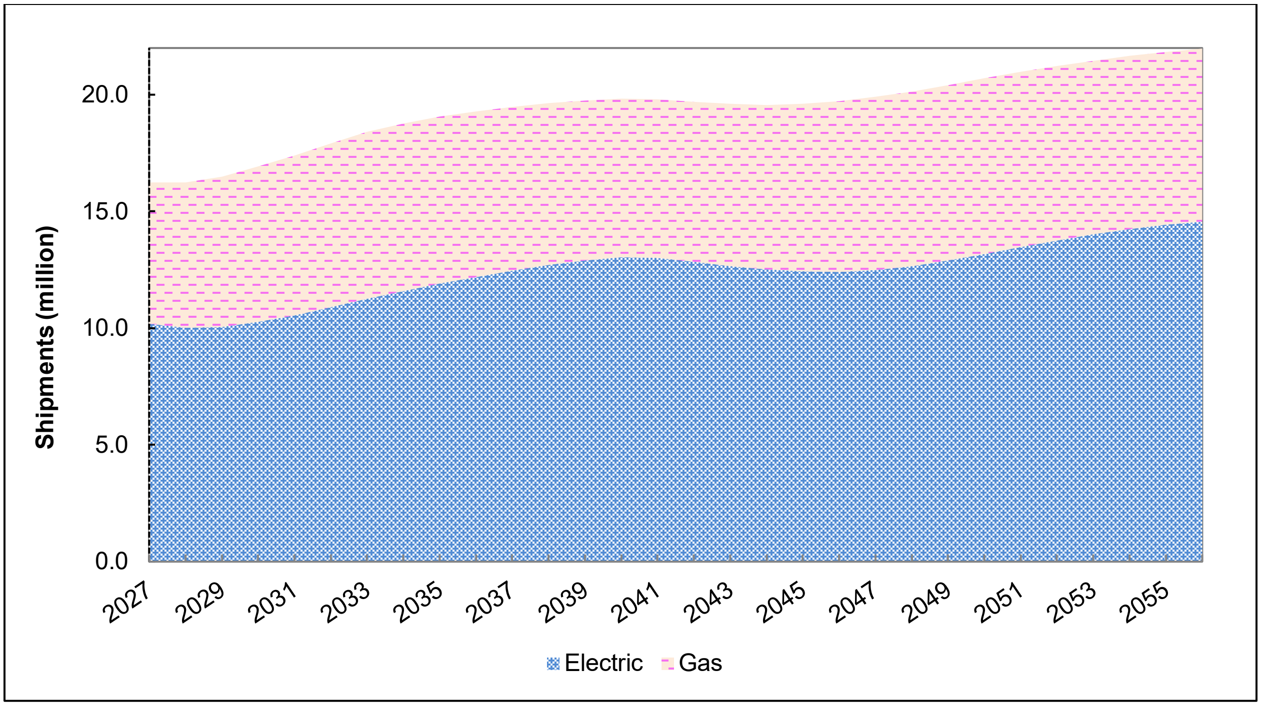

Figure 9.3.9 Cooking Products: Disaggregated No-New-Standards Case Shipments Projection

9.4 IMPACT OF INCREASED PURCHASE PRICE ON SHIPMENTS

9.4.1 Purchase Price Elasticity

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 cooking tops, the combined market of electric and gas cooking tops 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 cooking top. Therefore, the new construction market segment in the shipments model, remains inelastic to a potential purchase price increase. A potential increase in purchase price of the cooking top in the replacement market could, however, 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 estimated the impact on this segment through the use of purchase price elasticity.

DOE's regression analysis estimates the relative price elasticity of demand for cooking tops to be -0.367. This implies that a 1% price increase in relative price results in a 0.367 % decrease in aggregate shipments, all things being equal. Note that the relative price elasticity incorporates the impacts from purchase price, operating cost, household income and general economic conditions, such that the impact from any single effect can be mitigated by changes in the other dimensions. DOE estimates of *relative price* elasticity are short term estimates.

The relative price elasticity of -0.367 is consistent with estimates in existing literature for other durable goods. While DOE has tried to account for most of the factors that can affect the demand for cooking tops, it is possible that the resulting elasticity estimate may be biased because of changes in product attributes and improvement in energy efficiency over time. DOE's estimate of relative price elasticity accounts for such potential impacts by modeling the "unobservables" as random effects (Appendix 9A provides details on the data and modeling approach used to estimate the relative price). DOE believes that its estimate of the relative price elasticity of demand provides a reasonable assessment of the impact of purchase price, operating cost, and household income may have on product shipments given limitations on data.

Given that DOE's forecasts of shipments and national impacts attributable to standards is modelled over a long time frame, it needed to consider how the *relative price* elasticity estimates will be affected after a new standard takes effect. Since DOE estimates of *relative price* elasticity represent short-term elasticity values, the *relative price* elasticity needs to be adjusted to account for long-term adjustments that could occur in shipments. Because there were no existing studies looking at the relationship between short-run and long-run relative price elasticity estimates in durable goods, DOE relied on a study pertaining to automobiles.[9] The DOE study on automobiles found that immediately following a price change, automobile demand is more price elastic and subsequently becoming more inelastic with time until the relative price elasticity reaches a terminal value around the tenth year after the price change. Table 9.4.1 shows the relative change in the price elasticity of demand for automobiles over time. DOE developed a time series of relative price elasticities based on the relative change in the automobile price elasticity of demand. For years not shown in Table 9.4.1, DOE performed a linear interpolation to obtain the relative price elasticity.

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

	Years Following Price Change					
	1	**2**	**3**	**5**	**10**	**20**
Relative Change in Elasticity to 1st year	1.00	0.78	0.63	0.46	0.35	0.33
Relative Price Elasticity	-0.37	-0.29	-0.23	-0.17	-0.13	-0.12

9.4.2 Impact from Increase in Relative Price

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

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

Where:

dMS_j^p = percentage market share drop for class *p,* year *j*,
$RP\_std_p(j)$= relative price in the standards case for product class *p,* year *j*,
$RP_p\_nn_p(j)$= relative price in the no-new-standards case for product class *p,* year *j*, and
$e_{RP}(j)$ = relative price elasticity in year *j*.

To model the impact of the increase in relative price from a particular standard level on consumer conventional cooking product shipments, DOE assumed that the affected consumers would repair their product rather than replace it, extending the life of the product by 5 years. When the extended repaired units fail after 5 more years, they will be replaced with new ones.

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 no-new-standards case and the standards case, the affected stock (which represents the difference in the appliance stock for the no-new-standards 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 2027. Thus, all appliances purchased starting on the first day of the year 2027 are affected by the standard level.

9.6 RESULTS

This section presents the impacts on shipments resulting from each of the TSLs that DOE is considering for consumer conventional cooking products. Figure 9.6.1 shows projected annual shipments of consumer conventional cooking products in the no-new-standards case and under each standard case. As shown in Figure 9.6.1, total shipments under each standards case overlap, indicating potential TSL has no significant impact on cooking product shipments.

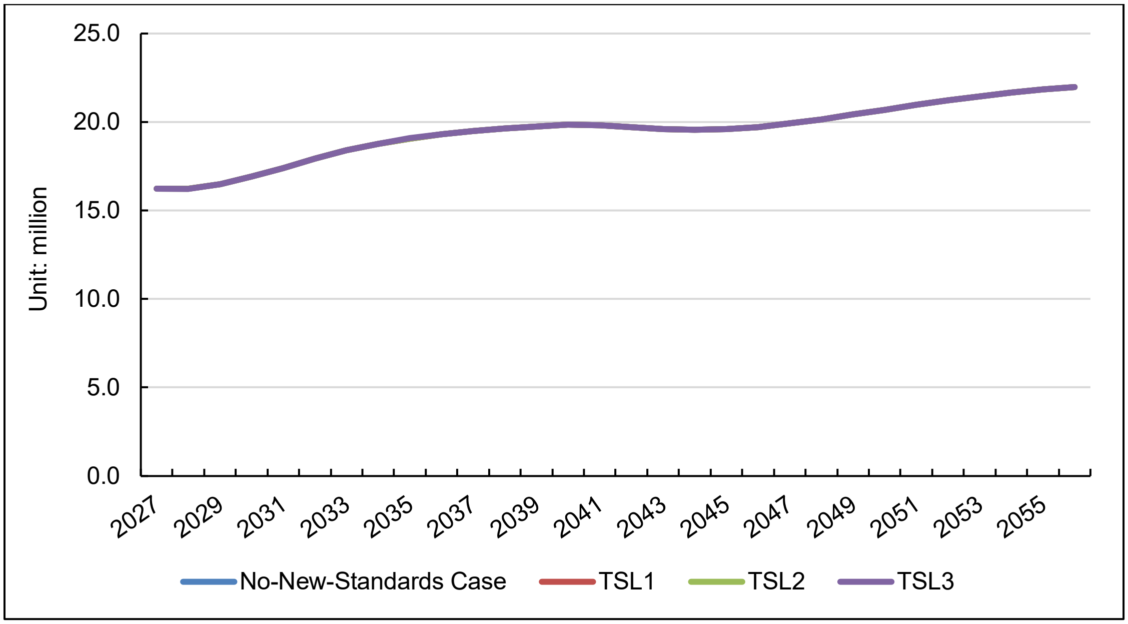

Figure 9.6.1 Projected Shipments for Consumer Conventional Cooking Products in the No-New-Standards Case and Each Trial Standards Level

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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 consumer conventional cooking 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 cooking 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 consumer conventional cooking products. 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 2027 - 2056. 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.

[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 *no-new-standards 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 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 the shipments projection for the no-new-standards 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 consumer conventional cooking products. The proposed criteria for grouping efficiency levels into TSLs to apply to each product class are outlined below, and the resulting efficiency level groupings by TSL are shown in Table 10.2.1 through Table 10.2.3. TSL 3 represents the maximum technologically feasible ("max-tech") improvements in energy efficiency for all product classes. TSL 2 represents an intermediate TSL. TSL 1 is configured with the minimum efficiency improvement in each product class corresponding to electronic controls for electric cooking tops, optimized burners for gas cooking tops, and switch mode power supplies for ovens. Table 10.2.1 includes the corresponding integrated annual energy consumption (IAEC) as measured by the August 2022 cooktop test procedure for each EL. Table 10.2.2 and Table 10.2.3 includes the corresponding integrated annual oven energy consumption (IE_{AO}) as measured by now-repealed December 2016 conventional oven test procedure.

[2] For example, a furnace may use both natural gas for heating and auxiliary electricity.

Table 10.2.1 Trial Standard Levels for Conventional Cooking Tops

TSL	Electric Open (Coil) Element Cooking Tops		Electric Smooth Element Cooking Tops		Gas Cooking Tops	
	EL	IAEC (kWh/yr)	EL	IAEC (kWh/yr)	EL	IAEC (kBtu/yr)
1	Baseline	199	1	207	1	1,440
2	Baseline	199	1	207	2	1,204
3	Baseline	199	3	179	2	1,204

Table 10.2.2 Trial Standard Levels for Conventional 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	IE_{AO} (kWh/yr)	EL	IE_{AO} (kWh/yr)	EL	IE_{AO} (kWh/yr)	EL	IE_{AO} (kWh/yr)
1	1	302.0	1	308.9	1	341.7	1	348.1
2	1	302.0	1	308.9	1	341.7	1	348.1
3	3	235.3	3	242.1	3	275.0	3	281.4

Table 10.2.3 Trial Standard Levels for Conventional 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	IE_{AO} (kBtu/yr)	EL	IE_{AO} (kBtu/yr)	EL	IE_{AO} (kBtu/yr)	EL	IE_{AO} (kBtu/yr)
1	1	2,041	1	2,062	1	1,915	1	1,937
2	1	2,041	1	2,062	1	1,915	1	1,937
3	2	1,908	2	1,929	2	1,781	2	1,804

10.3 PROJECTED EFFICIENCY TRENDS

10.3.1 No-New-Standards Case

A key component of DOE's estimates of NES and NPV for cooking products is the energy efficiency level projected for the no-new-standards case (without new energy conservation standards) and each standards case (with new energy conservation standards). The projected annual energy consumption represents the annual shipments-weighted energy efficiency of cooking products during the analysis period (that is, from the assumed effective date of a new standard to 30 years after that date).

In calculating the NES, per-unit average annual energy consumption is a direct function of product energy efficiency. For the NPV, the per-unit total installed cost is a direct function of energy efficiency. Because it is a function of per-unit annual energy consumption, the per-unit annual operating cost is indirectly dependent on product energy efficiency. The NES and NPV inputs are discussed further in sections 10.4 and 10.5.

To project the no-new-standards case energy efficiency for consumer conventional cooking products, DOE used the shipments-weighted integrated annual energy consumption (IAEC) as a starting point. DOE first used its engineering analysis results to estimate the no-new-standards case efficiency distributions under the current market for 2021. Given the lack of data on historic efficiency trends, DOE assumed that the estimated current distributions would apply in 2027 and throughout the analysis period. DOE then assumed there is no annual shipments weighted IAEC improvement during the analysis period between 2027 and 2056.

Table 10.3.1 through Table 10.3.6 show no-new-standards case efficiency distribution for each consumer conventional cooking product class in 2027, the first year of compliance.

Table 10.3.1 No-New-Standards Case Efficiency Distributions in 2027 for Electric Cooking Tops

Efficiency Level	Electric Open (Coil) Element Cooking Tops		Electric Smooth Element Cooking Tops	
	IAEC (kWh/yr)	Market Share (%)	IAEC (kWh/yr)	Market Share (%)
Baseline	199	100%	250	20%
1	--	--	207	50%
2	--	--	189	25%
3	--	--	179	5%

Table 10.3.2 No-New-Standards Case Efficiency Distributions in 2027 for Gas Cooking Tops

Efficiency Level	Gas Cooking Tops	
	IE_{AO} (kBtu/yr)	Market Share (%)
Baseline	1,775	48%
1	1,440	48%
2	1,204	4%

Table 10.3.3 No-New-Standards Case Efficiency Distributions in 2027 for Electric Standard Ovens

Efficiency Level	Freestanding		Built-in/Slide-in	
	IE_{AO} (kWh/yr)	Market Share (%)	IE_{AO} (kWh/yr)	Market Share (%)
Baseline	314.7	5%	321.2	5%
1	302.0	57%	308.9	65%
2	289.0	38%	295.9	30%
3	235.3	0%	242.1	0%

Table 10.3.4 No-New-Standards Case Efficiency Distributions in 2027 for Electric Self-Clean Ovens

Efficiency Level	Freestanding		Built-in/Slide-in	
	IE_{AO} (kWh/yr)	Market Share (%)	IE_{AO} (kWh/yr)	Market Share (%)
Baseline	354.4	5%	360.5	5%
1	341.7	18%	348.1	7%
2	328.7	77%	335.1	86%
3	275.0	0%	281.4	2%

Table 10.3.5 No-New-Standards Case Efficiency Distributions in 2027 for Gas Standard Ovens

Efficiency Level	Freestanding		Built-in/Slide-in	
	IE_{AO} (kBtu/yr)	Market Share (%)	IE_{AO} (kBtu/yr)	Market Share (%)
Baseline	2,085	4%	2,104	4%
1	2,041	34%	2,062	58%
2	1,908	62%	1,929	38%

Table 10.3.6 No-New-Standards Case Efficiency Distributions in 2027 for Gas Self-Clean Ovens

Efficiency Level	Freestanding		Built-in/Slide-in	
	IE_{AO} (kBtu/yr)	Market Share (%)	IE_{AO} (kBtu/yr)	Market Share (%)
Baseline	1,958	4%	1,979	4%
1	1,915	3%	1,937	19%
2	1,781	93%	1,804	77%

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 no-new-standards case that do not meet the standard under consideration would "roll up" to meet the new standard level. All efficiency shares in the no-new-standards 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 2027
eff = population-average efficiency trend relative to 2027

10.4 NATIONAL ENERGY SAVINGS

DOE calculates annual NES and cumulative NES throughout the projected period, which extends from 2027 to 2056. Positive values of NES represent energy savings, meaning national energy consumption under the proposed standards is lower than in the no-new-standards 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 no-new-standards case (without new standards) and for each TSL. The trial standard level is labelled *L*, with *L=0* corresponding to the no-new-standards 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:

$$AEC_y = \sum STOCK_V \times UEC_V$$

Where:

AEC = annual national energy consumption each year in quadrillion Btus (quads), summed over vintages of the product stock, $STOCK_V$;
$STOCK_V$ = stock of product (millions of units) of vintage V that survive in the year for which DOE calculated annual energy consumption;
UEC_V = annual energy consumption of consumer conventional cooking products in kilowatt-hours (kWh);
V = year in which the product was purchased as a new unit; and
y = year in the forecast.

10.4.2 Shipments and Product Stock

DOE projected shipments of each product class under the no-new-standards 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 no-new-standards case. 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, $y_0 = 2027$. 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 no-new-standards 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 (2027-2056). 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 2085 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). 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 2022 (AEO2022), following the methodology outlined in appendix 15A.[1] 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 2022 to the end of the AEO analysis period (2050). For years after 2050, DOE held the factors constant and equal to at the average value between 2046-2050.

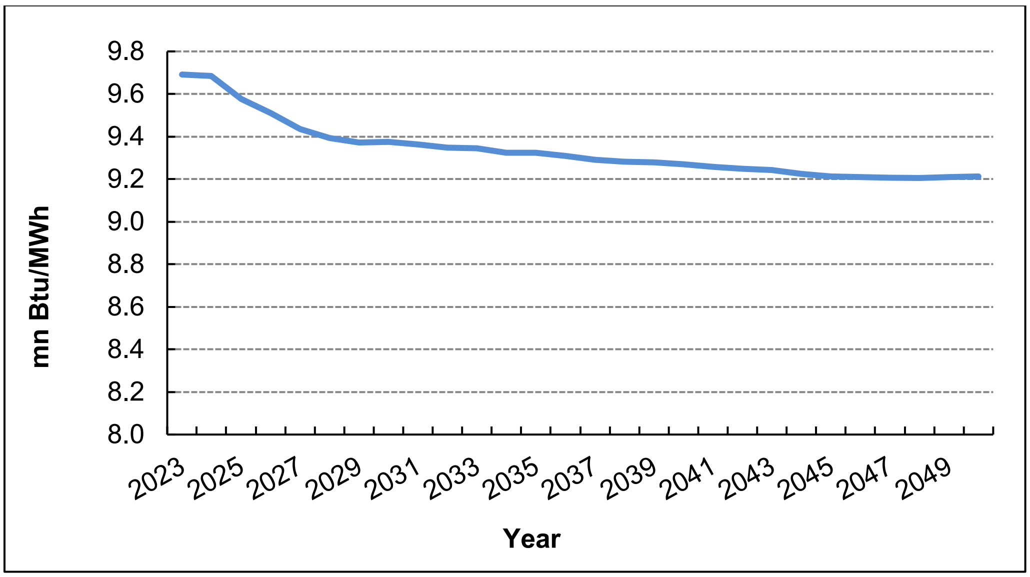

Figure 10.4.1 Site-to-Power Plant Energy Use Factor for Consumer Conventional Cooking Products

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 *AEO2022*. 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 no-new-standards 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 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 no-new-standards case and the change in the total installed cost relative to the no-new-standards 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 no-new-standards case
PV_{TIC} = present value of the increase in total installed cost relative to the no-new-standards 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 no-new-standards 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 2027 and concludes thirty years later in 2056. Operating costs are calculated until the units shipped in 2056 retire (2085).

10.5.2 Total Installed Cost

DOE described the total per-unit installed cost for each product class as a function of product efficiency in chapter 8. For the NPV calculation, DOE used the population average total installed cost exported from the life cycle cost (LCC) analysis in the first year of compliance (2027) for the no-new-standards 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 β(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 2027
L = trial standard level, with *L=0* corresponding to the no-new-standards case
UIC = average per-unit total installed cost 2027 exported from the LCC
b = equipment price trend relative to year 2027

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). See chapter 8 of this SNOPR TSD for details on the estimated learning rates for consumer conventional cooking products.

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 that was used in the life-cycle cost analysis (chapter 8). To estimate energy prices in future years, DOE multiplied the recent energy prices by a projection of annual national-average residential energy prices consistent with the AEO 2022 energy price trends. The energy prices and price trends are described in chapter 8.

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 no-new-standards case
F = fuel type
y_0 = compliance year 2027
e = electricity and gas price exported from the LCC
L = trial standard level, with $L=0$ corresponding to the no-new-standards case
a = fuel price trend

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 consumer conventional cooking 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.[2] DOE defined the present year as 2022.

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 consumer conventional cooking 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 consumer conventional cooking products by product class.

Table 10.6.1 Estimates of Cumulative Full-Fuel Cycle NES (quads)

Product Class	TSL1	TSL2	TSL3
Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
Electric Smooth Element Cooking Tops	0.12	0.12	0.22
Gas Cooking Tops	0.13	0.32	0.32
Electric Standard Oven, Freestanding	0.00	0.00	0.18
Electric Standard Oven, Built-In/Slide-In	0.00	0.00	0.02
Electric Self-Clean Oven, Freestanding	0.01	0.01	0.46
Electric Self-Clean Oven, Built-In/Slide-In	0.01	0.01	0.25
Gas Standard Oven, Freestanding	0.00	0.00	0.02
Gas Standard Oven, Built-In/Slide-In	0.00	0.00	0.00
Gas Self-Clean Oven, Freestanding	0.00	0.00	0.01
Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	0.00
All	**0.28**	**0.46**	**1.47**

10.6.2 Net Present Value of Consumer Benefit

This section provides results of calculating the NPV for each trial standard level considered for consumer conventional cooking 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 consumer conventional cooking 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 2021$)

Product Class	TSL1	TSL2	TSL3*
Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
Electric Smooth Element Cooking Tops	0.77	0.77	(27.26)
Gas Cooking Tops	0.02	0.77	0.77
Electric Standard Oven, Freestanding	0.02	0.02	(0.45)
Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.05)
Electric Self-Clean Oven, Freestanding	0.06	0.06	(0.41)
Electric Self-Clean Oven, Built-In/Slide-In	0.04	0.04	(0.10)
Gas Standard Oven, Freestanding	0.02	0.02	(0.20)
Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.02)
Gas Self-Clean Oven, Freestanding	0.02	0.02	(0.03)
Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
All	**0.96**	**1.71**	**(27.75)**

*Negative values denoted in parenthesis.

Table 10.6.3 Cumulative NPV Results based on Seven-Percent Discount Rates (billion 2021$)

Product Class	TSL1*	TSL2	TSL3*
Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
Electric Smooth Element Cooking Tops	0.31	0.31	(14.47)
Gas Cooking Tops	(0.05)	0.27	0.27
Electric Standard Oven, Freestanding	0.01	0.01	(0.40)
Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.04)
Electric Self-Clean Oven, Freestanding	0.03	0.03	(0.61)
Electric Self-Clean Oven, Built-In/Slide-In	0.01	0.01	(0.26)
Gas Standard Oven, Freestanding	0.01	0.01	(0.12)
Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.01)
Gas Self-Clean Oven, Freestanding	0.01	0.01	(0.02)
Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
All	**0.33**	**0.65**	**(15.68)**

*Negative values denoted in parenthesis.

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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 consumer 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 those subgroups. (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. Limited information was provided regarding the occupants age in DOE's Energy Information Administration's Residential Energy Consumption Survey of 2015 (RECS). DOE assumes that those households in which householder is at least 65 years of age and do not have members of age 17 or younger are senior-only households. Senior-only households represent 24 percent of the U.S. households.[1]

11.2.2 Low-Income Households

As defined in the RECS, 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. Although the 2015 RECS did not provide the low-income classification for the households, based on the demographic information provided in the 2015 RECS, DOE assigned a poverty level to each household and calculated the probability of being classified as a low-income household based on the household's income level. Based on DOE's assignment, 15 percent of the country's households in 2015 RECS data are regarded as low-income.

11.3 INPUTS TO THE CONSUMER SUBGROUP ANALYSIS

Table 11.3.1 through Table 11.3.11 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 Open Element (Coil) Cooking Tops: Weighted-Average Annual Energy Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kWh/year)		
Baseline	96.5	96.8	103.3

Table 11.3.2 Electric Smooth Element Cooking Tops: Weighted-Average Annual Energy Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kWh/year)		
Baseline	140.5	140.8	147.3
1	97.0	97.3	103.8
2	88.7	89.0	94.9
3	84.1	84.3	90.0

Table 11.3.3 Gas Cooking Tops: Weighted-Average Annual Energy Use

Efficiency Level	Gas Consumption			Electricity Consumption		
	All Households	Senior-Only	Low-Income	All Households	Senior-Only	Low-Income
	(kBtu/year)			(kWh/year)		
Baseline	810.6	734.2	816.9	8.8	8.8	8.8
1	655.0	593.3	660.1	8.8	8.8	8.8
2	545.4	494.0	549.6	8.8	8.8	8.8

Table 11.3.4 Electric Standard Ovens, Freestanding: Weighted-Average Annual Electricity Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kWh/year)		
Baseline	155.9	127.3	156.2
1	143.2	114.6	143.5
2	137.2	109.8	137.4
3	112.3	90.0	112.4

Table 11.3.5 Electric Standard Ovens, Built-In/Slide-In: Weighted-Average Annual Electricity Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kWh/year)		
Baseline	162.5	132.3	162.7
1	150.2	120.0	150.4
2	144.1	115.2	144.3
3	119.1	95.4	119.3

Table 11.3.6 Electric Self-Clean Ovens, Freestanding: Weighted-Average Annual Electricity Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kWh/year)		
Baseline	192.8	163.6	193.0
1	180.1	150.9	180.3
2	174.1	146.1	174.3
3	149.1	126.4	149.3

Table 11.3.7 Electric Self-Clean Ovens, Built-In/Slide-In: Weighted-Average Annual Electricity Use

Efficiency Level	All Households	Senior-Only	Low-Income
	(kWh/year)		
Baseline	198.9	168.3	199.1
1	186.6	156.0	186.8
2	180.5	151.2	180.8
3	155.6	131.5	155.8

Table 11.3.8 Gas Standard Ovens, Freestanding: Weighted-Average Annual Gas Use*

Efficiency Level	Gas Consumption (kBtu/year)			Electricity Consumption (kWh/year)		
	All Households	Senior-Only	Low-Income	All Households	Senior-Only	Low-Income
Baseline	928.0	714.6	937.7	18.3	18.3	18.3
1	927.7	714.4	937.4	5.6	5.6	5.6
2	866.7	667.4	875.7	5.6	5.6	5.6

Table 11.3.9 Gas Standard Ovens, Built-In/Slide-In: Weighted-Average Annual Gas Use*

Efficiency Level	Gas Consumption (kBtu/year)			Electricity Consumption (kWh/year)		
	All Households	Senior-Only	Low-Income	All Households	Senior-Only	Low-Income
Baseline	928.0	714.6	937.7	23.7	22.4	23.8
1	928.1	714.7	937.8	11.3	10.0	11.4
2	867.1	667.7	876.2	11.3	10.0	11.4

Table 11.3.10 Gas Self-Clean Ovens, Freestanding: Weighted-Average Annual Gas Use*

Efficiency Level	Gas Consumption (kBtu/year)			Electricity Consumption (kWh/year)		
	All Households	Senior-Only	Low-Income	All Households	Senior-Only	Low-Income
Baseline	986.7	813.6	994.5	24.3	24.3	24.3
1	986.8	813.7	994.7	11.6	11.6	11.6
2	925.4	766.4	932.6	11.6	11.6	11.6

Table 11.3.11 Gas Self-Clean Ovens, Built-In/Slide-In: Weighted-Average Annual Gas Use*

Efficiency Level	Gas Consumption			Electricity Consumption		
	All Households	Senior-Only	Low-Income	All Households	Senior-Only	Low-Income
	(kBtu/year)			(kWh/year)		
Baseline	986.7	813.6	994.5	30.1	28.7	30.2
1	986.8	813.7	994.7	17.7	16.3	17.8
2	925.8	766.8	933.1	17.7	16.3	17.8

11.4 RESULTS

Table 11.4.1 through Table 11.4.44 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 PC1 Electric Open (Coil) Element Cooking Tops

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
1-3	Baseline	$327	$14	$333	$660	--

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 PC1 Electric Open (Coil) Element Cooking Tops

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1-3	Baseline	0%	$0.00

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.3 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for PC2 Electric Smooth Element Cooking Tops

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$551	$20	$407	$959	--
1,2	1	$555	$14	$335	$889	0.6
--	2	$568	$13	$320	$889	2.4
3	3	$1,203	$12	$313	$1,516	86.6

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 PC2 Electric Smooth Element Cooking Tops

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1,2	1	0%	$13.30
--	2	31%	$13.76
3	3	95%	($580.13)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.5 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for PC3 Gas Cooking Tops

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$376	$14.9	$329	$705	--
1	1	$395	$12.7	$303	$698	8.6
2,3	2	$395	$11.2	$285	$680	5.0

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 PC3 Gas Cooking Tops

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1	1	29%	$3.65
2,3	2	19%	$21.37

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.7 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for PC4 Electric Standard Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$652	$18	$425	$1,077	--
1,2	1	$655	$16	$404	$1,058	1.8
--	2	$703	$16	$395	$1,099	22.1
3	3	$754	$13	$361	$1,115	20.4

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 11.4.8 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC4 Electric Standard Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1, 2	1	0%	$0.95
--	2	60%	($23.87)
3	3	86%	($40.40)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.9 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for PC5 Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$682	$19	$435	$1,116	--
1,2	1	$685	$17	$414	$1,098	1.9
--	2	$733	$17	$405	$1,139	22.6
3	3	$784	$14	$371	$1,155	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 11.4.10 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC5 Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1, 2	1	0%	$0.86
--	2	68%	($27.22)
3	3	87%	($43.69)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.11 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for PC6 Electric Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$698	$23	$491	$1,189	--
1,2	1	$701	$22	$469	$1,171	1.8
--	2	$750	$21	$461	$1,211	22.1
3	3	$801	$18	$426	$1,227	20.4

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 11.4.12 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC6 Electric Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1, 2	1	0%	$0.99
--	2	22%	($8.19)
3	3	82%	($24.72)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.13 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for PC7 Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$728	$24	$499	$1,228	--
1,2	1	$732	$22	$478	$1,210	1.9
--	2	$780	$22	$470	$1,250	22.5
3	3	$831	$19	$436	$1,267	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 11.4.14 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC7 Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1, 2	1	0%	$0.90
--	2	11%	($3.88)
3	3	79%	($20.02)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.15 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for PC8 Gas Standard Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$678	$40	$642	$1,320	--
1, 2	1	$681	$38	$625	$1,305	2.1
3	2	$715	$37	$614	$1,329	15.7

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 PC8 Gas Standard Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1, 2	1	1%	$0.56
3	2	34%	($8.51)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.17 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for PC9 Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$707	$40	$648	$1,355	--
1,2	1	$710	$39	$630	$1,341	2.2
3	2	$745	$38	$620	$1,365	16.0

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 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC9 Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1, 2	1	1%	$0.58
3	2	57%	($14.33)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.19 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for PC10 Gas Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$847	$42	$668	$1,515	--
1, 2	1	$850	$40	$650	$1,500	2.1
3	2	$884	$40	$640	$1,524	15.7

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 11.4.20 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC10 Gas Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1, 2	1	1%	$0.64
3	2	6%	($1.12)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.21 Senior Only Households: Summary of LCC and PBP Results by Efficiency Level for PC11 Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$876	$42	$673	$1,550	--
1, 2	1	$880	$41	$656	$1,536	2.2
3	2	$914	$40	$646	$1,560	16.0

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 Senior Only Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC11 Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1, 2	1	1%	$0.50
3	2	21%	($4.92)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.23 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC1 Electric Open (Coil) Element Cooking Tops

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
1-3	Baseline	$327	$15	$349	$676	--

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 PC1 Electric Open (Coil) Element Cooking Tops

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1-3	Baseline	0%	$0.00

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.25 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC2 Electric Smooth Element Cooking Tops

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$552	$21	$424	$976	--
1,2	1	$555	$15	$351	$906	0.5
--	2	$568	$14	$336	$904	2.3
3	3	$1,181	$13	$327	$1,508	82.4

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 PC2 Electric Smooth Element Cooking Tops

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1,2	1	0%	$13.71
--	2	30%	$15.47
3	3	94%	($556.90)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.27 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC3 Gas Cooking Tops

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
0	Baseline	$376	$15.4	$334	$710	--
1	1	$394	$13.3	$308	$703	8.5
2,3	2	$394	$11.7	$290	$684	5.0

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 PC3 Gas Cooking Tops

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1	1	28%	$3.56
2,3	2	18%	$21.06

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.29 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC4 Electric Standard Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$652	$22	$480	$1,132	--
1,2	1	$655	$21	$457	$1,112	1.7
--	2	$704	$20	$446	$1,150	19.8
3	3	$754	$16	$403	$1,158	17.1

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 11.4.30 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC4 Electric Standard Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1,2	1	0%	$1.00
--	2	59%	($22.32)
3	3	79%	($29.95)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.31 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC5 Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$682	$23	$492	$1,174	--
1,2	1	$685	$22	$470	$1,155	1.8
--	2	$734	$21	$459	$1,193	20.2
3	3	$784	$17	$416	$1,200	17.3

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 11.4.32 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC5 Electric Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1,2	1	0%	$0.95
--	2	67%	($25.42)
3	3	80%	($32.96)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.33 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC6 Electric Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	0	$699	$28	$549	$1,248	--
1,2	1	$702	$26	$526	$1,228	1.7
--	2	$751	$25	$516	$1,266	19.8
3	3	$801	$22	$473	$1,274	17.1

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 11.4.34 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC6 Electric Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1,2	1	0%	$1.07
--	2	22%	($7.80)
3	3	75%	($15.42)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.35 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC7 Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$729	$29	$560	$1,289	--
1,2	1	$732	$27	$538	$1,270	1.8
--	2	$781	$26	$527	$1,308	20.2
3	3	$831	$23	$484	$1,316	17.3

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 11.4.36 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC7 Electric Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1,2	1	0%	$0.96
--	2	11%	($3.49)
3	3	72%	($10.89)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.37 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC8 Gas Standard Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$677	$45	$699	$1,377	--
1,2	1	$680	$43	$677	$1,358	1.7
3	2	$714	$42	$663	$1,378	12.0

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 11.4.38 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC8 Gas Standard Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1,2	1	1%	$0.72
3	2	34%	($6.77)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.39 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC9 Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$707	$46	$709	$1,416	--
1,2	1	$710	$44	$687	$1,397	1.7
3	2	$744	$43	$673	$1,417	12.3

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 11.4.40 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC9 Gas Standard Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1,2	1	1%	$0.74
3	2	56%	($11.63)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.41 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC10 Gas Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$846	$46	$711	$1,558	--
1,2	1	$850	$44	$689	$1,539	1.7
3	2	$884	$43	$675	$1,559	12.1

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 11.4.42 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC10 Gas Self-Clean Ovens, Freestanding

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1,2	1	0%	$0.90
3	2	5%	($0.60)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

Table 11.4.43 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for PC11 Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Average Costs 2021$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
--	Baseline	$876	$47	$721	$1,597	--
1,2	1	$879	$45	$700	$1,579	1.7
3	2	$913	$44	$686	$1,599	12.3

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 11.4.44 Low Income Households: Summary of Life-Cycle Costs Savings Relative to the Base Case Efficiency Distribution for PC11 Gas Self-Clean Ovens, Built-In/Slide-In

TSL	Efficiency Level	Life-Cycle Cost Savings	
		% of Consumers that Experience	Average Savings*, **
		Net Cost	2021$
1,2	1	1%	$0.67
3	2	20%	($3.58)

*The calculation excludes households with zero LCC savings (no impact).
**Figures in parentheses denote negative values.

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.

In the absence to data specific to each consumer subgroup, DOE assumed the efficiency distribution developed for the reference case analysis (see section chapter 8 of this SNOPR TSD of this document for details). However, for gas cooking tops, this likely overestimates the negative impact to low-income households that are more likely to purchase traditional residential-style gas cooking tops which tend to have fewer high output burners and slimmer grates relative to commercial-style gas cooking tops. These households are more likely to purchase products above the baseline at EL 1 or EL 2. As both EL 1 and EL 2 have the same installed cost (see Table 11.4.27) a standard for these consumers would not lead to an increase in purchase price and would result in operating cost savings for consumers that purchase EL 1 in the no-new-standards case and EL 2 in a standards case.

REFERENCES

1. U.S. Department of Energy–Energy Information Administration. *Residential Energy Consumption Survey, 2015 Public Use Data Files*. 2015. Washington, D.C. (Last accessed October 4, 2017.) http://www.eia.gov/consumption/residential/data/2015/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. 6295(o)(2)(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 consumer conventional cooking products, 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 no-new-standards case and the various trial standard levels (TSLs) in the standards cases. 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 phases. Phase I, "Industry Profile," consisted of preparing an industry characterization for the consumer conventional cooking product industry. This characterization included data on sales volumes, pricing, employment, and financial structure. In phase II, "Industry Cash Flow Analysis," DOE used the GRIM to assess the potential impacts of new and amended energy conservation standards on manufacturers. In phase III, "Subgroup Impact Analysis," DOE developed additional analyses for subgroups that may be affected in various ways. Each phase of the MIA is described in greater detail in the following sections.

12.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the consumer conventional cooking product industry that built upon the market and technology assessment prepared for this rulemaking, see chapter 3 of this supplemental notice of proposed rulemaking (SNOPR) 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 margins, 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 consumer appliance markets, and general product characteristics. The industry profile included a top-down cost analysis of consumer conventional cooking product 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 used public information to develop its initial characterization of the industry, including Securities and Exchange Commission (SEC) 10-K reports,[a] Standard & Poor's (S&P) stock reports,[b] market research tools (*i.e.,* D&B Hoovers[c]), corporate annual reports, and the U.S. Census Bureau's 2020 Annual Survey of Manufactures (ASM).[d] DOE also used information from its engineering analysis to enhance its industry profile.

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 consumer conventional cooking product 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 per-unit production costs, 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 on consumer conventional cooking product manufacturers. In performing this analysis, DOE used the financial values derived during Phase I and the shipment projections derived in the shipment analysis.

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 which are developed in other analyses. DOE derived the MPCs from the engineering analysis through purchasing and tearing down products. DOE then estimated typical manufacturer margins for consumer conventional cooking products from public financial reports and interviews with manufacturers to derive manufacturer selling prices (MSPs) for all covered consumer conventional cooking products. In addition to the no-new-standards case scenario, DOE developed alternative manufacturer margin scenarios for the standards case scenarios for the GRIM based on discussions with manufacturers. DOE's shipments analysis, presented in chapter 9 of this SNOPR TSD, provided the basis for the shipment projections used in the GRIM. The financial parameters were developed using publicly available manufacturer data and were revised with information submitted confidentially during manufacturer interviews. The GRIM results are compared to no-new-standards 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 no-new-standards case and in the standards cases.

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[a] www.sec.gov/edgar.shtml
[b] www.spglobal.com/ratings/en/
[c] app.avention.com
[d] www.census.gov/programs-surveys/asm/data/tables.html

12.2.3 Phase III: Subgroup Analysis

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. DOE identified two manufacturer subgroups (small business manufacturers and commercial-style manufacturers) that could be disproportionately impacted by new and amended energy conservation standards. As a result, DOE will analyze the small business manufacturer and commercial-style manufacturer subgroups in a separate impact analysis.

12.2.3.1 Manufacturer Subgroup Analysis

For the small business manufacturer subgroup, DOE used the Small Business Administration (SBA) small business size standards published on July 14, 2022, 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.[e] 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
Major Household Appliance Manufacturing	N/A	1,500	335220

DOE used DOE's compliance certification database (CCD),[f] California Energy Commission's (CEC's) MAEDBC database,[g] Canada's Natural Resources Canada (NRCan) database,[h] information from previous stages of this rulemaking, and individual company websites to create a list of companies that potentially sell consumer conventional cooking products covered by this rulemaking. Additionally, DOE received feedback from interested parties in response to previous stages from this rulemaking. DOE contacted select companies on its list, as necessary, to determine whether they met the SBA's definition of a consumer conventional cooking product 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 15 companies that sell consumer conventional cooking products covered by this rulemaking and qualify as a small business per the SBA employment threshold for this industry. DOE has analyzed small businesses as part of the regulatory flexibility analysis presented in the SNOPR notice and section 12.5.1 of this TSD.

[e] The size standards are available on the SBA's website at www.sba.gov/content/table-small-business-size-standards
[f] www.regulations.doe.gov/certification-data
[g] cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx
[h] oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.welcome-bienvenue.

For the commercial-style manufacturer subgroup, DOE attempted to identify conventional cooking product manufacturers that primarily sell commercial-style products. Commercial-style products are gas cooking products that are primarily marketed as commercial-style, either as a standalone product or as a component of a conventional range. Commercial-style manufacturers could also be small businesses. The results of this subgroup analysis are presented in section 12.5.2.

12.2.3.2 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. DOE examined potential impacts of new and amended standards on manufacturing capacity. These include 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; and estimates for any one-time changes to existing PPE. DOE's estimates of the one-time capital changes affect the cash-flow estimates in the GRIM. These estimates can be found in section 12.3.7; DOE's discussion of the capacity impacts can be found in section 12.6.2.

12.2.3.3 Direct 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, DOE obtained data from the U.S. Census Bureau's 2020 ASM about current direct employment trends in the consumer conventional cooking product industry. The employment impacts are reported in section 12.6.1.

12.2.3.4 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. DOE identified regulations relevant to consumer conventional cooking product 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 12.6.3.

12.3 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.

12.3.1 Overview of the GRIM

The basic structure of the GRIM, illustrated in Figure 12.3.1, 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 reference year of the analysis, 2022, and continuing to 2056. The model calculates the INPV by summing the stream of annual discounted cash flows during this period and adding a discounted terminal value.[1]

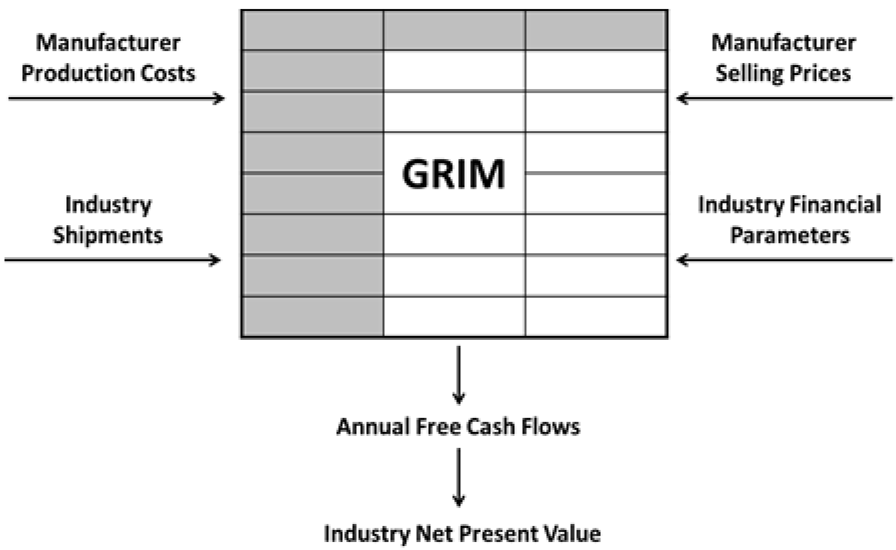

Figure 12.3.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the no-new-standards case and the standard cases induced by new and amended energy conservation standards. The difference in INPV between the no-new-standards case and the standard cases represents the estimated financial impact of the new and amended energy conservation standards on manufacturers. Appendix 12A provides more technical details and user information for the GRIM.

