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

RESIDENTIAL CLOTHES WASHERS

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CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses and results supporting the information presented in the direct final rule and executive summary for residential clothes washers. This TSD reports on the activities and analyses conducted in the period following the preliminary analysis of this rulemaking.

1.2 OVERVIEW OF STANDARDS FOR RESIDENTIAL CLOTHES WASHERS

The Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163 (42 United States Code (U.S.C.) 6291–6309), established an energy conservation program for major household appliances. The National Energy Conservation Policy Act of 1978 (NECPA), Pub. L. 95-619, amended EPCA to add Part C[a] of Title III (42 U.S.C. 6311–6317), which established an energy conservation program for certain industrial equipment. Additional amendments to EPCA give DOE the authority to regulate the energy efficiency of several products, including residential clothes washers—the products that are the focus of this document. The amendments to EPCA in the National Appliance Energy Conservation Act of 1987 (NAECA), Pub. L. 100-12, established standards for residential clothes washers, as well as requirements for determining whether these standards should be amended. (42 U.S.C. 6295(g))

NAECA established the first prescriptive standards for residential clothes washers, requiring that all rinse cycles of clothes washers manufactured after January 1, 1988, shall include an unheated water option, but may have a heated water rinse option, and further required that DOE conduct two cycles of rulemakings to determine if more stringent standards are justified.[b] (42 U.S.C. 6295 (g)(2) and (4)) On May 14, 1991, DOE published a final rule in the *Federal Register* (FR) establishing the first set of performance standards for residential clothes washers; the compliance date of the new standards was May 14, 1994. 56 FR 22279. DOE conducted a second standards rulemaking for residential clothes washers, publishing a January 2001 final rule revising the energy conservation standards; the revised standards became effective in two phases, with compliance dates of January 1, 2004, and January 1, 2007. 66 FR 3314.

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[a] Part C has been redesignated Part A-1 in the United States Code for editorial reasons.

[b] DOE defines "clothes washer" under EPCA as "a consumer product designed to clean clothes, utilizing a water solution of soap and/or detergent and mechanical agitation or other movement, and must be one of the following classes: automatic clothes washers, semi-automatic clothes washers, and other clothes washers." 10 CFR 430.2.

As part of its priority-setting activities for fiscal year 2006, DOE conducted analyses for residential clothes washers to estimate the energy savings potential of amended standards. DOE determined that amended standards could result in energy savings for residential clothes washers of 5.5 quads cumulative over the period of 2004–2030. A summary of the analyses is available on DOE's website at *www1.eere.energy.gov/buildings/appliance_standards/pdfs/2006_activities_data_sheets.pdf*

1.3 PROCESS FOR SETTING ENERGY CONSERVATION STANDARDS

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

1) the economic impact of the standard on the manufacturers and consumers of the affected products;

2) the savings in operating costs throughout the estimated average life of the product compared to any increases in the initial cost or maintenance expense;

3) the total projected amount of energy savings likely to result directly from the imposition of the standard;

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

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

6) the need for national energy conservation; and

7) other factors the Secretary considers relevant.

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

DOE considers 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 or not to adopt a proposed energy conservation standard, it must first solicit comments on the proposed standard. (42 U.S.C. 6295(m)(2)(B); 42 U.S.C. 6295(p)(2)) 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))

After the publication of the framework document, the energy conservation standards rulemaking process involves three additional, formal public notices, which DOE publishes in the *Federal Register*. The first of the rulemaking notices is a notice of public meeting (NOPM), which is designed to publicly vet the models and tools used in the preliminary rulemaking and to facilitate public participation before the next stage. The second notice is the notice of proposed rulemaking (NOPR), which presents a discussion of comments received in response to the NOPM and the preliminary analyses and analytical tools; analyses of the impacts of potential amended energy conservation standards on consumers, manufacturers, and the Nation; DOE's weighting of these impacts of amended energy conservation standards; and the proposed energy conservation standards for the product. The third notice is the final rule, which presents a discussion of the comments received in response to the NOPR; the revised analyses; DOE's weighting of these impacts; the amended energy conservation standards DOE is adopting for the product; and the compliance dates of the amended energy conservation standards.

DOE initiated the current rulemaking on August 28, 2009 by publishing a notice announcing the availability of the framework document, the "Energy Conservation Standards Rulemaking Framework Document for Residential Clothes Washers." In this notice, DOE also announced a public meeting and requested public comment on the matters raised in the framework document. 74 FR 44306 (Aug. 28, 2009). The framework document described the procedural and analytical approaches that DOE anticipated using to evaluate energy conservation standards for clothes washers and identified various issues to be resolved in conducting this rulemaking. The framework document is available at http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/clothes_washers_framework.pdf.

DOE held a public meeting on September 21, 2009, where it presented the contents of the framework document; described the analyses it planned to conduct during the rulemaking; sought comments from interested parties on these subjects; and, in general, sought to inform interested parties about, and facilitate their involvement in, the rulemaking. Interested parties commented about numerous issues relating to each one of the analyses listed in Table 1.3.1. At the meeting and during the period for commenting on the framework document, DOE received many comments that helped it identify and resolve issues involved in this rulemaking. DOE then began to gather additional information to perform a preliminary analysis to help develop potential energy conservation standards for residential clothes washers.

Table 1.3.1 Analyses Under the Process Rule

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

In response to the framework document, DOE received the "Agreement on Minimum Federal Efficiency Standards, Smart Appliances, Federal Incentives and Related Matters for Specified Appliances" (the "Joint Petition"), a comment submitted by groups representing manufacturers, energy and environmental advocates, and consumer groups (collectively, the "Joint Petitioners"). This collective set of comments, which DOE refers to in this notice as the "Joint Petition"[c] recommends specific energy conservation standards and their compliance dates for residential clothes washers that, in the commenters' view, would satisfy the EPCA requirements in 42 U.S.C. 6295(o).