12.3.2 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 analysis, the engineering analysis, and manufacturer interviews.

12.3.2.1 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 consumer conventional cooking products, 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 consumer conventional cooking product 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

12.3.2.2 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.

12.3.2.3 Shipments Analysis

The GRIM estimates manufacturer revenues based on total unit shipment projections and the distribution of those shipments by efficiency level. Changes in sales volumes and efficiency mix over time can significantly affect manufacturer finances. For this analysis, the GRIM uses the NIA's annual shipment projections derived from the shipments analysis from 2022 (the reference year) to 2056 (the end year of the analysis period). See chapter 9 of this TSD for additional details.

12.3.2.4 Engineering Analysis

The engineering analysis establishes the relationship between MPC and the efficiency level for all consumer conventional cooking products covered in this rulemaking. This relationship serves as the basis for the cost-benefit calculations for consumers, manufacturers, and the nation. In determining the cost-efficiency relationship, DOE estimates the increase in manufacturing costs associated with increasing the efficiency of products above the baseline up to the maximum technologically feasible ("max-tech") efficiency level for each product class.

DOE based its engineering analysis on commercially available consumer conventional cooking products that met the design options identified in the technology assessment and screening analysis (chapters 3 and 4 of this SNOPR TSD). DOE's engineering approach consisted of the following steps: 1) identifying representative product classes to analyze, 2) selecting baseline consumer conventional cooking products, 3) identifying more efficient substitutes for the baseline consumer conventional cooking products, and 4) developing efficiency levels for the product classes. DOE developed MPCs for each product class at each efficiency level 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 (BOM) for the purchased units.

Using the BOM for each consumer conventional cooking product, DOE was able to create an aggregated MPC based on the material costs from the BOM, the labor costs based on an average labor rate and the labor hours necessary to manufacture the consumer conventional cooking product 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 the national impact analysis (NIA) after applying the appropriate manufacturer margin and distribution chain markup to each unit. See chapter 5 of this SNOPR TSD for a complete discussion of the engineering analysis.

12.3.3 Financial Parameters

As part of the MIA, DOE estimated eight key financial parameters for use in the GRIM. DOE developed its initial estimates of industry financial parameters based the SEC 10-Ks and compared these financial parameters to the ones used in the notice of proposed determination (NOPD) for consumer conventional cooking products that DOE published on December 14, 2020 ("December 2020 NOPD"). 85 FR 80982.

Table 12.3.1 Financial Parameters for the Consumer Conventional Cooking Products Industry

Financial Parameter	Value Used in GRIM (%)
Tax Rate *(% of taxable income)*	21.0
Working Capital *(% of revenue)*	4.5
SG&A *(% of revenue)*	11.2
R&D *(% of revenue)*	2.4
Depreciation *(% of revenues)*	3.4
Capital Expenditures *(% of revenue)*	3.3
Net PPE *(% of revenue)*	16.2

12.3.4 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 consumer conventional cooking product industry based on representative companies, using the following formula:

WACC = After-Tax Cost of Debt x (Debt Ratio) + Cost of Equity x (Equity Ratio)

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

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 consumer conventional cooking product industry is 15.5 percent.

Table 12.3.2 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 12.3.3 presents the derivation of the cost of debt and the capital structure of the industry (*i.e.,* the debt ratio [debt/total capital]).

Table 12.3.3 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	5.7	4.8
Debt/Total Capital %	33.2	27.3	45.5

Using public information for both these companies, the initial estimate for the consumer conventional cooking product 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 consumer conventional cooking product industry. This is the same value that was used in the December 2020 NOPD.

12.3.5 Trial Standard Levels

DOE developed TSLs for consumer conventional cooking products consistent with the engineering analysis. DOE analyzed 11 product classes for consumer conventional cooking products. Table 12.3.4 shows the efficiency levels at each TSL for the consumer conventional cooking products analyzed by DOE.

Table 12.3.4 Trial Standard Levels for Consumer Conventional Cooking Products

Product Class	Product Class Description	TSL 1	TSL 2	TSL 3
1	Electric Open (Coil) Element Cooking Tops	Baseline	Baseline	Baseline
2	Electric Smooth Element Cooking Tops	EL 1	EL 1	EL 3
3	Gas Cooking Tops	EL 1	EL 2	EL 2
4	Electric Standard Ovens, Freestanding	EL 1	EL 1	EL 3
5	Electric Standard Ovens, Built-in/Slide-in	EL 1	EL 1	EL 3
6	Electric Self-Clean Ovens, Freestanding	EL 1	EL 1	EL 3
7	Electric Self-Clean Ovens, Built-in/Slide-in	EL 1	EL 1	EL 3
8	Gas Standard Ovens, Freestanding	EL 1	EL 1	EL 2
9	Gas Standard Ovens, Built-in/Slide-in	EL 1	EL 1	EL 2
10	Gas Self-Clean Ovens, Freestanding	EL 1	EL 1	EL 2
11	Gas Self-Clean Ovens, Built-in/Slide-in	EL 1	EL 1	EL 2

12.3.6 Production Costs

During the engineering analysis, DOE developed the MPCs for all product classes at each efficiency level analyzed. DOE purchased a number of units for each product class, then tested and tore down those units to create a unique BOM for each of the purchased units. Using the BOM for each consumer conventional cooking product, DOE was able to create an aggregated MPC based on the material costs from the BOM, the labor costs based on an average labor rate and the labor hours necessary to manufacture the consumer conventional cooking products analyzed, and the overhead costs, including depreciation, based on a markup applied to the material and labor costs based on the materials used.

Table 12.3.5 through Table 12.3.15 show the average MPC estimates for consumer conventional cooking products used in the GRIM for each product class at each efficiency level.

Table 12.3.5 Manufacturer Production Cost Breakdown (2021$) for Electric Open (Coil) Element Cooking Tops

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$71.66	$10.87	$4.03	$12.28	$98.84	1.20	$118.61

Table 12.3.6 Manufacturer Production Cost Breakdown (2021$) for Electric Smooth Element Cooking Tops

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$161.18	$24.46	$9.07	$27.61	$222.32	1.20	$266.78
EL 1	$162.75	$24.69	$9.16	$27.88	$224.48	1.20	$269.38
EL 2	$169.19	$25.67	$9.52	$28.98	$233.37	1.20	$280.04
EL 3	$351.99	$53.41	$19.81	$60.30	$485.51	1.20	$582.61

Table 12.3.7 Manufacturer Production Cost Breakdown (2021$) for Gas Cooking Tops

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$92.74	$14.07	$5.22	$15.89	$127.92	1.20	$153.50
EL 1	$101.74	$15.44	$5.73	$17.43	$140.33	1.20	$168.40
EL 2	$101.74	$15.44	$5.73	$17.43	$140.33	1.20	$168.40

Table 12.3.8 Manufacturer Production Cost Breakdown (2021$) for Electric Standard Ovens, Freestanding

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$208.60	$31.65	$11.74	$35.73	$287.72	1.20	$345.26
EL 1	$210.07	$31.87	$11.82	$35.99	$289.75	1.20	$347.70
EL 2	$233.33	$35.40	$13.13	$39.97	$321.83	1.20	$386.20
EL 3	$257.73	$39.10	$14.50	$44.15	$355.49	1.20	$426.59

Table 12.3.9 Manufacturer Production Cost Breakdown (2021$) for Electric Standard Ovens, Built-in/Slide-in

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$220.55	$33.46	$12.41	$37.78	$304.20	1.20	$365.04
EL 1	$222.02	$33.69	$12.49	$38.03	$306.23	1.20	$367.48
EL 2	$245.27	$37.21	$13.80	$42.02	$338.31	1.20	$405.97
EL 3	$269.68	$40.92	$15.18	$46.20	$371.97	1.20	$446.36

Table 12.3.10 Manufacturer Production Cost Breakdown (2021$) for Electric Self-Clean Ovens, Freestanding

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$227.24	$34.48	$12.79	$38.93	$313.44	1.20	$376.13
EL 1	$228.72	$34.70	$12.87	$39.18	$315.47	1.20	$378.56
EL 2	$251.97	$38.23	$14.18	$43.17	$347.55	1.20	$417.06
EL 3	$276.38	$41.93	$15.55	$47.35	$381.21	1.20	$457.45

Table 12.3.11 Manufacturer Production Cost Breakdown (2021$) for Electric Self-Clean Ovens, Built-in/Slide-in

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$239.19	$36.29	$13.46	$40.98	$329.92	1.20	$395.90
EL 1	$240.66	$36.51	$13.54	$41.23	$331.95	1.20	$398.34
EL 2	$263.92	$40.04	$14.85	$45.21	$364.03	1.20	$436.84
EL 3	$288.33	$43.75	$16.23	$49.39	$397.69	1.20	$477.23

Table 12.3.12 Manufacturer Production Cost Breakdown (2021$) for Gas Standard Ovens, Freestanding

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$222.29	$33.73	$12.51	$38.08	$306.60	1.20	$367.92
EL 1	$223.85	$33.96	$12.60	$38.35	$308.76	1.20	$370.51
EL 2	$240.38	$36.47	$13.53	$41.18	$331.56	1.20	$397.87

Table 12.3.13 Manufacturer Production Cost Breakdown (2021$) for Gas Standard Ovens, Built-in/Slide-in

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$234.23	$35.54	$13.18	$40.13	$323.07	1.20	$387.68
EL 1	$235.80	$35.78	$13.27	$40.39	$325.24	1.20	$390.29
EL 2	$252.32	$38.28	$14.20	$43.23	$348.03	1.20	$417.64

Table 12.3.14 Manufacturer Production Cost Breakdown (2021$) for Gas Self-Clean Ovens, Freestanding

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$290.61	$44.09	$16.35	$49.78	$400.84	1.20	$481.01
EL 1	$292.18	$44.33	$16.44	$50.05	$403.01	1.20	$483.61
EL 2	$308.71	$46.84	$17.37	$52.88	$425.80	1.20	$510.96

Table 12.3.15 Manufacturer Production Cost Breakdown (2021$) for Gas Self-Clean Ovens, Built-in/Slide-in

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$302.56	$45.91	$17.03	$51.83	$417.32	1.20	$500.78
EL 1	$304.13	$46.14	$17.12	$52.10	$419.49	1.20	$503.39
EL 2	$320.65	$48.65	$18.05	$54.93	$442.28	1.20	$530.74

12.3.7 Capital and Product Conversion Costs

DOE expects new and amended energy conservation standards for consumer conventional cooking products to cause manufacturers to incur conversion costs to bring their production facilities and product designs into compliance with the proposed standards. For the MIA, DOE classified these conversion costs into two major groups: (1) capital conversion costs, which include additional lab space and testing equipment (for those manufacturers conducting testing in-house) and (2) product conversion costs, which also include per unit testing costs (conducted either in-house or at a third-party lab). 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 conversion costs (including the capital investments associated with conducting DOE compliance testing) and a bottom-up analysis to calculate the product conversion costs (including the engineering time associated with conducting all the necessary DOE compliance testing) for consumer conventional cooking product manufacturers. DOE asked manufacturers during interviews to estimate the total capital conversion costs they would incur to be able to produce consumer conventional cooking products at specific efficiency levels. Additionally, DOE asked manufacturers the costs associated with any potential new lab space to conduct in-house testing and the equipment they would need to purchase to conduct DOE compliance testing. DOE then summed these values provided by manufacturers to arrive at a total industry capital conversion cost estimate for consumer conventional cooking products. DOE assumed that capital conversion costs associated with testing would be the same across all TSLs, while capital conversion costs associated with manufacturing more efficient products would increase at higher TSLs.

DOE's estimates of the capital conversion costs for all consumer conventional cooking products can be found in Table 12.3.16.

Table 12.3.16 Capital Conversion Costs for all Consumer Conventional Cooking Products by TSL

Product Class	Product Class Description	Testing CCC *(millions 2021$)*	Non-Testing Capital Conversion Costs *(millions 2021$)*			Total Capital Conversion Costs *(millions 2021$)*		
		All TSLs	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 1**	**TSL 2**	**TSL 3**
1	Electric Open (Coil) Element Cooking Tops	2.45	-	-	-	2.45	2.45	2.45
2	Electric Smooth Element Cooking Tops	2.45	3.75	3.75	75.00	6.20	6.20	77.45
3	Gas Cooking Tops	4.90	30.00	45.00	45.00	34.89	49.89	49.89
4 & 5	Electric Standard Ovens	-	3.75	3.75	116.25	3.75	3.75	116.25
6 & 7	Electric Self-Clean Ovens	-	3.75	3.75	116.25	3.75	3.75	116.25
8 & 9	Gas Standard Ovens	-	3.75	3.75	41.25	3.75	3.75	41.25
10 & 11	Gas Self-Clean Ovens	-	3.75	3.75	41.25	3.75	3.75	41.25
All	**Total**	**9.78**	**48.75**	**63.75**	**435.00**	**58.54**	**73.54**	**444.79**

Using feedback from manufacturer interviews, DOE estimated a per model product conversion cost for each product class at each efficiency level. DOE then used DOE's CCD, CEC's MAEDBC database, Canada's NRCan database, information from previous stages of this rulemaking, and individual company websites to create a database of all conventional cooking product models covered by this rulemaking. DOE estimated there were approximately 2,300 unique basic models of cooking tops and 2,300 unique basic models of ovens. DOE used the shipment analysis to estimate the model efficiency distributions for each product class.

To estimate the per-model testing costs, DOE asked manufacturers about the testing cost estimates used in the test procedure final rule that DOE published on August 22, 2022 ("August 2022 TP Final Rule"). 87 FR 51492, 51532–51533. Manufacturers stated the in-house cost estimates should be increased. For this SNOPR, DOE increased the per-burner testing time to be 8 hours per burner. DOE estimated that the average cooking top model has 5 burners. Therefore, DOE estimated it would take a technician approximately 40 hours to test each cooking top basic model in-house. DOE continued to use the third-party per-model testing cost of $8,200 for all cooking tops.

To estimate the per-model redesign costs. DOE estimated the engineering hours to redesign a single model for each product class at each efficiency level. Table 12.3.17 displays the estimated per-model redesign engineering hour estimates.

Table 12.3.17 Per-Model Engineering Hours to Redesign each Consumer Conventional Cooking Product by Product Class and Efficiency Level

Product Class	Engineering Hours to Redesign One Model		
	EL 1	EL 2	EL 3*
Electric Smooth Element Cooking Tops	160 hrs	1,200 hrs	8,480 hrs
Gas Cooking Tops	1,040 hrs	1,560 hrs	
Electric Standard Ovens	160 hrs	4,320 hrs	8,480 hrs
Electric Self-Clean Ovens	160 hrs	4,320 hrs	8,480 hrs
Gas Standard Ovens	160 hrs	4,320 hrs	
Gas Self Clean Ovens	160 hrs	4,320 hrs	

* Black shading indicates that there is no EL 3 for that product class. EL 2 is the max-tech for that product class.

Using the per-model engineering hour estimates in Table 12.3.17, the total number of consumer conventional cooking product models estimate previously discussed, the product class and efficiency distribution in the shipment analysis, and the wage rate from the Bureau of Labor Statistics,[i] DOE estimated the total redesign costs for each product class at each TSL. The results of these product conversion cost estimates are presented in Table 12.3.18.

Table 12.3.18 Product Conversion Costs for all Consumer Conventional Cooking Products by TSL

Product Class	Product Class Description	Testing PCC *(millions 2021$)*	Non-Testing Product Conversion Costs *(millions 2021$)*			Total Product Conversion Costs *(millions 2021$)*		
		All TSLs	TSL 1	TSL 2	TSL 3	TSL 1	TSL 2	TSL 3
1	Electric Open (Coil) Element Cooking Tops	2.80	-	-	-	2.80	2.80	2.80
2	Electric Smooth Element Cooking Tops	3.35	1.53	1.53	385.39	4.88	4.88	388.75
3	Gas Cooking Tops	4.51	32.18	96.53	96.58	36.69	101.04	101.04
4 & 5	Electric Standard Ovens	-	0.18	0.18	185.96	0.18	0.18	185.96
6 & 7	Electric Self-Clean Ovens	-	0.65	0.65	675.85	0.65	0.65	675.85
8 & 9	Gas Standard Ovens	-	0.15	0.15	38.64	0.15	0.15	38.64
10 & 11	Gas Self-Clean Ovens	-	0.18	0.18	8.59	0.18	0.18	8.59
All	**Total**	**10.67**	**34.86**	**99.21**	**1,391**	**45.53**	**109.88**	**1,402**

[i] Hourly wage for a Mechanical Engineer is $46.64 (www.bls.gov/oes/current/oes172141.htm) and wage make approximately 70.4% of total compensation for a "Private Industry Worker" (www.bls.gov/news.release/archives/ecec_06162022.pdf).

12.3.8 Markup Scenarios

In the no-new-standards case, DOE used a manufacturer margin of 17 percent for all consumer conventional cooking products. This corresponds to a manufacturer markup of 1.20. In the standards cases, DOE used two 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 scenario and (2) a preservation of operating profit scenario. These scenarios lead to different margin values, which when applied to the inputted MPCs, result in varying revenue and cash-flow impacts.

12.3.8.1 Preservation of Gross Margin Scenario

Under the preservation of gross margin scenario, DOE applied the same "gross margin percentage" across all efficiency levels in the standards-cases that is used in the no-new-standards case. This scenario assumes that manufacturers would be able to maintain the same margin of 17 percent, that is used in the no-new-standards case, in all standards cases, even as the MPCs increase due to energy conservation standards. This margin is the same margin that was used in the December 2020 NOPD. This scenario represents the upper bound to industry profitability under new and amended energy conservation standards.

12.3.8.2 Preservation of Operating Profit Scenario

Under the preservation of operating profit scenario, DOE modeled a situation in which manufacturers are not able to increase per-unit operating profit in proportion to increases in MPCs. Under this scenario, as the MPCs increase, manufacturers reduce their margins (on a percentage basis) to a level that maintains the no-new-standards operating profit (in absolute dollars). The implicit assumption behind this scenario is that the industry can only maintain its operating profit in absolute dollars after compliance with new and amended standards. Therefore, operating profit in percentage terms is reduced between the no-new-standards case and the analyzed standards cases. DOE adjusted the margins in the GRIM at each TSL to yield approximately the same earnings before interest and taxes in the standards case in the year after the compliance date of the new and amended standards as in the no-new-standards case. This scenario represents the lower bound to industry profitability under new and amended energy conservation standards

For consumer conventional cooking products, Table 12.3.19 through Table 12.3.29 list the product classes DOE analyzed with the corresponding preservation of operating profit markups at each analyzed efficiency level.

Table 12.3.19 Preservation of Operating Profit for Electric Open (Coil) Element Cooking Tops

Efficiency Level	Markups by Selected EL
	Baseline
Baseline	1.200

Table 12.3.20 Preservation of Operating Profit for Electric Smooth Element Cooking Tops

Efficiency Level	Markups by Selected EL			
	Baseline	EL 1	EL 2	EL 3
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	1.178

Table 12.3.21 Preservation of Operating Profit for Gas Cooking Tops

Efficiency Level	Markups by Selected EL		
	Baseline	EL 1	EL 2
Baseline	1.200		
EL 1	1.200	1.198	
EL 2	1.200	1.200	1.198

Table 12.3.22 Preservation of Operating Profit for Electric Standard Ovens, Freestanding

Efficiency Level	Markups by Selected EL			
	Baseline	EL 1	EL 2	EL 3
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	1.194

Table 12.3.23 Preservation of Operating Profit for Electric Standard Ovens, Built-in/Slide-in

Efficiency Level	Markups by Selected EL			
	Baseline	EL 1	EL 2	EL 3
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	1.194

Table 12.3.24 Preservation of Operating Profit for Electric Self-Clean Ovens, Freestanding

Efficiency Level	Markups by Selected EL			
	Baseline	EL 1	EL 2	EL 3
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	1.195

Table 12.3.25 Preservation of Operating Profit for Electric Self-Clean Ovens, Built-In/Slide-In

Efficiency Level	Markups by Selected EL			
	Baseline	EL 1	EL 2	EL 3
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	1.196

Table 12.3.26 Preservation of Operating Profit for Gas Standard Ovens, Freestanding

Efficiency Level	Markups by Selected EL		
	Baseline	EL 1	EL 2
Baseline	1.200		
EL 1	1.200	1.200	
EL 2	1.200	1.200	1.199

Table 12.3.27 Preservation of Operating Profit for Gas Standard Ovens, Built-In/Slide-In

Efficiency Level	Markups by Selected EL		
	Baseline	EL 1	EL 2
Baseline	1.200		
EL 1	1.200	1.200	
EL 2	1.200	1.200	1.198

Table 12.3.28 Preservation of Operating Profit for Gas Self-Clean Ovens, Freestanding

Efficiency Level	Markups by Selected EL		
	Baseline	EL 1	EL 2
Baseline	1.200		
EL 1	1.200	1.200	
EL 2	1.200	1.200	1.200

Table 12.3.29 Preservation of Operating Profit for Gas Self-Clean Ovens, Built-in/Slide-in

Efficiency Level	Markups by Selected EL		
	Baseline	EL 1	EL 2
Baseline	1.200		
EL 1	1.200	1.200	
EL 2	1.200	1.200	1.199

12.4 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, the GRIM estimates the financial impact on the consumer conventional cooking product industry. The following sections detail additional inputs and assumptions for consumer conventional cooking products. 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.

12.4.1 Impacts on Industry Net Present Value

The INPV calculated in the GRIM measures the consumer conventional cooking product industry value and is used in the MIA to compare the economic impacts of different TSLs in the standards cases. The INPV is the sum of all net cash flows discounted at the industry's cost of capital, or discount rate. The consumer conventional cooking product GRIM estimates cash flows from 2022 to 2056. This timeframe models both the short-term impacts on the industry from the announcement of the standards until the compliance date (2024 until a compliance date of 2027) and a long-term assessment over the 30-year analysis period used in the NIA (2027–2056).

In the MIA, DOE compares the INPV of the no-new-standards case to that of each TSL in the standards cases. The difference between the no-new-standards case and a standards case INPV is an estimate of the economic impacts that proposing that particular TSL would have on the industry. For the consumer conventional cooking product industry, DOE examined the two scenarios previously described: the preservation of gross margin scenario and the preservation of operating profit scenario.

Table 12.4.1 and Table 12.4.2 provide the INPV estimates for the two scenarios for the consumer conventional cooking product industry.

Table 12.4.1 Changes in Industry Net Present Value for Consumer Conventional Cooking Products – Preservation of Gross Margin Scenario

	Units	No-New Standards Case	Trial Standard Level		
			1	2	3
INPV	*2021$ millions*	1,607	1,506	1,456	422
Change in INPV	*2021$ millions*	-	(100.7)	(150.4)	(1,185.1)
	%	-	(6.3)	(9.4)	(73.8)
Product Conversion Costs	*2021$ millions*	-	45.5	109.9	1,401.6
Capital Conversion Costs	*2021$ millions*	-	58.5	73.5	444.8
Total Conversion Costs	*2021$ millions*	-	104.1	183.4	1,846.4

* Parentheses indicate negative values.

Table 12.4.2 Changes in Industry Net Present Value for Consumer Conventional Cooking Products – Preservation of Operating Profit Scenario

	Units	No-New Standards Case	Trial Standard Level		
			1	2	3
INPV	*2021$ millions*	1,607	1,502	1,452	238
Change in INPV	*2021$ millions*	-	(105.1)	(154.8)	(1,368.6)
	%	-	(6.5)	(9.6)	(85.2)
Product Conversion Costs	*2021$ millions*	-	45.5	109.9	1,401.6
Capital Conversion Costs	*2021$ millions*	-	58.5	73.5	444.8
Total Conversion Costs	*2021$ millions*	-	104.1	183.4	1,846.4

* Parentheses indicate negative values.

12.4.2 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 12.4.1 and Figure 12.4.2 present the annual free cash flows from 2022 through 2032 for the no-new-standards case and different TSLs in the standards cases. In addition, Table 12.4.3 presents estimated free cash flow impacts in the year prior to the standard (2026).

Annual cash flows are discounted to the reference year, 2022. After the standards announcement date, industry cash flows begin to decline as companies use their financial resources to prepare for the new and amended energy conservation standards. Cash flows between the announcement date and the compliance date are driven by the level of conversion costs and the proportion of these investments spent each year. The more stringent the energy conservation standard, and the higher the expected conversion costs, the greater the impact on industry cash flows in the years leading up to the compliance date. This is because product conversion costs increase operational expenses, thereby reducing net operating profit, while capital conversion costs increase capital expenses, resulting in higher cash outflows and further reducing free cash flow.

In the estimated year new and amended standards take effect (2027), there is 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, carrying higher inventory to sell more expensive product, and higher accounts receivable for more expensive product.

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 scenario, the margin is held constant to yield the same gross margin percentage in the standards cases as in the no-new-standards case in the years after the standards take effect. The implicit assumption is that manufacturers can freely pass on manufacturer margins at higher cost per unit. 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 no-new-standards case. The larger the MPC 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 no-new-standards case because the absolute dollar amount of the gross margin does not change despite an increase in sales and investments. Therefore, the gross margin as a percentage is reduced.

Table 12.4.3 presents free cash flow impacts in the year before the standard takes effect (2026). Figure 12.4.1 and Figure 12.4.2 present the annual free cash flows for the consumer conventional cooking product industry.

Table 12.4.3 Industry Free Cash Flow Impacts in the Year before Compliance (2026)

	Units	No-New-Standards-Case	Trial Standard Level*		
			1	2	3
Free Cash Flow (2026)	*2021$ millions*	132.9	90.3	60.7	(666.2)
Change in Free Cash Flow	*2021$ millions*	-	(42.5)	(72.2)	(799.0)
	%	-	(32.0)	(54.3)	(601.4)

* Parentheses indicate negative values.

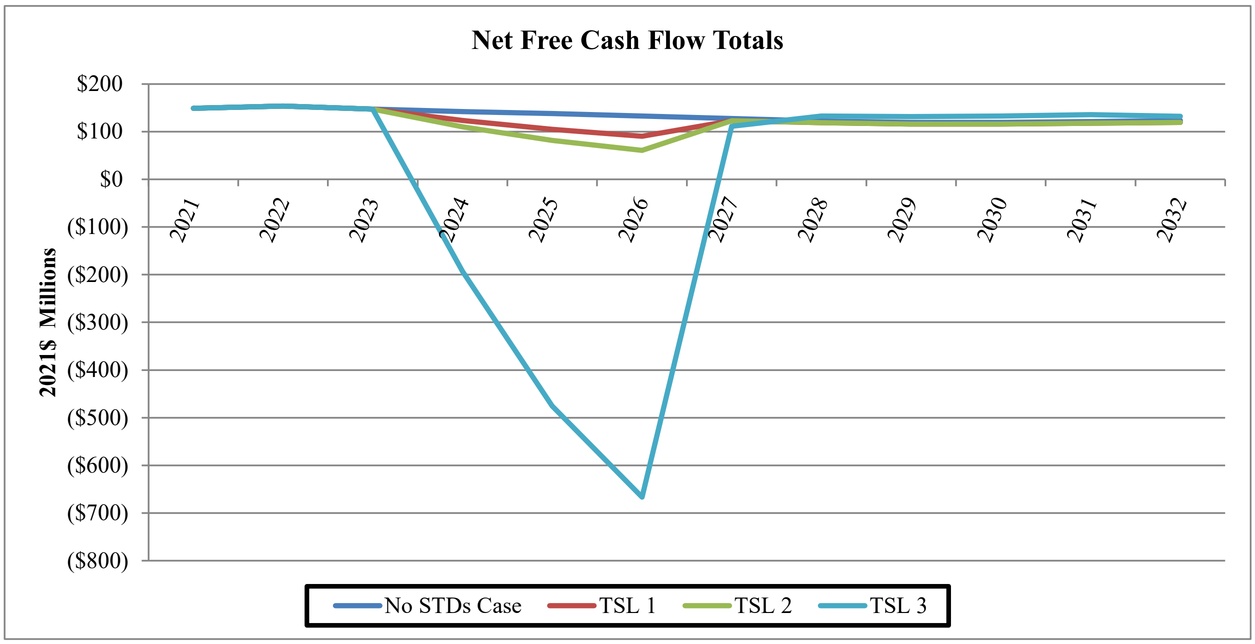

Figure 12.4.1 Annual Industry Free Cash Flows for Consumer Conventional Cooking Products – Preservation of Gross Margin Scenario

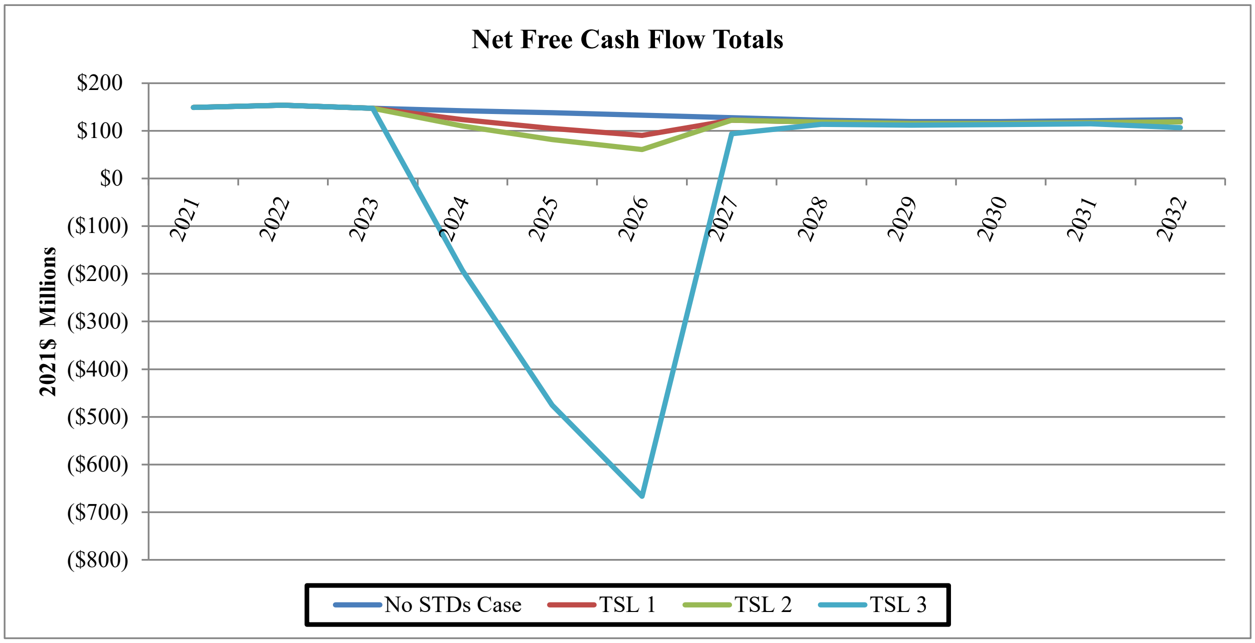

Figure 12.4.2 Annual Industry Free Cash Flows for Consumer Conventional Cooking Products – Preservation of Operating Profit Scenario

12.5 IMPACTS ON MANUFACTURER SUBGROUPS

As described in Section 12.2.3, DOE identified two manufacturer subgroups for consumer conventional cooking product manufacturers: small business manufacturers and commercial-style manufacturers. The results of this manufacturer subgroup analysis are described in the following section.

12.5.1 Impacts on Small Business Manufacturers

DOE conducted a focused inquiry into small business manufacturers of the products covered by this rulemaking. DOE used the SBA's small business size standards to determine whether any small entities would be subject to the requirements of the rule. The size standards are listed by NAICS code as well as by industry description and are available at www.sba.gov/document/support--table-size-standards. Manufacturing cooking tops is classified under NAICS 335220, "major household appliance manufacturing." The SBA sets a threshold of 1,500 employees or fewer for an entity to be considered as a small business for this category. DOE used available public information to identify potential small manufacturers.

DOE accessed DOE's CCD, CEC's MAEDbS, and NRCan's database to create a list of companies that import or otherwise manufacture the products covered by this SNOPR. Additionally, in response to the September 2016 SNOPR, Felix Storch provided a list of potential small businesses not previously identified in the September 2016 SNOPR. Once DOE created a list of potential manufacturers, DOE used market research tools to determine whether any companies met SBA's definition of a small entity—based on the total number of employees for each company including parent, subsidiary, and sister entities—and gather annual revenue estimates.

Based on DOE's analysis, DOE identified 34 companies potentially manufacturing consumer conventional cooking products covered by this rulemaking. DOE screened out companies that have more than 1,500 total employees or are entirely foreign owned and operated, and therefore do not meet SBA's requirements to be considered a small entity. Of the 34 companies DOE identified as manufacturing consumer conventional cooking products sold in the United States, 15 were identified as potential small businesses.

DOE is proposing TSL 2 in this SNOPR. For all oven product classes, TSL 2 requires that the ovens not be equipped with a linear power supply. Based on DOE's shipments analysis more than 95 percent of ovens use a switch-mode power supply (SMPS) and therefore are not equipped with a linear power supply. Based on DOE's shipment analysis, DOE assumed most, if not all, small businesses already use SMPSs for the ovens they manufacturer. If any small businesses do still use linear power supplies in their ovens, there would be minimal conversion costs to these small businesses, as SMPSs can be purchased as a separate component and would most likely not require a significant redesign to incorporate. The remainder of this cost analysis focuses on the costs associated with complying with the proposed cooking top energy conservation standards.

As stated in the previous section, DOE identified 15 potential small manufacturers of consumer conventional cooking products. All 15 of these small businesses manufacture cooking tops. These 15 small businesses can be grouped into two manufacturing groups: those that manufacture entry level cooking tops and those that manufacture premium cooking tops.

Gas cooking top entry level products typically have thinner non-continuous grates with only one high input rate (HIR) burner (*i.e.,* a burner with an input rate above 14,000 British thermal units per hour (Btu/h)), although some of these small businesses may offer a limited number of models with thicker continuous grates and more than one HIR burner. Electric cooking top entry level products typically have electric coil element cooking tops (although a few small businesses may have up to 25 percent of their electric ranges or electric cooking tops using electric smooth element cooking tops). These entry level small businesses usually compete on price in the market.

Gas cooking top premium products typically have thicker continuous grates with multiple HIR burners. Electric cooking top premium products use smooth element, typically with induction technology. Small businesses manufacturing premium products do not offer electric coil element cooking tops. Lastly, small businesses manufacturing premium products typically compete on the high quality and professional look and design of their products. These ranges or cooking tops are typically significantly more expensive than entry level products.

Based on data from each small business's websites, DOE estimated the number of basic models each small business offers.

Table 12.5.1 Number of Unique Basic Models for each Small Business

Manufacturer	Small Business Type	Number of Cooking Top Basic Models (By Product Class)		
		Gas	Smooth Element	Open (Coil) Element
Small Business 1	Entry Level	4	4	-
Small Business 2	Entry Level	14	-	13
Small Business 3	Entry Level	3	2	3
Small Business 4	Entry Level	-	30	-
Small Business 5	Entry Level	24	-	13
Small Business 6	Entry Level	27	13	28
Small Business 7	Premium	14	-	-
Small Business 8	Premium	42	-	-
Small Business 9	Premium	16	-	-
Small Business 10	Premium	24	5	-
Small Business 11	Premium	12	-	-
Small Business 12	Premium	11	-	-
Small Business 13	Premium	13	-	-
Small Business 14	Premium	14	1	-
Small Business 15	Premium	20	7	-

DOE estimated the small business conversion costs and testing costs using the same methodology used to estimate the industry conversion costs, described in section 12.3.7 of this SNOPR TSD. There are two types of conversion costs that small businesses could incur due to the proposed standards: product conversion costs (including any testing costs) and capital conversion costs. Felix Storch commented in response to the September 2016 SNOPR that small manufacturers often lack the staff with expertise to fully understand the test procedures, complexities and nuances of the regulations. Additionally, Felix Storch commented that small manufacturers pay substantially more and have longer lead times for energy testing. In the August 2022 TP Final Rule, DOE estimated a lower per-unit testing cost for testing done in-house and a more costly third-party laboratory per-unit testing cost. DOE assumed all small businesses would incur the more costly third-party laboratory per-unit testing cost, as most small businesses do not have in-house testing capabilities or capacity to test all their products in accordance with the DOE test procedure. 87 FR 51492, 51532–51533 (Aug. 22, 2022).

Product conversion costs are investments in R&D, testing, marketing, and other non-capitalized costs necessary to make product designs comply with new and amended energy conservation standards. Capital conversion costs are investments in property, plant, and equipment necessary to adapt or change existing production facilities such that new compliant product designs can be fabricated and assembled. Manufacturers would have to incur testing costs for all cooking tops since DOE is proposing to establish a new energy conservation standard for cooking tops. Therefore, even products that meet the proposed energy conservation standard would incur testing costs to test these cooking tops to demonstrate compliance with the proposed energy conservation standards. However, manufacturers would only incur R&D product conversion costs and capital conversion costs if they have products that do not meet the energy conservation standards.

Based on the estimated model counts for each cooking top product class shown in Table 12.5.1 and the conversion cost and testing cost methodology used to calculate industry conversion costs, DOE estimated the conversion costs and testing costs for each small business, displayed in Table 12.5.2. DOE then used D&B Hoovers to estimate the annual revenue for each small business. Manufacturers will have 3 years between publication of a final rule and compliance with the energy conservation standards. Therefore, DOE presents the estimated conversion costs and testing costs as a percent of the estimated 3 years of annual revenue for each small business.

Table 12.5.2 Estimated Conversion Costs and Annual Revenue for each Small Business

Manufacturer	Small Business Type	Total Conversion and Testing Costs	Annual Revenue	Conversion Costs as a % of 3-Years of Annual Revenue
Small Business 1	Entry Level	$358,000	$950,000	13%
Small Business 2	Entry Level	$814,000	$8,780,000	3%
Small Business 3	Entry Level	$945,400	$58,630,000	1%
Small Business 4	Entry Level	$303,400	$31,370,000	<1%
Small Business 5	Entry Level	$221,400	$23,980,000	<1%
Small Business 6	Entry Level	$336,800	$107,350,000	<1%
Small Business 7	Premium	$2,227,050	$2,730,000	27%
Small Business 8	Premium	$4,021,200	$5,000,000	27%
Small Business 9	Premium	$3,612,600	$8,800,000	14%
Small Business 10	Premium	$2,784,800	$7,990,000	12%
Small Business 11	Premium	$2,830,500	$8,648,000	11%
Small Business 12	Premium	$2,338,600	$10,970,000	7%
Small Business 13	Premium	$5,685,100	$32,600,000	6%
Small Business 14	Premium	$2,450,150	$19,800,000	4%
Small Business 15	Premium	$2,561,700	$23,730,000	4%
Average Small Business	**-**	**$2,099,380**	**$23,421,867**	**3%**

12.5.2 Impacts on Commercial-Style Manufacturers

DOE also identified the commercial-style manufacturer subgroup as a potential manufacturer subgroup that could be adversely impacted by this rulemaking based on the results of the industry characterization.

The commercial-style manufacturer subgroup consists of consumer conventional cooking product manufacturers that primarily sell gas cooking tops, gas ovens, and electric self-clean ovens marketed as commercial-style, either as a stand-alone product or as a component of a conventional range. For the cooking top product classes, while commercial-style manufacturers do not produce electric open (coil) element cooking tops, some commercial-style manufacturers do produce electric smooth element cooking tops. Of those commercial-style manufacturers that do produce electric smooth element cooking tops, all these manufacturers have products that use induction technology and would be able to meet the max-tech for this product class.

Commercial-style manufacturers would likely face more difficulty meeting potential standards set for the gas cooking top product class than other consumer conventional cooking product manufacturers. All analyzed efficiency levels for the gas cooking top product class are achievable with continuous cast-iron grates and at least one HIR burner. Therefore, while commercial-style manufacturers would likely have to redesign a higher portion of their gas cooking top models compared to other consumer conventional cooking product manufacturers, all efficiency levels for the gas cooking top product class are achievable for commercial-style manufacturers.

For the oven product classes, the vast majority of commercial-style electric and gas ovens already use SMPSs in their ovens and would not have difficulty meeting potential standard levels requiring SMPSs for any oven product classes. Additionally, commercial-style manufacturers typically have a higher percentage of gas oven models that use forced convection than other consumer conventional cooking product manufacturers. However, like the rest of the market, there are very few, if any, commercial-style electric ovens equipped with an oven separator, and it would be difficult for commercial-style manufacturers to convert all of their oven cavities into ovens equipped with an oven separator.

12.6 OTHER IMPACTS

12.6.1 Employment

DOE quantitatively assessed the impacts of new and amended energy conservation standards on direct employment. DOE used the GRIM to calculate the number of production employees from labor expenditures. DOE used statistical data from the 2019 ASM and the results of the engineering analysis to calculate industry-wide labor expenditures. Labor expenditures related to product manufacturing depend on the labor intensity of the product, the sales volume, and an assumption that wages remain fixed in real terms over time. The total labor expenditures in the GRIM were then converted to domestic production employment levels by dividing production labor expenditures by the annual payment per production worker.

Non-production employees account for those workers that are not directly engaged in the manufacturing of the covered products. This could include sales, human resources, engineering, and management. DOE estimated non-production employment levels by multiplying the number of consumer conventional cooking product workers by a scaling factor. The scaling factor is calculated by taking the ratio of the total number of employees, and the total production workers associated with the industry NAICS code 335220, which covers consumer conventional cooking product manufacturing.

The employment impacts shown in Table 12.6.1 represent the potential domestic production employment that could result following the 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 the 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 risk of manufacturers evaluating sourcing decisions in response to the new and amended energy conservation standards, the lower bound of the employment results includes DOE's estimate of the total number of U.S. production workers in the industry who could lose their jobs if some existing domestic production were moved outside of the United States. While the results present a range of domestic employment impacts following 2027, the following sections also include qualitative discussions of the likelihood of negative employment impacts at the various TSLs.

Using 2019 ASM data and interviews with manufacturers, DOE estimates that approximately 60 percent of the consumer conventional cooking products 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 4,322 domestic production workers involved in manufacturing consumer conventional cooking products in 2027. Table 12.6.1 shows the range of the impacts of the new and amended energy conservation standards on U.S. production workers in the consumer conventional cooking product industry.

Table 12.6.1 Potential Changes in the Total Number of All Domestic Consumer Conventional Cooking Products Production Workers in 2023

	No-New-Standards Case	Trial Standard Level		
		1	2	3
Domestic Production Workers in 2027	4,322	4,343	4,343	4,880
Domestic Non-Production Workers in 2027	631	634	634	713
Total Direct Employment in 2027	4,953	4,977	4,977	5,593
Potential Changes in Total Direct Employment in 2027*	-	0 – 21	0 – 21	(1,068) – 558

* 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 an increase in the number of domestic production workers for consumer conventional cooking products. The upper end of the range represents a scenario where manufacturers increase production hiring due to the increase in the labor associated with adding the required components to make consumer conventional cooking products 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.

At the lower end of the range, all examined TSLs show either no change in domestic production employment or a decrease in domestic production employment. The lower end of the domestic employment range assumes that gas cooking top domestic production employment does not change at any TSL. Manufacturing more efficient gas cooking tops by optimizing the burner and improving grates would not impact the location where production occurs for this product class. Additionally, this lower range assumes that TSLs set at Efficiency Level 1 (EL 1) for all oven product classes and the electric smooth element cooking top product class would not change the domestic production employment. EL 1 would require SMPSs for all oven product classes and can be achieved using low-standby-loss electronic controls for the electric smooth element cooking top product class. The majority of manufacturers already use SMPSs in their ovens and are able to meet the efficiency requirements at EL 1 for the electric smooth element cooking top product class. Adding these standby features to models currently not using these features would not change the location where production occurs for these product classes.

At the lower end of the range, DOE estimated that up to 50 percent of domestic production employment for the electric smooth element cooking top product class could be relocated abroad at max-tech. Additionally, DOE estimated that up to 25 percent of domestic production employment for the oven product classes could be relocated abroad at max-tech. DOE estimates that there would be approximately 584 domestic production employees involved in the production of electric smooth element cooking tops and 3,102 domestic production employees involved in the production covering all oven product classes in 2027 in the no-new-standards case. Using these values to estimate the lower end of the range, DOE estimated that up to 1,068 domestic production employees could be eliminated at TSL 3 (due to standards being set at max-tech for the electric smooth element cooking top product class and for all oven product classes).

DOE provides a range of potential impacts to domestic production employment as each manufacturer would make a business decision that best suits their individual product needs. However, manufacturers stated during interviews that due to the larger size of most consumer conventional cooking products, there are few units that are manufactured and shipped from far distances such as Asia or Europe. The vast majority of consumer conventional cooking products are currently made in North America. Some manufacturers stated that even significant changes to production lines would not cause them to shift their production abroad, as several manufacturers either only produce consumer conventional cooking products domestically or have made significant investments to continue to produce consumer conventional cooking products domestically.

12.6.2 Manufacturer Production Capacity

Manufacturers stated that any standard requiring induction heating technology for electric smooth element cooking tops would be very difficult to meet since there are approximately 5 percent of shipments currently using this technology. Additionally, any standards requiring oven separators for the electric oven product classes would be very difficult to meet since that would require completely redesigning the oven cavity of almost every electric oven model currently on the market.

All other ELs analyzed require making incremental improvements to existing designs and should not present any manufacturing capacity constraints given the 3-year compliance period for any new or amended standards proposed in this SNOPR.

12.6.3 Cumulative Regulatory Burden

One aspect of assessing manufacturer burden involves looking at the cumulative impact of multiple DOE standards and the product-specific regulatory actions of other Federal agencies that affect the manufacturers of a covered product or equipment. While any one regulation may not impose a significant burden on manufacturers, the combined effects of several existing or impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. In addition to energy conservation standards, other regulations can significantly affect manufacturers' financial operations. Multiple regulations affecting the same manufacturer can strain profits and lead companies to abandon product lines or markets with lower expected future returns than competing products. For these reasons, DOE conducts an analysis of cumulative regulatory burden as part of its rulemakings pertaining to appliance efficiency.

DOE evaluates product-specific regulations that will take effect approximately 3 years before or after the estimated 2027 compliance date of any new and amended energy conservation standards for consumer conventional cooking products. This information is presented in Table 12.6.2.

Table 12.6.2 Compliance Dates and Expected Conversion Expenses of Federal Energy Conservation Standards Affecting Conventional Cooking Product Manufacturers

Federal Energy Conservation Standard	Number of Manufacturers*	Number of Manufacturers Affected from this Rule**	Approx. Standards Year	Industry Conversion Costs *(millions)*	Industry Conversion Costs / Product Revenue***
Portable Air Conditioners 85 FR 1378 (Jan. 10, 2020)	11	1	2025	$320.9 (2015$)	6.7%
Room Air Conditioners† 87 FR 20608 (Apr. 7, 2022)	8	3	2026	$22.8 (2020$)	0.5%
Microwave Ovens† 87 FR 52282 (Aug. 24, 2022)	18	10	2026	$46.1 (2021$)	0.7%
Clothes Dryers† 87 FR 51734 (Aug. 23, 2022)	15	8	2027	$149.7 (2020$)	1.8%

* This column presents the total number of manufacturers identified in the energy conservation standard rule contributing to cumulative regulatory burden.
** This column presents the number of manufacturers producing consumer conventional cooking products that are also listed as manufacturers in the listed energy conservation standard contributing to cumulative regulatory burden.
*** This column presents industry conversion costs as a percentage of product revenue during the conversion period. Industry conversion costs are the upfront investments manufacturers must make to sell compliant products/equipment. The revenue used for this calculation is the revenue from just the covered product/equipment associated with each row. The conversion period is the time frame over which conversion costs are made and lasts from the publication year of the final rule to the compliance year of the energy conservation standard. The conversion period typically ranges from 3 to 5 years, depending on the rulemaking.
† Indicates a NOPR publication. Values may change on publication of a Final Rule.

In addition to the rulemaking listed in Table 12.6.2 DOE has ongoing rulemakings for other products or equipment that consumer conventional cooking product manufacturers produce, including air cleaners;[j] automatic commercial ice makers;[k] commercial clothes washers;[l] dehumidifiers;[m] miscellaneous refrigeration products;[n] refrigerators, refrigerator-freezers, and freezers;[o] and residential clothes washers.[p] If DOE proposes or finalizes any energy conservation standards for these products or equipment prior to finalizing energy conservation standards for consumer conventional cooking products, DOE will include the energy conservation standards for these other products or equipment as part of the cumulative regulatory burden for the consumer conventional cooking products final rule.

12.7 CONCLUSION

The following section summarizes the impacts for the scenarios DOE believes are most likely to capture the range of impacts on consumer conventional cooking product manufacturers as a result of proposed 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.

At TSL 1, DOE estimates impacts on INPV will range from $105.1 million to $100.7 million, which represents a change of 6.5 percent to 6.3 percent, respectively. At TSL 1, industry free cash-flow decrease to $90.3 million, which represents a decrease of approximately 42.5 percent, compared to the no-new-standards case value of $132.9 million in 2026, the year before the estimated compliance date.

TSL 1 would set the energy conservation standard at baseline for the electric open (coil) element cooking top product class and at EL 1 for all other product classes. DOE estimates that 100 percent of the electric open (coil) element cooking top shipments, 80 percent of the electric smooth element cooking top shipments, 52 percent of the gas cooking top shipments, 95 percent of the electric oven shipments, and 96 percent of the gas oven shipments would already meet or exceed the efficiency levels required at TSL 1 in 2027.

At TSL 1, DOE expects consumer conventional cooking product manufacturers to incur approximately $45.5 million in product conversion costs to redesign all non-compliant cooking top models and oven models, as well as to test all (both compliant and newly redesigned) cooking top models to DOE's cooking top test procedure. Additionally, consumer conventional cooking product manufacturers would incur approximately $58.5 million in capital conversion costs to purchase new tooling and equipment necessary to produce all electric smooth element cooking top models and all oven models to use SMPSs and to purchase new molds for grates and burners for gas cooking top models that would not meet this energy conservation standard.

[j] www.regulations.gov/docket/EERE-2021-BT-STD-0035
[k] www.regulations.gov/docket/EERE-2017-BT-STD-0022
[l] www.regulations.gov/docket/EERE-2019-BT-STD-0044
[m] www.regulations.gov/docket/EERE-2019-BT-STD-0043
[n] www.regulations.gov/docket/EERE-2020-BT-STD-0039
[o] www.regulations.gov/docket/EERE-2017-BT-STD-0003
[p] www.regulations.gov/docket/EERE-2017-BT-STD-0014

At TSL 1, the shipment-weighted average MPC for consumer conventional cooking products slightly increases by 0.5 percent relative to the no-new-standards case shipment-weighted average MPC in 2027. In the preservation of gross margin scenario, manufacturers can fully pass on this slight cost increase. The slight increase in shipment-weighted average MPC is outweighed by the $104.1 million in conversion costs, causing a moderately negative change in INPV at TSL 1 under the preservation of gross margin scenario.

Under the preservation of operating profit scenario, manufacturers earn the same per-unit operating profit as would be earned in the no-new-standards case, but manufacturers do not earn additional profit from their investments or higher MPCs. In this scenario, the 0.5 percent shipment-weighted average MPC increase results in a reduction in the margin after the analyzed compliance year. This reduction in the margin and the $104.1 million in conversion costs incurred by manufacturers cause a moderately negative change in INPV at TSL 1 under the preservation of operating profit scenario.

At TSL 2, DOE estimates impacts on INPV will range from $1254.8 million to $150.4 million, which represents a change of 9.6 percent to 9.4 percent, respectively. At TSL 2, industry free cash-flow decrease to $60.7 million, which represents a decrease of approximately 72.2 percent, compared to the no-new-standards case value of $132.9 million in 2026, the year before the estimated compliance date.

TSL 2 would set the energy conservation standard at baseline for the electric open (coil) element cooking top product class; at EL 1 for the electric smooth element cooking top and for all oven product classes (electric and gas); and at EL 2 for the gas cooking top product class, which represents max-tech for this product class. DOE estimates that 100 percent of the electric open (coil) element cooking top shipments, 80 percent of the electric smooth element cooking top shipments, 4 percent of the gas cooking top shipments, 95 percent of the electric oven shipments, and 96 percent of the gas oven shipments would already meet or exceed the efficiency levels required at TSL 2 in 2027.

At TSL 2, DOE expects consumer conventional cooking product manufacturers to incur approximately $109.9 million in product conversion costs at this TSL. This includes testing costs and product redesign costs. The majority of the product conversion costs are for gas cooking top manufacturers to redesign non-compliant gas cooking top models to meet this energy conservation standard, as well as to test all (both compliant and newly redesigned) cooking top models to DOE's cooking top test procedure. Additionally, consumer conventional cooking product manufacturers would incur approximately $73.5 million in capital conversion costs to purchase new tooling and equipment necessary to produce all electric smooth element cooking top models and all oven models to use SMPSs and to purchase new molds for grates and burners for gas cooking top models that would not meet this energy conservation standard.

At TSL 2, the shipment-weighted average MPC for consumer conventional cooking products slightly increases by 0.5 percent relative to the no-new-standards case shipment-weighted average MPC in 2027. In the preservation of gross margin scenario, manufacturers can fully pass on this slight cost increase. The slight increase in shipment-weighted average MPC is outweighed by the $183.4 million in conversion costs, causing a moderately negative change in INPV at TSL 2 under the preservation of gross margin scenario.

Under the preservation of operating profit scenario, the 0.5 percent shipment-weighted average MPC increase results in a reduction in the margin after the analyzed compliance year. This reduction in the margin and the $183.4 million in conversion costs incurred by manufacturers cause a moderately negative change in INPV at TSL 2 under the preservation of operating profit scenario.

At TSL 3, DOE estimates impacts on INPV will range from $1,368.6 million to $1,185.1 million, which represents a change of 85.2 percent to 73.8 percent, respectively. At TSL 3, industry free cash-flow decrease to $666.2 million, which represents a decrease of approximately 799.0 percent, compared to the no-new-standards case value of $132.9 million in 2026, the year before the estimated compliance date.

TSL 3 would set the energy conservation standard at baseline for the electric open (coil) element cooking top product class; at EL 2 for the gas cooking top product class and for all the gas oven product classes (standard and self-clean); and at EL 3 for the electric smooth element cooking top product class and for all the electric oven product classes (standard and self-clean). This represents max-tech for all product classes. DOE estimates that 100 percent of the electric open (coil) element cooking top shipments, 5 percent of the electric smooth element cooking top shipments, 4 percent of the gas cooking top shipments, zero percent of the electric standard oven (freestanding and built-in) shipments, zero percent of the electric self-clean oven (freestanding) shipments, 2 percent of the electric self-clean (built-in) shipments, 62 percent of gas standard oven (freestanding) shipments, 38 percent of the gas standard oven (built-in) shipments, 93 percent of the gas self-clean oven (freestanding) shipments, and 77 percent of the gas self-clean (built-in) shipments would already meet the efficiency levels required at TSL 3 in 2027.

At TSL 3, DOE expects consumer conventional cooking product manufacturers to incur approximately $1,401.6 million in product conversion costs at this TSL. This includes testing costs and product redesign costs. At this TSL, electric smooth element cooking top manufacturers would have to completely redesign most of their electric smooth element cooking top models to use induction technology. Electric oven manufacturers would have to completely redesign all of their electric oven models to use oven separators. Additionally, consumer conventional cooking product manufacturers would incur approximately $444.8 million in capital conversion costs to purchase new tooling and equipment necessary to produce the numerous redesigned cooking top and oven models at this TSL.

At TSL 3, the shipment-weighted average MPC for consumer conventional cooking products significantly increases by 17.7 percent relative to the no-new-standards case shipment-weighted average MPC in 2027. In the preservation of gross margin scenario, manufacturers can fully pass on this cost increase. The significant increase in shipment-weighted average MPC is outweighed by the $1,846.4 million in conversion costs, causing a significantly negative change in INPV at TSL 3 under the preservation of gross margin scenario.

Under the preservation of operating profit scenario, the 17.7 percent shipment-weighted average MPC increase results in a reduction in the margin after the analyzed compliance year. This reduction in the margin and the $1,846.4 million in conversion costs incurred by manufacturers cause a significantly negative change in INPV at TSL 3 under the preservation of operating profit scenario.

REFERENCES

1. 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 emissions and, if present, 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, which are included in accordance with DOE's FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011). These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion.

The analysis of power sector emissions of CO_2, NO_X, SO_2, and Hg uses emissions intensity factors intended to represent the marginal impacts of the change in electricity consumption associated with amended or new standards. The methodology is based on results published for the *Annual Energy Outlook (AEO)* prepared by the Energy Information Administration, including a set of side cases that implement a variety of efficiency-related policies. The methodology is described in appendix 13A in this TSD, and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014; Coughlin 2019).[1,2] The analysis presented in this chapter uses projections from *AEO 2022*.[3]

Emissions of SO_2 and NO_X from site combustion of natural gas or petroleum fuels are calculated using emissions intensity factors from a publication of the Environmental Protection Agency (EPA).[4] Power sector combustion emissions of CH_4 and N_2O are derived using Emission Factors for Greenhouse Gas Inventories published by the EPA, as are site combustion emissions of CO_2, CH_4 and N_2O.[a]

The FFC upstream emissions are estimated based on the methodology described in appendix 10B and in Coughlin (2013).[5] The upstream emissions include emissions from fuel combustion during extraction, processing, and transportation of fuels, and "fugitive" emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The emissions intensity factors are expressed in terms of physical units per MWh or MMBtu of site energy savings. Total emissions reductions are estimated by multiplying the emissions intensity factor by the energy savings calculated in the national impact analysis (chapter 10). 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 for the power plant types that supply electricity for cooking in homes.

Each annual version of the *AEO* incorporates the projected impacts of existing air quality regulations on emissions. The *AEO* generally represents current Federal and State legislation and final implementation regulations in place as at the time of its preparation. For details, see

[a] https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_apr2021.pdf.

Summary of Legislation and Regulations Included in the *AEO 2022*, Appendix, Electric power sector.[b]

13.2 EMISSIONS IMPACT RESULTS

Table 13.2.1 presents the estimated cumulative emissions reductions for the lifetime of products sold in 2027-2056 for each TSL. Negative values indicate that emissions increase.

Table 13.2.1 Cumulative Emissions Reduction for Potential Standards for Consumer Conventional Cooking Products

	TSL		
	1	**2**	**3**
Power Sector and Site Emissions			
CO_2 (million metric tons)	10.7	19.6	50.7
CH_4 (thousand tons)	0.473	0.657	2.99
N_2O (thousand tons)	0.061	0.079	0.405
NO_X (thousand tons)	7.72	15.5	31.3
SO_2 (thousand tons)	2.16	2.20	16.6
Hg (tons)	0.014	0.014	0.108
Upstream Emissions			
CO_2 (million metric tons)	1.17	2.33	4.80
CH_4 (thousand tons)	121	244	479
N_2O (thousand tons)	0.003	0.005	0.017
NO_X (thousand tons)	18.1	36.3	73.7
SO_2 (thousand tons)	0.028	0.033	0.194
Hg (tons)	0.00005	0.00005	0.00038
Total Emissions			
CO_2 (million metric tons)	11.9	21.9	55.5
CH_4 (thousand tons)	121	245	482
N_2O (thousand tons)	0.064	0.084	0.422
NO_X (thousand tons)	25.9	51.8	105
SO_2 (thousand tons)	2.18	2.24	16.7
Hg (tons)	0.014	0.014	0.108

Figure 13.2.1 through Figure 13.2.6 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 2027-2056.

[b] https://www.eia.gov/outlooks/aeo/assumptions/pdf/summary.pdf

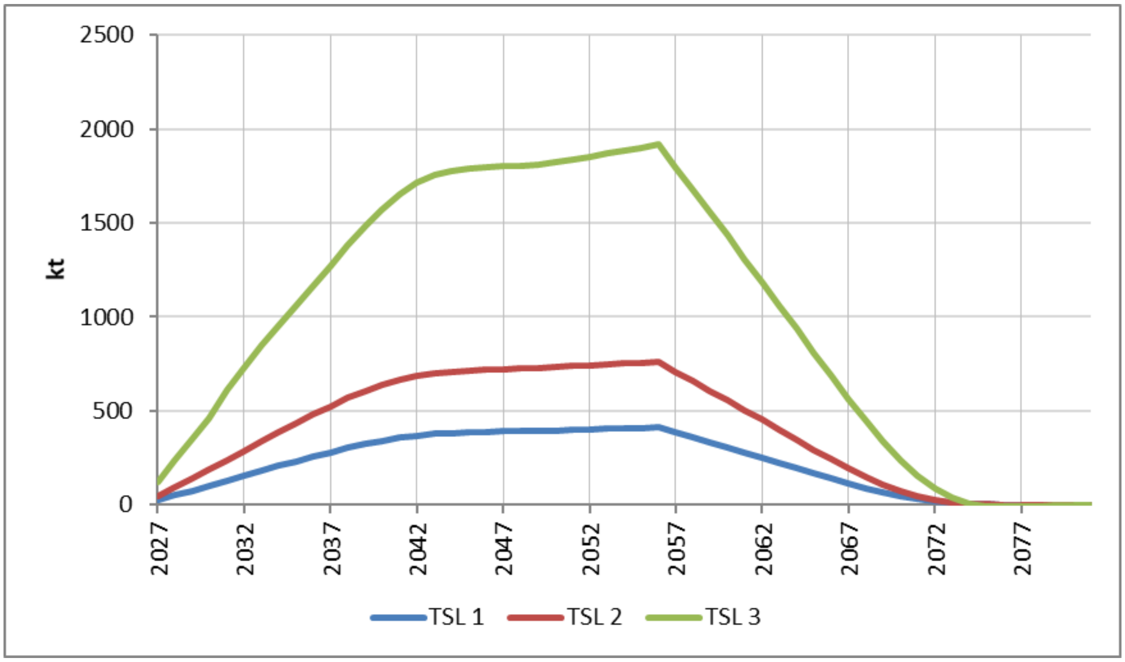

Figure 13.2.1 Consumer Conventional Cooking Products: CO_2 Total Emissions Reduction

Figure 13.2.2 Consumer Conventional Cooking Products: SO_2 Total Emissions Reduction

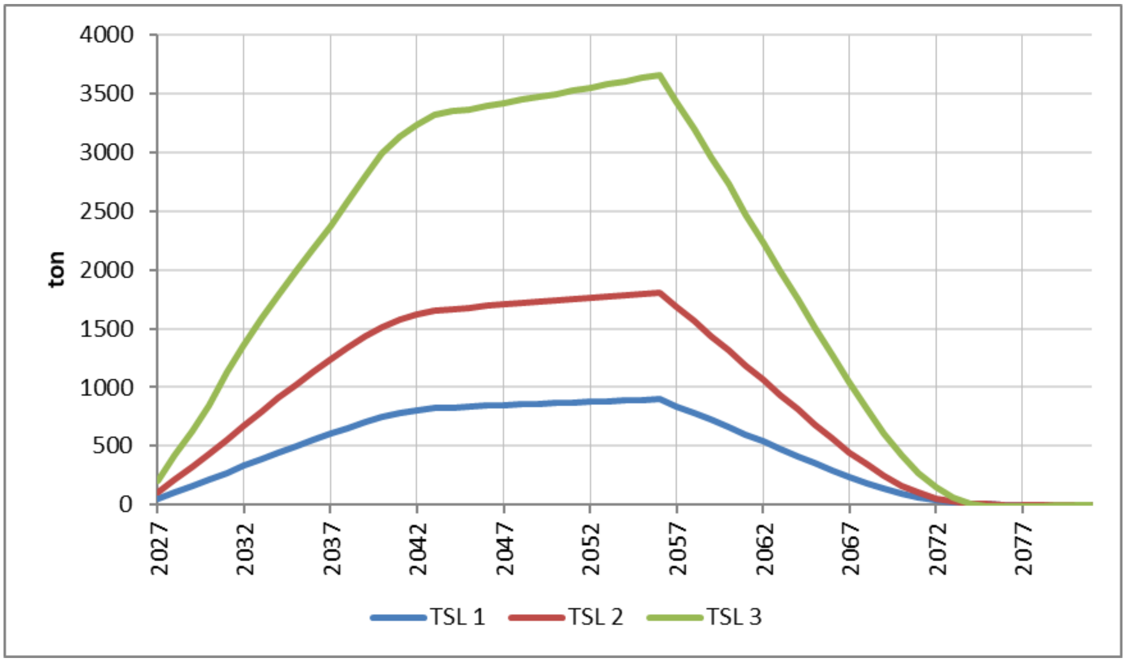

Figure 13.2.3 Conventional Cooking Products: NO_x Total Emissions Reduction

Figure 13.2.4 Consumer Conventional Cooking Products: Hg Total Emissions Reduction

Figure 13.2.5 Consumer Conventional Cooking Products: N_2O Total Emissions Reduction

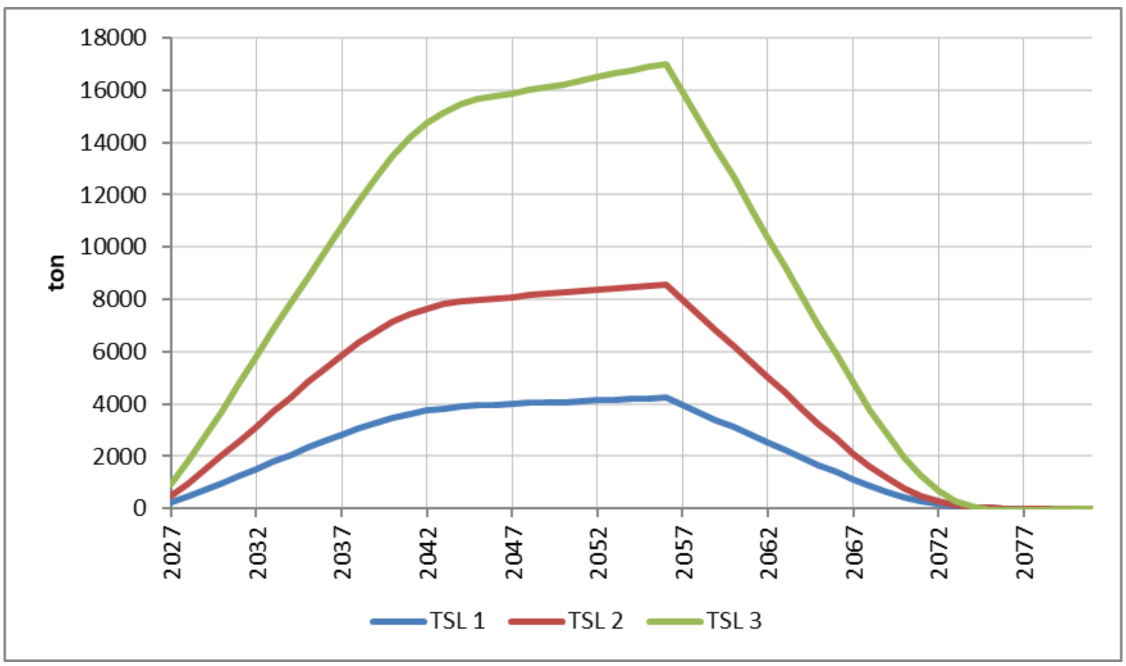

Figure 13.2.6 Consumer Conventional Cooking Products: CH_4 Total Emissions Reduction

Table 13.2.2 displays annual emissions reductions from the proposed standards (TSL 2).

Table 13.2.2 Emissions Reduction at Proposed Standard Level (TSL 2)

Emissions Year	CO_2 (Million Metric tons)	CH_4 ('000 tons)	N_2O ('000 tons)	NO_X ('000 tons)	SO_2 ('000 tons)	Hg (tons)
2027	0.0	0.5	0.0	0.1	0.0	0.00003
2028	0.1	1.0	0.0	0.2	0.0	0.00006
2029	0.1	1.5	0.0	0.3	0.0	0.00008
2030	0.2	2.0	0.0	0.4	0.0	0.00011
2031	0.2	2.6	0.0	0.6	0.0	0.00013
2032	0.3	3.1	0.0	0.7	0.0	0.00016
2033	0.3	3.7	0.0	0.8	0.0	0.00019
2034	0.4	4.3	0.0	0.9	0.0	0.00021
2035	0.4	4.8	0.0	1.0	0.0	0.00024
2036	0.5	5.4	0.0	1.1	0.0	0.00027
2037	0.5	5.9	0.0	1.2	0.1	0.00030
2038	0.6	6.3	0.0	1.3	0.1	0.00033
2039	0.6	6.8	0.0	1.4	0.1	0.00035
2040	0.6	7.1	0.0	1.5	0.1	0.00037
2041	0.7	7.4	0.0	1.6	0.1	0.00038
2042	0.7	7.7	0.0	1.6	0.1	0.00039
2043	0.7	7.8	0.0	1.7	0.1	0.00040
2044	0.7	7.9	0.0	1.7	0.1	0.00041
2045	0.7	8.0	0.0	1.7	0.1	0.00042
2046	0.7	8.0	0.0	1.7	0.1	0.00043
2047	0.7	8.1	0.0	1.7	0.1	0.00044
2048	0.7	8.2	0.0	1.7	0.1	0.00045
2049	0.7	8.2	0.0	1.7	0.1	0.00046
2050	0.7	8.2	0.0	1.7	0.1	0.00047
2051	0.7	8.3	0.0	1.8	0.1	0.00047
2052	0.7	8.3	0.0	1.8	0.1	0.00048
2053	0.7	8.4	0.0	1.8	0.1	0.00048
2054	0.8	8.4	0.0	1.8	0.1	0.00049
2055	0.8	8.5	0.0	1.8	0.1	0.00049
2056	0.8	8.5	0.0	1.8	0.1	0.00049
2057	0.7	8.0	0.0	1.7	0.1	0.00046
2058	0.7	7.4	0.0	1.6	0.1	0.00044
2059	0.6	6.8	0.0	1.4	0.1	0.00041
2060	0.6	6.2	0.0	1.3	0.1	0.00038
2061	0.5	5.6	0.0	1.2	0.1	0.00035
2062	0.5	5.0	0.0	1.1	0.0	0.00032

Emissions Year	CO_2 (Million Metric tons)	CH_4 (‘000 tons)	N_2O (‘000 tons)	NO_X (‘000 tons)	SO_2 (‘000 tons)	Hg (tons)
2063	0.4	4.4	0.0	0.9	0.0	0.00029
2064	0.3	3.8	0.0	0.8	0.0	0.00026
2065	0.3	3.2	0.0	0.7	0.0	0.00023
2066	0.2	2.7	0.0	0.6	0.0	0.00020
2067	0.2	2.1	0.0	0.4	0.0	0.00017
2068	0.1	1.6	0.0	0.3	0.0	0.00014
2069	0.1	1.2	0.0	0.2	0.0	0.00011
2070	0.1	0.8	0.0	0.2	0.0	0.00008
2071	0.0	0.5	0.0	0.1	0.0	0.00006
2072	0.0	0.3	0.0	0.1	0.0	0.00004
2073	0.0	0.1	0.0	0.0	0.0	0.00002
2074	0.0	0.1	0.0	0.0	0.0	0.00001
2075	0.0	0.0	0.0	0.0	0.0	0.00000
2076	0.0	0.0	0.0	0.0	0.0	0.00000
2077	0.0	0.0	0.0	0.0	0.0	0.00000
2078	0.0	0.0	0.0	0.0	0.0	0.00000
2079	0.0	0.0	0.0	0.0	0.0	0.00000
2080	0.0	0.0	0.0	0.0	0.0	0.00000
Cumulative	21.9	244.9	0.1	51.8	2.2	0.01396

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CHAPTER 14. MONETIZATION OF EMISSIONS REDUCTION BENEFITS

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CHAPTER 14. MONETIZATION OF EMISSIONS REDUCTION BENEFITS

14.1 INTRODUCTION

As part of its assessment of energy conservation standards for consumer conventional cooking products, the U.S. Department of Energy (DOE) considered the estimated monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur dioxide (SO_2) and nitrogen oxides (NO_X) that are expected to result from each of the potential standard levels considered. This chapter summarizes the basis for the benefit-per-ton values used for each of these emissions and presents the estimated total benefits for each TSL.

On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.

14.2 MONETIZING AVOIDED GREENHOUSE GAS EMISSIONS

DOE estimates the monetized benefits of the reductions in greenhouse gas (GHG) emissions of CO_2, CH_4, and N_2O by using a measure of the social cost (SC) of each pollutant (*e.g.,* SC-CO_2). These estimates represent the monetary value of the net harm to society associated with a marginal increase in emissions of these pollutants in a given year, or the benefit of avoiding that increase. These estimates are intended to include (but are not limited to) climate-change-related changes in net agricultural productivity, human health, property damages from increased flood risk, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. DOE exercises its own judgment in presenting monetized climate benefits as recommended by applicable Executive Orders, and DOE would reach the same conclusion presented in the SNOPR in the absence of the social cost of greenhouse gases, including the February 2021 interim estimates presented by the Interagency Working Group on the Social Cost of Greenhouse Gases.

DOE estimated the global social benefits of CO_2, CH_4, and N_2O reductions (*i.e.,* SC-GHGs) using the estimates presented in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order (EO) 13990, published in February 2021 by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG).[1] The SC-GHG is the monetary value of the net harm to society associated with a marginal increase in emissions in a given year, or the benefit of avoiding that increase. In principle, SC-GHGs includes the value of all climate change impacts, including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-GHGs therefore, reflects the societal value of reducing emissions of the gas in question by one metric ton. The SC-GHGs is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect CO_2, N_2O and CH_4 emissions. As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, DOE agrees that the interim SC-GHG estimates represent the most appropriate estimate of the SC-GHG until revised estimates have been developed reflecting the latest peer-reviewed science.

The SC-GHGs estimates presented here were developed over many years, using transparent process, peer-reviewed methodologies, the best science available at the time of that process, and with input from the public. Specifically, in 2009, an IWG that included the DOE and other executive branch agencies and offices was established to ensure that agencies were using the best available science and to promote consistency in the social cost of carbon (SC-CO_2) values used across agencies. The IWG published SC-CO_2 estimates in 2010 that were developed from an ensemble of three widely cited integrated assessment models (IAMs) that estimate global climate damages using highly aggregated representations of climate processes and the global economy combined into a single modeling framework. The three IAMs were run using a common set of input assumptions in each model for future population, economic, and CO_2 emissions growth, as well as equilibrium climate sensitivity – a measure of the globally averaged temperature response to increased atmospheric CO_2 concentrations. These estimates were updated in 2013 based on new versions of each IAM. In August 2016 the IWG published estimates of the social cost of methane (SC-CH_4) and nitrous oxide (SC-N_2O) using methodologies that are consistent with the methodology underlying the SC-CO_2 estimates. The modeling approach that extends the IWG SC-CO_2 methodology to non-CO_2 GHGs has undergone multiple stages of peer review. The SC-CH_4 and SC-N_2O estimates were developed by Marten et al. (2015) and underwent a standard double-blind peer review process prior to journal publication.[2]

In 2015, as part of the response to public comments received to a 2013 solicitation for comments on the SC-CO_2 estimates, the IWG announced a National Academies of Sciences, Engineering, and Medicine review of the SC-CO_2 estimates to offer advice on how to approach future updates to ensure that the estimates continue to reflect the best available science and methodologies. In January 2017, the National Academies released their final report, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, and recommended specific criteria for future updates to the SC-CO_2 estimates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process.[3] Shortly thereafter, in March 2017, President Trump issued Executive Order 13783, which disbanded the IWG, withdrew the previous TSDs, and directed agencies to ensure SC-CO_2 estimates used in regulatory analyses are consistent with the guidance contained in OMB's Circular A-4, "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates" (EO 13783, Section 5(c)). Benefit-cost analyses following E.O. 13783 used SC-GHG estimates that attempted to focus on the U.S.-specific share of climate change damages as estimated by the models and were calculated using two discount rates recommended by Circular A-4, 3 percent and 7 percent. All other methodological decisions and model versions used in SC-GHG calculations remained the same as those used by the IWG in 2010 and 2013, respectively.

On January 20, 2021, President Biden issued Executive Order 13990, which re-established the IWG and directed it to ensure that the U.S. Government's estimates of the social cost of carbon and other greenhouse gases reflect the best available science and the 2017 recommendations of the National Academies. The IWG was tasked with first reviewing the SC-GHG estimates currently used in Federal analyses and publishing interim estimates within 30 days of the EO that reflect the full impact of GHG emissions, including by taking global damages into account. The interim SC-GHG estimates published in February 2021 are used here to estimate the climate benefits for this proposed rulemaking. The EO instructs the IWG to undertake a fuller update of the SC-GHG estimates that takes into consideration the advice of the National Academies (2017) and other recent scientific literature.

The February 2021 SC-GHG TSD provides a complete discussion of the IWG's initial review conducted under EO 13990. In particular, the IWG found that the SC-GHG estimates used under EO 13783 fail to reflect the full impact of GHG emissions in multiple ways. First, the IWG found that the SC-GHG estimates used under E.O. 13783 fail to fully capture many climate impacts that affect the welfare of U.S. citizens and residents, and those impacts are better reflected by global measures of the SC-GHG. Examples of omitted effects from the EO 13783 estimates include direct effects on U.S. citizens, assets, and investments located abroad, supply chains, U.S. military assets and interests abroad, and tourism, and spillover pathways such as economic and political destabilization and global migration that can lead to adverse impacts on U.S. national security, public health, and humanitarian concern. In addition, assessing the benefits of U.S. GHG mitigation activities requires consideration of how those actions may affect mitigation activities by other countries, as those international mitigation actions will provide a benefit to U.S. citizens and residents by mitigating climate impacts that affect U.S. citizens and residents. A wide range of scientific and economic experts have emphasized the issue of reciprocity as support for considering global damages of GHG emissions. If the United States does not consider impacts on other countries, it is difficult to convince other countries to consider the impacts of their emissions on the United States. The only way to achieve an efficient allocation of resources for emissions reduction on a global basis—and so benefit the U.S. and its citizens—is for all countries to base their policies on global estimates of damages. As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, DOE agrees with this assessment and, therefore, in this proposed rule DOE centers attention on a global measure of SC-GHG. This approach is the same as that taken in DOE regulatory analyses from 2012 through 2016. A robust estimate of climate damages that accrue only to U.S. citizens and residents does not currently exist in the literature. As explained in the February 2021 TSD, existing estimates are both incomplete and an underestimate of total damages that accrue to the citizens and residents of the U.S. because they do not fully capture the regional interactions and spillovers discussed above, nor do they include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature. As noted in the February 2021 SC–GHG TSD, the IWG will continue to review developments in the literature, including more robust methodologies for estimating a U.S.-specific SC–GHG value, and explore ways to better inform the public of the full range of carbon impacts. As a member of the IWG, DOE will continue to follow developments in the literature pertaining to this issue.

Second, the IWG found that the use of the social rate of return on capital (7 percent under current OMB Circular A-4 guidance) to discount the future benefits of reducing GHG emissions inappropriately underestimates the impacts of climate change for the purposes of estimating the SC-GHG. Consistent with the findings of the National Academies (2017) and the economic literature, the IWG continued to conclude that the consumption rate of interest is the theoretically appropriate discount rate in an intergenerational context, and recommended that discount rate uncertainty and relevant aspects of intergenerational ethical considerations be accounted for in selecting future discount rates.[4,5,6,7] Furthermore, the damage estimates developed for use in the SC-GHG are estimated in consumption-equivalent terms, and so an application of OMB Circular A-4's guidance for regulatory analysis would then use the consumption discount rate to calculate the SC-GHG. DOE agrees with this assessment and will continue to follow developments in the literature pertaining to this issue. DOE also notes that while OMB Circular A-4, as published in 2003, recommends using 3% and 7% discount rates as "default" values, Circular A-4 also reminds agencies that "different regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues and the sensitivity of the benefit and cost estimates to the key assumptions." On discounting, Circular A-4 recognizes that "special ethical considerations arise when comparing benefits and costs across generations," and Circular A-4 acknowledges that analyses may appropriately "discount future costs and consumption benefits…at a lower rate than for intragenerational analysis." In the 2015 Response to Comments on the Social Cost of Carbon for Regulatory Impact Analysis, OMB, DOE, and the other IWG members recognized that "Circular A-4 is a living document" and "the use of 7 percent is not considered appropriate for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself." Thus, DOE concludes that a 7% discount rate is not appropriate to apply to value the social cost of greenhouse gases in the analysis presented in this analysis. In this analysis, to calculate the present and annualized values of climate benefits, DOE uses the same discount rate as the rate used to discount the value of damages from future GHG emissions, for internal consistency. That approach to discounting follows the same approach that the February 2021 TSD recommends "to ensure internal consistency—i.e., future damages from climate change using the SC-GHG at 2.5 percent should be discounted to the base year of the analysis using the same 2.5 percent rate." DOE has also consulted the National Academies' 2017 recommendations on how SC-GHG estimates can "be combined in RIAs with other cost and benefits estimates that may use different discount rates." The National Academies reviewed "several options," including "presenting all discount rate combinations of other costs and benefits with [SC-GHG] estimates."

As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, DOE agrees with this assessment and will continue to follow developments in the literature pertaining to this issue.

While the IWG works to assess how best to incorporate the latest, peer reviewed science to develop an updated set of SC-GHG estimates, it set the interim estimates to be the most recent estimates developed by the IWG prior to the group being disbanded in 2017. The estimates rely on the same models and harmonized inputs and are calculated using a range of discount rates. As explained in the February 2021 SC-GHG TSD, the IWG has recommended that agencies revert to the same set of four values drawn from the SC-GHG distributions based on three discount rates as were used in regulatory analyses between 2010 and 2016 and subject to public comment. For each discount rate, the IWG combined the distributions across models and socioeconomic emissions scenarios (applying equal weight to each) and then selected a set of four values recommended for use in benefit-cost analyses: an average value resulting from the model runs for each of three discount rates (2.5 percent, 3 percent, and 5 percent), plus a fourth value, selected as the 95th percentile of estimates based on a 3 percent discount rate. The fourth value was included to provide information on potentially higher-than-expected economic impacts from climate change. As explained in the February 2021 SC-GHG TSD, and DOE agrees, this update reflects the immediate need to have an operational SC-GHG for use in regulatory benefit-cost analyses and other applications that was developed using a transparent process, peer-reviewed methodologies, and the science available at the time of that process. Those estimates were subject to public comment in the context of dozens of proposed rulemakings as well as in a dedicated public comment period in 2013.

There are a number of limitations and uncertainties associated with the SC-GHG estimates. First, the current scientific and economic understanding of discounting approaches suggests discount rates appropriate for intergenerational analysis in the context of climate change are likely to be less than 3 percent, near 2 percent or lower.[1] Second, the IAMs used to produce these interim estimates do not include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature and the science underlying their "damage functions" – i.e., the core parts of the IAMs that map global mean temperature changes and other physical impacts of climate change into economic (both market and nonmarket) damages – lags behind the most recent research. For example, limitations include the incomplete treatment of catastrophic and non-catastrophic impacts in the integrated assessment models, their incomplete treatment of adaptation and technological change, the incomplete way in which inter-regional and intersectoral linkages are modeled, uncertainty in the extrapolation of damages to high temperatures, and inadequate representation of the relationship between the discount rate and uncertainty in economic growth over long time horizons. Likewise, the socioeconomic and emissions scenarios used as inputs to the models do not reflect new information from the last decade of scenario generation or the full range of projections. The modeling limitations do not all work in the same direction in terms of their influence on the SC-CO_2 estimates. However, as discussed in the February 2021 TSD, the IWG has recommended that, taken together, the limitations suggest that the interim SC-GHG estimates used in this final rule likely underestimate the damages from GHG emissions. DOE concurs with this assessment.

DOE's derivations of the SC-GHGs (*i.e.,* SC-CO_2, SC-N_2O, and SC-CH_4) values are discussed in the following sections.

14.2.1 Social Cost of Carbon

The SC-CO_2 values used for DOE's analysis were generated using the values presented in the 2021 TSD from the IWG. Table 14.2.1 shows the four sets of SC-CO_2 estimates in five-year increments from 2020 to 2070.[a] DOE expects additional climate benefits to accrue for any longer-life consumer conventional cooking products, but a lack of available SC-CO_2 estimates for emissions years beyond 2070 prevents DOE from monetizing these additional benefits in this analysis. The case labeled "95th percentile" refers to values in the 95th percentile of simulations.

[a] The values for the years after 2050 are based on modeling conducted by EPA for the "Revised 2023 and Later Model Year Light-Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis" published by EPA in December 2021. See Appendix 14A.

Appendix 14A provides the full set of SC-CO_2 estimates. For purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance of including all four sets of SC-CO_2 values.

Table 14.2.1 Annual SC-CO_2 Values based on 2021 Interagency Update, 2020–2070 (2020 dollars per metric ton)*

Year	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
2020	14	51	76	151
2025	17	56	83	169
2030	19	62	89	186
2035	22	67	96	205
2040	25	73	103	224
2045	28	79	109	242
2050	32	84	116	259
2055	35	89	122	265
2060	38	93	128	275
2065	44	100	135	300
2070	49	108	143	326

* Values are rounded off to the nearest dollar.

DOE multiplied the CO_2 emissions reduction estimated for each year by the SC-CO_2 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 specific discount rate that had been used to obtain the SC-CO_2 values in each case.

14.2.2 Social Cost of Methane and Nitrous Oxide

The SC-CH_4 and SC-N_2O values used for the present analysis were generated using the values presented in the 2021 TSD from the IWG. Table 14.2.2 shows the four sets of SC-CH_4 and SC- N_2O estimates from the latest interagency update in 5-year increments from 2020 to 2070. For purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance of including all four sets of SC-CH_4 and SC- N_2O values. The full set of annual values is reported in appendix 14A of this TSD.

DOE multiplied the CH_4 and N_2O emissions reduction estimated for each year by the SC-CH_4 and SC-N_2O estimates for that year in each of the cases. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the cases using the specific discount rate that had been used to obtain the SC-CH_4 and SC-N_2O estimates in each case.

Table 14.2.2 Annual $SC-CH_4$ and $SC-N_2O$ Values based on 2021 Interagency Update, 2020–2070 (2020$ per metric ton)*

Year	$SC-CH_4$				$SC-N_2O$			
	Discount Rate and Statistic				Discount Rate and Statistic			
	5%	3%	2.5%	3%	5%	3%	2.5 %	3%
	Average	Average	Average	95th percentile	Average	Average	Average	95th percentile
2020	663	1,480	1,946	3,893	5,760	18,342	27,037	48,090
2025	799	1,714	2,223	4,533	6,766	20,520	29,811	54,108
2030	935	1,948	2,499	5,173	7,772	22,698	32,585	60,125
2035	1,106	2,224	2,817	5,939	9,007	25,149	35,632	66,898
2040	1,277	2,500	3,136	6,705	10,241	27,600	38,678	73,670
2045	1,464	2,778	3,450	7,426	11,687	30,238	41,888	80,766
2050	1,651	3,057	3,763	8,147	13,133	32,875	45,098	87,863
2055	1,772	3,221	3,942	8,332	14,758	35,539	48,236	94,117
2060	1,899	3,395	4,130	8,539	16,424	38,300	51,507	100,845
2065	2,508	4,163	4,960	11,177	19,687	42,625	56,397	115,590
2070	3,130	4,976	5,867	14,079	23,018	47,072	61,428	130,928

* Values are rounded off to the nearest dollar.