EPCA allows DOE to issue a direct final rule establishing an energy conservation standard on receipt of a statement submitted jointly by interested persons that are fairly representative of relevant points of view (including representatives of manufacturers of covered products, States, and efficiency advocates) that contains recommendations with respect to an energy conservation standard that are in accordance with the provisions of 42 U.S.C. 6295(o). DOE has concluded that the recommendations of the Joint Petition satisfy the requirements of 42 U.S.C. 6295(o). Therefore, DOE is publishing this direct final rule concurrently with a notice of proposed rulemaking that proposes identical energy conservation standards and compliance dates. If DOE receives adverse comment and determines that such comment may provide a reasonable basis for withdrawing the direct final rule, this final rule will be withdrawn and DOE will proceed with the proposed rule.

[c] DOE Docket No. EERE–2008–BT–STD–0019, Comment 32. DOE considered the Joint Petitioners' comments to supersede earlier comments by the listed parties regarding issues subsequently discussed in the Joint Petition.

As part of the information gathering and sharing process, DOE organized and held interviews with manufacturers of the residential clothes washers considered in this rulemaking as part of the engineering analysis. DOE selected companies that represented production of all types of products, ranging from small to large manufacturers, and included the Association of Home Appliance Manufacturers (AHAM) member companies. DOE had four objectives for these interviews: (1) solicit manufacturer feedback on the draft inputs to the engineering analysis; (2) solicit feedback on topics related to the preliminary manufacturer impact analysis; (3) provide an opportunity, early in the rulemaking process, to express manufacturers' concerns to DOE; and (4) foster cooperation between manufacturers and DOE. DOE incorporated the information gathered during the engineering interviews with manufacturers into its engineering analysis (chapter 5) and the manufacturer impact analysis (chapter 12).

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

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

1.4 STRUCTURE OF THE DOCUMENT

This TSD outlines the analytical approaches used in this rulemaking. The TSD consists of 14 chapters, an emissions analysis, a regulatory impact analysis, a monetization analysis, a panel analysis, and appendices.

Chapter 1	Introduction: provides an overview of the appliance standards program and how it applies to this rulemaking, and outlines the structure of the document.
Chapter 2	Analytical Framework: describes the rulemaking process.
Chapter 3	Market and Technology Assessment: characterizes the market for the considered products and the technologies available for increasing product efficiency.

Chapter 4	Screening Analysis: identifies all the design options that improve efficiency of the considered products, and determines which technology options are viable for consideration in the engineering analysis.
Chapter 5	Engineering Analysis: discusses the methods used for developing the relationship between increased manufacturer price 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 (NIA).
Chapter 10	National Impact Analysis: assesses the national energy savings, and the national net present value of total consumer costs and savings, expected to result from specific, potential energy conservation standards for residential clothes washers.
Chapter 11	Consumer Subgroup Analysis: discusses the effects of standards on different subgroups of consumers.
Chapter 12	Manufacturer Impact Analysis: discusses the effects of standards on the finances and profitability of product manufacturers.
Chapter 13	Employment Impact Analysis: discusses the effects of standards on national employment.
Chapter 14	Utility Impact Analysis: discusses certain effects of the considered standards on electric and gas utilities.
Chapter 15	Emissions Analysis: discusses the effects of standards on three pollutants—sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury—as well as carbon dioxide emissions.

Chapter 16	Monetization of Emission Reductions Benefits
Chapter 17	Regulatory Impact Analysis: discusses the impact of non-regulatory alternatives to efficiency standards.
Chapter 18	Do Standards Increase Consumer Welfare? Evidence from a 2007 Change In Energy Efficiency Requirements for Clothes Washers
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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Section 6295(o)(2)(A) of the Energy Policy and Conservation Act (EPCA), Pub. L. 94-163, 42 U.S.C. 6291 *et seq*. requires the U.S. Department of Energy (DOE) to set forth energy conservation standards that achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. This chapter describes the general analytical framework that DOE uses in developing such standards, and in particular, amended energy conservation standards for residential clothes washers. The analytical framework is a description of the methodology, the analytical tools, and the relationships among the various analyses that are part of this rulemaking.

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

Figure 2.1.1 Flow Diagram of Analyses for the Rulemaking Process

The analyses performed for this direct final rule and reported in this technical support document (TSD) are listed below.

- A market and technology assessment to characterize the relevant product markets and existing technology options, including prototype designs.

- A screening analysis to review each technology option to decide whether it is technologically feasible; is practical to manufacture, install, and service; would adversely affect product utility or product availability; or would have adverse effects on health and safety.

- An engineering analysis to develop cost-efficiency relationships, which indicate the manufacturer's cost of achieving increased efficiency.

- A markups analysis to develop distribution channel markups that relate the manufacturer production cost (MPC) to the cost to the consumer.

- An analysis of the annual energy and water use of the considered products.

- Life-cycle cost (LCC) and payback period (PBP) analyses to calculate, at the consumer level, the discounted savings in operating costs (minus maintenance and repair costs) throughout the estimated average lifetime of the covered products, compared to any increase in purchase and installation cost likely to result directly from imposition of a given standard.

- A shipments analysis to forecast shipments of residential clothes washers, 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 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).

- A manufacturer impact analysis to assess the potential impacts of energy conservation standards on manufacturers' capital conversion expenditures, marketing costs, shipments, and research and development costs.

In this direct final rule, DOE presents the results of the above analyses, incorporating revisions to the analyses based on comments and new information received. DOE also presents results of the following additional analyses in the direct final rule:

- An LCC subgroup analysis to evaluate variations in consumer characteristics that might cause a standard to affect particular consumer subpopulations, such as low-income households, differently than the overall population.

- A manufacturer impact analysis to estimate the financial impact of standards on manufacturers and to calculate impacts on competition, employment, and manufacturing capacity.

- A utility impact analysis to estimate the effects of proposed standards on electric, gas, or oil utilities.

- An employment impact analysis to assess the aggregate impacts on national employment.

- An environmental impact analysis to estimate the effects of amended standards on emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury (Hg).