14.3 VALUATION OF OTHER EMISSIONS REDUCTIONS

As noted in chapter 13, new or amended energy conservation standards would reduce SO_2 emissions from electricity generation, and NO_X emissions in those States that are not affected by caps. For each of the considered TSLs, DOE estimated monetized values of NO_X and SO_2 emissions reductions from electricity generation using the latest benefit-per-ton estimates for that sector from the EPA's Benefits Mapping and Analysis Program.[b] DOE used EPA's values for $PM_{2.5}$-related benefits associated with NO_X and SO_2 and for ozone-related benefits associated with NO_X for 2025, 2030, 2035 and 2040, calculated with discount rates of 3 percent and 7 percent. DOE used linear interpolation to define values for the years not given in the 2025 to 2040 period; for years beyond 2040 the values are held constant.

The ozone-related benefits associated with NO_X occur only in the ozone-season (May to September). EPA data indicate that ozone-season NO_X emissions from electricity generation are slightly less than half of all-year NO_X emissions. DOE accounted for this characteristic in its methodology.

The estimate of the monetized $PM_{2.5}$ benefits associated with NOx and SO_2 is based on DOE's interpretation of the best available scientific literature. DOE does not include the health benefits of reductions in direct $PM_{2.5}$. Below is a summary of key assumptions and associated uncertainties in estimating the emissions monetization of $PM_{2.5}$.

[b] *Estimating the Benefit per Ton of Reducing PM2.5 Precursors from 21 Sectors.* https://www.epa.gov/benmap/estimating-benefit-ton-reducing-directly-emitted-pm25-pm25-precursors-and-ozone-precursors

A significant assumption is the relationship between particle composition/size and premature mortality. The PM Integrated Science Assessment concluded that “many constituents of $PM_{2.5}$ can be linked with multiple health effects, and the evidence is not yet sufficient to allow differentiation of those constituents or sources that are more closely related to specific outcomes”.[8] Additionally, the EPA Benefits Mapping and Analysis Program assumed that the health impact function for fine particles is log-linear without a threshold. Thus, the estimates include health benefits from reducing fine particles in areas with different concentrations of $PM_{2.5}$, including both areas that do not meet the fine particle standard and those areas that are in attainment and reflect the full distribution of $PM_{2.5}$ air quality simulated above. DOE also notes that EPA's published values assumed there is a “cessation” lag between the change in PM exposures and the total realization of changes in mortality effects. Although this does not impact the total number of deaths, it does impact the timing of deaths.

DOE combined the EPA data with data from *AEO2022* to estimate benefit-per-ton values by sector. Appendix 14B provides methodological details and values that DOE used. The results presented in this chapter use benefit-per-ton values for the residential sector. DOE multiplied the emissions reduction (in tons) in each year by the associated $/ton values, and then discounted each series using discount rates of 3 percent and 7 percent as appropriate.

The considered standards for consumer conventional cooking products also reduce NOx and SO_2 emissions from combustion at the home. To monetize the value of these emissions reductions, DOE used benefit-per-ton estimates from the Benefits Mapping and Analysis Program’s 2018 report Technical Support Document Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors.[9] Although none of the sectors refers specifically to residential and commercial buildings, the sector called “Area sources” would be a reasonable proxy for residential and commercial buildings. "Area sources" represents all emission sources for which states do not have exact (point) locations in their emissions inventories. Because exact locations would tend to be associated with larger sources, "area sources" would be fairly representative of small dispersed sources like homes and businesses.[c]

The EPA document provides high and low estimates for 2025 and 2030 at 3 and 7 percent discount rates (Table 14.3.1). DOE converted the values to 2021$, and interpolated and extrapolated values in a similar manner as described above.

[c] The sector “Area sources” was not used in the EPA’s most recent analysis that DOE used for the electricity generation sector.

Table 14.3.1 Summary of the Total Dollar Value per Ton of Directly Emitted $PM_{2.5}$ Precursor Reduced from Area Sources (2015$)

Year of Emission	Low		High	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
	NO_X			
2025	9,700	8,800	22,000	20,000
2030	11,000	9,500	24,000	21,000
	SO_2			
2025	61,000	55,000	140,000	120,000
2030	67,000	60,000	150,000	140,000

14.4 ESTIMATED BENEFITS

14.4.1 Benefits for Considered TSLs

The tables in this section show the emissions monetization results for each considered TSL.

Table 14.4.1 Present Social Value of Cumulative CO_2 Emissions Reduction from Potential Standards for Consumer Conventional Cooking Products

TSL	SC-CO_2 Case			
	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th percentile
	million 2021$			
1	105	463	729	1,405
2	194	854	1,345	2,594
3	488	2,154	3,395	6,539

Table 14.4.2 Present Social Value of Cumulative Methane Emissions Reduction from Potential Standards for Consumer Conventional Cooking Products

TSL	SC-CH_4 Case			
	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
	million 2021$			
1	49.6	152	213	402
2	101	308	432	814
3	197	604	848	1,597

Table 14.4.3 Present Social Value of Cumulative Nitrous Oxide Emissions Reduction from Potential Standards for Consumer Conventional Cooking Products

TSL	SC-N_2O Case			
	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
	million 2021$			
1	0.213	0.880	1.38	2.35
2	0.282	1.16	1.82	3.10
3	1.41	5.82	9.09	15.5

Table 14.4.4 Present Social Value of Cumulative NO_X and SO_2 Emissions Reduction from Potential Standards for Consumer Conventional Cooking Products

TSL	NO_X		SO_2	
	7% discount rate	3% discount rate	7% discount rate	3% discount rate
	million 2021$		*million 2021$*	
1	298	794	41.1	109
2	573	1522	41.9	111
3	1300	3482	319	843

14.4.2 Annual and Cumulative Benefits for Proposed Standards (TSL 2)

The tables in this section present climate and health benefits estimated for the proposed standards. The benefits of reduced CO_2, CH_4, and N_2O emissions are collectively referred to as climate benefits. The benefits of reduced SO_2 and NO_X emissions are collectively referred to as health benefits.

The annual values reflect the benefits from reduced emissions in each year. The associated benefits accrue over very many years in the case of GHG emissions, and over several years in the case of NOx and SO_2 emissions. The time stream of benefits has been discounted to estimate the benefit-per-ton values for each year, but the total benefits associated with each emissions year are not discounted in these tables. The cumulative present value does reflect discounting at the noted discount rates.

Table 14.4.5 Climate Benefits from GHG Emissions Reduction (CO_2, CH_4, and N_2O) at Proposed Standards (TSL 2) for Consumer Conventional Cooking Products (million 2021$)

Emissions Year*	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2027	1.25	3.63	5.16	10.6
2030	5.55	15.7	22.2	46.1
2035	15.1	40.6	56.3	120
2040	25.4	65.6	89.8	195
2045	32.2	79.7	108	236
2050	37.1	88.6	118	262
2055	41.8	96.0	128	277
2060	33.2	74.4	98.6	210
2065	21.1	43.7	56.8	127
2070	6.12	12.0	15.4	35.6
Cumulative PV**	295	1,163	1,779	3,411
Annualized	23.3	66.8	93.8	196

* Annual benefits shown are undiscounted values.
** The same discount rate used to discount the value of damages from future emissions in each SC-GHG case is used to calculate the present value of avoided emissions in that case for internal consistency.

Table 14.4.6 Climate Benefits from Changes in CO_2 Emissions from Proposed Standards (TSL 2) for Consumer Conventional Cooking Products (million 2021$)

Emissions Year*	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
2027	0.852	2.79	4.07	8.39
2028	1.76	5.70	8.30	17.2
2029	2.72	8.73	12.7	26.4
2030	3.75	12.0	17.3	36.1
2031	4.88	15.4	22.2	46.6
2032	6.09	19.0	27.4	57.7
2033	7.39	22.8	32.7	69.3
2034	8.68	26.6	38.0	80.9
2035	10.0	30.4	43.4	92.7
2036	11.4	34.2	48.7	105

Emissions Year*	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
2037	12.8	38.1	54.0	117
2038	14.2	41.9	59.3	128
2039	15.5	45.4	64.1	139
2040	16.7	48.6	68.5	149
2041	17.9	51.5	72.3	158
2042	18.9	53.8	75.4	165
2043	19.7	55.7	77.9	171
2044	20.5	57.3	79.8	176
2045	21.1	58.6	81.5	180
2046	21.7	59.8	83.0	184
2047	22.3	61.0	84.4	187
2048	22.9	62.2	85.9	191
2049	23.5	63.4	87.4	195
2050	24.2	64.6	88.8	198
2051	25.0	65.4	90.7	200
2052	25.6	66.5	92.1	202
2053	26.2	67.7	93.5	204
2054	26.8	68.8	94.9	206
2055	27.4	70.0	96.3	209
2056	28.1	71.1	97.8	212
2057	26.7	67.1	92.1	200
2058	25.2	63.0	86.3	187
2059	23.6	58.7	80.3	173
2060	21.9	54.3	74.1	160
2061	20.5	49.9	68.0	147
2062	18.9	45.4	61.6	134
2063	17.2	40.6	55.0	121
2064	15.3	35.8	48.3	107
2065	13.4	30.8	41.5	92.2
2066	11.4	25.9	34.8	77.6
2067	9.34	21.0	28.1	63.2
2068	7.35	16.3	21.8	49.3
2069	5.48	12.0	16.1	36.5
2070	3.83	8.31	11.1	25.2
Cumulative Present Value (all years)**	194	854	1345	2594
Annualized (all years)	15.3	49.1	71.0	149

* Annual benefits shown are undiscounted values.

** The same discount rate used to discount the value of damages from future emissions in each SC-GHG case is used to calculate the present value of avoided emissions in that case for internal consistency.

Table 14.4.7 Climate Benefits from Changes in Methane Emissions from Proposed Standards (TSL 2) for Consumer Conventional Cooking Products (million 2021$)

Emissions Year*	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
2027	0.395	0.838	1.08	2.22
2028	0.826	1.74	2.24	4.61
2029	1.29	2.71	3.48	7.18
2030	1.80	3.75	4.81	9.96
2031	2.37	4.89	6.26	13.0
2032	2.98	6.12	7.81	16.3
2033	3.65	7.43	9.45	19.8
2034	4.34	8.77	11.1	23.4
2035	5.05	10.2	12.9	27.1
2036	5.79	11.6	14.6	30.9
2037	6.54	13.0	16.4	34.7
2038	7.27	14.4	18.1	38.5
2039	7.98	15.7	19.7	42.1
2040	8.65	16.9	21.2	45.4
2041	9.27	18.0	22.5	48.3
2042	9.82	19.0	23.7	50.8
2043	10.3	19.7	24.6	52.9
2044	10.7	20.4	25.4	54.6
2045	11.1	21.0	26.1	56.2
2046	11.5	21.6	26.8	57.8
2047	11.8	22.2	27.4	59.2
2048	12.2	22.8	28.1	60.8
2049	12.6	23.3	28.8	62.2
2050	12.9	23.9	29.4	63.7
2051	13.2	24.4	30.0	64.5
2052	13.5	24.8	30.4	65.1
2053	13.7	25.2	30.9	65.8
2054	14.0	25.6	31.3	66.5
2055	14.3	26.0	31.8	67.1
2056	14.6	26.4	32.2	67.8
2057	13.8	24.9	30.4	63.6
2058	13.0	23.3	28.4	59.3
2059	12.1	21.7	26.4	54.9
2060	11.2	20.0	24.4	50.4
2061	10.8	18.9	22.9	48.4
2062	10.2	17.7	21.3	45.8
2063	9.5	16.2	19.4	42.5
2064	8.67	14.6	17.4	38.7
2065	7.71	12.8	15.2	34.3
2066	6.65	10.9	13.0	29.7

Emissions Year*	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
2067	5.53	9.00	10.7	24.7
2068	4.39	7.08	8.38	19.7
2069	3.28	5.26	6.21	14.7
2070	2.29	3.64	4.29	10.3
Cumulative Present Value (all years)**	101	308	432	814
Annualized (all years)	7.97	17.7	22.8	46.8

* Annual benefits shown are undiscounted values.
** The same discount rate used to discount the value of damages from future emissions in each SC-GHG case is used to calculate the present value of avoided emissions in that case for internal consistency.

Table 14.4.8 Climate Benefits from Changes in N_2O Emissions from Proposed Standards (TSL 2) for Consumer Conventional Cooking Products (million 2021$)

Emissions Year*	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
2026	0.001	0.004	0.006	0.011
2027	0.003	0.008	0.012	0.022
2028	0.004	0.012	0.018	0.033
2029	0.006	0.017	0.024	0.044
2030	0.007	0.021	0.031	0.057
2031	0.009	0.026	0.037	0.069
2032	0.011	0.031	0.045	0.083
2033	0.013	0.036	0.051	0.095
2034	0.014	0.040	0.057	0.107
2035	0.016	0.045	0.063	0.119
2036	0.018	0.050	0.070	0.132
2037	0.020	0.055	0.077	0.146
2038	0.022	0.060	0.084	0.159
2039	0.024	0.064	0.089	0.170
2040	0.025	0.068	0.095	0.181
2041	0.027	0.071	0.100	0.191
2042	0.028	0.074	0.103	0.197
2043	0.029	0.076	0.105	0.203
2044	0.030	0.078	0.107	0.207
2045	0.031	0.079	0.109	0.212
2046	0.032	0.081	0.111	0.215
2047	0.032	0.082	0.113	0.219
2048	0.033	0.083	0.115	0.223
2049	0.034	0.085	0.117	0.227
2050	0.035	0.087	0.119	0.231
2051	0.036	0.089	0.122	0.236
2052	0.037	0.091	0.124	0.241
2053	0.038	0.093	0.127	0.247

Emissions Year*	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
2054	0.040	0.095	0.129	0.252
2055	0.041	0.097	0.132	0.258
2056	0.039	0.093	0.125	0.245
2057	0.037	0.088	0.118	0.231
2058	0.035	0.082	0.111	0.217
2059	0.033	0.077	0.104	0.203
2060	0.031	0.072	0.096	0.191
2061	0.029	0.067	0.089	0.177
2062	0.027	0.061	0.081	0.163
2063	0.025	0.055	0.073	0.148
2064	0.022	0.048	0.064	0.132
2065	0.020	0.042	0.055	0.115
2066	0.017	0.035	0.047	0.097
2067	0.014	0.029	0.038	0.079
2068	0.011	0.022	0.029	0.062
2069	0.008	0.017	0.022	0.046
2070	0.282	1.16	1.82	3.10
Cumulative Present Value (all years)**	0.022	0.067	0.096	0.178
Annualized (all years)	0.001	0.004	0.006	0.011

* Annual benefits shown are undiscounted values.

** The same discount rate used to discount the value of damages from future emissions in each SC-GHG case is used to calculate the present value of avoided emissions in that case for internal consistency.

Table 14.4.9 Health Benefits from Changes in NO_x and SO_2 Emissions from Proposed Standards (TSL 2) for Consumer Conventional Cooking Products (million 2021$)

Emissions Year*	NOx (as $PM_{2.5}$ and Ozone)		SO_2	
Discount Rate	**7%**	**3%**	**7%**	**3%**
2027	4.64	5.17	0.553	0.615
2028	9.63	10.7	1.07	1.19
2029	14.9	16.6	1.48	1.64
2030	20.7	23.2	1.86	2.07
2031	26.8	29.9	2.20	2.45
2032	33.6	37.5	2.59	2.89
2033	40.7	45.4	3.11	3.47
2034	47.2	52.6	3.39	3.78
2035	54.0	60.2	3.84	4.27
2036	60.5	67.5	4.22	4.70
2037	67.1	74.8	4.65	5.18
2038	73.9	82.4	5.05	5.62
2039	80.5	89.7	5.54	6.16
2040	85.9	95.7	5.86	6.51
2041	89.3	100	6.11	6.79
2042	92.0	103	6.30	7.00
2043	94.2	105	6.49	7.21
2044	95.3	106	6.61	7.35
2045	96.1	107	6.68	7.43
2046	97.2	108	6.79	7.54
2047	97.8	109	6.83	7.60
2048	99.0	110	6.89	7.66
2049	100	111	6.97	7.75
2050	100	112	7.15	7.95
2051	101	112	7.21	8.01
2052	101	113	7.27	8.08
2053	102	114	7.33	8.15
2054	103	114	7.39	8.21
2055	103	115	7.45	8.28
2056	104	116	7.51	8.35
2057	97.0	108	7.06	7.85
2058	90.0	100	6.61	7.35
2059	83.0	92.5	6.16	6.85
2060	75.9	84.5	5.71	6.35
2061	68.7	76.6	5.26	5.85
2062	61.5	68.5	4.81	5.35
2063	54.2	60.4	4.36	4.85

Emissions Year*	NOx (as $PM_{2.5}$ and Ozone)		SO_2	
Discount Rate	**7%**	**3%**	**7%**	**3%**
2064	47.0	52.4	3.91	4.35
2065	39.9	44.4	3.46	3.84
2066	32.9	36.7	3.00	3.33
2067	26.2	29.3	2.54	2.83
2068	20.1	22.4	2.09	2.33
2069	14.5	16.2	1.66	1.84
2070	9.82	10.9	1.25	1.39
2071	6.11	6.81	0.886	0.984
2072	3.43	3.83	0.577	0.641
2073	1.71	1.90	0.337	0.374
2074	0.732	0.82	0.170	0.189
2075	0.264	0.294	0.071	0.079
2076	0.076	0.085	0.023	0.026
2077	0.017	0.018	0.006	0.006
2078	0.002	0.003	0.001	0.001
2079	0.000	0.000	0.000	0.000
2080	0.000	0.000	0.000	0.000
Cumulative Present Value (all years)	573	1522	42	111
Annualized (all years)	60.5	87.4	4.42	6.37

* Annual benefits shown are undiscounted values.

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CHAPTER 15. UTILITY IMPACT ANALYSIS

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CHAPTER 15. UTILITY IMPACT ANALYSIS

15.1 INTRODUCTION

In the utility impact analysis, the U.S. Department of Energy (DOE) analyzes several aggregate impacts on electric and gas utilities that DOE projects would result for each trial standard level (TSL).

15.2 ELECTRIC UTILITIES

The electric 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. The current analysis is based on results published for the *AEO 2022*.[2]

DOE's *AEO*-based methodology has a number of advantages:

- 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 reference and side cases to estimate the utility impacts enhances the transparency of DOE's analysis.

The details of the methodology vary based on the number and type of side cases published with each edition of the *AEO*. The approach adopted for this analysis is described in appendix 15A. A more detailed discussion of the general approach is presented in K. Coughlin, "Utility Sector Impacts of Reduced Electricity Demand."[3,4]

This chapter presents the results for consumer conventional cooking products.

15.2.1 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

[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 2022*. 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 utility impact factors are presented in appendix 15A. For consumer conventional cooking products DOE used the impact factors for cooking in homes.

15.2.2 Utility Impact Results

15.2.2.1 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.

[b] These units are identical to GW/TWh.

Figure 15.2.1 Consumer Conventional Cooking Products: Total Electric Capacity Reduction

Figure 15.2.2 Consumer Conventional Cooking Products: Coal Capacity Reduction

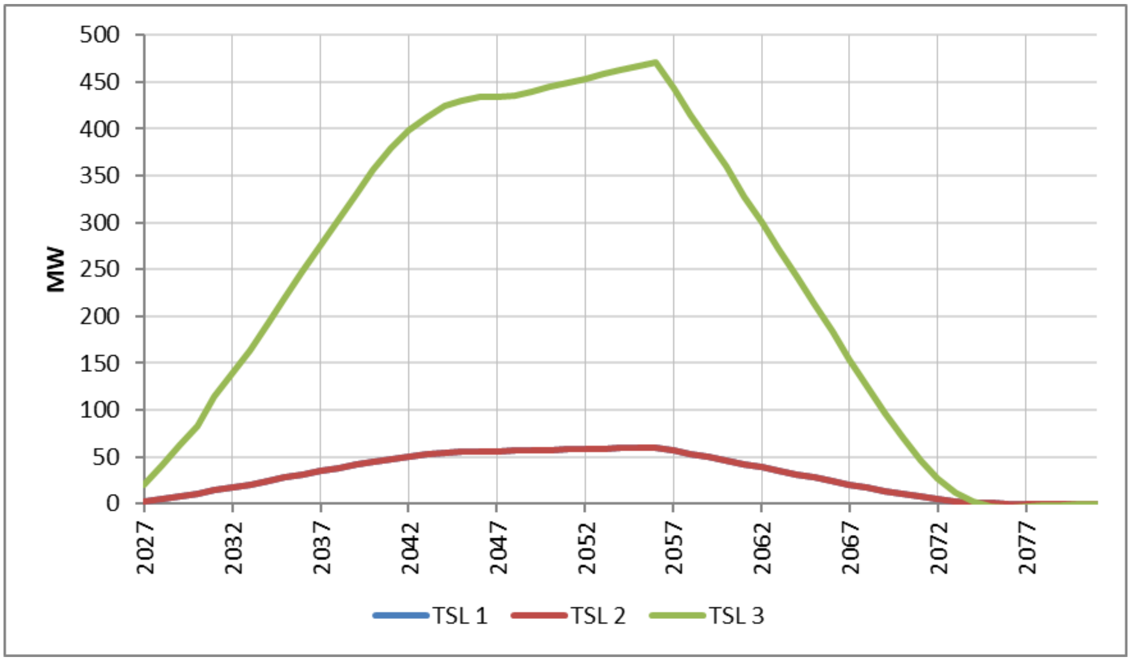

Figure 15.2.3 Consumer Conventional Cooking Products: Gas Combined Cycle Capacity Reduction

Figure 15.2.4 Consumer Conventional Cooking Products: Peaking Capacity Reduction

Figure 15.2.5 Consumer Conventional Cooking Products: Renewables Capacity Reduction

15.2.2.2 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.

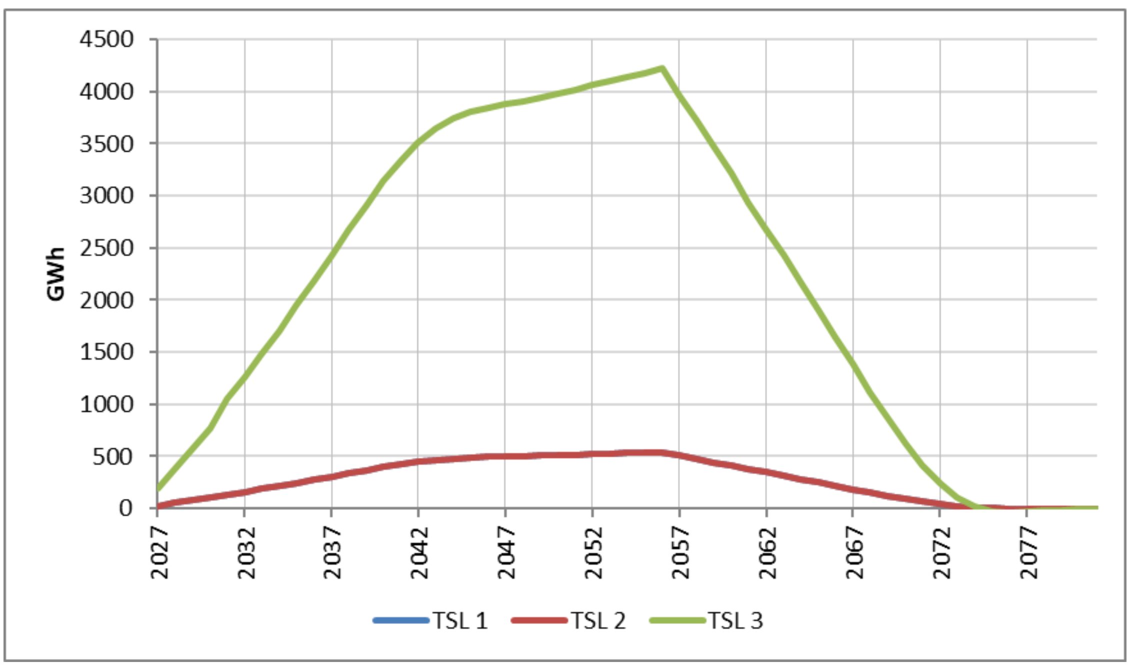

Figure 15.2.6 Consumer Conventional Cooking Products: Total Generation Reduction

Figure 15.2.7 Consumer Conventional Cooking Products: Coal Generation Reduction

Figure 15.2.8 Consumer Conventional Cooking Products: Gas Combined Cycle Generation Reduction

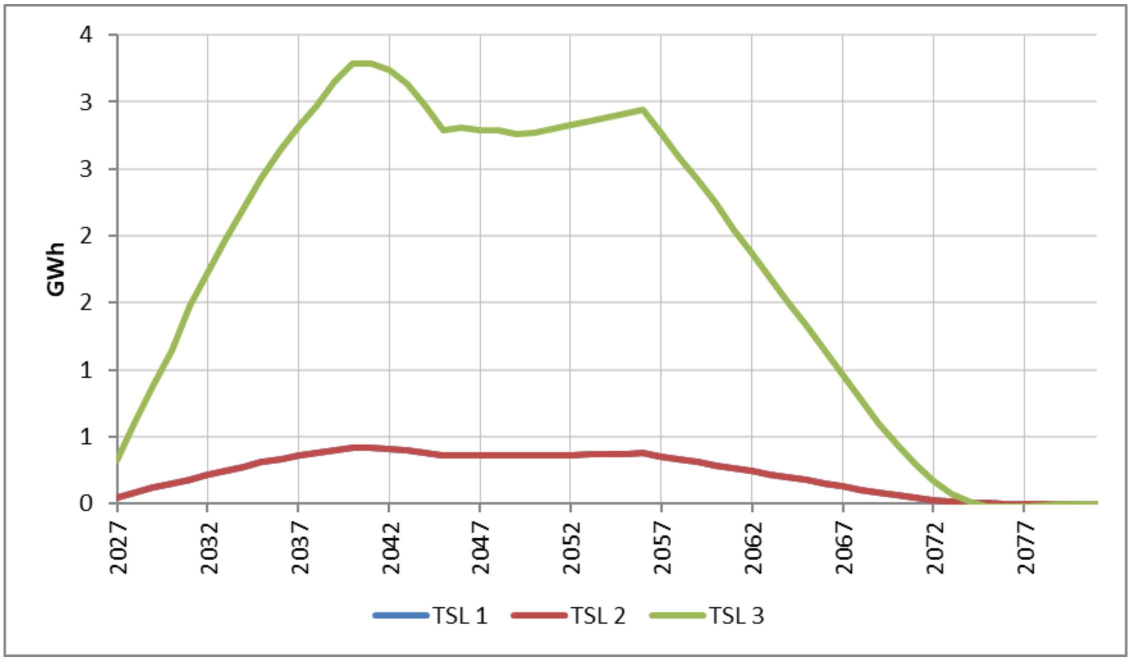

Figure 15.2.9 Consumer Conventional Cooking Products: Oil Generation Reduction

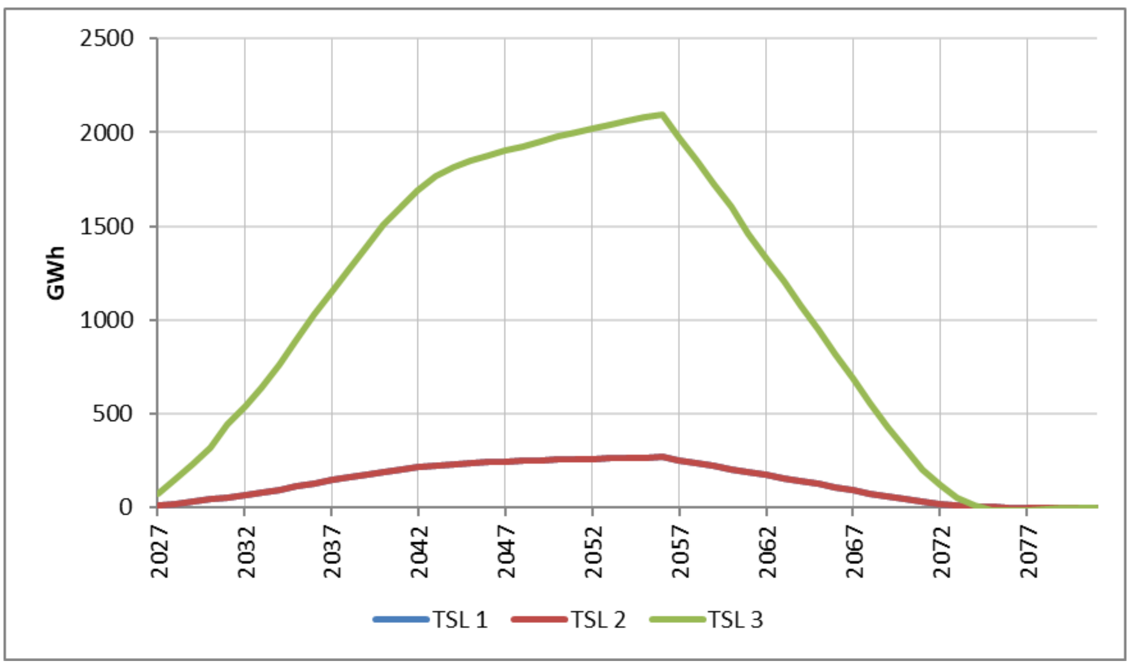

Figure 15.2.10 Consumer Conventional Cooking Products: Renewables Generation Reduction

15.2.2.3 Results Summary

Table 15.2.1 presents a summary of the utility impact results for conventional cooking products.

Table 15.2.1 Consumer Conventional Cooking Products: Summary of Electric Utility Impact Results

	TSL		
	1	2	3
Installed Capacity Reduction (MW)			
2027	9.00	9.00	66.7
2030	36.6	36.6	276
2035	91.9	91.9	727
2040	150	150	1,190
Electricity Generation Reduction (GWh)			
2027	25.8	25.8	192
2030	103	103	776
2035	246	246	1,946
2040	396	396	3,137

15.3 GAS UTILITIES

The gas utility impact analysis considers the projected effect of potential standards on aggregate natural gas delivered to consumers in million cubic feet. Figure 15.3.1 shows the annual change in natural gas delivered to consumers that result for each TSL. For reference, total U.S. natural gas delivered to consumers was 27,440,492 million cubic feet in 2021.

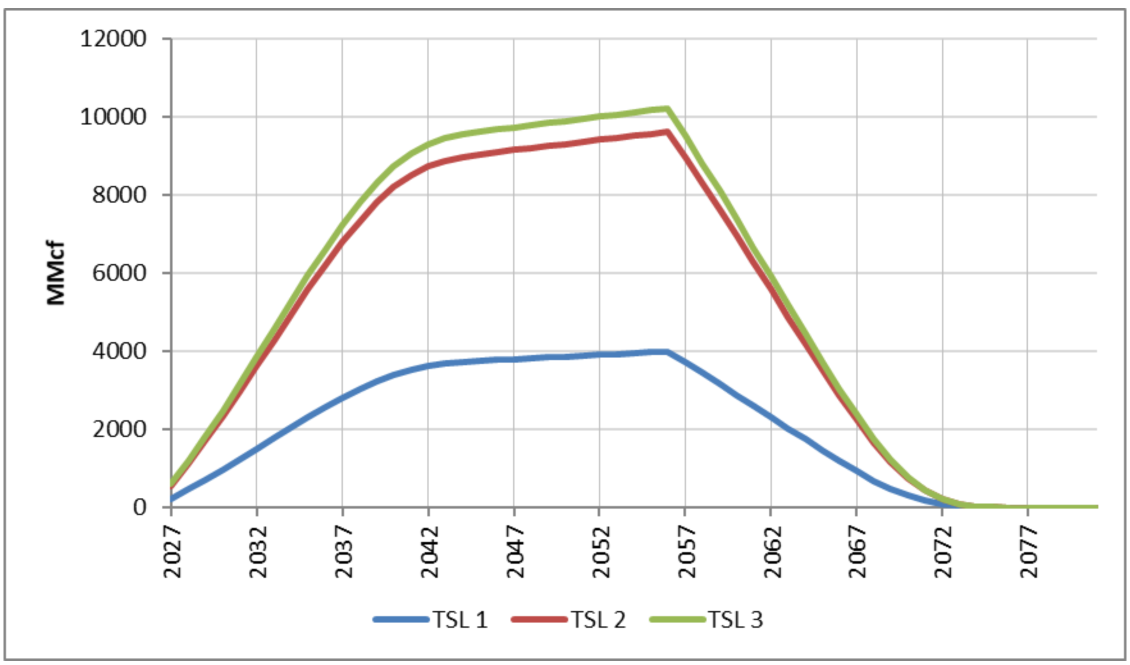

Figure 15.3.1 Consumer Conventional Cooking Products: Total Reduction in Natural Gas Delivered to Consumers

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CHAPTER 16. EMPLOYMENT IMPACT ANALYSIS

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16.1 INTRODUCTION

DOE's employment impact analysis for consumer conventional 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 cooking products. Job increases or decreases reported in this chapter are separate from the direct 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 4 (Impact of Sector Energy Technologies) [2] 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 goods sector (as mentioned above ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the rule generally increases the purchase price of 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 2026, in terms of thousands of jobs. Approximately 26% of cooking products are imported, with the remaining 74% domestically produced. The net employment impact estimate is sensitive to assumptions regarding the return to the U.S. economy of money spent on imported 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 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	2027	2032
TSL 1	0.0 to 0.1	0.1 to 0.2
TSL 2	0.0 to 0.1	0.2
TSL 3	-0.7 to 2.9	-0.3 to 4.9

For context, the Congressional Budget Office projects that during this timeframe, the unemployment rate will be approximately 4.1%, close to "full employment." [5] 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 2031, are included in the second column of Table 16.4.1.

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CHAPTER 17. REGULATORY IMPACT ANALYSIS

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17.1 INTRODUCTION

The Administrator of the Office of Information and Regulatory Affairs (OIRA) in the OMB has determined that the regulatory action in this document is a significant regulatory action under section (3)(f) of 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 a modified[a] version of 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 level (TSL) for the consumer 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 the two product classes of consumer conventional cooking products covered by this RIA.[b]

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.

[a] For this RIA, DOE developed an alternative NIA model where shipments in the policy case do not account for any consumer-choice decision making. DOE believes that the national benefits from standards calculated this way are more comparable to the benefits from the alternative policies.
[b] This RIA covers the two product classes that make up most of the energy savings: electric smooth cooking tops and gas cooking tops.

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 consumer 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 this 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 shipment distribution across 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 no-new-standards case, 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 consumer 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 government expenditures on tax credits and rebates would be covered to a significant extent by income taxes paid by consumers in the aggregate, 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 (2027-2056).
- Net Present Value (NPV), represents the value of net monetary savings in 2022, expressed in 2021$, from equipment purchased during the 30-year analysis period starting in the effective date of the policy (2027-2056). DOE calculated the NPV as the difference between the present values of installed equipment cost and operating expenditures in the no-new-standards 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 consumer conventional cooking products relative to their no-new-standards 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 .2.1 shows the minimum energy efficiency of the consumer conventional cooking products product classes at each TSL.

Table 17.2.1 Minimum Energy Efficiency by TSL

	TSL 1	**TSL 2**	TSL 3
Electric Smooth Cooking Tops (kWh/yr)	207	**207**	179
Gas Cooking Tops (MMBtu/yr)	1440	**1204**	1204

DOE assumed that the effects of non-regulatory policies would last from the effective date of standards—2027—through the end of the analysis period, which is 2056.

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 consumer 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 consumer conventional cooking products. (Because the alternative of "No New Regulatory Action" has no energy or economic impacts, essentially representing the NIA no-new-standards 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 consumer conventional cooking products constitutes the no-new-standards case, as described in chapter 10, National Impact Analysis. The no-new-standards 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 consumer 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, 8] 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, 6] DOE decided that the most appropriate available method for this RIA 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.

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[c] XENERGY is now owned by KEMA, Inc. (www.kema.com)

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, 6, 9]

DOE modeled the effects of a consumer rebate policy for consumer 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 no-new-standards case. It used the interpolation method presented in Blum et al (2011)[10] to create customized penetration curves based on relationships between actual no-new-standards 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 consumer conventional cooking products. DOE did not find rebate programs for the product classes covered in this RIA. DOE assumed that a rebate program would cover all or part of the increased installed cost of units that meet the target efficiency levels compared to units meeting the baseline efficiency level. Based on that assumption, DOE calibrated the customized penetration curves it developed for each product class covered by this RIA to best reflect the market barrier levels that consumer rebates for consumer 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 consumer conventional cooking products via a rebate that would pay – depending on the product class – part or all of the increased installed cost of units that meet the target efficiency levels compared to units meeting the baseline efficiency level.[d] DOE then estimated a market representative rebate value for each product class covered by this RIA which it applied in the calculation of the B/C ratio of consumer conventional cooking products under the effect of consumer rebates. (Appendix 17A presents the market representative rebate amounts.) DOE assumed that rebates would remain in effect at the same level throughout the forecast period (2027-2056).

[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.

DOE first calculated the B/C ratio of a consumer conventional cooking products 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 consumer 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 Smooth Cooking Tops			
B/C Ratio without Rebate	20.4	**20.4**	0.1
Rebate Amount (2021$)	3.27	**3.27**	100.00
B/C Ratio with Rebate	infinite	**infinite**	0.2
Estimated Market Barriers	Mod	**Mod**	No
Gas Cooking Tops			
B/C Ratio without Rebate	1.0	**1.8**	1.8
Rebate Amount (2021$)	18.52	**18.52**	18.52
B/C Ratio with Rebate	infinite	**infinite**	infinite
Estimated Market Barriers	No	**Mod**	Mod

* Mod: Moderate market barriers; Low-Mod: Low-to-Moderate market barriers.

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 consumer conventional cooking products that meet the target levels both with and without a rebate incentive. Table 17.3.1 indicates the estimated levels of market barriers corresponding to the penetration curves DOE calculated to represent the market behavior for consumer conventional cooking products at the proposed TSL.

[e] The cash flow of the operating cost savings is discounted to the purchase year using a 7 percent discount rate.

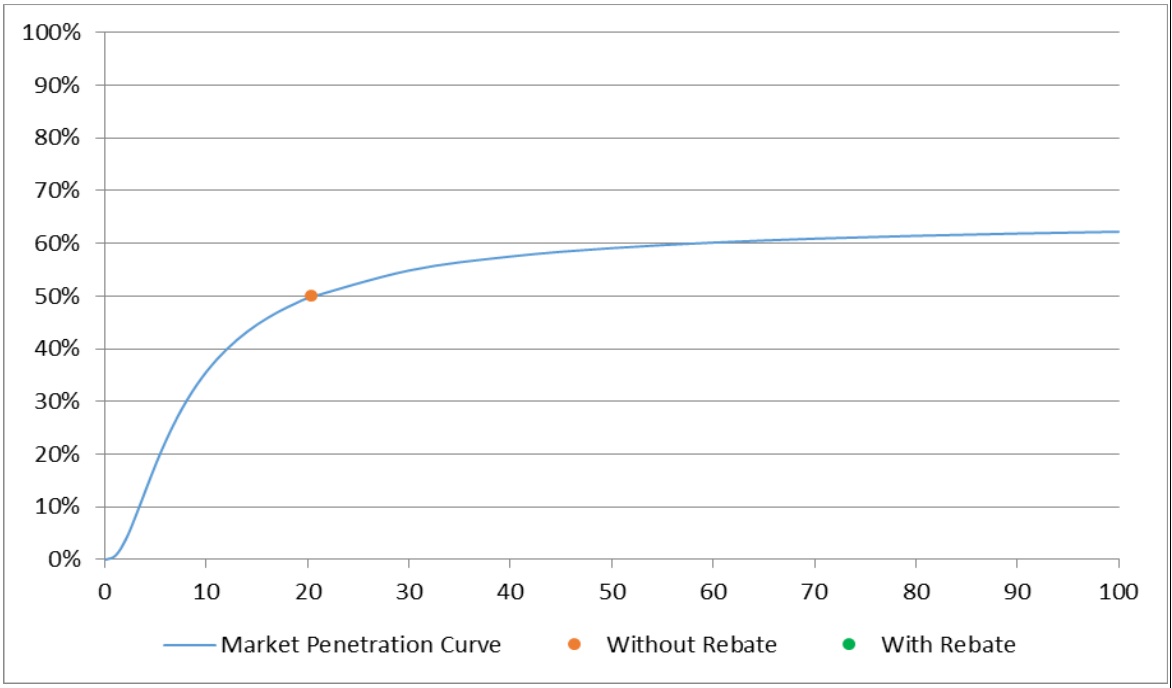
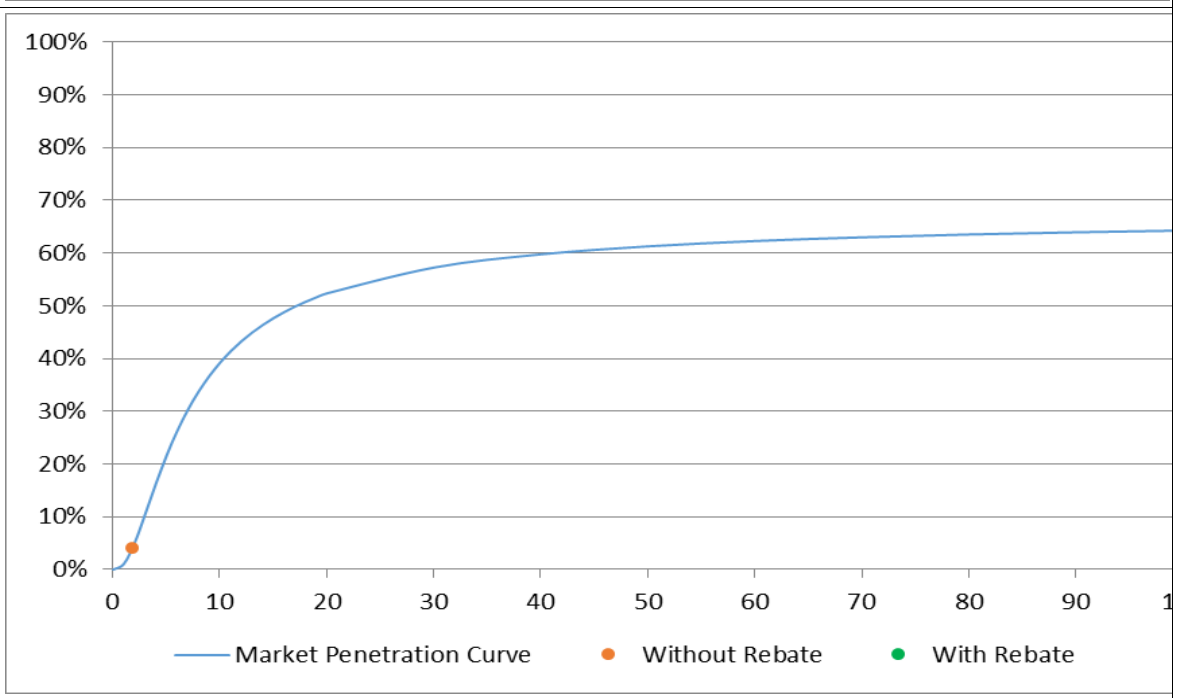
	Proposed TSL
Electric Smooth Cooking Tops	
Gas Cooking Tops	

Figure 17.3.1 Market Penetration Curves for Consumer Conventional cooking Products[f]

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

[f] Because the B/C ratio with rebates is infinite for both product classes (see Table 17.3.1), the data points that refer to the market penetration with rebates are not shown in either of the two charts.

share of units that meet the target level in the no-new-standards 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 consumer conventional cooking products regarding the market penetration of products in 2027 that meet the target levels at each TSL given a consumer rebate.

Table 17.3.2 Market Penetrations in 2027 Attributable to Consumer Rebates

	TSL 1	**TSL 2**	TSL 3
Electric Smooth Cooking Tops			
Base-Case Market Share	50.0%	**50.0%**	5.0%
Policy Case Market Share	65.1%	**65.1%**	6.4%
Increased Market Share	15.1%	**15.1%**	1.4%
Gas Cooking Tops			
Base-Case Market Share	48.0%	**4.0%**	4.0%
Policy Case Market Share	96.0%	**67.1%**	67.1%
Increased Market Share	48.0%	**63.1%**	63.1%

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 consumer conventional cooking products.

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.[11, 12] 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.[13]

In preparing its assumptions to estimate the effects of tax credits on consumer purchases of consumer 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.[14] 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.[15,16] 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.[17] 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 consumer 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.[18] 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 consumer conventional cooking products (See Figure 17.3.1).

Table 17.3.3 summarizes DOE's assumptions for consumer conventional cooking products regarding the market penetration of products in 2027 that meet the target levels at each TSL given a consumer tax credit.

Table 17.3.3 Market Penetrations in 2027 Attributable to Consumer Tax Credits

	TSL 1	**TSL 2**	TSL 3
Electric Smooth Cooking Tops			
Base-Case Market Share	50.0%	**50.0%**	5.0%
Policy Case Market Share	59.1%	**59.1%**	5.8%
Increased Market Share	9.1%	**9.1%**	0.8%
Gas Cooking Tops			
Base-Case Market Share	48.0%	**4.0%**	4.0%
Policy Case Market Share	76.8%	**41.9%**	41.9%
Increased Market Share	28.8%	**37.9%**	37.9%

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 consumer conventional cooking products that meet the efficiency level for the proposed TSL. Because the increase in market penetration for consumer tax credits is proportional to the increase in market penetration DOE calculated for consumer rebates, they follow similar increasing trends over the analysis period.

17.3.4 Manufacturer Tax Credits

To analyze the potential effects of a policy that offers tax credits to manufacturers that produce consumer 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.[g] Because the direct price effect is approximately equivalent to the announcement effect,[11] DOE estimated that a manufacturer tax credit would induce half the number of consumers assumed to take advantage of a consumer tax credit to purchase more efficient products. Thus, the assumed participation rate is equal to 30 percent of the number of consumers who would participate in a rebate program.

DOE attempted to investigate manufacturer response to the Energy Efficient Appliance Credits for manufacturers mandated by EPACT 2005.[14] 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.

[g] 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.

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 consumer conventional cooking products. (See Figure 17.3.1).

Table 17.3.4 summarizes DOE's assumptions for consumer conventional cooking products regarding the market penetration of products in 2027 that meet the target levels at each TSL given a manufacturer tax credit.

Table 17.3.4 Market Penetrations in 2027 Attributable to Manufacturer Tax Credits

	TSL 1	**TSL 2**	TSL 3
Electric Smooth Cooking Tops			
Base-Case Market Share	50.0%	**50.0%**	5.0%
Policy Case Market Share	54.5%	**54.5%**	5.4%
Increased Market Share	4.5%	**4.5%**	0.4%
Gas Cooking Tops			
Base-Case Market Share	48.0%	**4.0%**	4.0%
Policy Case Market Share	62.4%	**22.9%**	22.9%
Increased Market Share	14.4%	**18.9%**	18.9%

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 consumer conventional cooking products. Because the increase in market penetration for manufacturer tax credits is proportional to the increase in market penetration DOE calculated for consumer rebates, they follow similar increasing trends over the analysis period.

17.3.5 Voluntary Energy Efficiency Targets

DOE assumed that voluntary energy efficiency targets would lead manufacturers of consumer 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 no-new-standards case for consumer conventional cooking products, DOE observed a moderate level of market barriers for more efficient consumer conventional cooking products. 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 consumer conventional cooking products in the no-new-standards case and in the policy case of voluntary energy efficiency targets. DOE followed the methodology presented by Blum et al (2011)[10] to evaluate the effects that such a reduction in market barriers would have on the market penetration of efficient consumer conventional cooking products.[h] The methodology relies on interpolated market penetration curves to calculate – given a B/C ratio – how the market penetration of more efficient units increases as the market barrier level to those units decreases.

Table 17.3.5 Market Barriers Changes Attributable to Voluntary Energy Efficiency Targets (TSL 2)

	No-new-standards Case	Voluntary Energy Efficiency Targets
Electric Smooth Cooking Tops	Moderate	Moderate
Gas Cooking Tops	Moderate	Low

Table 17.3.6 summarizes DOE's assumptions for consumer conventional cooking products regarding the market penetration of products in 2027 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.

[h] 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 17.3.6 Market Penetrations in 2027 Attributable to Voluntary Energy Efficiency Targets

	TSL 1	**TSL 2**	TSL 3
Electric Smooth Cooking Tops			
Base-Case Market Share	50.0%	**50.0%**	5.0%
Policy Case Market Share	50.7%	**50.7%**	5.2%
Increased Market Share	0.7%	**0.7%**	0.2%
Gas Cooking Tops			
Base-Case Market Share	48.0%	**4.0%**	4.0%
Policy Case Market Share	48.0%	**4.7%**	4.7%
Increased Market Share	0.0%	**0.7%**	0.7%

Table 17.3.7 Market Penetrations in Selected Years Attributable to Voluntary Energy Efficiency Targets for TSL 2

	2027	**2036**	**2056**
Electric Smooth Cooking Tops			
Base-Case Market Share	50.0%	50.0%	50.0%
Policy Case Market Share	50.7%	57.2%	59.2%
Increased Market Share	0.7%	7.2%	9.2%
Gas Cooking Tops			
Base-Case Market Share	4.0%	4.0%	4.0%
Policy Case Market Share	4.7%	37.0%	41.5%
Increased Market Share	0.7%	33.0%	37.5%

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 consumer conventional cooking products that meet the efficiency level 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 consumer 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 the 2036 level), the increase in energy prices leads 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.[22, 23]

DOE assumed that government agencies would administer bulk purchasing programs for consumer conventional cooking products. At the federal level, this type of program could lead to FEMP procurement guidelines for consumer conventional cooking products, which would refer to the target levels of the proposed TSL as the minimum efficiency levels of consumer conventional cooking products to be purchased. 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.[24] 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 consumer 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 consumer conventional cooking products. This subset would consist primarily of public housing and housing on military bases.

According to the 2019 American Housing Survey (AHS 2019), about 1.1 percent of all U.S. households are housing units in a public housing authority that rely on electricity for cooking and 0.6 percent rely on gas for cooking.[i] DOE therefore estimated that the percent of U.S. housing units constituting the market to which this policy would apply is 1.1 percent for electric smooth cooking tops and 0.6 percent for gas cooking tops.

DOE estimated that starting in 2027, each year of a bulk government purchase policy would result in an increasing percent of shipments of government-purchased units beyond the no-new-standards case that would meet the target efficiency level. DOE estimated that within 10 years (by 2036) bulk government purchasing programs would result in 80 percent[j] of the market for consumer conventional cooking products used in publicly owned housing meeting the target

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[i] https://www.census.gov/programs-surveys/ahs/data/2019/ahs-2019-public-use-file--puf-/ahs-2019-national-public-use-file--puf-.html

[j] 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 no-new-standards case scenario.

level. DOE modeled the bulk government purchase program assuming that the market share for consumer conventional cooking products achieved in 2036 would be at least maintained throughout the rest of the forecast period.

Table 17.3.8 summarizes DOE's assumptions for consumer conventional cooking products regarding the market penetration of products in 2027 that meet the target levels at each TSL given bulk government purchases.

Table 17.3.8 Market Penetrations in 2027 Attributable to Bulk Government Purchases

	TSL 1	**TSL 2**	TSL 3
Electric Smooth Cooking Tops			
Base-Case Market Share	50.0%	50.0%	5.0%
Policy Case Market Share	50.0%	50.0%	5.1%
Increased Market Share	0.02%	0.02%	0.1%
Gas Cooking Tops			
Base-Case Market Share	48.0%	4.0%	4.0%
Policy Case Market Share	48.0%	4.0%	4.0%
Increased Market Share	0.02%	0.04%	0.04%

The increased market shares attributable to bulk government purchases shown in Table 17.3.8 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 consumer conventional cooking products. Market penetrations increase over the first 10 years of the forecast period, and steady for the rest of the analysis period.

17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

Figure 17.4.1 and Figure 17.4.2 show the effects of each non-regulatory policy alternative on the market penetration of more efficient consumer conventional cooking products. Relative to the no-new-standards 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.

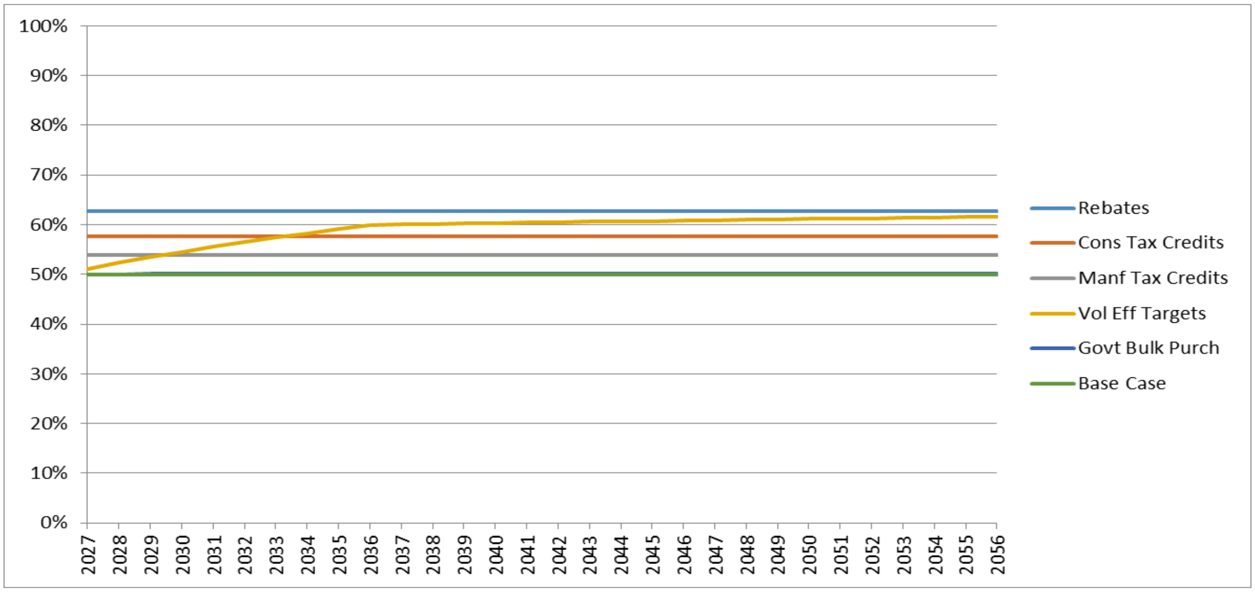

Figure 17.4.1 Market Penetration of Efficient Electric Smooth Cooking Tops (TSL 2)

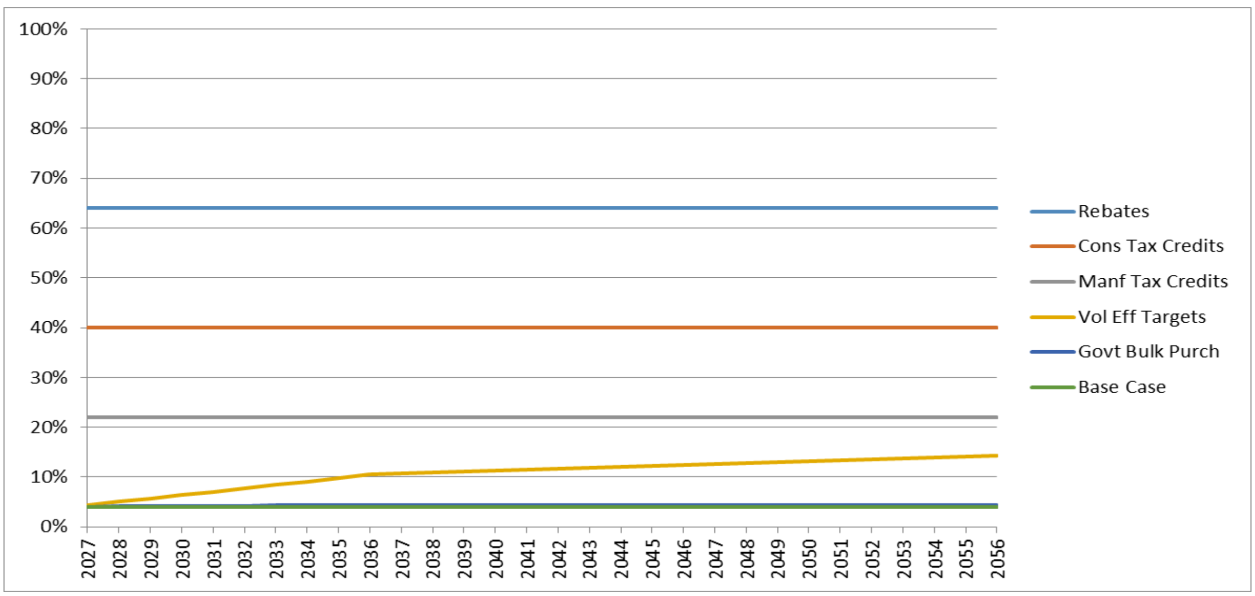

Figure 17.4.2 Market Penetration of Efficient Gas Cooking Tops (TSL 2)

Table 17.4.1 shows the national energy savings and net present value for the five non-regulatory policy alternatives analyzed in detail for consumer conventional cooking products. The target level for each policy corresponds to the same efficient technology proposed for standards at TSL 2. The case in which no regulatory action is taken with regard to consumer conventional cooking products constitutes the no-new-standards 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 calculated as described in footnote ‘a’. Energy savings are given in quadrillion British thermal units (quads) of primary energy savings.[k] The NPVs shown in Table 17.4.1 are based on two discount rates, 7 percent and 3 percent. Under both discount rates, the proposed standards carry a considerably higher NPV than any non-regulatory alternative.

The policy with the highest projected cumulative energy savings is consumer rebates. Savings from manufacturer tax credits and consumer tax credits range from 18.9 to 37.8 percent of the savings from proposed standards calculated as described in footnote 'a'. Bulk government purchases have the lowest cumulative energy savings. Overall, the energy saving benefits from the alternative policies, range from 0.1 percent to 62.9 percent of the benefits from the proposed standards calculated as described in footnote 'a'.

Table 17.4.1 Impacts of Non-Regulatory Policy Alternatives (TSL 2)

Policy Alternative	Energy Savings* *quads*		Net Present Value* *million 2021$*	
			7% Disc Rate	3% Disc Rate
Consumer Rebates	0.257	62.9%***	594.9	1382
Consumer Tax Credits	0.154	37.8%	356.9	829.2
Manufacturer Tax Credits	0.077	18.9%	178.5	414.6
Voluntary Energy Efficiency Targets	0.009	2.1%	17.3	57.2
Bulk Government Purchases	0.0003	0.1%	0.7	1.7
Proposed Standards**	0.408	100.0%	854.5	2,191

* For products shipped 2027-2056.
**Calculated as described in footnote 'a'.
***The percentages show how the energy savings from each policy alternative compare to the (primary) energy savings from the proposed standards (represented in the table as 100%), when the latter are calculated as described in footnote 'a'.

[k] For the alternative policies whose market penetration depends on B/C ratio, the energy savings in Table 17.4.1 correspond to the case where the cash flow of the operating cost savings was discounted to the purchase year using a 7 percent discount rate.

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APPENDIX 6A. DETAILED DATA FOR EQUIPMENT PRICE MARKUPS

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6A.1 STATE SALES TAX RATES

Table 6A.1.1 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	8.70%	Kentucky	6.00%	North Dakota	6.25%
Alaska	1.30%	Louisiana	9.40%	Ohio	7.20%
Arizona	7.30%	Maine	5.50%	Oklahoma	8.60%
Arkansas	9.15%	Maryland	6.00%	Oregon	0.00%
California	8.80%	Massachusetts	6.25%	Pennsylvania	6.35%
Colorado	6.40%	Michigan	6.00%	Rhode Island	7.00%
Connecticut	6.35%	Minnesota	7.45%	South Carolina	7.45%
Delaware	0.00%	Mississippi	7.05%	South Dakota	6.00%
Dist. of Columbia	6.00%	Missouri	7.05%	Tennessee	9.50%
Florida	7.00%	Montana	0.00%	Texas	8.00%
Georgia	7.40%	Nebraska	6.10%	Utah	7.15%
Hawaii	4.45%	Nevada	8.25%	Vermont	6.10%
Idaho	6.05%	New Hampshire	0.00%	Virginia	5.75%
Illinois	8.60%	New Jersey	6.60%	Washington	9.30%
Indiana	7.00%	New Mexico	7.05%	West Virginia	6.15%
Iowa	6.95%	New York	8.45%	Wisconsin	5.45%
Kansas	8.40%	North Carolina	7.00%	Wyoming	5.40%

Source: The Sales Tax Clearinghouse at https://thestc.com/STRates.stm (Accessed June 6, 2022).

APPENDIX 7A. COOKING PRODUCTS: DETERMINATION OF ENERGY-USING COMPONENTS

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APPENDIX 7A. COOKING PRODUCTS: 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 308.7 kWh per year. Because DOE's analysis of cooking products consisted of analyzing conventional oven and cooking top product classes, DOE had to disaggregate the range energy consumption into the portion allocated to the oven and the portion allocated to the cooking top. In addition, because oven and cooking top energy use may consist of several energy-using components (i.e., cooking, self-clean, and combined low power mode energy) and potential increases in efficiency may affect only a subset of these components, DOE had to further disaggregate the oven and cooking top 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 cooking tops; 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 308.7 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 low power mode energy consumption associated with electric ovens and cooking tops.

$$UEC_{eleccooking} = 308.7\ kWh/yr$$
$$= MSe_{SC} \times \left(E_{CO\_SC} + Esc\right) + (1 - MSe_{SC}) \times E_{CO\_STD} + E_{CA} + \left(E_{CTLP\_CK} + E_{CTLP\_OV}\right)$$

Where:

$UEC_{elec\ cooking}$ =	Annual energy consumption of electric cooking (kWh/yr),
MSe_{SC} =	Market share of electric ovens that are self-clean, 73.2%,[1]
E_{CO_SC} =	Annual cooking energy consumption of self-clean electric ovens (kWh/yr),
Esc =	Average annual self-clean energy consumption for electric self-clean ovens, 34.4 kWh (weighted average of freestanding and built-in values, as reported in Chapter 7w),
E_{CO_STD} =	Annual cooking energy consumption of standard electric ovens (kWh/yr),
E_{CA} =	Annual energy consumption of electric cooking tops (kWh/yr),

E_{CTLP_CK} =	Combined low power mode for electric cooktops, 32.4 (kWh/yr) (weighted average of electric smooth and coil cooktops)
E_{CTLP_OV} =	Combined low power mode for electric ovens, 18.2 (kWh/yr) (weighted average of freestanding and built-in values)

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 estimated baseline cooking efficiencies.

$$Re_{SC\_STD} = \frac{E_{AO\_SC}}{E_{AO\_STD}} = 1.0179$$

Where:

E_{AO_SC} =	Annual baseline cooking energy in active mode for self-clean ovens, 301.7 kWh/yr,
E_{AO_STD} =	Annual baseline cooking energy in active mode for standard ovens, 296.4 kWh/yr,

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:

$$E_{CO\_STD} = \frac{308.7 - MSe_{SC} \times E_{SC} - E_{CTLP\_CK} - E_{CTLP\_OV}}{MSe_{SC} \times Re_{SC\_STD} + 1 - MSe_{SC} + R_{CT\_STD}}$$
$$= \frac{308.7 - 73.2\% \times 34.4 - 32.4 - 18.2}{73.2\% \times 1.0179 + 1 - 73.2\% + 0.6793} = 137.6\ kWh/yr$$

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:

$$E_{CO\_SC} = Re_{SC\_STD} \times E_{CO\_STD}$$
$$= 1.0179 \times 137.6 = 140.1\ kWh/yr$$

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	Cooking Top		Standard Oven		Self-Clean Oven	
	Electric Coil	Electric Smooth	FS	BI/SI	FS	BI/SI
Cooking Energy (kWh/yr)	93.5	93.5	137.6	137.6	140.1	140.1
Self-clean Energy (kWh/yr)					34.4	34.4
Fan Energy (kWh/yr)				7.0		6.6
Combined Low Power Energy (kWh/yr)	3	47	18.3	17.8	18.3	17.8
Total (kWh/yr)	96.5	140.5	155.9	162.4	192.8	198.9

7A.3 METHODOLOGY FOR ESTABLISHING GAS COOKING ENERGY-USING COMPONENTS

DOE estimated the annual energy consumption of gas cooking products based on the active cooking energy consumption values that DOE deduced from the electric range annual energy consumption of 308.7 kWh per year. DOE assumed that the ratio of the test-to-field annual active energy consumption values for electric cooking products applied to gas cooking products as well. DOE used the following equations to calculate the annual cooking energy consumption of gas cooking products.

$$E_{CO\_SC\_GAS} = \frac{E_{CO\_SC\_ELEC}}{E_{AO\_SC\_ELEC}} \times E_{AO\_SC\_GAS} = 761.4\ kBtu/yr$$

$$E_{CO\_STD\_GAS} = \frac{E_{CO\_STD\_ELEC}}{E_{AO\_STD\_ELEC}} \times E_{AO\_STD\_GAS} = 938.7\ kBtu/yr$$

Where:

$E_{CO\_SC\_GAS}$ = Annual cooking energy consumption of gas self-clean ovens,
$E_{CO\_SC\_ELEC}$ = Annual cooking energy consumption of electric self-clean ovens,

$E_{AO\_SC\_ELEC}$ = Annual active mode test energy consumption of electric self-clean ovens,
$E_{AO\_SC\_GAS}$ = Annual active mode test energy consumption of gas self-clean ovens,
$E_{CO\_STD\_GAS}$ = Annual cooking energy consumption of gas standard ovens,
$E_{CO\_STD\_ELEC}$ = Annual cooking energy consumption of electric standard ovens,
$E_{AO\_STD\_GAS}$ = Annual active mode test energy consumption of gas standard ovens, and
$E_{AO\_STD\_ELEC}$ = Annual active mode test energy consumption of electric standard ovens,

Table 7A.3.1 summarizes the energy-using components of gas cooking products. Self-clean, and combined low power mode energy consumption values are described and reported in Chapter 7, Table 7.2.3 for gas standard ovens and self-clean ovens.

Table 7A.3.1 Gas Cooking Products: Energy-Using Components

Energy-Using Components	Standard Oven		Self-clean Oven		Cooking Top
	Freestanding	Built-In/Slide-In	Freestanding	Built-In/Slide-In	Gas
Cooking Energy (kBtu/yr)	938.7	938.7	761.4	761.4	810.1
Self-clean Energy					
Gas (kBtu/yr)			234	234	
Electric (kWh/yr)			6	6	
Fan Energy (kWh/yr)		5.9		6.3	
Combined Low Power Mode Energy (kWh/yr)*	18.3	17.9	18.3	17.9	30
Total					
Gas (kBtu/yr)	1001.2	1020.0	1078.3	1098.5	840.1

*Combined low power mode energy for gas cooktops is in kBtu/yr

REFERENCES

1. U.S. Energy Information Administration, *Residential Energy Consumption Survey 2015*, Washington, DC. http://www.eia.gov/consumption/residential/data/2015/.

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 consumer 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 consumer 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 consumer conventional cooking products. 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 1,000–10,000 (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) 2015 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 2015 household data for each product type. During a Crystal Ball simulation, DOE uses these household characteristics to determine the analysis parameters.

Energy Use	Provides energy use components for all product classes at every efficiency level.
No-New-Standards Case Efficiency Distribution	Gives the market shares for efficiency levels in the no-new-standards case.
Equipment Prices	Develops total installed cost for cooking tops in 2021$. 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 for electricity and natural gas used in the LCC and PBP analysis.
Energy Price Trends	Contains the electricity and natural gas price trends for the reference, high, and low economic growth scenarios based on AEO 2022.
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 consumer conventional cooking products.
Forecast Cells	Gives details regarding base-case efficiency distributions for all cooking tops. Median, minimum, maximum, and average values are given, along with 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} 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 FOR CONSUMER CONVENTIONAL COOKING PRODUCTS

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APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN LCC ANALYSIS FOR CONSUMER CONVENTIONAL COOKING PRODUCTS

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 drawing conclusions 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 USING CRYSTAL BALL TO PERFORM PROBABILITY ANALYSES

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.

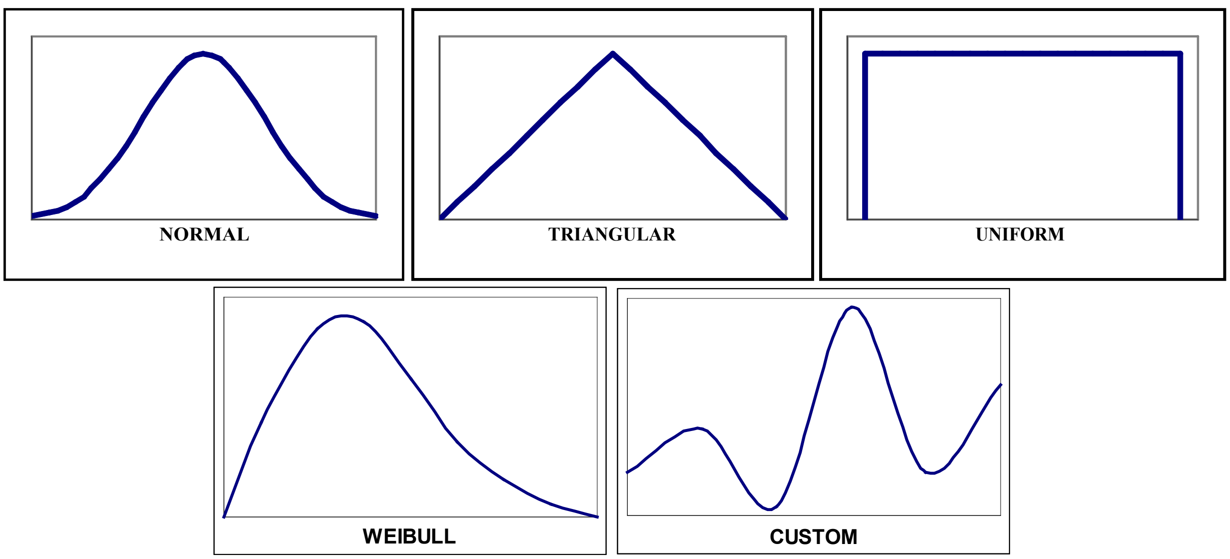

Figure 8B.5.1 Normal, Triangular, Uniform, Weibull, and Custom Probability Distributions

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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APPENDIX 8C. LIFETIME DISTRIBUTIONS

8C.1 INTRODUCTION

The U.S. Department of Energy (DOE) characterized the lifetime of both fuel types of consumer conventional cooking products being considered for new energy efficiency standards (electric and gas consumer conventional cooking products). DOE characterized consumer 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.2.1 shows the average values used to determine the Weibull distribution parameters alpha and beta. For consumer 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 consumer conventional cooking top or an oven. DOE estimated that the maximum lifetime percentile for both fuel types was 99 percent.

Table 8C.2.1 Consumer Conventional Cooking Products

Product Fuel Type	Expert Opinion Values		Weibull Parameters	
	Average *year*	Maximum percentile %	Alpha (scale)	Beta (shape)
Electric	16.8	99	16.88	6.99
Gas	14.5	99	14.56	5.73

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 consumer conventional cooking products.

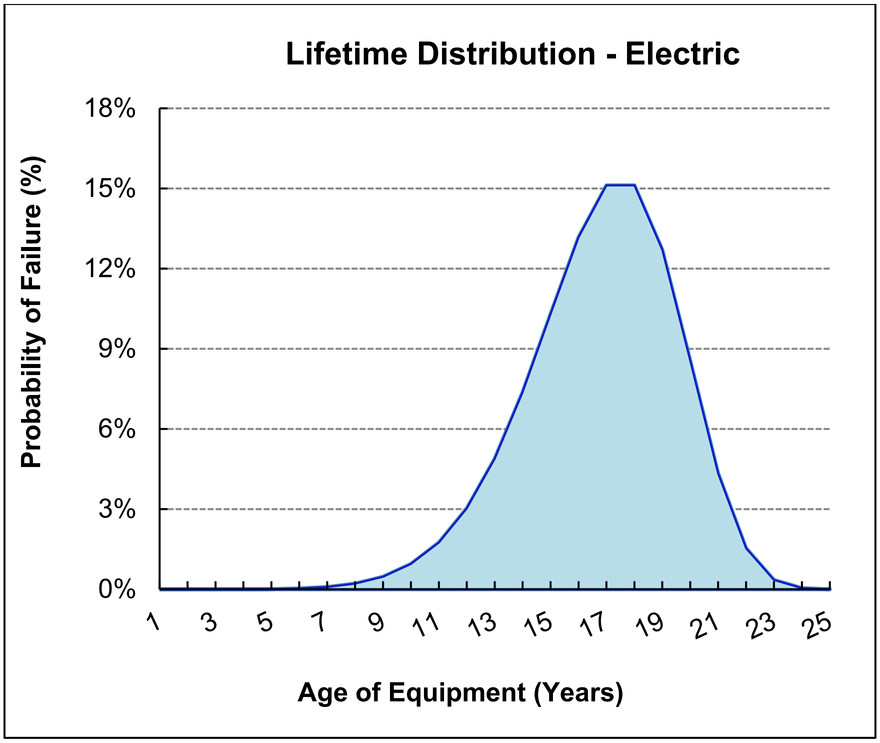

Figure 8C.2.1 Surviving Probability of Electric Consumer Conventional Cooking Products

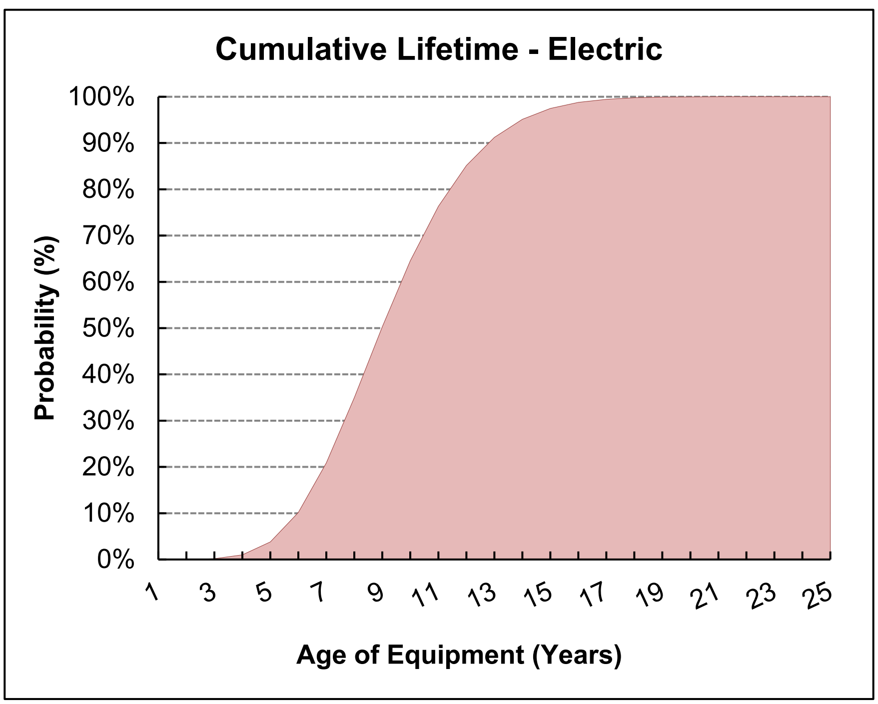

Figure 8C.2.2 Cumulative Lifetime Length of Electric Consumer Conventional Cooking

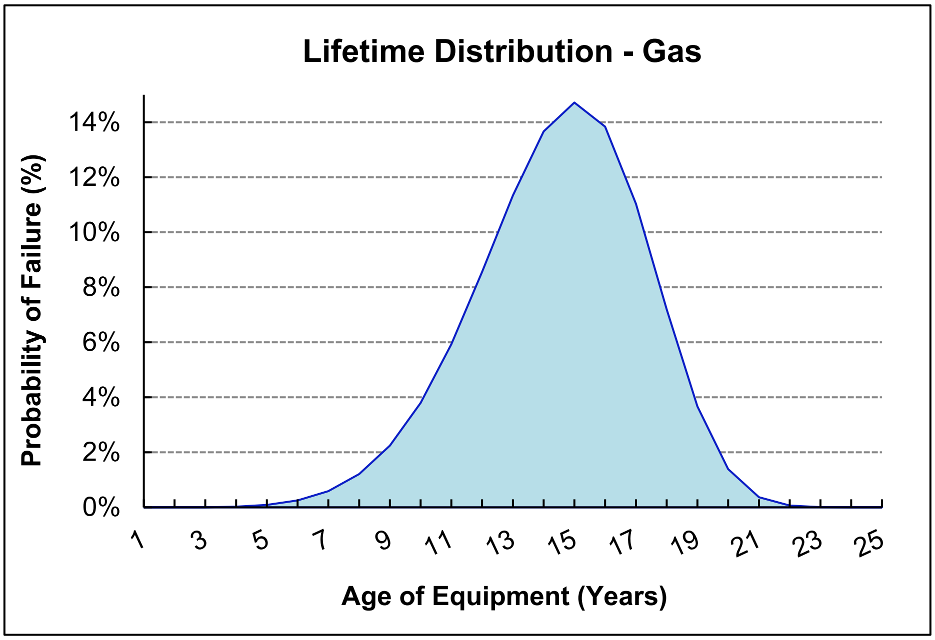

Figure 8C.2.3 Surviving Probability of Gas Consumer Conventional Cooking Products

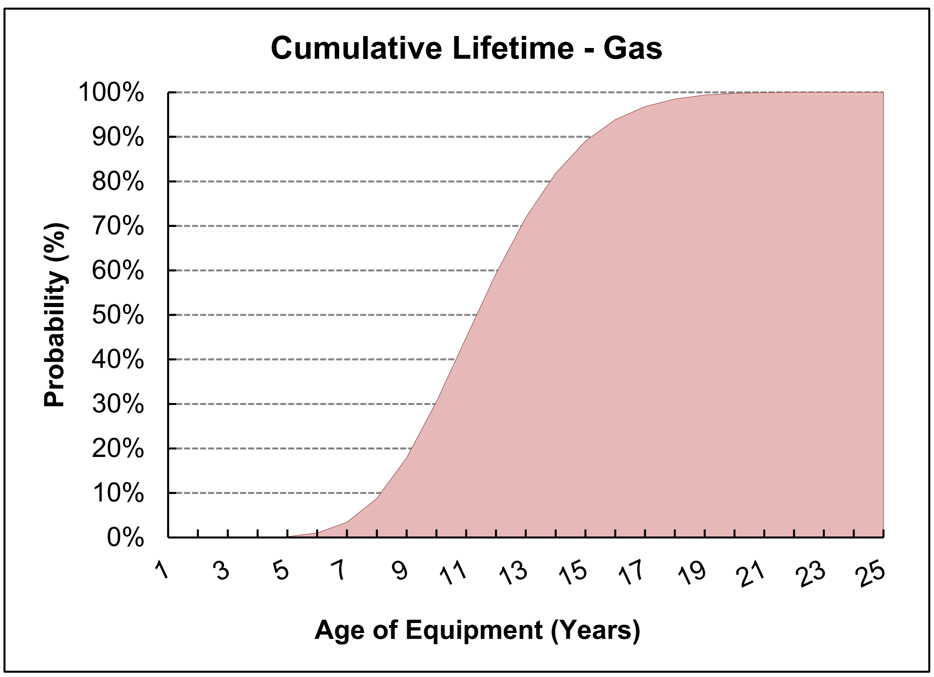

Figure 8C.2.4 Cumulative Lifetime Length of Gas Consumer Conventional Cooking Products

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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 USED FOR RESIDENTIAL DISCOUNT RATES

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APPENDIX 8D. DISTRIBUTIONS USED FOR RESIDENTIAL DISCOUNT RATES

8D.1 INTRODUCTION

The Department of Energy (DOE) derived consumer discount rates for the life-cycle cost (LCC) analysis using data on interest or return rates for various types of debt and equity to calculate a real effective discount rate for each household in the Federal Reserve Board's *Survey of Consumer Finances* (*SCF*) in 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.[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.1.1 Distribution of Rates for Equity Classes

Figure 8D.1.1 through Figure 8D.1.6 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 (1991-2020). The rates for stocks are the annual returns on the Standard and Poor's 500 for 1991–2020.[2] The interest rates associated with AAA corporate bonds were collected from Moody's time-series data for 1991–2020.[3] Rates on Certificates of Deposit (CDs) accounts came from Cost of Savings Index (COSI) data covering 1991–2020.[4,a] The interest rates associated with state and local bonds (20-bond municipal bonds) were collected from Federal Reserve Board economic data time-series for 1991–2020.[9,b] The interest rates associated with treasury bills (30-Year treasury constant maturity rate) were collected from Federal Reserve Board economic data time-series for 1991–2020.[10,c] Rates for money market accounts are based on three-month money market account rates reported by Organization for Economic Cooperation and Development (OECD) from 1991–2020.[12] Rates for savings accounts are assumed to be half the average real money market rate. Rates for mutual funds are a weighted average of the stock rates and the bond rates.[d] The 30-year average nominal interest rates are shown in Table 8D.1.1. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year (see Figure 8D.1.7). In addition, DOE adjusted the nominal rates to real effective rates by accounting for the fact that interest on such equity types is taxable. The capital gains marginal tax rate varies for each household based on income as shown in chapter 7 (the impact of this is not shown in Figure 8D.1.1 through Figure 8D.1.6, which are only adjusted for inflation).

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[a] The Wells COSI is based on the interest rates that the depository subsidiaries of Wells Fargo & Company pay to individuals on certificates of deposit (CDs), also known as personal time deposits. Wells Fargo COSI started in November 2009.[5] From July 2007 to October 2009 the index was known as Wachovia COSI[6] and from January 1984 to July 2007 the index was known as GDW (or World Savings) COSI.[7,8]

[b] This index was discontinued in 2016. To calculate the 2017 and after values, DOE compared 1981-2020 data for 30-Year Treasury Constant Maturity Rate[10] and Moody's AAA Corporate Bond Yield[3] to the 20-Bond Municipal Bond Index data.[9]

[c] From 2003-2005 there are no data. For 2003-2005, DOE used 20-Year Treasury Constant Maturity Rate.[11]

[d] SCF reports what type of mutual funds the household has (*e.g.,* stock mutual fund, savings bond mutual fund, etc.). For mutual funds with a mixture of stocks and bonds, the mutual fund interest rate is a weighted average of the stock rates (two-thirds weight) and the savings bond rates (one-third weight).