- A regulatory impact analysis to examine major alternatives to proposed amended energy conservation standards that potentially could achieve substantially the same regulatory goal at a lower cost.

DOE developed this analytical framework and documented its initial findings in the *Energy Conservation Standards Rulemaking Framework Document for Residential Clothes Washers* (the framework document). DOE announced the availability of the framework document in a Notice of Public Meeting and Availability of a Framework Document published in the *Federal Register* on August 28, 2009. 74 FR 44306. DOE presented the analytical approach to interested parties during a public meeting on September 21, 2009. The framework document is available at www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/clothes_washers_framework.pdf .

In response to the publication of the framework document and the associated public meeting, DOE received comments from interested parties regarding its analytical approach. In the direct final rule notice, DOE: (1) summarizes the key comments received from interested parties and describes DOE's responses to those comments; and (2) summarizes any significant changes in the analytical approach made since publishing the framework document. This final rule TSD contains details of the final analyses conducted for residential clothes washers.

2.2 MARKET AND TECHNOLOGY ASSESSMENT

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

2.2.1 Market Assessment

When DOE begins an energy conservation standards rulemaking, it develops information that provides an overall picture of the market for the products considered, including the nature of the products, the industry structure, and market characteristics for the products. This activity consists of both quantitative and qualitative efforts based primarily on publicly available information. The subjects addressed in the market assessment for residential clothes washers included manufacturers, trade associations, and the quantities and types of products sold and offered for sale. DOE examined both large and small and foreign and domestic residential clothes washer manufacturers. DOE also examined publicly available data from the key trade association for this product category, the Association of Home Appliance Manufacturers (AHAM). DOE reviewed shipment data collected by AHAM and *Appliance* magazine to evaluate annual shipment trends. Finally, DOE reviewed other energy efficiency programs from utilities, individual States, and other organizations. Chapter 3 of the 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 use to attain higher performance levels. In consultation with interested parties, DOE develops a list of technologies for consideration. Initially, these technologies encompass all those it believes are technologically feasible.

DOE developed its list of technologically feasible design options for residential clothes washers through consultation with manufacturers of components and systems, and from trade publications and technical papers. Since many options for improving product efficiency are available in existing units, product literature and direct examination provided additional information.

Chapter 3 of the TSD includes the detailed list of all technology options identified for residential clothes washers.

2.3 SCREENING ANALYSIS

The screening analysis examines various technologies as to whether they: (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an

adverse impact on product utility or availability; and (4) have adverse impacts on health and safety. DOE developed an initial list of efficiency-enhancement options from the technologies identified as technologically feasible in the technology assessment. Then DOE, in consultation with interested parties, reviewed the list to determine if these options are practicable to manufacture, install, and service, would adversely affect product utility or availability, or would have adverse impacts on health and safety. In addition, DOE removed from the list technology options that lack energy consumption data as well as technology options whose energy consumption could not be adequately measured by existing DOE test procedures. In the engineering analysis, DOE further considered efficiency enhancement options that it did not screen out in the screening analysis. Chapter 4 of the TSD contains details on the screening analysis for residential clothes washers.

2.4 ENGINEERING ANALYSIS

The engineering analysis (chapter 5 of the final rule TSD) establishes the relationship between the manufacturing production cost (MPC) and the efficiency for each class of residential clothes washers. The purpose of the analysis is to estimate the incremental MPCs for a product that would result from increasing efficiency levels above the level of the baseline model in each product class. This relationship serves as the basis for cost/benefit calculations in terms of individual consumers, manufacturers, and the nation. Chapter 5 discusses the product classes DOE analyzed, the representative baseline units, the incremental efficiency levels, the methodology DOE used to develop the manufacturing production costs, the cost-efficiency curves, and the impact of efficiency improvements on the considered products.

The engineering analysis considered technologies not eliminated in the screening analysis, although certain technologies were not analyzed due to negligible incremental efficiency improvements or the inability of the existing DOE test procedures to measure any reduction in energy use. DOE considered the remaining technologies, designated as design options, in developing the cost-efficiency curves.

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

DOE proposed used the efficiency-level approach for residential clothes washers, combined with the cost-assessment approach to develop a cost for each efficiency level. This approach involved physically disassembling commercially available products, consulting with outside experts, reviewing publicly available cost and performance information, and modeling equipment cost. The efficiency levels that DOE considered in the engineering analysis are

attainable using technologies currently available on the market in residential clothes washers. In addition, DOE associated each efficiency level with specific technologies that manufacturers might use to provide interested parties with additional transparency of assumptions and results and the ability to perform independent analyses for verification. Chapter 5 of this TSD describes the methodology and results of the efficiency level analysis used to derive the cost-efficiency relationships.

2.5 MARKUPS ANALYSIS

DOE performed a markup analysis to convert the manufacturer costs estimated in the engineering analysis to consumer prices, which then were used in the LCC and PBP and manufacturer impact analyses. DOE calculated markups for baseline products (baseline markups) and for more efficient products (incremental markups). The incremental markup relates the change in the manufacturer sales price 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 TSD provides details on DOE's development of markups for residential clothes washers.

2.6 ENERGY AND WATER USE ANALYSIS

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

2.7 LIFE-CYCLE COST AND PAYBACK PERIOD ANALSYIS

New energy conservation standards usually decrease a product's operating expenses, and usually increase its price. DOE analyzes the net effect of amended standards on consumers by evaluating the net life cycle cost (LCC). To evaluate the net LCC, DOE uses the cost-efficiency relationship derived in the engineering analysis and the energy and water costs derived from the energy and water use analysis. Inputs to the LCC calculation include the installed cost of a product to the consumer (consumer purchase price plus installation cost), operating expenses (energy expenses and maintenance costs), the lifetime of the unit, and a discount rate.

Because the installed cost of a product typically increases while operating costs typically decrease under new standards, there is a time in the life of products having higher-than-baseline efficiency when the net operating-cost benefit (in dollars) since the time of purchase is equal to the incremental first cost of purchasing the product. The time required for products to reach this cost-equivalence point is known as the payback period (PBP).