Table 8D.1.1 30-Year Average Nominal Interest Rates for Household Equity Type

Type of Equity	30 Year Average Nominal Rate (%)
Savings accounts	2.58
Money market accounts	2.84
Certificate of deposit	3.15
Treasury Bills (T-bills)	4.82
State/Local bonds	4.62
AAA Corporate Bonds	5.68
Stocks (S&P 500)	12.03
Mutual funds	9.63

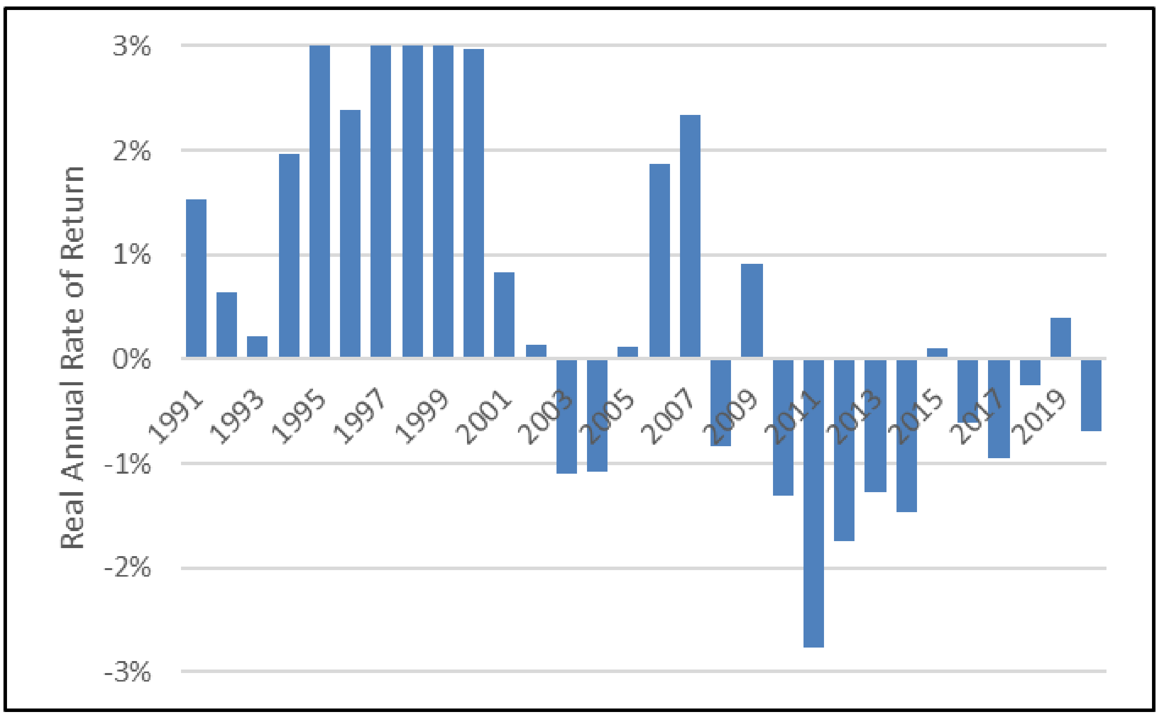

Figure 8D.1.1 Distribution of Annual Rate of Money Market Accounts

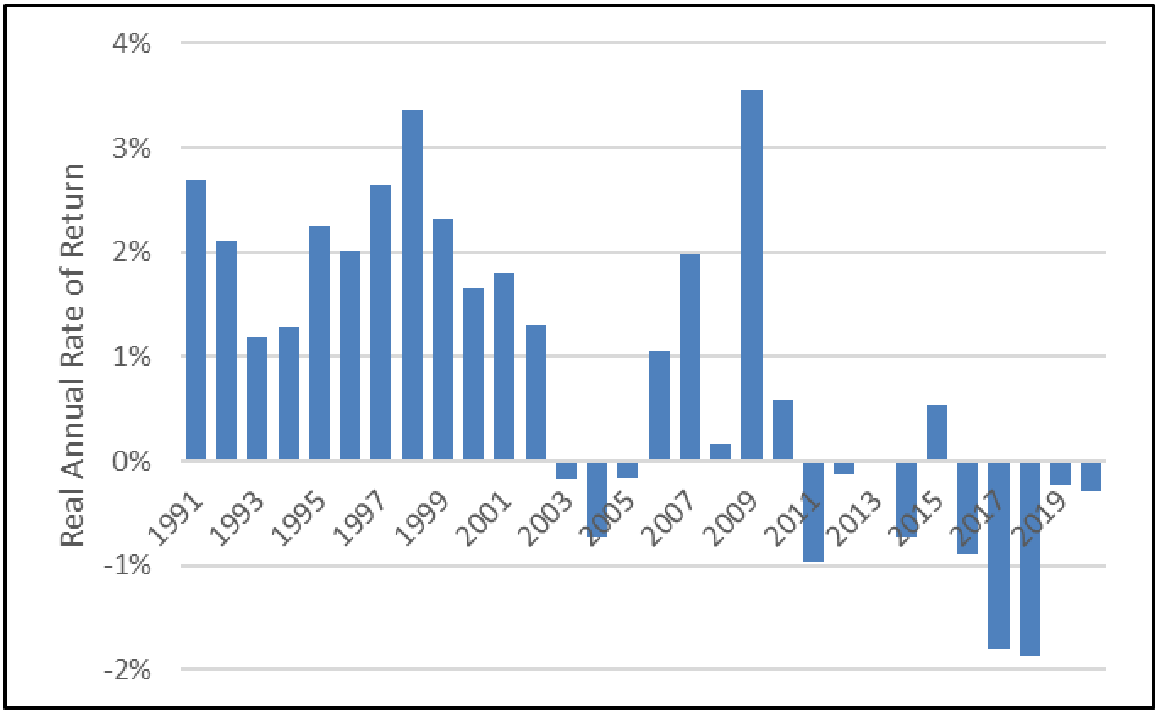

Figure 8D.1.2 Distribution of Annual Rate of Return on CDs

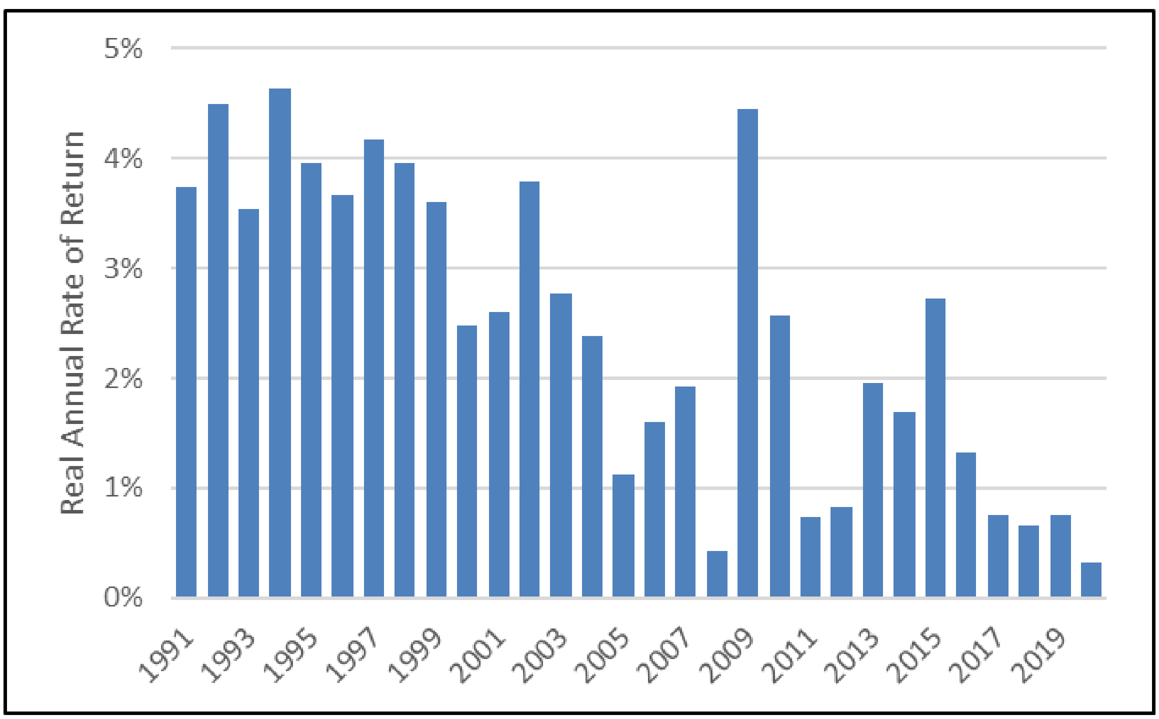

Figure 8D.1.3 Distribution of Annual Rate of Return on Savings Bonds (30 Year Treasury Bills)

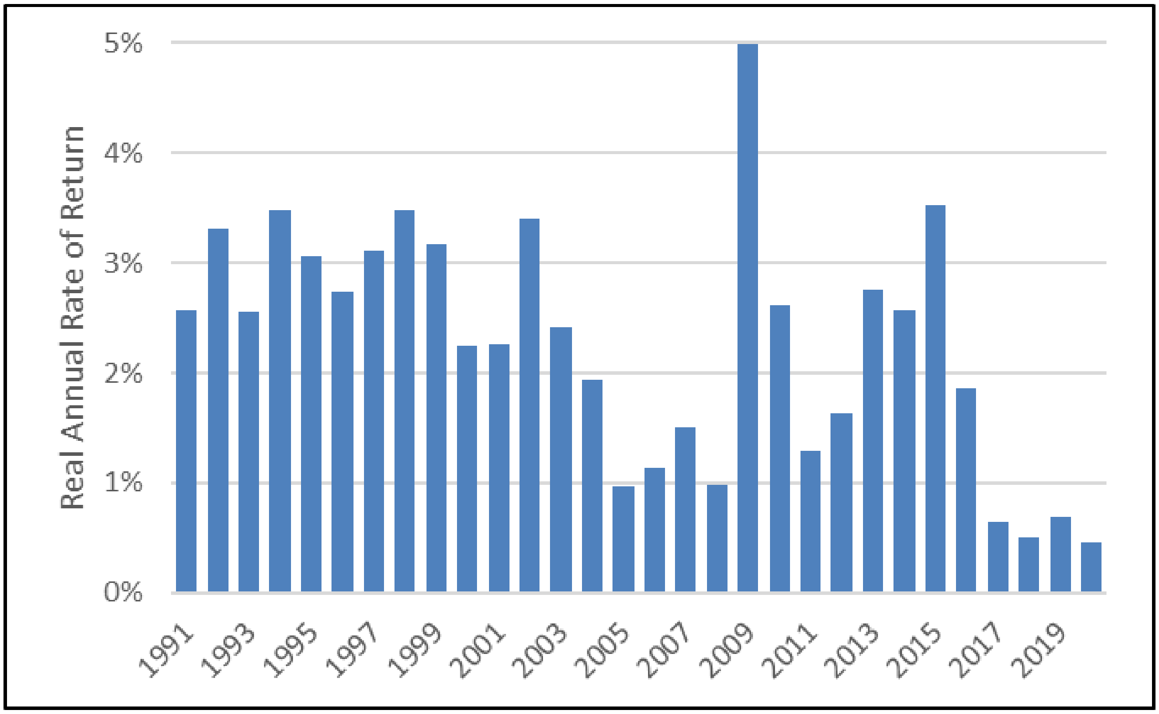

Figure 8D.1.4 Distribution of Annual Rate of State and Local Bonds

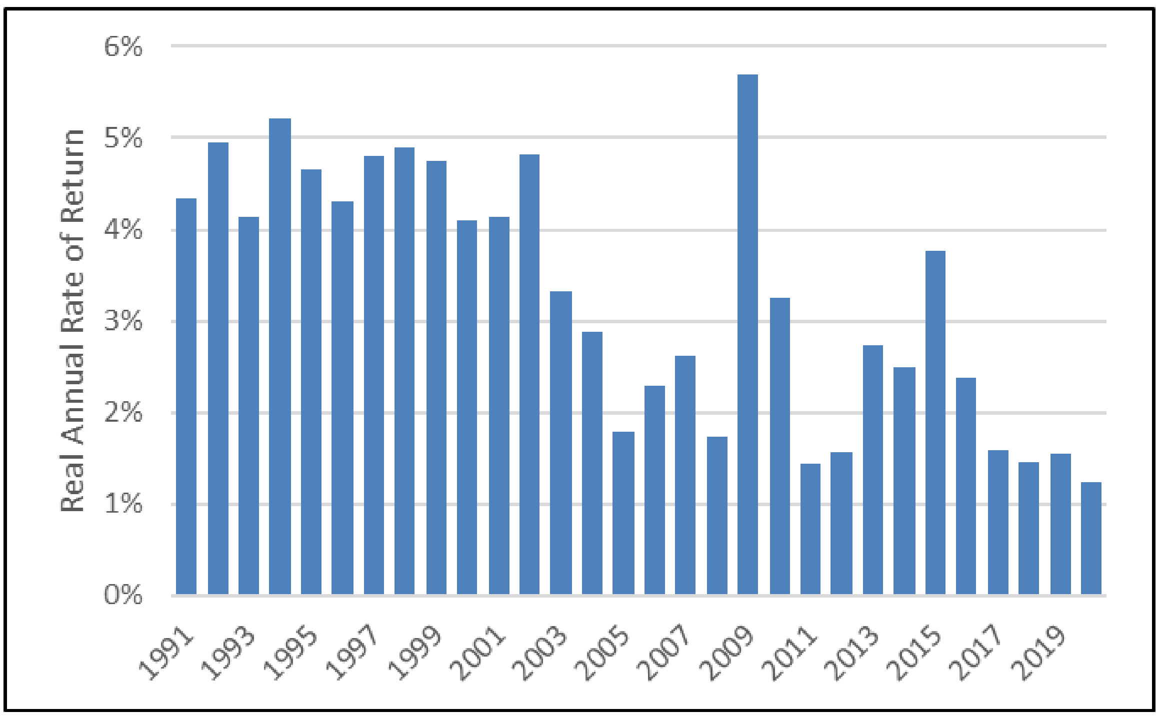

Figure 8D.1.5 Distribution of Annual Rate of Return on Corporate AAA Bonds

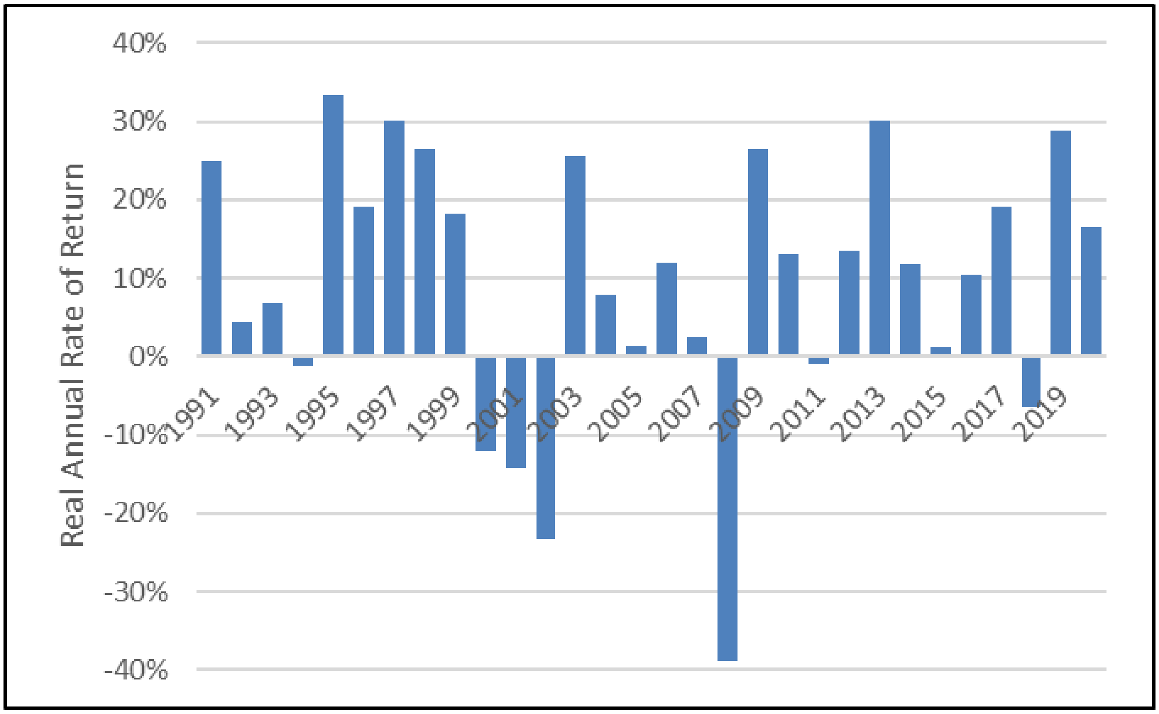

Figure 8D.1.6 Distribution of Annual Rate of Return on S&P 500

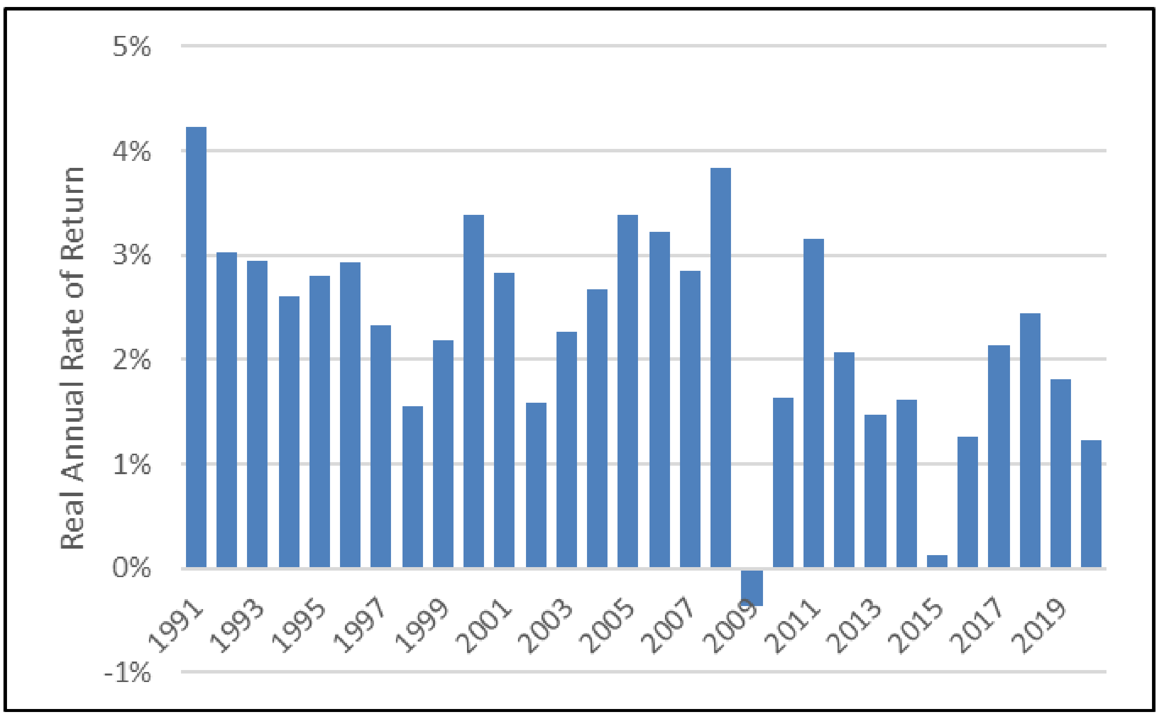

Figure 8D.1.7 Annual Consumer Price Index (CPI) Rate

8D.2 DISTRIBUTION OF REAL EFFECTIVE DISCOUNT RATES BY INCOME GROUP

Real effective discount rates were calculated for each household of the SCF using the method described in Chapter 7. Interest rates for asset types were as described in 8D.1.1. 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, 2010, 2013, 2016, and 2019. 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 provides a graphical representation of the real effective discount rate distributions by income group, while Table 8D.2.1 provides the full distributions as used in the LCC analysis.

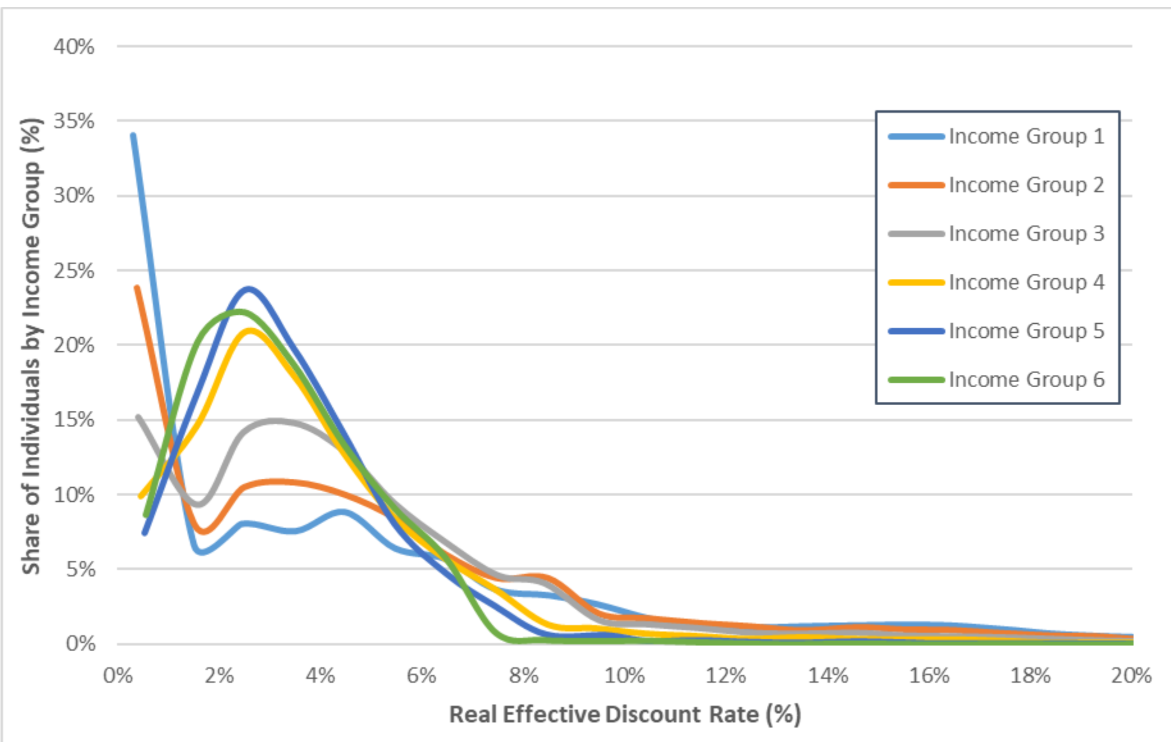

Figure 8D.2.1 Distribution of Real Discount Rates by Income Group

Table 8D.2.1 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	0.31	34.02	0.38	23.86	0.42	15.15	0.47	9.89	0.53	7.46	0.56	8.66
1-2	1.51	6.63	1.52	7.99	1.57	9.30	1.58	14.62	1.57	16.85	1.58	20.22
2-3	2.45	8.04	2.49	10.51	2.49	14.15	2.52	20.89	2.51	23.73	2.50	22.21
3-4	3.51	7.54	3.49	10.82	3.49	14.76	3.49	17.96	3.48	19.77	3.47	18.75
4-5	4.48	8.82	4.48	10.00	4.48	12.88	4.47	12.81	4.46	14.11	4.48	13.32
5-6	5.47	6.40	5.46	8.44	5.46	9.42	5.46	8.48	5.46	8.06	5.47	9.11
6-7	6.47	5.68	6.47	5.99	6.46	6.83	6.46	5.73	6.49	4.70	6.47	5.80
7-8	7.46	3.64	7.47	4.42	7.50	4.58	7.45	3.66	7.42	2.61	7.46	0.79
8-9	8.52	3.24	8.48	4.42	8.43	4.05	8.50	1.30	8.45	0.66	8.42	0.29
9-10	9.47	2.65	9.49	2.04	9.50	1.58	9.46	1.05	9.63	0.62	9.64	0.22
10-11	10.50	1.69	10.46	1.72	10.43	1.31	10.42	0.70	10.44	0.22	10.37	0.25
11-12	11.48	1.16	11.53	1.40	11.51	1.04	11.53	0.52	11.42	0.28	11.54	0.14
12-13	12.51	1.09	12.47	1.19	12.54	0.74	12.46	0.33	12.49	0.16	12.40	0.06
13-14	13.54	1.17	13.52	0.91	13.50	0.69	13.49	0.45	13.43	0.11	13.30	0.01
14-15	14.52	1.24	14.57	1.13	14.60	0.74	14.51	0.34	14.54	0.19	14.43	0.06
15-16	15.56	1.29	15.55	0.97	15.53	0.56	15.44	0.30	15.43	0.13	15.65	0.02
16-17	16.49	1.22	16.39	0.94	16.46	0.51	16.42	0.31	16.17	0.06	16.40	0.01
17-18	17.58	0.95	17.50	0.73	17.51	0.44	17.48	0.21	17.54	0.06	17.93	0.03
18-19	18.41	0.70	18.47	0.56	18.41	0.34	18.38	0.10	18.47	0.06	18.50	0.01
19-20	19.45	0.52	19.40	0.50	19.45	0.22	19.60	0.09	19.41	0.05	19.17	0.01
20-21	20.56	0.44	20.42	0.26	20.38	0.18	20.41	0.09	20.47	0.04	20.13	0.02
21-22	21.44	0.54	21.43	0.34	21.34	0.16	21.44	0.08	21.38	0.06	0.00	0.00
22-23	22.51	0.39	22.48	0.23	22.58	0.08	22.72	0.03	0.00	0.00	0.00	0.00
23-24	23.41	0.17	23.52	0.13	23.41	0.10	23.44	0.02	0.00	0.00	23.89	0.03
24-25	24.61	0.18	24.47	0.10	24.56	0.04	24.09	0.01	0.00	0.00	0.00	0.00
25-26	25.35	0.16	25.40	0.10	25.47	0.06	25.33	0.03	25.80	0.00	0.00	0.00
26-27	26.52	0.13	26.47	0.03	26.50	0.05	0.00	0.00	0.00	0.00	0.00	0.00
27-28	27.49	0.07	27.41	0.02	27.41	0.03	27.27	0.03	27.14	0.00	0.00	0.00
28-29	28.14	0.09	28.29	0.05	28.38	0.01	0.00	0.00	0.00	0.00	0.00	0.00
29-30	29.87	0.01	29.37	0.01	29.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>30	68.17	0.14	125.34	0.19	135.29	0.02	53.85	0.00	0.00	0.00	0.00	0.00
Total	4.76	100.00	4.99	100.00	4.54	100.00	3.84	100.00	3.47	100.00	3.23	100.00

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APPENDIX 9A. PRICE ELASTICITY OF DEMAND FOR CONSUMER CONVENTIONAL COOKING PRODUCTS

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APPENDIX 9A. PRICE ELASTICITY OF DEMAND FOR CONSUMER CONVENTIONAL COOKING PRODUCTS

9A.1 INTRODUCTION

DOE estimated a price-elasticity of demand for cooking products to support the simulation of the repair-or-replace decision making the Department accounted for in its NIA. The price-elasticity is used to estimate the number of households that – as a response to new energy efficiency standards – would repair a failing unit rather than replace it. DOE developed a semi-parametric, generalized additive model for the estimation of the price-elasticity of demand for cooking products. This appendix provides a brief description of the methodology and data DOE used for that estimation.

9A.2 METHODOLOGY FOR PRICE-ELASTICITY ESTIMATES

Price-elasticity of demand can be measured in several ways depending on data availability, preference of the analyst and some other factors. One of the most common approaches applies a constant elasticity model on aggregate time series data, with a log-log relationship between demand and price. DOE developed on such approach and extended it to include macroeconomic indicators which the Department believes account for relevant macroeconomic factors that would affect the purchase of cooking products. The three macroeconomic indicators DOE used are: (a) the real median household income; (b) the number of new houses sold; and (c) a measure of near-time consumer attitudes about investments in durable goods. Similar to the relationship between demand and price, DOE assumed a log-log relationship between demand and household income. As for the other two macroeconomic indicators, DOE did not make any assumption on their relationship to demand. Rather, the Department used a non-parametric approach to estimate their effect on the demand of cooking products. In a non-parametric regression model the coefficients of the independent variables are estimated from smoothing functions (curves) that lead to best fittings.

Beyond those three macroeconomic variables, DOE further accounted for unobserved macroeconomic effects on purchase of cooking products. DOE associated the unobserved macroeconomic effects to both the shipment year, which is included in the model as a factor (*dummy* variable), and to other random effects. Finally, since the data DOE used discriminate between shipments of electric and gas cooking products, the Department included in its model the product type – based on the fuel – also as a factor.

The regression model DOE used to estimate the price-elasticity for cooking products is:

$$\ln(S_{mt}) = \beta_0 + \gamma \ln(P_{mt}) + \beta_1 \ln(INC_t) + \mathrm{s}(NH_t) + \mathrm{s}(ICS_t) + m + t + \varepsilon_r + \varepsilon_{mt}$$

where:

m Cooking product type (1: electric; 2: gas),
t Shipment year,
S_{mt} Shipments of m in t,

β_0 Constant effect (regression intercept),
γ Price-elasticity estimate,
P_{mt} Shipments-weighted average price of m in t,
β_1 Income-elasticity estimate,
INC_t Real median household income in t,
$s(x)$ Smoothing function of variable x,
NH_t New houses sales in t,
ICS_t Index of Consumer Sentiment in t,
ε_r Unobserved macroeconomic random effects,
ε_{mt} Unobserved stochastic error associated to m in t.

9A.3 DATA AND RESULTS

DOE relied on the US Census Bureau's Current Industrial Report (CIR)[1] as its main source of data for the elasticity estimation. The CIR reports regular and accurate intercensal estimates of shipments and value of shipments for cooking ranges and other major household appliances. DOE used data from 1973 to 2010 in its estimation of a price-elasticity for cooking products. Annual shipments were obtained directly from CIR; annual appliance prices were estimated by dividing the annual values of shipments by the number of shipments in each year.

DOE further relied on three additional data sources for the macroeconomic indicators described above. DOE used the report "Income, Poverty, and Health Insurance Coverage in the United States: 2012"[2] from the US Census Bureau's Current Population Reports to inform the real median household income variable in its regression model. In addition, DOE used the "New One-Family Houses Sold"[3] report from the US Census Bureau's Current Construction Reports to account for new houses sales in the model above. The report provides statistics for new privately owned houses sold and for sale in the US. Finally, DOE used the University of Michigan's Index of Consumer Sentiment[4] (ICS) to inform the corresponding variable in the regression model above. One of the objectives of the ICS is to allow for incorporating empirical measures of consumer expectations into models of spending and saving behavior.

DOE used those four data sets in the regression model described above. The model presented an R-squared value of 0.954. All variables included in the model are statistically significant, with all p-values equal or lower than 0.001. Further, a Wald test of significance[5] performed on the parametric and smooth terms resulted in p-values equal or lower than 0.011. The resulting price-elasticity DOE estimated for cooking products is -0.367.

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APPENDIX 10A. USER INSTRUCTIONS FOR SHIPMENTS AND NATIONAL IMPACT ANALYSIS SPREADSHEET

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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 consumer 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 no-new-standards and standards cases for the selected product classes.
LCC Inputs	This sheet contains the inputs from the Life-cycle cost analysis.
Efficiency Distribution_ Cooktop	This sheet contains no-new-standards case and standards case efficiency trends for cooking tops.
Efficiency Distribution_ Oven	This sheet contains no-new-standards 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.
No-New-Standards Case Ship._Electric Cooking Products	This sheet calculates the estimation of no-new-standards case shipments for electric cooking products.
No-New-Standards Case Ship._Gas Cooking Products	This sheet calculates the estimation of no-new-standards case shipments for gas cooking products.

No-New-Standards Case Ship. Cooking Top & Oven	This sheet calculates the estimation of no-new-standards case shipments for cooking tops and ovens.
Cooking Top No-New-Stds & Stds Case	This sheet calculates the estimation of no-new-standards case and standards case shipments for cooking tops. 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 no-new-standards case energy use and operating costs for that year and the standard case energy use and operating costs in the same year.
Oven No-New-Stds & Stds Case	This sheet calculates the estimation of no-new-standards 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 no-new-standards 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.
Energy Prices	This worksheet contains projected average and marginal 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 product 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. Relative Price Elasticity: To change the relative price elasticity, use the drop-down menu and select the desired price elasticity scenario (No impact, or RP elasticity – 0.367).

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 ANALYSIS

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APPENDIX 10B. FULL-FUEL-CYCLE ANALYSIS

10B.1 INTRODUCTION

This appendix summarizes the methods the U.S. Department of Energy (DOE) used to calculate the estimated full-fuel-cycle (FFC) energy savings from potential energy conservation standards. The FFC measure includes point-of-use (site) energy; the energy losses associated with generation, transmission, and distribution of electricity; and the energy consumed in extracting, processing, and transporting or distributing primary fuels. DOE's 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.

In the national energy savings calculation, DOE estimates the site, primary and full-fuel-cycle (FFC) energy consumption for each standard level, for each year in the analysis period. DOE defines 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.[a] The site energy consumption is used to calculate the energy cost input to the net present value (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). 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.
- 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.

For electricity from the grid, site energy is measured in terawatt-hours (TWh). The primary energy of a unit of grid electricity is equal to the heat content of the fuels used to generate that electricity, including transmission and distribution losses.[b] DOE typically measures the primary energy associated with the power sector in quads (quadrillion Btu). 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 electricity generated from renewable sources (wind, solar, and hydro). For the former, the upstream fuel cycle relates

[a] For fossil fuels, this is the site of combustion of the fuel.
[b] For electricity sources like nuclear energy and renewable energy, the primary energy is calculated using the EIA convention as described below.

to the fuel consumed at the power plant. There is no upstream component for the latter, because no fuel *per se* is used.

10B.2 SITE-TO-PRIMARY ENERGY FACTORS

DOE uses heat rates to convert site electricity savings in TWh to primary energy savings in quads. The heat rates are developed as a function of the sector, end-use and year of the analysis period. For this analysis DOE uses output of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS).[2] EIA uses the NEMS model to produce the *Annual Energy Outlook* (*AEO*). DOE's approach uses the most recently available edition, in this case *AEO 2022*.[3] The *AEO* publication includes a reference case and a series of side cases incorporating different economic and policy scenarios. DOE calculates marginal heat rates as the ratio of the change in fuel consumption to the change in generation for each fossil fuel type, where the change is defined as the difference between the reference case and the side case. DOE calculates a marginal heat rate for each of the principal fuel types: coal, natural gas and oil. DOE uses the EIA convention of assigning a heat rate of 10.5 Btu/Wh to nuclear power and 9.5 Btu/Wh to electricity from renewable sources.

DOE multiplied the fuel share weights for sector and end-use, described in appendix 15A of this TSD, by the fuel specific marginal heat rates, and summed over all fuel types, to define a heat rate for each sector/end-use. This step incorporates the transmission and distribution losses. In equation form:

$$h(u,y) = (1 + TDLoss) * \sum_{r,f} g(r,f,y)\, H(f,y)$$

Where:

$TDLoss$ = the fraction of total generation that is lost in transmission and distribution, equal to 0.07037
u = an index representing the sector/end-use (e.g. commercial cooling)
y = the analysis year
f = the fuel type
$H(f,y)$ = the fuel-specific heat rate
$g(r,f,y)$ = the fraction of generation provided by fuel type f for end-use u in year y
$h(u,y)$ = the end-use specific marginal heat rate

The sector/end-use specific heat rates are shown in Table 10B.2.1. These heat rates convert site electricity to primary energy in quads; i.e., the units used in the table are quads per TWh.

Table 10B.2.1 Electric Power Heat Rates (MMBtu/MWh) by Sector and End-Use

	2025	2030	2035	2040	2045	2050+
Residential						
Clothes Dryers	9.591	9.390	9.339	9.283	9.225	9.225
Cooking	9.577	9.375	9.325	9.270	9.212	9.213
Freezers	9.606	9.403	9.349	9.290	9.231	9.231
Lighting	9.620	9.426	9.376	9.320	9.261	9.261
Refrigeration	9.605	9.403	9.349	9.291	9.231	9.231
Space Cooling	9.497	9.266	9.202	9.143	9.086	9.086
Space Heating	9.637	9.446	9.397	9.340	9.281	9.281
Water Heating	9.599	9.403	9.354	9.299	9.241	9.242
Other Uses	9.590	9.390	9.340	9.284	9.226	9.226
Commercial						
Cooking	9.500	9.296	9.253	9.203	9.150	9.152
Lighting	9.521	9.317	9.272	9.220	9.166	9.168
Office Equipment (Non-Pc)	9.460	9.250	9.208	9.159	9.107	9.110
Office Equipment (Pc)	9.460	9.250	9.208	9.159	9.107	9.110
Refrigeration	9.580	9.379	9.330	9.275	9.217	9.218
Space Cooling	9.474	9.240	9.178	9.119	9.063	9.063
Space Heating	9.645	9.454	9.404	9.347	9.287	9.287
Ventilation	9.582	9.382	9.333	9.278	9.220	9.221
Water Heating	9.499	9.296	9.254	9.205	9.151	9.154
Other Uses	9.477	9.269	9.226	9.177	9.125	9.127
Industrial						
All Uses	9.477	9.269	9.226	9.177	9.125	9.127

10B.3 FFC METHODOLOGY

The methods used to calculate FFC energy use are summarized here. The mathematical approach to determining FCC is discussed in Coughlin (2012).[4] Details related to the modeling of the fuel production chain are presented in Coughlin (2013).[5]

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 may 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 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).

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.

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.

The method for performing the full-fuel-cycle analysis utilizes data and projections published in the *AEO 2022*. Table 10B.3.1 summarizes the 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.3.1 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 *AEO 2022* 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, however, arises exclusively from variables taken from the *AEO*.

10B.4 ENERGY MULTIPLIERS FOR THE FULL FUEL CYCLE

FFC energy multipliers for selected years are presented in Table 10B.4.1. The 2050 value was held constant for the analysis period beyond 2050, which is the last year in the *AEO 2022* projection. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation throughout the forecast period.

Table 10B.4.1 Energy Multipliers for the Full Fuel Cycle (Based on *AEO 2022*)

	2025	2030	2035	2040	2045	2050+
Electricity (grid)	1.044	1.041	1.039	1.039	1.039	1.039

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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 1981 to 2021 to project future price for conventional gas cooking products, and PPI data of "electric household ranges, ovens, surface cooking units and equipment" from 1967 to 2021to project future price for conventional electric cooking products. 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 conventional cooking products. The two price sensitivity scenarios DOE considered for both types of conventional cooking products 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 CONVENTIONAL GAS COOKING PRODUCTS

For the price sensitivity analysis for conventional gas cooking products, 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 2002 to 2021 and the high price decline scenario is based on the "gas household ranges, ovens, surface cooking units and equipment" PPI series from 1981 to 2001. 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 conventional gas cooking products. 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 conventional gas cooking products under low price decline and high price decline scenarios.

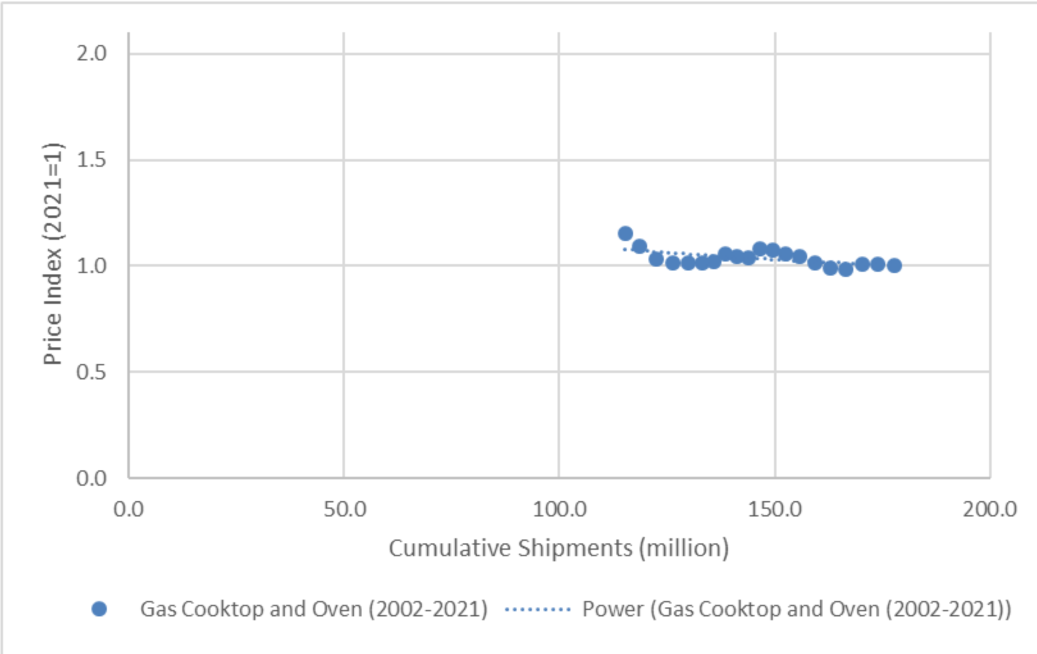

Figure 10C.2.1 Low Price Decline Scenario: Relative Price versus Cumulative Shipments of Conventional Gas Cooking Products from 2002 to 2021

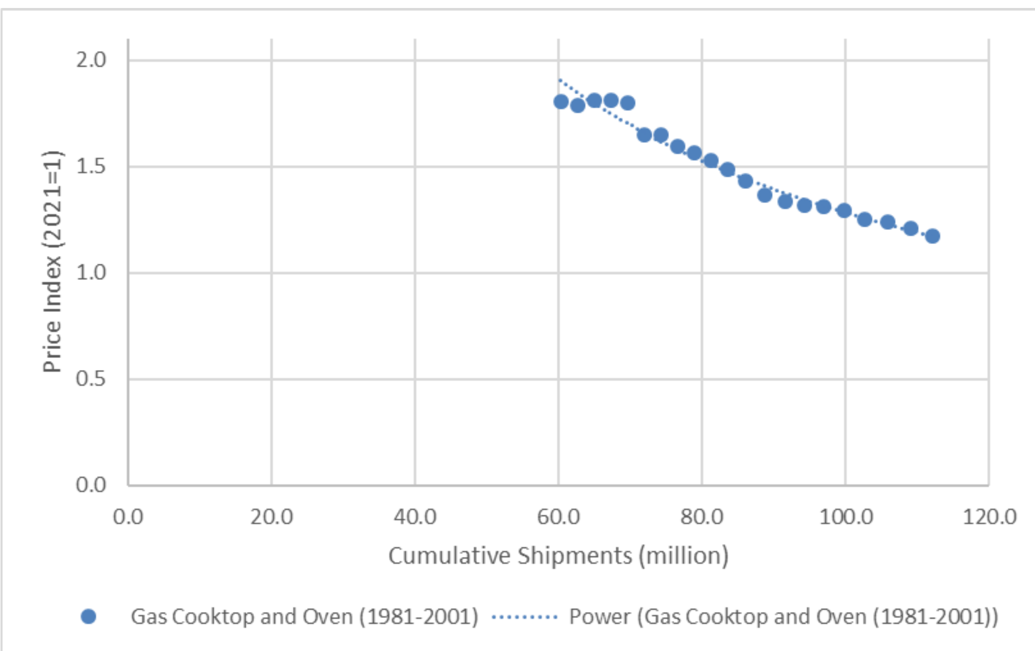

Figure 10C.2.2 High Price Decline Scenario: Relative Price versus Cumulative Shipments of Conventional Gas Cooking Products from 1981 to 2001

For the low price decline scenario, the parameter values obtained are:

P_o = $2.406^{+1.958}_{-1.080}$ (95% confidence), and
b = 0.169±0.120 (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 $11.1^{+7.1}_{-7.7}$% (95% confidence).

For the high price decline scenario, the parameter values obtained are:

P_o = $46.809^{+14.900}_{-11.302}$ (95% confidence), and
b = 0.781±0.062 (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 $41.8^{+2.5}_{-2.6}$% (95% confidence).

DOE then derived two price factor indices for conventional gas cooking products, 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 CONVENTIONAL ELECTRIC COOKING PRODUCTS

For the price sensitivity analysis, DOE used the same experience curve approach as the default case to forecast future prices of conventional electric cooking products. The low price decline scenario is based on the “electric household ranges, ovens, surface cooking units and equipment” PPI series from 1967 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 2021 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 conventional electric cooking products with power-law functional form.

Figure 10C.3.1 and Figure 10C.3.2 present the fit of experience curve for conventional electric cooking products under low price decline and high price decline scenarios.

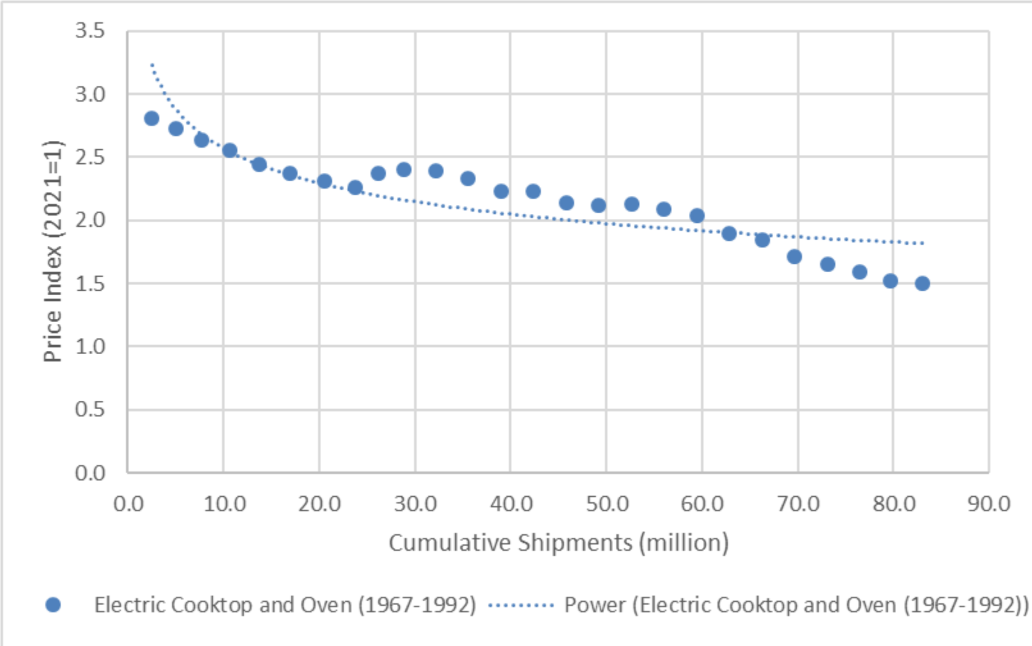

Figure 10C.3.1 Low Price Decline Scenario: Relative Price versus Cumulative Shipments of Conventional Electric Cooking Products from 1967 to 1992

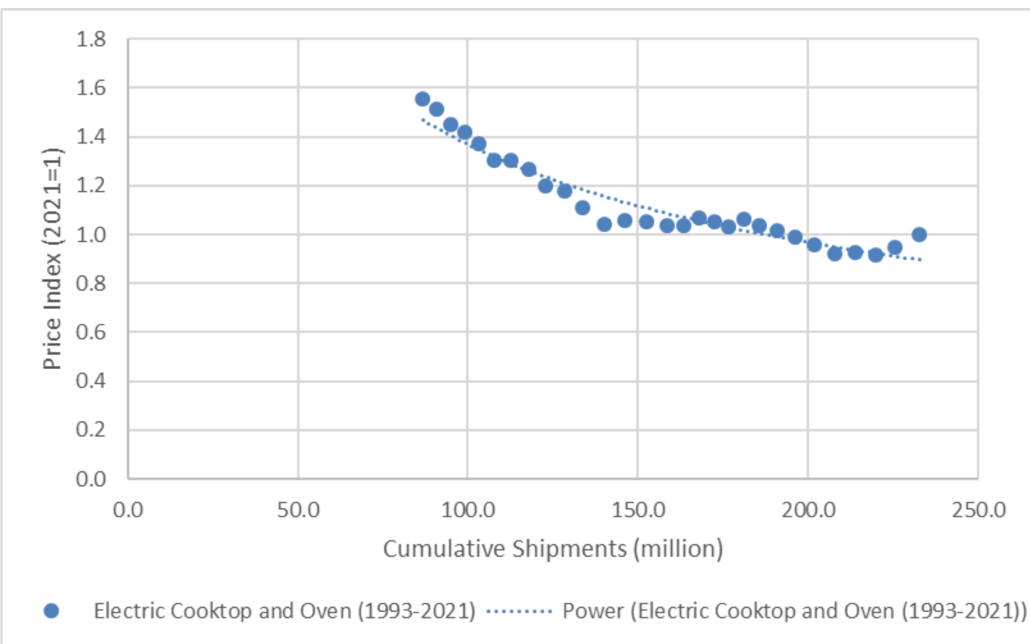

Figure 10C.3.2 High Price Decline Scenario: Relative Price versus Cumulative Shipments of Conventional Electric Cooking Products from 1993 to 2021

For the low price decline scenario, the parameter values obtained are:

$P_o = 3.749^{+0.625}_{-0.536}$ (95% confidence), and
b = 0.164±0.043 (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 $10.7^{+2.6}_{-2.7}\%$ (95% confidence).

For the high price decline scenario, the parameter values obtained are:

$P_o = 13.677^{+1.606}_{-3.446}$ (95% confidence), and
b = 0.500±0.058 (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 $29.3^{+2.8}_{-2.9}\%$ (95% confidence).

DOE then derived two price factor indices for conventional electric cooking products, 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 conventional gas and electric cooking products respectively.

Table 10C.4.1 Price Trend Scenarios

Product	Scenario	Price Trend	Learning Rate %	Annual Price Decline Rate %
Conventional Gas Cooking Products	Default	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1981 to 2021)	35.40	1.00
	Low Price Decline	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (2002 to 2021)	11.06	0.27
	High Price Decline	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1981 to 2001)	41.81	1.24

Product	Scenario	Price Trend	Learning Rate %	Annual Price Decline Rate %
Conventional Electric Cooking Products	Default	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1967 to 2021)	20.20	0.69
	Low Price Decline	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1967 to 1992)	10.73	0.35
	High Price Decline	Experience curve estimation using gas household ranges, ovens, surface cooking units and equipment PPI (1993 to 2021)	29.28	1.05

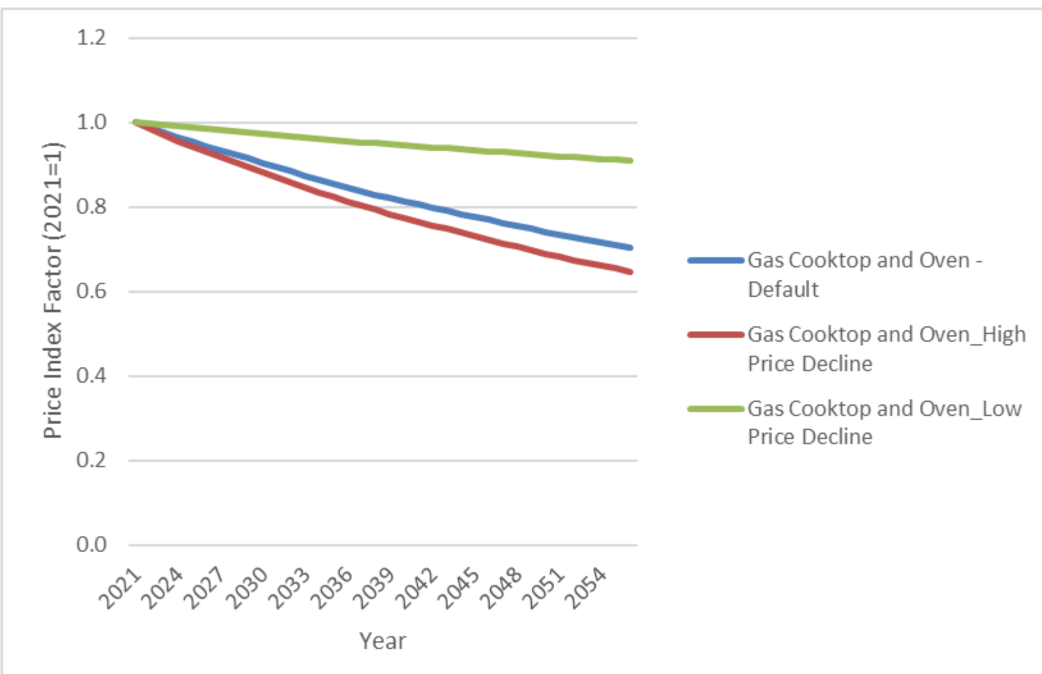

Figure 10C.4.1 Conventional Gas Cooking Product Price Factor Indexes for the Default Case and Sensitivity Cases

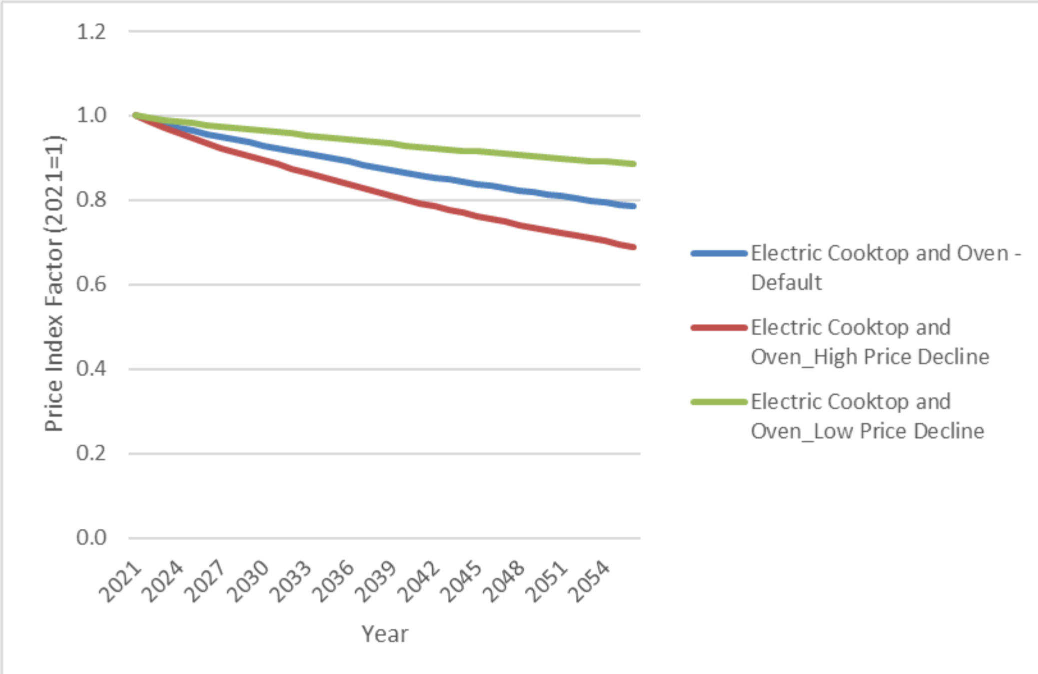

Figure 10C.4.2 Conventional Electric Cooking Product Price Factor Indexes for the Default Case and Sensitivity Cases

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 2021$)

Discount Rates	Product Class	TSL 1	TSL 2	TSL 3
Default	Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
	Electric Smooth Element Cooking Tops	0.77	0.77	(27.26)
	Gas Cooking Tops	0.02	0.77	0.77
	Electric Standard Oven, Freestanding	0.02	0.02	(0.45)
	Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.05)
	Electric Self-Clean Oven, Freestanding	0.06	0.06	(0.41)
	Electric Self-Clean Oven, Built-In/Slide-In	0.04	0.04	(0.10)
	Gas Standard Oven, Freestanding	0.02	0.02	(0.20)
	Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.02)
	Gas Self-Clean Oven, Freestanding	0.02	0.02	(0.03)
	Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
	All	**0.96**	**1.71**	**(27.75)**
	Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00

Discount Rates	Product Class	TSL 1	TSL 2	TSL 3
Low Price Decline	Electric Smooth Element Cooking Tops	0.77	0.77	(28.45)
	Gas Cooking Tops	(0.05)	0.70	0.70
	Electric Standard Oven, Freestanding	0.02	0.02	(0.50)
	Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.05)
	Electric Self-Clean Oven, Freestanding	0.06	0.06	(0.50)
	Electric Self-Clean Oven, Built-In/Slide-In	0.04	0.04	(0.15)
	Gas Standard Oven, Freestanding	0.02	0.02	(0.25)
	Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.02)
	Gas Self-Clean Oven, Freestanding	0.02	0.02	(0.04)
	Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
	All	**0.88**	**1.63**	**(29.26)**
High Price Decline	Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
	Electric Smooth Element Cooking Tops	0.78	0.78	(26.09)
	Gas Cooking Tops	0.05	0.80	0.80
	Electric Standard Oven, Freestanding	0.02	0.02	(0.41)
	Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.04)
	Electric Self-Clean Oven, Freestanding	0.06	0.07	(0.31)
	Electric Self-Clean Oven, Built-In/Slide-In	0.04	0.04	(0.05)
	Gas Standard Oven, Freestanding	0.02	0.02	(0.19)
	Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.02)
	Gas Self-Clean Oven, Freestanding	0.02	0.02	(0.02)
	Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
	All	**0.99**	**1.74**	**(26.34)**

Table 10C.5.2 Consumer Conventional Cooking Products: Net Present Value of Consumer Impacts Under Alternative Product Price Forecasts (7 Percent Discount Rate, billion 2021$)

Discount Rates	Product Class	TSL 1	TSL 2	TSL 3
Default	Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
	Electric Smooth Element Cooking Tops	0.31	0.31	(14.47)
	Gas Cooking Tops	(0.05)	0.27	0.27
	Electric Standard Oven, Freestanding	0.01	0.01	(0.40)
	Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.04)
	Electric Self-Clean Oven, Freestanding	0.03	0.03	(0.61)
	Electric Self-Clean Oven, Built-In/Slide-In	0.01	0.01	(0.26)
	Gas Standard Oven, Freestanding	0.01	0.01	(0.12)

Discount Rates	Product Class	TSL 1	TSL 2	TSL 3
Default	Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.01)
	Gas Self-Clean Oven, Freestanding	0.01	0.01	(0.02)
	Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
	All	**0.33**	**0.65**	**(15.68)**
Low Price Decline	Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
	Electric Smooth Element Cooking Tops	0.31	0.31	(15.02)
	Gas Cooking Tops	(0.09)	0.23	0.23
	Electric Standard Oven, Freestanding	0.01	0.01	(0.43)
	Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.04)
	Electric Self-Clean Oven, Freestanding	0.03	0.03	(0.66)
	Electric Self-Clean Oven, Built-In/Slide-In	0.01	0.01	(0.29)
	Gas Standard Oven, Freestanding	0.01	0.01	(0.14)
	Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.01)
	Gas Self-Clean Oven, Freestanding	0.01	0.01	(0.03)
	Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
	All	**0.29**	**0.61**	**(16.40)**
High Price Decline	Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
	Electric Smooth Element Cooking Tops	0.31	0.31	(13.92)
	Gas Cooking Tops	(0.04)	0.28	0.28
	Electric Standard Oven, Freestanding	0.01	0.01	(0.38)
	Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.04)
	Electric Self-Clean Oven, Freestanding	0.03	0.03	(0.56)
	Electric Self-Clean Oven, Built-In/Slide-In	0.01	0.01	(0.24)
	Gas Standard Oven, Freestanding	0.01	0.01	(0.12)
	Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.01)
	Gas Self-Clean Oven, Freestanding	0.01	0.01	(0.02)
	Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
	All	**0.34**	**0.66**	**(15.00)**

APPENDIX 10D. NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE USING ALTERNATIVE GROWTH SCENARIOS

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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 2022* (AEO 2022).[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.

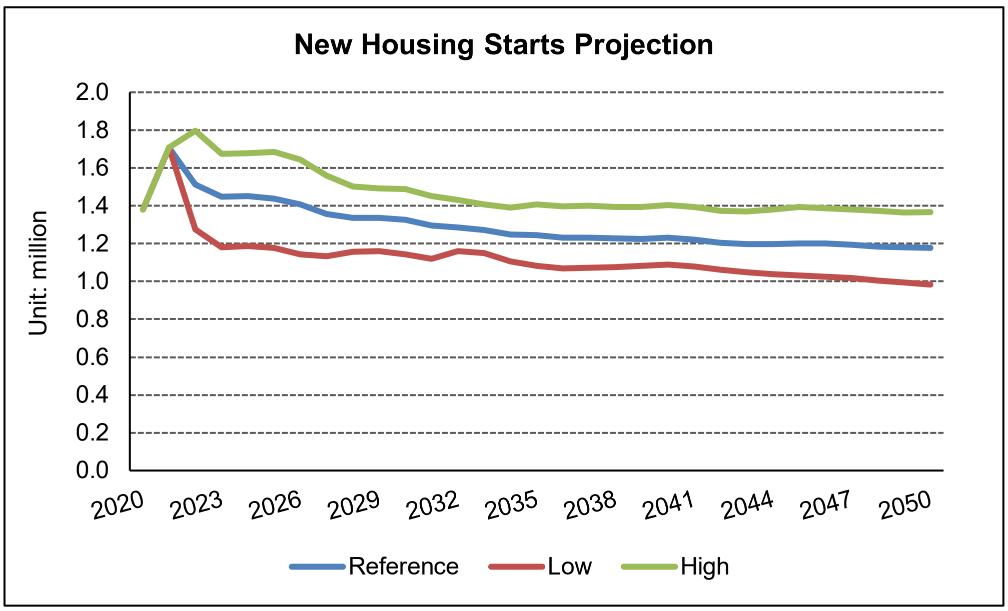

Figure 10D.1.1 New Housing Starts Projection under Alternative AEO2022 Economic Growth Scenarios

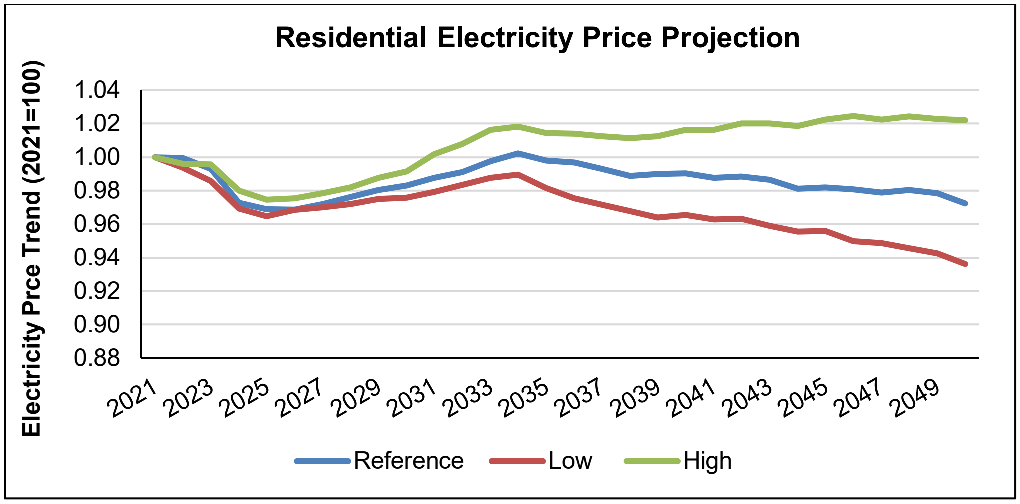

Figure 10D.1.2 Average Residential Electricity Price Projection under Alternative AEO2022 Economic Growth Scenarios

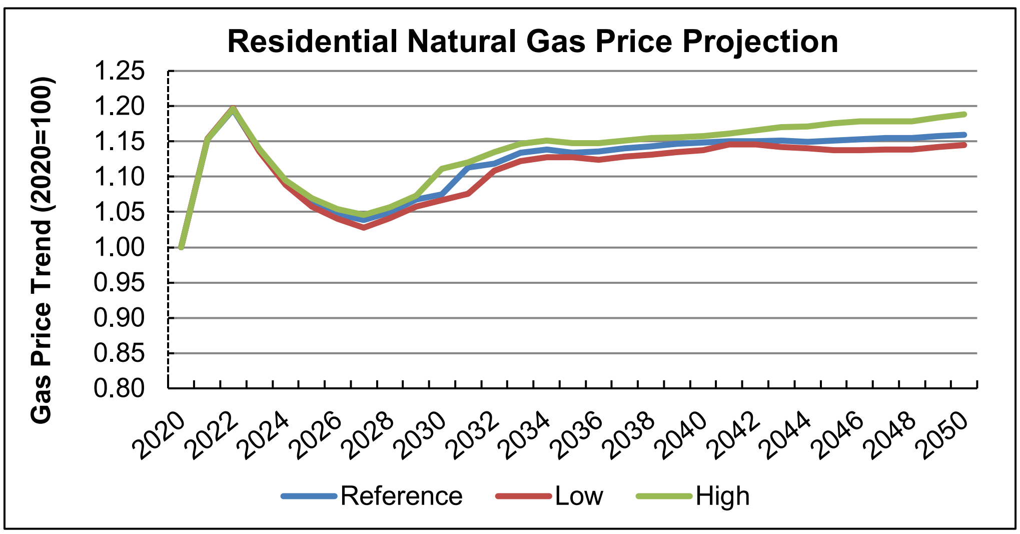

Figure 10D.1.3 Average Residential Natural Gas Price Forecasts under Alternative AEO2022 Economic Growth Scenarios

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 Open (Coil) Element Cooking Tops	0.00	0.00	0.00
Electric Smooth Element Cooking Tops	0.12	0.12	0.23
Gas Cooking Tops	0.13	0.32	0.32
Electric Standard Oven, Freestanding	0.00	0.03	0.19
Electric Standard Oven, Built-In/Slide-In	0.00	0.00	0.02
Electric Self-Clean Oven, Freestanding	0.01	0.07	0.48
Electric Self-Clean Oven, Built-In/Slide-In	0.01	0.04	0.26
Gas Standard Oven, Freestanding	0.00	0.02	0.02
Gas Standard Oven, Built-In/Slide-In	0.00	0.00	0.00
Gas Self-Clean Oven, Freestanding	0.00	0.02	0.01
Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	0.00
All	**0.29**	**0.63**	**1.52**

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 2021$)	Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
	Electric Smooth Element Cooking Tops	0.83	0.83	(28.17)
	Gas Cooking Tops	0.03	0.81	0.81
	Electric Standard Oven, Freestanding	0.03	0.03	(0.34)
	Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.04)
	Electric Self-Clean Oven, Freestanding	0.07	0.07	(0.14)
	Electric Self-Clean Oven, Built-In/Slide-In	0.04	0.04	0.05
	Gas Standard Oven, Freestanding	0.02	0.02	(0.21)
	Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.02)
	Gas Self-Clean Oven, Freestanding	0.02	0.02	(0.03)
	Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
	All	**1.05**	**1.83**	**(28.08)**
7% (billion 2021$)	Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
	Electric Smooth Element Cooking Tops	0.33	0.33	(14.93)
	Gas Cooking Tops	(0.05)	0.28	0.28

Discount Rates	Product Class	TSL 1*	TSL 2	TSL 3*
7% (billion 2021$)	Electric Standard Oven, Freestanding	0.01	0.01	(0.36)
	Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.04)
	Electric Self-Clean Oven, Freestanding	0.03	0.03	(0.52)
	Electric Self-Clean Oven, Built-In/Slide-In	0.01	0.01	(0.21)
	Gas Standard Oven, Freestanding	0.01	0.01	(0.12)
	Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.01)
	Gas Self-Clean Oven, Freestanding	0.01	0.01	(0.02)
	Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
	All	**0.36**	**0.69**	**(15.94)**

*Negative values denoted in parentheses.

10D.3 NIA 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 Open (Coil) Element Cooking Tops	0.00	0.00	0.00
Electric Smooth Element Cooking Tops	0.11	0.11	0.21
Gas Cooking Tops	0.13	0.31	0.31
Electric Standard Oven, Freestanding	0.00	0.00	0.18
Electric Standard Oven, Built-In/Slide-In	0.00	0.00	0.01
Electric Self-Clean Oven, Freestanding	0.01	0.01	0.44
Electric Self-Clean Oven, Built-In/Slide-In	0.01	0.01	0.24
Gas Standard Oven, Freestanding	0.00	0.00	0.02
Gas Standard Oven, Built-In/Slide-In	0.00	0.00	0.00
Gas Self-Clean Oven, Freestanding	0.00	0.00	0.01
Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	0.00
All	**0.27**	**0.45**	**1.41**

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 2021$)	Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
	Electric Smooth Element Cooking Tops	0.72	0.72	(26.33)
	Gas Cooking Tops	0.02	0.74	0.74
	Electric Standard Oven, Freestanding	0.02	0.02	(0.55)
	Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.05)
	Electric Self-Clean Oven, Freestanding	0.06	0.06	(0.64)
	Electric Self-Clean Oven, Built-In/Slide-In	0.03	0.03	(0.22)
	Gas Standard Oven, Freestanding	0.02	0.02	(0.20)
	Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.02)
	Gas Self-Clean Oven, Freestanding	0.02	0.02	(0.03)
	Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
	All	**0.90**	**1.62**	**(27.29)**
7% (billion 2021$)	Electric Open (Coil) Element Cooking Tops	0.00	0.00	0.00
	Electric Smooth Element Cooking Tops	0.29	0.29	(14.00)
	Gas Cooking Tops	(0.05)	0.26	0.26
	Electric Standard Oven, Freestanding	0.01	0.01	(0.43)
	Electric Standard Oven, Built-In/Slide-In	0.00	0.00	(0.04)
	Electric Self-Clean Oven, Freestanding	0.02	0.02	(0.69)
	Electric Self-Clean Oven, Built-In/Slide-In	0.01	0.01	(0.31)
	Gas Standard Oven, Freestanding	0.01	0.01	(0.12)
	Gas Standard Oven, Built-In/Slide-In	0.00	0.00	(0.01)
	Gas Self-Clean Oven, Freestanding	0.01	0.01	(0.02)
	Gas Self-Clean Oven, Built-In/Slide-In	0.00	0.00	(0.00)
	All	**0.30**	**0.61**	**(15.37)**

*Negative values denoted in parentheses.

REFERENCES

1. U.S. Department of Energy-Energy Information Administration. *Annual Energy Outlook 2022 with Projections to 2050,* 2022. Washington, DC. Report Number: DOE/EIA-0383(2022). http://www.eia.gov/forecasts/aeo/

APPENDIX 12A. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

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APPENDIX 12A. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

12A.1 INTRODUCTION AND PURPOSE

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards on manufacturers in aggregate. The basic mode of analysis is to estimate the change in the value of the industry, or industry net present value (INPV), following new and/or amended energy conservation standard, as represented by trial standard levels.

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 no-standards case) and under different trial standard levels (*i.e.*, the standards cases).

Outputs from the model consist of summary financial metrics, graphs of major variables, and access to the complete cash flow calculation.

12A.2 MODEL DESCRIPTION

The basic structure of the GRIM is a standard annual cash flow analysis that uses financial parameters, shipments from the national impact analysis, and manufacturing production costs 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: an industry income statement and an industry cash flow statement. 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 output sheet ("No STDs Case DCF" tab) of the GRIM. Please refer to Figure 12.A.1.

Industry Income Statement

(1) ***Revenues:*** The GRIM presents annual revenues for the industry. Revenues are calculated by multiplying unit sales at each efficiency level by the associated manufacturer sales price. Annual revenues are the sum of revenues from all efficiency levels in a given year.

(2) ***Total Shipments:*** Total annual shipments for the industry were obtained from the National Impact Analysis. Total shipments are the sum of shipments for all efficiency levels in a given year. Shipments by TSL, product class, and efficiency level can be found in the "Shipments" tab of the GRIM.

(3) ***MPC:*** The manufacturer production cost (MPC).

(4) ***Overhead:*** The portion of MPC that accounts for production facility overhead, including utilities, maintenance, property tax, and insurance. The annual overhead cost is the sum of the overhead component of MPC for all units shipped in a year.

(5) ***Standard SG&A:*** Selling, general, and administrative (SG&A) expenses are calculated by multiplying revenue by the SG&A percentage found on the "Financials" tab of the GRIM.

(6) ***R&D:*** Research and development (R&D) expenses are calculated by multiplying revenue by the R&D value found on the "Financials" tab of the GRIM.

(7) ***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 new and/or amended energy conservation standards. The GRIM allocates these costs over the period between the standard's announcement year (*i.e.,* publication of a final rule) and the compliance year. Product conversion cost details can be found in the "Conversion Costs" tab of the GRIM.

(8) ***Stranded Assets:*** In the compliance year of the standard, the GRIM can include a one-time write-off of assets that become obsolete or non-performing due to new and/or amended standards. Stranded asset details can be found in the "Conversion Costs" tab of the GRIM.

(9) ***Earnings Before Interest and Taxes (EBIT):*** Includes profits before deductions for interest paid and taxes.

(10) ***Taxes:*** Industry tax expenses calculated by multiplying EBIT by the tax rate contained in "Financials" tab of the GRIM.

(11) ***Net Operating Profits After Taxes (NOPAT):*** Computed by subtracting manufacturer production costs (Materials + Labor + Overhead + Depreciation), SG&A, R&D, Product Conversion Costs, and Taxes from Revenues.

Industry Cash Flow Statement

(1) ***NOPAT***: This is a repeat of NOPAT in the Industry Income Statement.

(2) ***Depreciation***: Industry depreciation is added back into the Statement of Cash Flows because it is a non-cash expense.

(3) ***Loss on Disposal of Stranded Assets:*** This is a repeat of Stranded Assets in the Industry Income Statement. This is added back into the Statement of Cash Flows because it is a non-cash expense.

(4) ***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. The Working Capital percentage can be found on the "Financials" tab of the GRIM.

(5) ***Cash Flow from Operations***: Calculated by taking NOPAT, adding back the non-cash items Depreciation and Loss on Disposal of Stranded Assets, and subtracting the Change in Working Capital.

(6) ***Ordinary Capital Expenditures:*** Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of revenues based on the value on the "Financials" tab of the GRIM.

(7) ***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. Capital conversion cost details can be found in the "Conversion Costs" tab of the GRIM.

(8) ***Free Cash Flow:*** Annual cash flow from operations and investments; computed by subtracting Ordinary Capital Expenditures and Capital Conversion Costs from Cash Flows from Operations.

(9) ***Free Cash Flow:*** This is a repeat of Free Cash Flow from the Industry Cash Flow Statement.

(10) ***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. The terminal growth rate can be found in the "Financials" tab of the GRIM.

(11) ***Present Value Factor:*** Factor used to calculate an estimate of the present value of an amount to be received in the future that is calculated using the industry's Weighted Average Cost of Capital, found on the "Financials" tab of the GRIM.

(12) ***Discounted Cash Flow:*** Free Cash Flows multiplied by the Present Value Factor. For the final year of the analysis, the discounted cash flow includes the discounted Terminal Value.

(13) ***Industry Net Present Value (INPV):*** The sum of Discounted Cash Flows from the reference year to the terminal year of the GRIM analysis.

Standard Case DCF   **Navigation**

Industry Income Statement (in 2020$ millions)	2018	Ref Yr 2019	2020	Ancmt Yr 2021	2022	2023	2024	2025	Std Yr 2026	2027	2028
Revenues	$ 8,529.7	$ 8,929.4	$ 9,308.1	$ 9,586.6	$ 9,786.7	$ 9,970.5	$ 10,207.6	$ 10,365.0	$ 10,549.2	$ 10,761.7	$ 10,977.4
Total Shipments *(million units)*	6.534	6.831	7.113	7.320	7.470	7.606	7.644	7.757	7.889	8.041	8.195
- MPC	$ 6,357.7	$ 6,655.4	$ 6,937.6	$ 7,145.0	$ 7,294.2	$ 7,431.1	$ 7,607.6	$ 7,724.8	$ 7,862.0	$ 8,020.3	$ 8,180.8
- Standard SG&A	$ 1,347.7	$ 1,410.8	$ 1,470.7	$ 1,514.7	$ 1,546.3	$ 1,575.3	$ 1,612.8	$ 1,637.7	$ 1,666.8	$ 1,700.4	$ 1,734.4
- R&D	$ 189.4	$ 198.2	$ 206.6	$ 212.8	$ 217.3	$ 221.3	$ 226.6	$ 230.1	$ 234.2	$ 238.9	$ 243.7
- Product Conversion Costs	$ -	$ -	$ 0.8	$ 6.8	$ 14.3	$ 17.9	$ 0.8	$ -	$ -	$ -	$ -
- Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 9.2	$ -	$ -
Earnings Before Interest and Taxes (EBIT)	$ 635.0	$ 664.9	$ 692.4	$ 707.3	$ 714.6	$ 724.8	$ 759.8	$ 772.4	$ 777.0	$ 802.2	$ 818.4
Per Unit EBIT *($/unit)*	$ 97.18	$ 97.34	$ 97.35	$ 96.62	$ 95.67	$ 95.30	$ 99.40	$ 99.57	$ 98.49	$ 99.76	$ 99.87
EBIT/Revenues (%)	*7.4%*	*7.4%*	*7.4%*	*7.4%*	*7.3%*	*7.3%*	*7.4%*	*7.5%*	*7.4%*	*7.5%*	*7.5%*
- Taxes	$ 215.9	$ 226.1	$ 235.4	$ 240.5	$ 243.0	$ 246.4	$ 258.3	$ 262.6	$ 264.2	$ 272.8	$ 278.3
Net Operating Profit after Taxes (NOPAT)	**$ 419.1**	**$ 438.8**	**$ 457.0**	**$ 466.8**	**$ 471.7**	**$ 478.4**	**$ 501.4**	**$ 509.8**	**$ 512.8**	**$ 529.5**	**$ 540.2**

Industry Cash Flow Statement											
NOPAT	$ 419.1	$ 438.8	$ 457.0	$ 466.8	$ 471.7	$ 478.4	$ 501.4	$ 509.8	$ 512.8	$ 529.5	$ 540.2
+ Depreciation	$ 153.5	$ 160.7	$ 167.5	$ 172.6	$ 176.2	$ 179.5	$ 183.7	$ 186.6	$ 189.9	$ 193.7	$ 197.6
+ Loss on Disposal of Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 9.2	$ -	$ -
- Change in Working Capital	$ -	$ 39.6	$ 37.5	$ 27.6	$ 19.8	$ 18.2	$ 23.5	$ 15.6	$ 18.2	$ 21.0	$ 21.3
Cash Flows from Operations	$ 572.6	$ 560.0	$ 587.1	$ 611.8	$ 628.0	$ 639.6	$ 661.7	$ 680.8	$ 693.7	$ 702.1	$ 716.4
- Ordinary Capital Expenditures	$ 170.6	$ 178.6	$ 186.2	$ 191.7	$ 195.7	$ 199.4	$ 204.2	$ 207.3	$ 211.0	$ 215.2	$ 219.5
- Capital Conversion Costs	$ -	$ -	$ 1.2	$ 10.4	$ 22.0	$ 27.5	$ -	$ -	$ -	$ -	$ -
Free Cash Flow	**$ 402.0**	**$ 381.4**	**$ 399.7**	**$ 409.7**	**$ 410.3**	**$ 412.8**	**$ 457.5**	**$ 473.5**	**$ 482.7**	**$ 486.9**	**$ 496.9**

Discounted Industry Cash Flow											
Free Cash Flow	$ 402.0	$ 381.4	$ 399.7	$ 409.7	$ 410.3	$ 412.8	$ 457.5	$ 473.5	$ 482.7	$ 486.9	$ 496.9
Terminal Value	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor	*0.000*	*1.000*	*0.901*	*0.812*	*0.731*	*0.659*	*0.593*	*0.535*	*0.482*	*0.434*	*0.391*
Discounted Cash Flow	$ -	$ 381.4	$ 360.1	$ 332.5	$ 300.0	$ 271.9	$ 271.5	$ 253.1	$ 232.5	$ 211.3	$ 194.2

INPV at No STDs Case $ 4,652.2

Net PPE	$ -	$ 17.9	$ 37.7	$ 67.2	$ 108.8	$ 156.2	$ 176.6	$ 197.3	$ 209.2	$ 230.7	$ 252.7
Net PPE as % of Sales	0.0%	0.2%	0.4%	0.7%	1.1%	1.6%	1.7%	1.9%	2.0%	2.1%	2.3%
Net Working Capital	$ 844.4	$ 884.0	$ 921.5	$ 949.1	$ 968.9	$ 987.1	$ 1,010.6	$ 1,026.1	$ 1,044.4	$ 1,065.4	$ 1,086.8
Return on Invested Capital (ROIC)	49.63%	48.66%	47.64%	45.93%	43.77%	41.84%	42.24%	41.67%	40.91%	40.85%	40.33%
Weighted Average Cost of Capital (WACC)	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%
Return on Sales (EBIT/Sales)	7.44%	7.45%	7.44%	7.38%	7.30%	7.27%	7.44%	7.45%	7.37%	7.45%	7.46%

Figure 12A.2.1 Detailed Income Statement and Cash Flow Statement Example

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. DOE's methodology is based on results published with the most recent edition of the *Annual Energy Outlook (AEO)* which is published by the Energy Information Agency (EIA). For this analysis DOE used *AEO 2022*.[1] DOE developed end-use specific emissions intensity coefficients, in units of mass of pollutant per kWh of site (grid) electricity, for each pollutant. The methodology is based on the more general approach used for all the utility sector impacts calculations, which is described in appendix 15A of this TSD and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014; Coughlin, 2019).[2,3] This appendix describes the methodology used to estimate the upstream emissions factors, and presents the values used for all emissions factors.

13A.2 POWER SECTOR AND SITE EMISSIONS FACTORS

Power sector marginal emissions factors are calculated by looking at the difference, over the full analysis period, in fuel consumption and emissions across a variety of cases published with the AEO. The analysis produces a set of emissions intensity factors that quantify the reduction in emissions of a given pollutant per unit reduction of fuel used in (grid) electricity generation for each of the primary fossil fuel types (coal, natural gas and oil). These factors are combined with estimates of the fraction of generation allocated to each fuel type, also calculated from *AEO 2022* data, for each sector and end-use. The result is a set of end-use specific marginal emissions intensity factors, summarized 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). Power sector emissions factors are presented in Table 13A.4.2 Table 13A.4.2 through Table 13A.4.7.

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. To quantify the reduction in these emissions from a considered standard level, DOE used emissions intensity factors from Environmental Protection Agency (EPA) publications.[4] These factors, presented in Table 13A.4.1, are constant in time. The EPA defines SO_2 emissions in terms of a formula that depends on the sulfur content of the fuel. The typical use of petroleum-based fuels in buildings if for heating, and a typical sulfur content for heating oils is a few hundred parts-per-million (ppm). The value provided in Table 13A.4.1 corresponds to a sulfur content of approximately 100 ppm.

13A.3 UPSTREAM FACTORS

The FFC upstream emissions are estimated based on the methodology developed by Coughlin (2013).[5] 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).[5] 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).[6] This review includes estimates of the difference between fugitive emissions factors for conventional production of natural vs. unconventional (shale or tight gas). These estimates rely in turn on data gathered by EPA under new GHG reporting requirements for the petroleum and natural gas industries.[7,8] The value for methane, if it were translated to a leakage rate, would be equivalent to 1.3%. Actual leakage rates of methane at various stages of the production process are highly variable and the subject of ongoing research. In a comprehensive review of the literature, Brandt et al. (2014)[8] find that, while regional studies with very high emissions rates may not be representative of typical natural gas systems, it is also true that official inventories have most likely underestimated methane emissions. 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 2022* 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 the site electricity supplied from the grid and site use of the fuel.

Table 13A.4.1 Site Combustion Emissions Factors

Species	Natural Gas g/mcf	Distillate Oil g/bbl
CH_4	1.03E+00	1.33E+01
CO_2	5.47E+04	4.46E+05
N_2O	1.03E-01	8.65E+00
NO_x	4.36E+01	3.62E+02
SO_2	2.73E-01	2.20E+02

Table 13A.4.2 Power Sector Emissions Factors for CO_2 (Million Short Tons (MMsT)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	477	417	369	341	324	313
Cooking	472	412	365	337	321	310
Freezers	486	424	376	347	330	318
Lighting	486	424	375	346	328	316
Refrigeration	485	424	376	347	329	318
Space Cooling	457	400	358	333	318	308
Space Heating	492	429	379	349	331	319
Water Heating	478	417	369	340	324	312
Other Uses	477	416	368	340	324	312
Commercial Sector						
Cooking	440	383	340	316	302	292
Lighting	449	391	347	322	307	297
Office Equipment (Non-Pc)	426	370	330	307	294	285
Office Equipment (Pc)	426	370	330	307	294	285
Refrigeration	473	412	365	337	321	310
Space Cooling	449	393	352	328	314	305
Space Heating	495	432	381	351	333	321
Ventilation	473	413	366	338	321	310
Water Heating	439	382	339	315	301	291
Other Uses	432	376	334	311	297	288
Industrial Sector						
All Uses	432	376	334	311	297	288

Table 13A.4.3 Power Sector Emissions Factors for CH_4 (Million Short Tons (MMst)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	0.0374	0.0328	0.0282	0.0250	0.0227	0.0214
Cooking	0.0365	0.0320	0.0276	0.0244	0.0222	0.0210
Freezers	0.0385	0.0338	0.0291	0.0258	0.0234	0.0221
Lighting	0.0389	0.0342	0.0294	0.0260	0.0236	0.0223
Refrigeration	0.0384	0.0337	0.0290	0.0257	0.0234	0.0221
Space Cooling	0.0330	0.0289	0.0249	0.0221	0.0201	0.0190
Space Heating	0.0398	0.0350	0.0301	0.0267	0.0242	0.0228
Water Heating	0.0377	0.0331	0.0284	0.0252	0.0229	0.0216
Other Uses	0.0373	0.0327	0.0282	0.0250	0.0227	0.0214
Commercial Sector						
Cooking	0.0317	0.0278	0.0239	0.0212	0.0193	0.0182
Lighting	0.0330	0.0289	0.0249	0.0221	0.0201	0.0190
Office Equipment (Non-Pc)	0.0294	0.0257	0.0221	0.0196	0.0179	0.0169
Office Equipment (Pc)	0.0294	0.0257	0.0221	0.0196	0.0179	0.0169
Refrigeration	0.0366	0.0322	0.0277	0.0245	0.0223	0.0210
Space Cooling	0.0317	0.0278	0.0239	0.0213	0.0193	0.0183
Space Heating	0.0403	0.0354	0.0305	0.0270	0.0245	0.0231
Ventilation	0.0368	0.0323	0.0278	0.0246	0.0224	0.0211
Water Heating	0.0316	0.0277	0.0238	0.0211	0.0192	0.0181
Other Uses	0.0304	0.0266	0.0229	0.0203	0.0185	0.0175
Industrial Sector						
All Uses	0.0304	0.0266	0.0229	0.0203	0.0185	0.0175

Table 13A.4.4 Power Sector Emissions Factors for Hg (Short Tons (sT)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	1.207	1.067	0.994	0.955	0.886	0.939
Cooking	1.175	1.038	0.967	0.929	0.862	0.913
Freezers	1.249	1.104	1.029	0.989	0.918	0.973
Lighting	1.267	1.120	1.044	1.004	0.932	0.988
Refrigeration	1.246	1.101	1.026	0.987	0.916	0.970
Space Cooling	1.033	0.910	0.846	0.812	0.752	0.796
Space Heating	1.304	1.153	1.075	1.034	0.960	1.018
Water Heating	1.220	1.078	1.005	0.965	0.896	0.950
Other Uses	1.205	1.065	0.992	0.953	0.885	0.937
Commercial Sector						
Cooking	0.996	0.878	0.816	0.782	0.725	0.767
Lighting	1.045	0.922	0.857	0.822	0.762	0.807
Office Equipment (Non-Pc)	0.907	0.798	0.740	0.709	0.656	0.694
Office Equipment (Pc)	0.907	0.798	0.740	0.709	0.656	0.694
Refrigeration	1.181	1.043	0.971	0.933	0.866	0.917
Space Cooling	0.984	0.867	0.805	0.772	0.715	0.756
Space Heating	1.322	1.169	1.090	1.049	0.974	1.033
Ventilation	1.186	1.048	0.976	0.938	0.870	0.922
Water Heating	0.992	0.874	0.812	0.779	0.721	0.763
Other Uses	0.945	0.832	0.773	0.741	0.686	0.725
Industrial Sector						
All Uses	0.945	0.832	0.773	0.741	0.686	0.725

Table 13A.4.5 Power Sector Emissions Factors for N_2O (Million Short Tons (MMsT)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	0.00528	0.00463	0.00398	0.00351	0.00317	0.00299
Cooking	0.00515	0.00452	0.00388	0.00343	0.00310	0.00292
Freezers	0.00544	0.00478	0.00410	0.00362	0.00327	0.00309
Lighting	0.00550	0.00484	0.00415	0.00366	0.00331	0.00312
Refrigeration	0.00543	0.00477	0.00410	0.00362	0.00327	0.00308
Space Cooling	0.00464	0.00406	0.00349	0.00308	0.00278	0.00263
Space Heating	0.00564	0.00496	0.00425	0.00376	0.00339	0.00320
Water Heating	0.00532	0.00467	0.00401	0.00354	0.00320	0.00301
Other Uses	0.00527	0.00463	0.00397	0.00350	0.00317	0.00298
Commercial Sector						
Cooking	0.00445	0.00390	0.00334	0.00295	0.00267	0.00251
Lighting	0.00464	0.00407	0.00349	0.00308	0.00278	0.00262
Office Equipment (Non-Pc)	0.00411	0.00359	0.00308	0.00272	0.00246	0.00232
Office Equipment (Pc)	0.00411	0.00359	0.00308	0.00272	0.00246	0.00232
Refrigeration	0.00517	0.00454	0.00390	0.00344	0.00311	0.00293
Space Cooling	0.00445	0.00390	0.00334	0.00296	0.00267	0.00252
Space Heating	0.00572	0.00502	0.00431	0.00381	0.00344	0.00324
Ventilation	0.00519	0.00456	0.00391	0.00345	0.00312	0.00294
Water Heating	0.00443	0.00388	0.00332	0.00294	0.00265	0.00250
Other Uses	0.00426	0.00372	0.00319	0.00282	0.00255	0.00240
Industrial Sector						
All Uses	0.00426	0.00372	0.00319	0.00282	0.00255	0.00240

Table 13A.4.6 Power Sector Emissions Factors for NO_x (Million Short Tons (MMsT)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	0.186	0.221	0.186	0.167	0.139	0.136
Cooking	0.183	0.218	0.183	0.164	0.137	0.134
Freezers	0.190	0.227	0.190	0.171	0.142	0.139
Lighting	0.191	0.227	0.190	0.171	0.142	0.139
Refrigeration	0.190	0.226	0.190	0.170	0.142	0.139
Space Cooling	0.173	0.206	0.174	0.157	0.131	0.129
Space Heating	0.194	0.231	0.194	0.173	0.144	0.141
Water Heating	0.186	0.222	0.186	0.167	0.139	0.136
Other Uses	0.185	0.221	0.185	0.166	0.139	0.136
Commercial Sector						
Cooking	0.166	0.196	0.165	0.149	0.124	0.122
Lighting	0.170	0.202	0.170	0.153	0.128	0.126
Office Equipment (Non-Pc)	0.158	0.187	0.157	0.142	0.119	0.117
Office Equipment (Pc)	0.158	0.187	0.157	0.142	0.119	0.117
Refrigeration	0.183	0.218	0.183	0.164	0.137	0.134
Space Cooling	0.169	0.201	0.170	0.153	0.128	0.126
Space Heating	0.196	0.233	0.195	0.175	0.145	0.142
Ventilation	0.184	0.218	0.183	0.165	0.137	0.135
Water Heating	0.165	0.196	0.165	0.148	0.124	0.122
Other Uses	0.161	0.191	0.161	0.145	0.121	0.120
Industrial Sector						
All Uses	0.161	0.191	0.161	0.145	0.121	0.120

Table 13A.4.7 Power Sector Emissions Factors for SO_2 (Million Short Tons (MMsT)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	0.269	0.217	0.169	0.147	0.135	0.137
Cooking	0.262	0.211	0.165	0.144	0.132	0.134
Freezers	0.278	0.224	0.175	0.153	0.140	0.142
Lighting	0.281	0.226	0.177	0.154	0.142	0.144
Refrigeration	0.278	0.224	0.175	0.152	0.140	0.142
Space Cooling	0.236	0.189	0.147	0.128	0.117	0.118
Space Heating	0.288	0.233	0.182	0.159	0.146	0.148
Water Heating	0.271	0.218	0.170	0.149	0.136	0.139
Other Uses	0.268	0.216	0.169	0.147	0.135	0.137
Commercial Sector						
Cooking	0.224	0.179	0.140	0.122	0.111	0.113
Lighting	0.234	0.188	0.147	0.128	0.117	0.118
Office Equipment (Non-Pc)	0.205	0.164	0.128	0.111	0.101	0.103
Office Equipment (Pc)	0.205	0.164	0.128	0.111	0.101	0.103
Refrigeration	0.263	0.212	0.165	0.144	0.132	0.134
Space Cooling	0.226	0.181	0.141	0.122	0.111	0.113
Space Heating	0.292	0.236	0.184	0.161	0.148	0.150
Ventilation	0.264	0.213	0.166	0.145	0.133	0.135
Water Heating	0.223	0.179	0.139	0.121	0.111	0.112
Other Uses	0.213	0.171	0.133	0.116	0.105	0.107
Industrial Sector						
All Uses	0.213	0.171	0.133	0.116	0.105	0.107

Table 13A.4.8 Electricity Upstream Emissions Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO_2	kg/MWh	27.1	24.8	23.3	22.8	22.7	22.6
CH_4	g/MWh	2233.3	2072.0	1959.8	1937.3	1957.8	1955.2
Hg	g/MWh	5.4E-06	4.7E-06	3.9E-06	3.3E-06	2.9E-06	2.6E-06
N_2O	g/MWh	0.152	0.136	0.121	0.110	0.102	0.098
NO_x	g/MWh	363.0	334.7	317.0	311.7	312.1	312.3
SO_2	g/MWh	2.4	2.1	1.8	1.6	1.4	1.3

Table 13A.4.9 Natural Gas Upstream Emissions Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO_2	kg/MMcf	7.1	7.1	7.2	7.2	7.1	7.2
CH_4	g/MMcf	691.1	692.9	694.2	694.2	692.8	693.7
Hg	g/MMcf	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
N_2O	g/MMcf	0.011	0.011	0.011	0.011	0.011	0.011
NO_x	g/MMcf	100.3	100.5	101.5	101.7	101.2	102.2
SO_2	g/MMcf	0.0	0.0	0.0	0.0	0.0	0.0

Table 13A.4.10 Petroleum Fuels Upstream Emission Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO_2	kg/bbl	69.7	69.8	70.3	71.6	71.8	72.1
CH_4	g/bbl	950.3	944.3	943.6	960.6	963.1	965.8
Hg	g/bbl	4.7E-06	4.7E-06	4.4E-06	4.1E-06	3.8E-06	3.7E-06
N_2O	g/bbl	0.582	0.587	0.596	0.605	0.604	0.605
NO_x	g/bbl	762.3	770.8	785.5	799.3	799.2	802.3
SO_2	g/bbl	13.8	13.9	14.0	14.2	14.2	14.2

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APPENDIX 14A. SOCIAL COST OF GREENHOUSE GAS VALUES, 2020-2070

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APPENDIX 14A. SOCIAL COST OF GREENHOUSE GAS VALUES, 2020-2070

14A.1 VALUES FOR SOCIAL COST OF GREENHOUSE GASES

The values in this appendix are taken from the model input files supporting the "Revised 2023 and Later Model Year Light-Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis" published by EPA in December 2021.[1,a] These values are themselves based on the 2020-2050 values in "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide; Interim Estimates under Executive Order 13990", published by the Interagency Working Group on Social Cost of Greenhouse Gases in February 2021.[2] For values between 2051-2070, EPA extrapolated based on methods, assumptions, and parameters identical to the 2020-2050 estimates published by the Interagency Working Group. Due to a lack of available SC-CO_2 estimates for emissions years beyond 2070, DOE did not monetize the climate benefits of GHG emissions reductions occurring after 2070. The values in EPA input files are in 2018$. DOE converted these to 2020$ using the GDP deflator.