Recognizing that several inputs to determining consumer LCC and PBP are either variable or uncertain, DOE uses Monte Carlo simulation and probability distributions to model both the uncertainty and variability in inputs. DOE uses Microsoft Excel 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.

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

2.8 SHIPMENTS ANALYSIS

Forecasts of product shipments are needed to calculate the national impacts of standards on energy use, NPV, and future manufacturer cash flows. DOE developed shipment forecasts based on an analysis of key market drivers for residential clothes washers. In DOE's shipments model, shipments of products are driven by new construction, stock replacements, and other types of purchases.

The shipments models take an accounting approach, tracking market shares of each product class and the vintage of units in the existing stock. Stock accounting uses product shipments as inputs to estimate the age distribution of in-service product stocks for all years. The age distribution of in-service product stocks is a key input to calculations of both the NES and NPV, because operating costs for any year depend on the age distribution of the stock.

DOE also considers the impacts on shipments from changes in product purchase price and operating cost associated with higher energy efficiency levels. Chapter 9 of this TSD provides additional details on the shipments analysis.

2.9 NATIONAL IMPACT ANALYSIS

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

DOE may conduct sensitivity analyses by running scenarios on specific input variables. Chapter 10 of this TSD provides additional details regarding the national impact analysis.

Several of the inputs for determining NES and NPV depend on the forecast trends in product energy efficiency. For the base case, DOE uses the efficiency distributions developed for the LCC analysis, and assumes some rate of change over the forecast period. In this analysis, DOE has used a roll-up scenario in developing its forecasts of efficiency trends after standards take effect. Under a roll-up scenario, all products that perform at levels below a prospective standard are moved, or rolled-up, to the minimum performance level allowed under the standard. Product efficiencies above the standard level under consideration would remain the same as before the revised standard takes effect.

2.9.1 National Energy and Water Savings

The inputs for determining the national energy and water savings (NES) for each product class are: (1) annual energy and water consumption per unit, (2) shipments, (3) product stock, (4) national energy and water consumption, and (5) site-to-source conversion factors for energy. DOE calculated national energy and water consumption by multiplying the number of units, or stock, of each product class (by vintage, or age) by the unit energy and water consumption (also by vintage). DOE calculated annual NES based on the difference in national energy and water consumption for the base case (without new efficiency standards) and for each efficiency standard being considered. DOE estimated energy consumption and savings based on site energy consumption, which it then converted to source energy. DOE estimated water consumption and savings based on site water use. DOE did not use a conversion factor for water because no such factor has been developed. Cumulative energy and water savings are the sum of the NES for each year.

2.9.2 Net Present Value of Consumer Benefit

The inputs for determining NPV of the total costs and benefits experienced by consumers are: (1) total annual installed cost, (2) total annual savings in operating costs, (3) a discount factor, (4) present value of costs, and (5) present value of savings. DOE calculated net savings each year as the difference in total savings in operating costs and total increases in installed costs between the base case and each standards case. DOE calculated savings over the life of each product 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 a discount factor based on real discount rates of 3 percent and 7 percent to discount future costs and savings to present values.

DOE calculated the difference in total installed cost between the base case and each standards case (*i.e.*, after standards take effect). Because the more efficient products bought in the standards case usually cost more than products bought in the base case, cost increases appear as negative values in the NPV.

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

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; (2) households solely occupied by senior citizens. Chapter 11 of this TSD describes the consumer subgroup analysis.

2.11 MANUFACTURER IMPACT ANALYSIS

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

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

2.12 UTILITY IMPACT ANALYSIS

The utility impact analysis estimates the effects of amended energy conservation standards on installed electricity generation capacity and electricity generation. For this analysis, DOE adapted NEMS, which is a large multi-sectoral, partial-equilibrium model of the U.S.

energy sector that the EIA has developed throughout the past decade, primarily for preparing EIA's *AEO*. In previous rulemakings, a variant of NEMS (currently termed NEMS-BT, BT referring to DOE's Building Technologies Program), was developed to better address the specific impacts of an energy conservation standard. NEMS, which is available in the public domain, produces a widely recognized baseline energy forecast for the United States. The typical NEMS outputs include forecasts of electricity and natural gas sales, prices, and electric generating capacity.

DOE conducts the utility impact analysis as a scenario that departs from the latest *Annual Energy Outlook* reference case. In other words, the energy savings impacts from amended energy conservation standards are modeled using NEMS-BT to generate forecasts that deviate from the *AEO* reference case. Chapter 13 describes the results of the utility impact analysis.

2.13 EMPLOYMENT IMPACT ANALYSIS

New or amended energy conservation standards can impact employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the plants that produce the covered products, and at the affiliated distribution and service companies, resulting from the adoption of new standards. 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 the adoption of standards. Chapter 14 describes the results of the employment impact analysis.

DOE investigated the combined direct and indirect employment impacts of standards using the Pacific Northwest National Laboratory (PNNL)'s "Impact of Sector Energy Technologies" (ImSET) model. The ImSET model, which was developed for DOE's Office of Planning, Budget, and Analysis, estimates the employment and income effects energy-saving technologies produced in buildings, industry, and transportation. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy conservation investments.

2.14 ENVIRONMENTAL ASSESSMENT

To comply with the National Environmental Policy Act and the requirements of 42 U.S.C. 6295(o)(2)(B)(i)(VI) and 6316(a), DOE prepared an environmental assessment of the impacts of amended energy conservation standards for residential clothes washers on the human environment. The primary environmental effects of these standards would be reduced power plant emissions resulting from reduced consumption of electricity. DOE assessed these environmental effects by using NEMS-BT to provide key inputs to its analysis. The portion of the environmental assessment that will be produced by NEMS-BT considers carbon dioxide (CO_2), nitrogen oxides (NO_x), and mercury (Hg). The environmental assessment also considers

impacts on SO_2 emissions and discusses particulate matter (PM) emissions. Chapter 15 describes the results of the environmental assessment.