Table 14A.1.1 Interim Social Cost of CO_2 Values from 2021 Interagency Update and 2021 EPA Light-Duty Vehicle Regulatory Impact Analysis, 2020–2070 (converted to 2020$ per Metric Ton of CO_2)*

	Discount Rate and Statistics			
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2020	14	51	76	151
2021	15	52	77	155
2022	15	53	79	158
2023	16	54	80	162
2024	16	55	81	165
2025	17	56	83	169
2026	17	57	84	172
2027	18	58	85	176
2028	18	59	87	179
2029	19	60	88	183
2030	19	62	89	186
2031	20	63	91	190
2032	20	64	92	194
2033	21	65	93	198
2034	22	66	95	201
2035	22	67	96	205
2036	23	68	97	209
2037	23	70	99	213
2038	24	71	100	217

[a] Model files available at: www3.epa.gov/otaq/ld/EPA-CCEMS-PostProcessingTool-Project-FRM.zip (last accessed January 18, 2022).

Discount Rate and Statistics				
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2039	25	72	101	220
2040	25	73	103	224
2041	26	74	104	228
2042	26	75	105	231
2043	27	76	107	235
2044	28	78	108	238
2045	28	79	109	242
2046	29	80	111	245
2047	30	81	112	249
2048	30	82	113	252
2049	31	83	115	256
2050	32	84	116	259
2051	32	85	118	260
2052	33	86	119	261
2053	34	87	120	262
2054	34	88	121	263
2055	35	89	122	265
2056	35	90	123	267
2057	36	91	124	269
2058	37	92	125	271
2059	37	92	127	273
2060	38	93	128	275
2061	39	95	129	280
2062	40	96	131	285
2063	41	98	132	290
2064	42	99	134	295
2065	44	100	135	300
2066	45	102	137	305
2067	46	103	138	311
2068	47	105	140	316
2069	48	106	141	321
2070	49	108	143	326

* Values are rounded off to the nearest dollar.

Table 14A.1.2 Interim Social Cost of CH_4 Values from 2021 Interagency Update and Interagency Update, 2021 EPA Light-Duty Vehicle Regulatory Impact Analysis, 2020–2070 (converted to 2020$ per Metric Ton of CH_4)*

	Discount Rate and Statistics			
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2020	663	1,480	1,946	3,893
2021	691	1,527	2,002	4,021
2022	718	1,574	2,057	4,149
2023	745	1,620	2,112	4,277
2024	772	1,667	2,167	4,405
2025	799	1,714	2,223	4,533
2026	826	1,761	2,278	4,661
2027	853	1,807	2,333	4,789
2028	880	1,854	2,388	4,917
2029	908	1,901	2,444	5,045
2030	935	1,948	2,499	5,173
2031	969	2,003	2,563	5,326
2032	1,003	2,058	2,626	5,479
2033	1,038	2,113	2,690	5,632
2034	1,072	2,168	2,754	5,786
2035	1,106	2,224	2,817	5,939
2036	1,140	2,279	2,881	6,092
2037	1,175	2,334	2,945	6,245
2038	1,209	2,389	3,008	6,399
2039	1,243	2,444	3,072	6,552
2040	1,277	2,500	3,136	6,705
2041	1,315	2,555	3,199	6,849
2042	1,352	2,611	3,261	6,993
2043	1,389	2,667	3,324	7,138
2044	1,427	2,722	3,387	7,282
2045	1,464	2,778	3,450	7,426
2046	1,502	2,834	3,512	7,570
2047	1,539	2,890	3,575	7,714
2048	1,576	2,945	3,638	7,859
2049	1,614	3,001	3,701	8,003
2050	1,651	3,057	3,763	8,147
2051	1,680	3,096	3,807	8,193
2052	1,703	3,128	3,841	8,228
2053	1,726	3,159	3,874	8,263
2054	1,749	3,190	3,908	8,297
2055	1,772	3,221	3,942	8,332

Emissions Year	Discount Rate and Statistics			
	5%, Average	3%, Average	2.5%, Average	3%, 95th
2056	1,797	3,256	3,979	8,373
2057	1,823	3,291	4,017	8,415
2058	1,848	3,326	4,055	8,456
2059	1,873	3,360	4,092	8,497
2060	1,899	3,395	4,130	8,539
2061	2,021	3,548	4,296	9,067
2062	2,143	3,702	4,462	9,594
2063	2,264	3,856	4,628	10,122
2064	2,386	4,009	4,794	10,650
2065	2,508	4,163	4,960	11,177
2066	2,632	4,325	5,141	11,758
2067	2,757	4,488	5,323	12,338
2068	2,881	4,651	5,504	12,919
2069	3,006	4,814	5,686	13,499
2070	3,130	4,976	5,867	14,079

* Values are rounded off to the nearest dollar.

Table 14A.1.3 Interim Social Cost of N_2O Values from 2021 Interagency Update and 2021 EPA Light-Duty Vehicle Regulatory Impact Analysis, 2020–2070 (converted to 2020$ per Metric Ton of N_2O)*

Emissions Year	Discount Rate and Statistics			
	5%, Average	3%, Average	2.5%, Average	3%, 95th
2020	5,760	18,342	27,037	48,090
2021	5,961	18,777	27,592	49,293
2022	6,162	19,213	28,147	50,497
2023	6,363	19,649	28,702	51,700
2024	6,565	20,084	29,257	52,904
2025	6,766	20,520	29,811	54,108
2026	6,967	20,955	30,366	55,311
2027	7,168	21,391	30,921	56,515
2028	7,370	21,827	31,476	57,718
2029	7,571	22,262	32,031	58,922
2030	7,772	22,698	32,585	60,125
2031	8,019	23,188	33,195	61,480
2032	8,266	23,678	33,804	62,834
2033	8,513	24,168	34,413	64,189
2034	8,760	24,659	35,023	65,543
2035	9,007	25,149	35,632	66,898

Discount Rate and Statistics				
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2036	9,253	25,639	36,241	68,252
2037	9,500	26,129	36,850	69,606
2038	9,747	26,619	37,460	70,961
2039	9,994	27,110	38,069	72,315
2040	10,241	27,600	38,678	73,670
2041	10,530	28,127	39,320	75,089
2042	10,819	28,655	39,962	76,508
2043	11,109	29,183	40,604	77,928
2044	11,398	29,710	41,246	79,347
2045	11,687	30,238	41,888	80,766
2046	11,976	30,765	42,530	82,186
2047	12,265	31,293	43,172	83,605
2048	12,555	31,820	43,814	85,024
2049	12,844	32,348	44,456	86,443
2050	13,133	32,875	45,098	87,863
2051	13,479	33,426	45,727	88,606
2052	13,798	33,954	46,354	89,984
2053	14,118	34,483	46,981	91,362
2054	14,438	35,011	47,609	92,739
2055	14,758	35,539	48,236	94,117
2056	15,091	36,092	48,890	95,463
2057	15,425	36,644	49,544	96,808
2058	15,758	37,196	50,199	98,154
2059	16,091	37,748	50,853	99,499
2060	16,424	38,300	51,507	100,845
2061	17,077	39,165	52,485	103,794
2062	17,730	40,030	53,463	106,743
2063	18,382	40,895	54,441	109,692
2064	19,035	41,760	55,419	112,641
2065	19,687	42,625	56,397	115,590
2066	20,354	43,515	57,403	118,657
2067	21,020	44,404	58,409	121,725
2068	21,686	45,293	59,416	124,793
2069	22,352	46,183	60,422	127,860
2070	23,018	47,072	61,428	130,928

* Values are rounded off to the nearest dollar.

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APPENDIX 14B. BENEFIT-PER-TON VALUES FOR NO_X AND SO_2 EMISSIONS FROM ELECTRICITY GENERATION

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APPENDIX 14B. BENEFIT-PER-TON VALUES FOR NO_X AND SO_2 EMISSIONS FROM ELECTRICITY GENERATION

14B.1 INTRODUCTION

This appendix describes the analytical methodology DOE uses to incorporate regional and end use sector variability in NO_X and SO_2 valuations into the emissions monetization. The regional values assigned to these emissions are based on benefit-per-ton estimates published by EPA for a variety of sectors, including electricity generation. EPA provides high and low estimates of benefit-per-ton of NO_X and SO_2 emissions reductions in forty regions of the continental USA. DOE combined these data with regional information on electricity consumption and emissions to define weighted-average national values for NO_X and SO_2 as a function of sector.

DOE's methodology uses results associated with the most recent edition of the *Annual Energy Outlook (AEO)* published by the Energy Information Agency (EIA). For this analysis DOE used the Reference case from *AEO2022*.[1] The *AEO* data are used to define two sets of factors that enter into the calculation: the distribution of sectoral electricity consumption by region, and the magnitude of NO_X and SO_2 emissions in each region.

14B.2 METHODOLOGY

14B.2.1 EPA Data

In 2022 EPA published an updated Technical Support Document (TSD) describing an approach for estimating the average avoided human health impacts and monetized benefits related to emissions of $PM_{2.5}$ and ozone precursors including NO_X and SO_2 from 21 sectors.[a] The EPA TSD includes estimates of the present value of the benefits of NO_X and SO_2 emissions reductions (*benefit-per-ton* estimates or BPT) for 2025, 2030, 2035 and 2040. For NO_X, EPA provides values for $PM_{2.5}$ –related benefits and for ozone-related benefits. Because the pollutants associated with NO_X as $PM_{2.5}$ and SO_2 emissions persist in the atmosphere over a period of years, reductions in any given year will have benefits in subsequent years. These future benefits are discounted and summed to provide a single value for the reduction of one ton of emissions in the emissions year.

For Electricity generating units, EPA estimated a benefit per-ton for each of the 48 contiguous continental states. Some states are aggregated into larger regions (CT-RI, DE-NJ, ID-OR-WA, ME-MA-NH-VT, and ND-SD), resulting in separate BPT estimates for forty regions. BPT values for NO_X and SO_2 as precursors to $PM_{2.5}$ include high and low impact scenarios; BPT

[a] U.S. Environmental Protection Agency. *Estimating the Benefit per Ton of Reducing Directly-Emitted $PM_{2.5}$, $PM_{2.5}$ Precursors and Ozone Precursors from 21 Sectors*. January 2022. https://www.epa.gov/system/files/documents/2021-10/source-apportionment-tsd-oct-2021_0.pdf

values for NO_X as a precursor to ozone include short and long-term impacts. For all data two rates of discounting (3% and 7%) are provided.

DOE used linear interpolation to define values for the years between 2025 and 2030, 2030 and 2035, and 2035 and 2040; for years beyond 2040 the value is held constant. DOE defined the total value of NO_X emissions reductions as the sum of the BPT value for $PM_{2.5}$ plus one half of the BPT value for ozone; the factor of one half accounts for the fact that ozone is primarily produced during the May-September period, so approximately half of NO_X emissions will produce ozone emissions.

14B.2.2 AEO Data

For this calculation DOE used the total annual emissions of NO_X and SO_2 for each of the *AEO*'s 25 Electricity Market Module (EMM) regions,[2] and data tables published with the NEMS code package.[b] The latter are used to map EPA regions to EMM regions, and to calculate the contribution of each utility customer sector (residential, commercial and industrial) to total pollutant emissions in each EMM region. The data are then combined to create time series of BPT values for each end use sector.

14B.2.3 Equations and Results

Consistent with its treatment of other utility and environmental impacts, DOE defines a times series of national average estimates of NO_X and SO_2 values.

The same methodology is applied to each pollutant type and EPA scenario (low-7%, low-3%, etc.). The notation is:

- y is the analysis year,
- m is a label for the EMM region,
- z is a label for the EOA region,
- w(z,m) is a matrix that maps EPA regions to EMM regions; it is defined as the fraction of total electricity sales within m to region z; $\sum_z w(z,m) = 1$ for all m,
- p(z,y) is the BPT estimate in EPA region z and year y,
- s is a label for the customer sector (commercial, residential, industrial)
- v(s, m) is the weight of sector s in EMM region m, defined as the fraction of total electricity sales within m to sector s; $\sum_s v(s,m) = 1$ for all m,
- M(m,y) is total pollutant emissions in EMM region m and year y.

[b] The NEMS package can be downloaded at https://www.eia.gov/outlooks/aeo/info_nems_archive.php. Once installed, the file path to the data files is aeo2021\reference\input\emm_db.zip. The data files are EMMCNTL_RDB.xlsx and LDSMSTR_RDB.xlsx.

The calculation proceeds in four steps:

1. Pollutant emissions are allocated to sector:

$$M1(m, s, y) = M(m, y) * v(s, m)$$

2. Sectoral pollutant emissions are mapped from EMM regions to EPA regions:

$$M2(z, s, y) = \sum_m M1(m, s, y) * w(z, m)$$

3. A weight is defined for EPA region z and sector s, based on pollutant emissions:

$$u(z, s, y) = M2(z, s, y)/[\ \sum_z M2(z, s, y)\ ]$$

4. The regional weights are used to define a national average BPT value for each sector:

$$P(s, y) = \sum z\ u(z, s, y) * p(z, y)$$

The results of this calculation are provided in Table 14B.2.1 for NO_X and in Table 14B.2.2 SO_2. DOE's prices are not significantly different than the EPA estimate of the US average. Although the EPA prices are held constant after 2040, the DOE prices may vary slightly in the period 2040-2050 due to the projected changes in regional emissions.

Table 14B.2.1 NO_X Benefit-per-ton Values by Sector (2016$/ Short Ton)

Sector	High, 3% Discount Rate				High, 7% Discount Rate			
	2025	2030	2040	2050	2025	2030	2040	2050
Commercial	59,241	66,019	82,131	82,876	53,063	59,110	73,642	74,313
Industrial	58,828	65,753	80,552	81,237	52,694	58,888	72,242	72,859
Residential	59,102	65,922	81,783	82,420	52,939	59,018	73,327	73,901
Sector	Low, 3% Discount Rate				Low, 7% Discount Rate			
	2025	2030	2040	2050	2025	2030	2040	2050
Commercial	59,116	65,718	81,447	82,181	52,955	58,840	73,030	73,691
Industrial	58,685	65,389	79,743	80,418	52,572	58,561	71,522	72,129
Residential	58,985	65,632	81,129	81,756	52,839	58,758	72,743	73,308

Table 14B.2.2 SO_2 Benefit-per-ton Values by Sector (2016$/ Short Ton)

Sector	High, 3% Discount Rate				High, 7% Discount Rate			
	2025	**2030**	**2040**	**2050**	**2050**	**2030**	**2040**	**2050**
Commercial	81,598	92,092	115,167	116,405	73,416	82,827	103,617	104,725
Industrial	81,144	91,307	113,106	114,293	73,001	82,120	101,782	102,844
Residential	81,160	91,610	114,227	115,430	73,023	82,398	102,776	103,852
Sector	**Low, 3% Discount Rate**				**Low, 7% Discount Rate**			
	2025	**2030**	**2040**	**2050**	**2025**	**2030**	**2040**	**2050**
Commercial	80,231	88,263	106,241	107,326	72,148	79,360	95,597	96,573
Industrial	79,821	87,548	104,421	105,453	71,775	78,712	93,950	94,878
Residential	79,820	87,850	105,429	106,477	71,780	78,983	94,859	95,802

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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; 2019).[1,2]

DOE's analysis uses output of the DOE/Energy Information Administration (EIA)'s most recent *Annual Energy Outlook* (*AEO*).[3] The *AEO* includes a reference case and a set of side cases that implement a variety of economic and policy scenarios. In 2015 EIA announced the adoption of a two-year release cycle for the *AEO*, alternating between a full set of scenarios and a shorter edition containing only five scenarios. DOE has adapted its calculation methodology to be independent of the type of scenarios available with each *AEO* publication.

15A.2 METHODOLOGY

Marginal reductions in electricity demand lead to marginal reductions in power sector generation, emissions, and installed capacity. Generally, DOE quantifies these reductions using marginal impact factors, which are time series defining the change in some power sector quantity that results from a unit change in site electricity demand. Because load shapes affect the mix of generation types on the margin, these impact factors depend on end-use and sector.

DOE's approach examines a series of *AEO* side cases to estimate the relationship between changes to power sector generation (TWh) by fuel type and changes to other supply-side power sector variables, including fuel consumption (quads) by fuel type, and installed capacity (GW) by fuel and technology type. DOE also calculates changes to power sector emissions; the methodology for computing these impacts is described in appendix 13A.

DOE uses load shape information from the NEMS code to relate marginal generation reductions by fuel type to marginal demand reductions by sector and end use. Because AEO side cases with electricity demand reductions are not always available, DOE defines the relationship between sector/end-use and generation fuel type using Reference case data. Specifically, DOE defines, for each sector and end-use, fuel-share weights equal to the percentage of each MWh used to serve that end-use load that is provided by each generation fuel type.

The load shape data provide an hourly profile defining total consumption of electricity for each sector/end-use. For each load DOE allocates consumption to one of 3 periods: on-peak, shoulder, and off-peak. These categories are used in the utility sector to correlate end-use consumption with supply types. On-peak hours are defined as 12pm to 5pm Monday through Saturday, June through September. Off-peak hours are 9pm to 6am daily and all day Sunday. All other hours are allocated to the shoulder period.

This leads to a set of weights $w(p,u,y)$ where:

y = the analysis year
u = an index representing the sector/end-use (e.g. commercial cooling)
p = the time-of-day period
$w(p,u,y)$ = the fraction of load u that is served in period p

By definition the sum of $w(p,u,y)$ over periods p is equal to one. On the supply-side, DOE allocates generation by each fuel type to one of the time-of-day periods. The allocation is based on the following rules:

1.1. The data are normalized so that total annual generation equals total annual consumption by sector and end-use;
1.2. The demand-side data are summed over sector/end-use to define a total demand for generation in each time-of-day period;
1.3. All petroleum-based generation is allocated to peak periods;
1.4. Base-load generation (nuclear and coal) is assumed to be equally likely to be on in all hours; hence, it is allocated to each period in proportion to the number of hours in that period;
1.5. Any unmet peak period demand is allocated to natural gas;
1.6. The remaining generation of all types is allocated to the remaining periods proportionally.

This leads to a second set of weights $z(p,f,y)$ where:

f = the fuel type
$z(p,f,y)$ = the fraction of load in period p that is served by fuel f

These weights are used to allocate a MWh of demand reduction for a given end-use to each fuel type. In defining the fuel-share weights for demand reductions, DOE makes one adjustment to the factors calculated from the Reference case data. An examination of all available *AEO* scenarios shows that both generation and installed capacity for nuclear power are unchanged across the projection period. This implies that the use of nuclear power is not affected by small changes in the supply/demand balance; hence, DOE assumes that the factor $z(p,f,y)$ is zero for nuclear power. The values of $z(p,f,y)$ for the other fuels are renormalized so that the sum of $z(p,f,y)$ across the remaining fuel types is equal to one.

DOE defines the generation fuel share weights $g(u,f,y)$ as the product

$$g(u,f,y) = \sum_p w(p,u,y)\, z(p,f,y).$$

Eq. 15A.1

For the sector/end-use defined by u, the product of the total annual site electricity savings times the factor *g(u,f,y)* defines the marginal generation reductions by fuel type. These marginal generation reductions can be related to marginal fuel use reductions (see appendix 10.B of this TSD) and to the marginal emissions reductions (see appendix 13A of this TSD). They are also related to the marginal installed capacity reductions through the capacity factor.

DOE uses a capacity factor to relate reductions in generation by fuel type to reductions in installed capacity by technology type. The capacity factor is defined as the magnitude of change in capacity given a unit change in generation. The technology types are coal, natural gas combined-cycle (NGCC), oil and gas steam (OGS), combustion turbine-diesel (CTD), and renewable sources. For NGCC the capacity factor is defined as the ratio of NGCC capacity to natural gas generation. DOE combines CTD and OGS DOE into a single *peak* capacity type, with capacity factor equal to the ratio of the sum of CTD plus OGS capacity to oil-fired generation. Each fuel type is then related to a unique capacity type. While marginal capacity factors can be calculated from *AEO* data, this approach produces results that are dominated by computational noise. Hence, DOE uses data for the *AEO Reference Case* to calculate grid-average capacity factors for each year of the analysis period, defined as *c(f,y)*. The capacity change for fuel/technology type *f* induced by a unit reduction in demand for sector/end-use u is given by the product *g(u,f,y)*c(f,y)*.

15A.3 MODEL RESULTS

Representative values of the impact factors for fuel share by fuel type, and capacity by technology type are provided in the tables below. The tables show the factors for two years, 2025 and 2050. The marginal heat rates are presented in appendix 10B and emissions factors are presented in in appendix 13A.

15A.3.1 Electricity Generation

Table 15A.3.1 and Table 15A.3.2 show the distribution across fuel types of a unit reduction in electricity demand by sector and end-use, referred to above as fuel-share weights. The fuel types are coal, natural gas, petroleum, and renewables. The values for cooling are representative of peaking loads, while the values for refrigeration are representative of flat loads. The data are shown for 2025 and 2050.

Table 15A.3.1 Fuel-Share Weights by Sector and End-Use (Values for 2025)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	25.3%	38.9%	0.2%	35.6%
Cooking	24.6%	39.3%	0.2%	35.9%
Freezers	26.2%	38.5%	0.2%	35.1%
Lighting	26.6%	37.9%	0.1%	35.5%
Refrigeration	26.1%	38.5%	0.2%	35.2%
Space Cooling	21.7%	42.4%	0.6%	35.3%
Space Heating	27.3%	37.3%	0.0%	35.4%
Water Heating	25.6%	38.5%	0.1%	35.8%
Other Uses	25.3%	38.9%	0.2%	35.7%
Commercial Sector				
Cooking	20.9%	41.6%	0.3%	37.3%
Lighting	21.9%	41.0%	0.3%	36.9%
Office Equipment (Non-Pc)	19.0%	42.9%	0.4%	37.7%
Office Equipment (Pc)	19.0%	42.9%	0.4%	37.7%
Refrigeration	24.8%	39.2%	0.2%	35.9%
Space Cooling	20.6%	43.1%	0.7%	35.5%
Space Heating	27.7%	37.1%	0.0%	35.2%
Ventilation	24.9%	39.1%	0.2%	35.9%
Water Heating	20.8%	41.6%	0.3%	37.4%
Other Uses	19.8%	42.3%	0.3%	37.5%
Industrial Sector				
All Uses	19.8%	42.3%	0.3%	37.5%

Table 15A.3.2 Fuel-Share Weights by Sector and End-Use (Values for 2050)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	14.1%	36.2%	0.1%	49.6%
Cooking	13.7%	36.5%	0.1%	49.7%
Freezers	14.6%	36.1%	0.1%	49.2%
Lighting	14.8%	35.1%	0.0%	50.0%
Refrigeration	14.6%	36.1%	0.1%	49.3%
Space Cooling	11.9%	40.5%	0.2%	47.3%
Space Heating	15.3%	34.6%	0.0%	50.2%
Water Heating	14.2%	35.7%	0.0%	50.1%
Other Uses	14.1%	36.2%	0.1%	49.7%
Commercial Sector				
Cooking	11.5%	38.1%	0.1%	50.3%
Lighting	12.1%	37.7%	0.1%	50.1%
Office Equipment (Non-Pc)	10.4%	39.3%	0.1%	50.1%
Office Equipment (Pc)	10.4%	39.3%	0.1%	50.1%
Refrigeration	13.8%	36.4%	0.1%	49.8%
Space Cooling	11.3%	41.2%	0.3%	47.3%
Space Heating	15.5%	34.4%	0.0%	50.1%
Ventilation	13.8%	36.3%	0.1%	49.8%
Water Heating	11.4%	38.0%	0.1%	50.4%
Other Uses	10.9%	38.8%	0.1%	50.2%
Industrial Sector				
All Uses	10.9%	38.8%	0.1%	50.2%

15A.3.2 Installed Capacity

Table 15A.3.3 and Table 15A.3.4 show the total change in installed capacity (GW) per unit of site electricity demand reduction for the five principal capacity types: coal, natural gas, peaking, renewables, and nuclear. The peaking category is the sum of the two NEMS categories oil and gas steam and combustion turbine/diesel. Data are shown for 2025 and 2050.

Table 15A.3.3 Capacity Impact Factors in GW per TWh Reduced Site Electricity Demand (Values for 2025)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	0.061	0.097	0.046	0.134
Cooking	0.060	0.098	0.052	0.135
Freezers	0.063	0.096	0.050	0.132
Lighting	0.064	0.095	0.017	0.133
Refrigeration	0.063	0.096	0.049	0.132
Space Cooling	0.052	0.106	0.174	0.133
Space Heating	0.066	0.093	0.002	0.133
Water Heating	0.062	0.096	0.028	0.135
Other Uses	0.061	0.097	0.043	0.134
Commercial Sector				
Cooking	0.051	0.104	0.078	0.140
Lighting	0.053	0.103	0.072	0.139
Office Equipment (Non-Pc)	0.046	0.107	0.106	0.142
Office Equipment (Pc)	0.046	0.107	0.106	0.142
Refrigeration	0.060	0.098	0.047	0.135
Space Cooling	0.050	0.108	0.188	0.134
Space Heating	0.067	0.093	0.000	0.132
Ventilation	0.060	0.098	0.045	0.135
Water Heating	0.050	0.104	0.074	0.140
Other Uses	0.048	0.106	0.095	0.141
Industrial Sector				
All Uses	0.048	0.106	0.095	0.141

Table 15A.3.4 Capacity Impact Factors in GW per TWh Reduced Site Electricity Demand (Values for 2050)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	0.031	0.111	0.052	0.187
Cooking	0.030	0.112	0.059	0.187
Freezers	0.032	0.110	0.057	0.185
Lighting	0.032	0.107	0.019	0.188
Refrigeration	0.032	0.110	0.056	0.185
Space Cooling	0.026	0.124	0.197	0.178
Space Heating	0.033	0.106	0.002	0.189
Water Heating	0.031	0.109	0.032	0.188
Other Uses	0.031	0.111	0.049	0.187
Commercial Sector				
Cooking	0.025	0.117	0.088	0.189
Lighting	0.027	0.115	0.082	0.188
Office Equipment (Non-Pc)	0.023	0.120	0.120	0.189
Office Equipment (Pc)	0.023	0.120	0.120	0.189
Refrigeration	0.030	0.111	0.054	0.187
Space Cooling	0.025	0.126	0.214	0.178
Space Heating	0.034	0.105	0.000	0.189
Ventilation	0.030	0.111	0.051	0.188
Water Heating	0.025	0.116	0.084	0.190
Other Uses	0.024	0.119	0.108	0.189
Industrial Sector				
All Uses	0.024	0.119	0.108	0.189

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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:
    - o Background material on XENERGY's approach,
    - o DOE's adjustment of these curves for this analysis, and
    - o 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 and Table 17A.2.2 show the annual increases in market shares of consumer 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.2.1 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Electric Smooth Cooking Tops (TSL 2)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets	Bulk Govt Purchases
2027	12.8%	7.7%	3.8%	1.2%	0.0%
2028	12.8%	7.7%	3.8%	2.4%	0.0%
2029	12.8%	7.7%	3.8%	3.5%	0.1%
2030	12.8%	7.7%	3.8%	4.6%	0.1%
2031	12.8%	7.7%	3.8%	5.6%	0.1%
2032	12.8%	7.7%	3.8%	6.5%	0.1%
2033	12.8%	7.7%	3.8%	7.4%	0.2%
2034	12.8%	7.7%	3.8%	8.3%	0.2%
2035	12.8%	7.7%	3.8%	9.2%	0.2%
2036	12.8%	7.7%	3.8%	10.0%	0.2%
2037	12.8%	7.7%	3.8%	10.1%	0.2%
2038	12.8%	7.7%	3.8%	10.2%	0.2%
2039	12.8%	7.7%	3.8%	10.3%	0.2%
2040	12.8%	7.7%	3.8%	10.3%	0.2%

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets	Bulk Govt Purchases
2041	12.8%	7.7%	3.8%	10.4%	0.2%
2042	12.8%	7.7%	3.8%	10.5%	0.2%
2043	12.8%	7.7%	3.8%	10.6%	0.2%
2044	12.8%	7.7%	3.8%	10.7%	0.2%
2045	12.8%	7.7%	3.8%	10.7%	0.2%
2046	12.8%	7.7%	3.8%	10.8%	0.2%
2047	12.8%	7.7%	3.8%	10.9%	0.2%
2048	12.8%	7.7%	3.8%	11.0%	0.2%
2049	12.8%	7.7%	3.8%	11.1%	0.2%
2050	12.8%	7.7%	3.8%	11.2%	0.2%
2051	12.8%	7.7%	3.8%	11.2%	0.2%
2052	12.8%	7.7%	3.8%	11.3%	0.2%
2053	12.8%	7.7%	3.8%	11.4%	0.2%
2054	12.8%	7.7%	3.8%	11.5%	0.2%
2055	12.8%	7.7%	3.8%	11.5%	0.2%
2056	12.8%	7.7%	3.8%	11.6%	0.2%

Table 17A.2.2 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Gas Cooking Tops (TSL 2)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets	Bulk Govt Purchases
2027	60.0%	36.0%	18.0%	0.4%	0.0%
2028	60.0%	36.0%	18.0%	1.0%	0.1%
2029	60.0%	36.0%	18.0%	1.7%	0.1%
2030	60.0%	36.0%	18.0%	2.3%	0.2%
2031	60.0%	36.0%	18.0%	3.0%	0.2%
2032	60.0%	36.0%	18.0%	3.7%	0.3%
2033	60.0%	36.0%	18.0%	4.4%	0.3%
2034	60.0%	36.0%	18.0%	5.1%	0.3%
2035	60.0%	36.0%	18.0%	5.9%	0.4%
2036	60.0%	36.0%	18.0%	6.6%	0.4%
2037	60.0%	36.0%	18.0%	6.8%	0.4%
2038	60.0%	36.0%	18.0%	7.0%	0.4%
2039	60.0%	36.0%	18.0%	7.2%	0.4%
2040	60.0%	36.0%	18.0%	7.4%	0.4%
2041	60.0%	36.0%	18.0%	7.6%	0.4%
2042	60.0%	36.0%	18.0%	7.7%	0.4%
2043	60.0%	36.0%	18.0%	7.9%	0.4%
2044	60.0%	36.0%	18.0%	8.1%	0.4%
2045	60.0%	36.0%	18.0%	8.3%	0.4%

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets	Bulk Govt Purchases
2046	60.0%	36.0%	18.0%	8.5%	0.4%
2047	60.0%	36.0%	18.0%	8.7%	0.4%
2048	60.0%	36.0%	18.0%	8.9%	0.4%
2049	60.0%	36.0%	18.0%	9.0%	0.4%
2050	60.0%	36.0%	18.0%	9.2%	0.4%
2051	60.0%	36.0%	18.0%	9.4%	0.4%
2052	60.0%	36.0%	18.0%	9.6%	0.4%
2053	60.0%	36.0%	18.0%	9.7%	0.4%
2054	60.0%	36.0%	18.0%	9.9%	0.4%
2055	60.0%	36.0%	18.0%	10.1%	0.4%
2056	60.0%	36.0%	18.0%	10.3%	0.4%

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 10-A. 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 consumer conventional cooking products to housing units in public housing authority. A separate module summarizes the market impacts from mandatory standards, calculated under the same market conditions as the alternative policies, and all policy alternatives. 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.

[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.

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 consumer 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 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

[c] XENERGY is now owned by KEMA, Inc. (www.kema.com)

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).

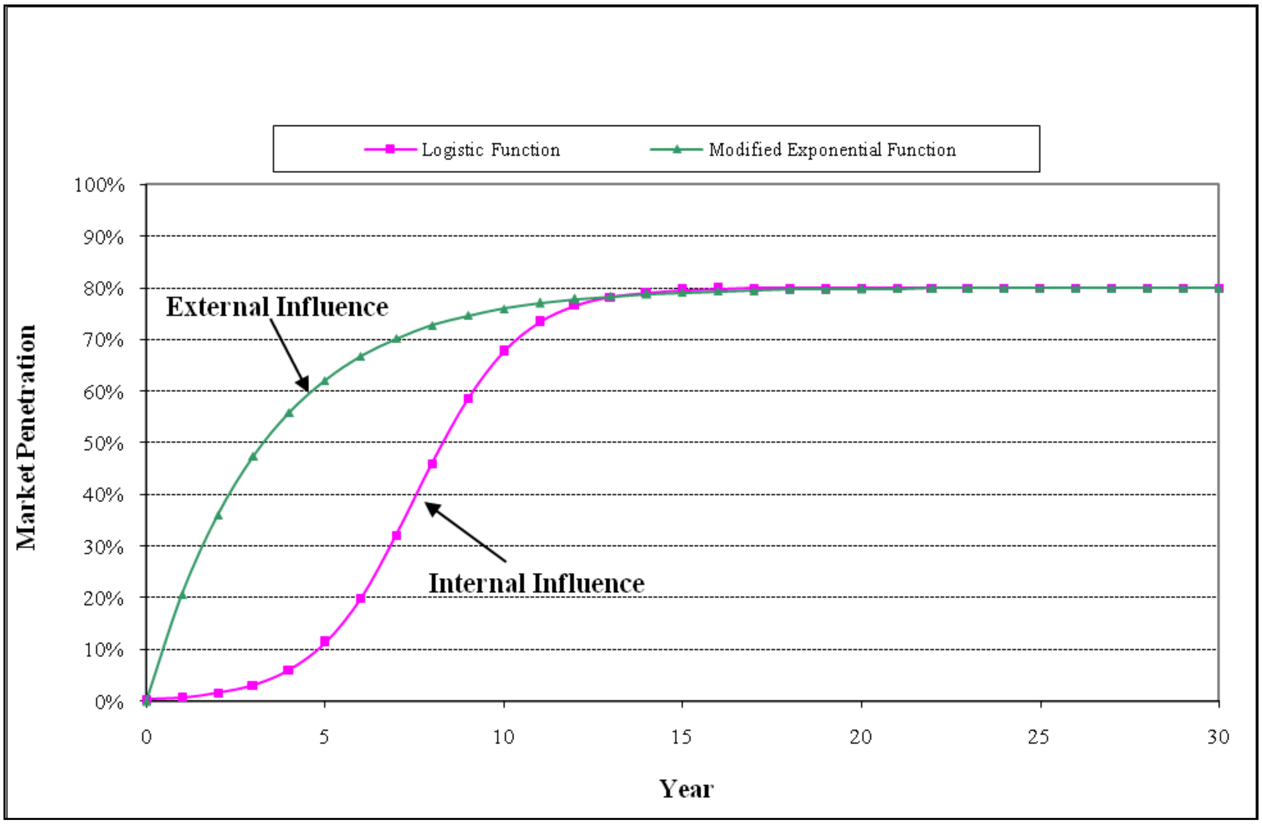

Figure 17A.4.1 S-Curves Showing Effects of External and Internal Sources on Adoption of New Technologies

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, 7] 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 no-new-standards 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)[8] 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 no-new-standards 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 internet search for rebate programs that offered incentives for consumer conventional cooking products in July, 2022. DOE could not find rebate programs for this product, and therefore assumed that a rebate program would pay for all or part of the increased installed cost. For gas cooking tops, DOE assumed that a rebate would cover all of the increased installed costs, given that the increased installed costs are less than 5% of the total installed costs. For electric cooking tops, DOE assumed that a rebate would cover all of the increased installed cost at TSL 1 and 2, given that for these two TSLs, the increased installed costs are less than 3% of the total installed costs; at TSL 3, DOE assumed a $100 rebate, which would cover approximately 15% of the increased installed cost. Table 17A.5.1 shows the rebate amounts DOE estimated for the proposed efficiency levels of the product classes covered by this RIA.

Table 17A.5.1 Rebates Amounts for Consumer Conventional Cooking Products*

	TSL 1	TSL 2	TSL 3
Electric cooking tops	$3.27	$3.27	$100.00
Gas cooking tops	$18.52	$18.52	$18.52

* In 2021$.

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.[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.[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 <u>any</u> qualifying energy property expenditure (which also included installation of efficient windows, doors and roofs) were 3.1 and 3.2 percent in 2006 and 2007 respectively.

DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. While this tax credit was available from 1979 through 1985, DOE located data for only the first three years of the program.[15], [16], [17] For those three years - 1979, 1980, and 1981 - the percentages of taxpayers filing Form 5695 were 6.4 percent, 5.2 percent, and 4.9 percent. Given that the data from this earlier tax credit program were not disaggregated by type of energy property, this data series served only to indicate a possible trend of greater participation in the initial program year, followed by slightly smaller participation in subsequent years. However, DOE did not find detailed analysis of this program to indicate the possible reasons for such a trend. Also, this trend varies from the more stable trend shown in the EPAct 2005 energy tax credit program data for its first two program years.

As discussed in chapter 17, DOE analyzed the percentage of participation in consumer tax credit programs using its estimates of consumer participation in rebate programs that was based on benefit/cost data specific to each product class of consumer 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.[20] 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.[21]

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.[22, 23] 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).[22]

Montana has had an Energy Conservation Tax Credit for residential measures since 1998.[24] The tax credit covers various residential energy and water efficient products, including split system central air conditioning; package system central air conditioning; split system air source heat pumps; package system heat pumps; natural gas, propane, or oil furnaces; hot water boilers; advanced main air circulating fans; heat recovery ventilators; gas, oil, or propane water heaters; electric heat pump water heaters; low-flow showerheads and faucets; light fixtures; and controls. In 2002 the amount of the credit was increased from 5 percent of product costs (up to $150) to 25 percent (up to $500) per taxpayer. The credit can be used for products installed in new construction or remodeling projects. The tax credit covers only that part of the cost and materials that exceed established standards of construction.

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