2.14.1 Carbon Dioxide

In the absence of any Federal emissions control regulation of power plant emissions of CO_2, a DOE standard is likely to result in reductions of these emissions. The CO_2 emissions reductions likely to result from a standard will be estimated using NEMS-BT and national energy savings estimates drawn from the NIA spreadsheet model. The net benefit of the standard is the difference between emissions estimated by NEMS-BT at each standard level considered and the *AEO* Reference Case. NEMS-BT tracks CO_2 emissions using a detailed module that provides results with broad coverage of all sectors and inclusion of interactive effects.

2.14.2 Sulfur Dioxide

SO_2 emissions from affected Electric Generating Units (EGUs) are subject to nationwide and regional emissions cap and trading programs, and DOE has preliminarily determined that these programs create uncertainty about the standards' impact on SO_2 emissions. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for affected EGUs in all 50 states and the District of Columbia (D.C.). SO_2 emissions from 28 eastern states and D.C. are also limited under the Clean Air Interstate Rule (CAIR, 70 Fed. Reg. 25162 (May 12, 2005)), which created an allowance-based trading program that would have gradually replaced the Title IV program in those states and D.C. Although CAIR has been remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit), see *North Carolina v. EPA*, 550 F.3d 1176 (D.C. Cir. 2008), it will remain in effect until it is replaced by a rule consistent with the D.C. Circuit's earlier opinion in *North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir. 2008). On July 6, 2010, EPA proposed the Transport Rule, a replacement for CAIR, which would limit emissions from EGUs in 32 states, potentially through the interstate trading of allowances, among other options. 75 FR 45210 (Aug. 2, 2010).

The attainment of emissions caps is typically flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the imposition of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. However, if the standard resulted in a permanent increase in the quantity of unused emissions allowances, there would be an overall reduction in SO_2 emissions from the standards. While there remains some uncertainty about the ultimate effects of efficiency standards on SO_2 emissions covered by the existing cap and trade system, the NEMS-BT modeling system that DOE uses to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2.

2.14.3 Nitrogen Oxides

NEMS-BT also has an algorithm for estimating NO_x emissions from power generation. As with SO_2 emissions, these emissions will be affected by CAIR and its replacement. The recent legal history surrounding CAIR, including its proposed replacement by the Transport Rule, is discussed above.

Much like SO_2 emissions, a cap on NO_x emissions would mean that energy conservation standards may have little or no physical effect on these emissions in the 28 eastern states and the D.C. covered by CAIR or any states covered by the proposed Transport Rule. Because all states covered by CAIR opted to reduce NO_x emissions through participation in cap-and-trade programs for electric generating units, emissions from these sources are currently capped across the CAIR region.

DOE used NEMS-BT to estimate the emissions reductions from possible standards in the states where emissions are not capped.

2.14.4 Mercury

Similar to emissions of SO_2 and NO_X, future emissions of Hg would have been subject to emissions caps. In May 2005, EPA issued the Clean Air Mercury Rule (CAMR). 70 FR 28606 (May 18, 2005). CAMR would have permanently capped emissions of mercury for new and existing coal-fired power plants in all States by 2010. However, on February 8, 2008, the DC Circuit issued its decision in *New Jersey v. Environmental Protection Agency*, in which it vacated CAMR. 517 F.3d 574 (D.C. Cir. 2008) EPA has decided to develop emissions standards for power plants under the Clean Air Act (Section 112), consistent with the DC Circuit's opinion on the CAMR. See http://www.epa.gov/air/mercuryrule/pdfs/certpetition_withdrawal.pdf. Pending EPA's forthcoming revisions to the rule, DOE is excluding CAMR from its Environmental Analysis. In the absence of CAMR, a DOE standard would likely reduce Hg emissions and DOE plans to use NEMS-BT to estimate these emission reductions. However, DOE continues to review the impact of rules that reduce energy consumption on Hg emissions, and may revise its assessment of Hg emission reductions in future rulemakings.

2.14.5 Particulate Matter

DOE acknowledges that particulate matter (PM) exposure can impact human health. Power plant emissions can have either direct or indirect impacts on PM. A portion of the pollutants emitted by a power plant are in the form of particulates as they leave the smoke stack. These are direct, or primary, PM emissions. However, the great majority of PM emissions associated with power plants are in the form of secondary sulfates, which are produced at a significant distance from power plants by complex atmospheric chemical reactions that often involve the gaseous (non-particulate) emissions of power plants, mainly SO_2 and NO_x. The quantity of the secondary sulfates produced is determined by a very complex set of factors including the atmospheric quantities of SO_2 and NO_x, and other atmospheric constituents and conditions. Because these highly complex chemical reactions produce PM comprised of different constituents from different sources, EPA does not distinguish direct PM emissions from power plants from the secondary sulfate particulates in its ambient air quality requirements, PM monitoring of ambient air quality, or PM emissions inventories. For these reasons, it is not currently possible to determine how the amended standard impacts either direct or indirect PM emissions. Therefore, DOE is not planning to assess the impact of these standards on PM emissions. Further, as described previously, it is uncertain whether efficiency standards will

result in a net decrease in power plant emissions of SO_2 and NO_x, since those pollutants are now largely regulated by cap and trade systems.

2.14.6 Monetization of Emissions Reduction Benefits

In this section, DOE explains how it plans to monetize the benefits associated with emissions reductions. For those emissions for which real national emission reductions are anticipated (CO_2, Hg, and NO_x for 22 states), only ranges of estimated economic values based on environmental damage studies of varying quality and applicability are available. Therefore, DOE reports estimates of monetary benefits derived using these values and consider these benefits in weighing the costs and benefits of each of the standard levels considered.

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

At the time of this notice, the most recent interagency estimates of the potential global benefits resulting from reduced CO_2 emissions in 2010 were $4.7, $21.4, $35.1, and $64.9 per metric ton in 2007 dollars. These values are then adjusted to 2009$ using the standard GDP deflator value for 2008 and 2009. For emissions (or emissions reductions) that occur in later years, these values grow in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although preference will be given to consideration of the global benefits of reducing CO_2 emissions. *See* appendix 15-A of this TSD for the full range of annual SCC estimates from 2010 to 2050. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the discount rates that had been used to obtain the SCC values in each case.

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

DOE also intends to estimate the potential monetary benefit of reduced NO_X emissions resulting from the standard levels it considers. For NO_x emissions, available estimates suggest a very wide range of monetary values for NO_X emissions, ranging from $370 per ton to $3,800 per ton of NO_X from stationary sources, measured in 2001$ (equivalent to a range of $447 to $4,591 per ton in 2009$). Refer to the OMB, Office of Information and Regulatory Affairs, "2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities," for additional information. In accordance with U.S. Office of

Management and Budget (OMB) guidance, DOE will conduct two calculations of the monetary benefits derived using each of the economic values used for NO_x, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.

DOE does not plan to monetize estimates of Hg in this rulemaking. DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg in its rulemakings.

2.15 REGULATORY IMPACT ANALYSIS

DOE prepared a regulatory impact analysis (RIA) under Executive Order 12866, "Regulatory Planning and Review," 58 FR 51735, October 4, 1993, which was subject to review under the Executive Order by the Office of Information and Regulatory Affairs (OIRA) at the Office of Management and Budget. The RIA evaluated non-regulatory alternatives to standards, in terms of their ability to achieve significant energy savings in the considered products at a reasonable cost, and compared the effectiveness of each one to the effectiveness of the adopted standards. Chapter 16 of this TSD describes the results of the regulatory impact analysis.

DOE recognizes that voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties can result in substantial improvements to energy efficiency or reductions in energy consumption. DOE considered the likely effects of non-regulatory initiatives on product energy use, consumer utility, and LCC. DOE based its assessment on the actual impacts of any such initiatives to date, but also considered information presented regarding the impacts that any existing initiative might have in the future.

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter provides a profile of the residential clothes washer 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. Present and past industry structure and industry financial information help DOE in the process of conducting the manufacturer impact analysis.

3.2 PRODUCT DEFINITIONS

DOE defines "clothes washer" under the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 United States Code (U.S.C.) 6291–6309) as follows:

- *Clothes washer* means a consumer product designed to clean clothes, utilizing a water solution of soap and/or detergent and mechanical agitation or other movement, and must be one of the following classes: automatic clothes washers, semi-automatic clothes washers, and other clothes washers.

- *Automatic clothes washer* means a class of clothes washers which has a control system which is capable of scheduling a preselected combination of operations, such as regulation of water temperature, regulation of water fill level, and performance of wash, rinse, drain, and spin functions without the need for user intervention subsequent to the initiation of machine operation. Some models may require user intervention to initiate these different segments of the cycle after the machine has begun operation, but they do not require the user to intervene to regulate the water temperature by adjusting the external water faucet valves.

- *Semi-automatic clothes washer* means a class of clothes washer that is the same as an automatic clothes washer except that user intervention is required to regulate the water temperature by adjusting the external water faucet valves.

- *Other clothes washer* means a class of clothes washer which is not automatic or semi-automatic clothes washer.

(10 CFR 430.2)

3.3 PRODUCT CLASSES

DOE separated residential clothes washers into product classes and has formulated separate energy conservation standards for each class. The criteria for separation into different product classes are: (1) type of energy used; (2) capacity; or (3) other performance-related features such as those that provide utility to the consumer, or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 U.S.C. 6295 (q))

Currently, DOE divides residential clothes washers into five product classes based on location of access, capacity and features, such as suds saving. For the existing energy conservation standards, DOE defines residential clothes washers in the following classes:

- Top-loading, compact (less than 1.6 cubic feet capacity);
- Top-loading, standard (1.6 cubic feet or greater capacity);
- Top-loading, semi-automatic;
- Front-loading; and
- Suds-saving.

In a supplemental advance notice of proposed rulemaking (ANOPR) for clothes washers published on November 19, 1998 (hereafter, the "November 1998 Supplemental ANOPR"), DOE proposed to eliminate the top-loading semi-automatic and suds-saving product classes because they do not offer any added utility which is inherently less energy efficient and therefore would require protection from the energy conservation standards. 63 FR 64348. Interested parties did not provide any comment in response to this proposed elimination. In the final rule published on January 12, 2001 (hereafter, the "January 2001 Final Rule"), due to the continued absence of information available to analyze these classes and ensure that they could meet the proposed standard levels, DOE maintained these product classes but did not subject them to minimum energy conservation standards. 66 FR 3322.

On August 21, 2009, DOE published a framework document (hereafter, the "Framework Document"), in which it considered, and solicited comment on, the validity of retaining the top-loading semi-automatic and suds-saving product classes. DOE is unaware of any top-loading semi-automatic or suds-saving clothes washers currently on the market. Also, the current DOE test procedure cannot measure the possible energy savings associated with suds savings. Interested parties generally agreed with the elimination of these two product classes, and therefore, DOE is proposing to eliminate these two product classes.

The Joint Stakeholder agreement (the "Joint Petition") between manufacturers and advocates[a] (the "Joint Petitioners") recommends splitting the current front-loading product class into two separate product classes based on capacity:

- Front-loading, compact (less than 1.6 cubic feet capacity)
- Front-loading, standard (1.6 cubic feet or greater capacity)

DOE is currently unaware of any front-loading clothes washers on the market that meet the definition of a compact front-loading product class.

DOE believes the product classes proposed in the Joint Petition represent the results of extensive negotiations among all interested parties, including manufacturers with full knowledge of products on the market and potential capabilities of products not currently manufactured. Therefore, DOE has chosen to separate residential clothes washers into the following four product classes:

- Top-loading, compact (less than 1.6 cubic feet capacity);
- Top-loading, standard (1.6 cubic feet or greater capacity);
- Front-loading, compact (less than 1.6 cubic feet capacity); and
- Front-loading, standard (1.6 cubic feet or greater capacity).

3.4 PRODUCT TEST PROCEDURES

Test procedures exist for clothes washers to determine energy efficiency and annual energy use as the basis for representation and determination of compliance with energy conservation standards. The U.S. government established the first Federal test procedure for clothes washers in 1977. In the 1990's, DOE began revising the clothes washer test procedure because the existing test procedure did not cover new clothes washer technologies such as high spin speed and adaptive fill control, and because comments submitted by the Association of Home Appliance Manufacturers (AHAM) stated that consumer habits showed a reduction in the use of hot water and energy. In 1997, DOE published a final rule establishing a new test procedure for clothes washers to more accurately establish their efficiency and energy use; the new test procedure became effective on January 1, 2004 (hereafter, the "1997 Final Rule.) The key changes made from the original to new test procedure include: (1) replacing the energy factor (EF) descriptor, which only calculated the energy use of the clothes washer itself, with a modified energy factor (MEF), which accounts for the remaining moisture content (RMC) of clothes leaving the washer, thereby crediting a reduction in clothes drying energy use; (2) specifying different water temperatures for testing; (3) specifying test cloth loads for all classes

[a] "Agreement on Minimum Federal Efficiency Standards, Smart Appliances, Federal Incentives and Related Matters for Specified Appliances," DOE Docket No. EERE–2008–BT–STD–0019, Comment 32. DOE considered the Joint Petitioners' comments to supersede earlier comments by the listed parties regarding issues subsequently discussed in the Joint Petition.

of clothes washers; and (4) revising the average number of use cycles in a year to reflect current consumer usage patterns. 62 FR 45484 (August 27, 1997). In 1998, DOE published a correction to the 1997 Final Rule, correcting the introductory note to the new clothes washer test procedure. 63 FR 16669 (April 6, 1998).

In 2001, as part of its energy conservation standards rulemaking for clothes washers, DOE amended its clothes washer test procedure, incorporating changes to the energy test cloth, RMC, and extractor testing. 66 FR 3330 (January 12, 2001). Again in 2003, DOE amended its clothes washer test procedure, including the following revisions: (1) replacing the lowest spin cycle speed of 50 gravitation (g) force with a spin cycle of 100 g for testing the cloth used in the extraction phase of the test procedure; and (2) specifying the use of additional statistical analysis to qualify the interactive effect between different lots of the test cloth and spin speeds to improve consistency with the baseline data. 68 FR 62198 (October 31, 2003).

Standby power measurement was not incorporated into the DOE test procedure for residential clothes washers established by the 2003 final rule. Section 310 of the Energy Independence and Security Act of 2007 (EISA 2007), Pub. L. No. 110-142 amends Section 325 of EPCA to require that the test procedure for residential clothes washers be amended to include measurement of standby mode and off mode energy use, taking into consideration the most current version of the International Electrotechnical Commission (IEC) Standard 62301 *Household electrical appliances – Measurement of standby power* (IEC Standard 62301) and IEC Standard 62087 *Methods of measurement for the power consumption of audio, video and related equipment*.[b] EPCA, as amended by EISA 2007, also states that the final rule for this test procedure shall be published no later than June 30, 2009. (42 U.S.C. 6295(gg)) DOE notes that the current version of IEC Standard 62301 is designated IEC Standard 62301, Second Edition, 2011. The Second Edition amended the definitions of modes to include off mode(s), network connected standby mode(s), and disconnected mode as well as standby mode(s). DOE also notes that EISA 2007 amends EPCA to require that standby mode and off mode energy consumption be integrated into the overall energy efficiency, energy consumption, or other energy descriptor unless the Secretary determines that – (i) the current test procedures for a covered product already fully account for and incorporate standby mode and off mode energy consumption of the covered product; or (ii) such an integrated test procedure is technically infeasible for a particular covered product, in which case the Secretary shall prescribe a separate standby mode and off mode energy use test procedure for the covered product, if technically feasible. (42 U.S.C. 6295(gg)(2)(A))

To support this rulemaking, a test procedure change to incorporate standby mode and off mode energy consumption in residential clothes washers was initiated in parallel with the current rulemaking. DOE integrated standby and off mode energy use into the revised test procedure by establishing an "integrated modified energy factor" (IMEF), which also includes amended calculations of energy use in the active mode. The revised test procedure also establishes an

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

"integrated water factor" (IWF), a metric that incorporates water usage from all cycles included in the energy test cycle rather than just the cold wash cycle. 77 FR 13888 (March 7, 2012).

In developing the amended rule, DOE also investigated test procedures used by countries that are considered leaders in reducing standby power. Those countries, which include Japan, Korea, and Australia/New Zealand, all follow and/or reference IEC Standard 62301.

3.5 MANUFACTURER TRADE GROUPS

DOE recognizes the importance of trade groups in disseminating information and promoting the interests of the industry that they support. To gain insight into the residential clothes washer 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 the Association of Home Appliance Manufacturers (AHAM) as a trade group that supports, or has an interest in, the residential clothes washer industry. AHAM,[c] formed in 1967, aims to enhance the value of the home appliance industry through leadership, public education and advocacy. AHAM provides services to its members including government relations; certification programs for room air conditioners, dehumidifiers and room air cleaners; an active communications program; and technical services and research. In addition, AHAM conducts other market and consumer research studies and publishes a biennial *Fact Book*. AHAM also develops and maintains technical standards for various appliances to provide uniform, repeatable procedures for measuring specific product characteristics and performance features.

3.6 MANUFACTURER INFORMATION

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

3.6.1 Manufacturers and Market Shares

Using publicly available data (*e.g.*, *Appliance Magazine* and market assessments performed by third parties), DOE estimates the market shares for domestic manufacturers of residential clothes washers. Manufacturers may offer multiple brand names. Some of the brand names originated from independent appliance manufacturers that have been acquired over time, and domestic manufacturers may use their brand on products manufactured overseas. This

[c] For more information, visit *www.aham.org*.

analysis may also include off-shore manufacturers that maintain a significant domestic presence via a U.S. entity.

DOE estimates that there are 17 residential clothes washer manufacturers selling into the domestic market, of which several are foreign-owned companies with manufacturing facilities outside of the United States. The majority of market share is held by four major manufacturers, including Whirlpool Corporation (Whirlpool)/Maytag Corporation (Maytag), GE Consumer & Industrial (GE), AB Electrolux (Frigidaire), and LG Electronics (LG).[1] As discussed in section 3.6.2, Maytag and Whirlpool merged in 2006 but have continued to maintain both product lines to this date. The combined Maytag-Whirlpool entity accounts for approximately 64 percent of the residential clothes washer market. Together, the four main manufacturers comprise 92 percent of the residential clothes washer market. Other manufacturers include Alliance Laundry Systems LLC (Alliance), AM Appliance Group (formerly ASKO, Inc.), BSH Home Appliances Corporation (Bosch-Siemens), Equator Corporation (Equator), Fagor America, Inc. (Fagor), Fisher & Paykel Appliances Limited (Fisher & Paykel), Haier America Trading, LLC (Haier), Indesit Company (Indesit), Miele Inc. (Miele), Samsung Electronics America, Inc. (Samsung), Staber Industries, Inc. (Staber), and Felix Storch, Inc. (Summit). Table 3.6.1 lists these manufacturers. Figure 3.6.1 illustrates the 2008 market shares for the domestic residential clothes washer market.

The U.S. Census Bureau's 2006 *Annual Survey of Manufactures* reports one U.S. company engaged primarily in the manufacture of household laundry equipment (North American Industry Classification System (NAICS) code 335224). In 2006, that company employed 13,298 workers and shipped more than $4.9 billion of products.[2]

Table 3.6.1 Major and Other Residential Clothes Washer Manufacturers

Major Manufacturers	**Other Manufacturers**
Whirlpool/Maytag	Alliance
GE	Asko
Electrolux (Frigidaire)	Bosch-Siemens
LG	Equator
	Fagor
	Fisher & Paykel
	Haier
	Indesit
	Miele
	Samsung
	Staber
	Summit

Figure 3.6.1 2008 Residential Clothes Washer Market Shares[3]

Table 3.6.2 shows the market share for residential clothes washer manufacturers between 2000 and 2008. Figure 3.6.2 shows this data graphically. The market share for Whirlpool and GE has remained relatively stable since 2000, while Electrolux and Maytag's market share has decreased by 6 percent over that period. LG has grown from a negligible market share in 2006 to a 6-percent market share in 2008. According to ENERGY STAR, foreign manufacturers such as Bosch-Siemens, LG, Samsung, and Fisher & Paykel are beginning to gain traction in the U.S. market, expanding floor space with national appliance retailers.[4]

Table 3.6.2 2000–2008 Clothes Washer Market Share[5]

	Market Share *(%)*								
Company	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
Whirlpool	64	51	51	51	51	51	51	50	50
Maytag	*	16	18	19	20	21	23	22	22
GE	16	17	18	17	17	17	18	18	16
Electrolux (Frigidaire)	6	6	9	9	9	9	8	8	10
LG	6	2	-	-	-	-	-	-	-
Others	8	10	4	4	3	2	0	2	2

* Maytag market share for 2008 included in Whirlpool data.

Figure 3.6.2 2000–2008 Clothes Washer Market Share

3.6.2 Mergers and Acquisitions

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

According to the September 2009 issue of *Appliance Magazine*, Whirlpool (including Maytag), GE, and Electrolux comprise 85 percent of the core appliance market share. "Core appliances" include dishwashers, clothes dryers, freezers, ranges, refrigerators, and clothes washers. Figure 3.6.3 illustrates the breakdown of 2008 market shares in the core appliance category.

Figure 3.6.3 2008 Core Appliance Market Shares[6]

On August 22, 2005, Whirlpool, headquartered in Benton Harbor, Michigan, and Maytag, based in Newton, Iowa, announced plans to merge in a deal worth $2.7 billion.[7] Maytag shareholders approved the merger on December 22, 2005. Shortly after announcing the merger, Whirlpool submitted a pre-merger notification to the U.S. Department of Justice (DOJ). The DOJ

Antitrust Division initiated an investigation into the effects of the merger, including potential lessening of competition or the creation of a monopoly.

Opponents of the merger asserted that the combined companies would control as much as 70 percent of the residential laundry market and as much as 50 percent of the residential dishwasher market.[8] Industry analysts noted that Whirlpool's large potential residential laundry market share was skewed because the company produces clothes washers for Sears, which sells them under their Kenmore in-house brand. Whirlpool must periodically bid with other manufacturers to keep the Kenmore contract, and Sears controls the pricing of the Kenmore units. Without Kenmore, the market share of share of a combined Maytag-Whirlpool company would be slightly less than 30 percent in U.S. major appliances, Whirlpool claimed.[9]

In early January 2006, U.S. Senator Tom Harkin and U.S. Representative Leonard Boswell, both of Iowa, called upon the DOJ to block the merger, claiming it would give Whirlpool an unfair advantage in the home appliance industry. The Congressmen wrote that if the DOJ does not block the deal, the agency should at least "require that Whirlpool divest the washer and dryer portions of Maytag to a viable purchaser who will have the financial capability and desire to continue to operate that business."[10]

On March 29, 2006, DOJ closed its investigation and approved the merger. DOJ claims "that the proposed transaction is not likely to reduce competition substantially. The combination of strong rival suppliers with the ability to expand sales significantly and large cost savings and other efficiencies that Whirlpool appears likely to achieve indicates that this transaction is not likely to harm consumer welfare."[11]

The DOJ Antitrust Division focused its investigation on residential laundry, although it considered impacts across all products offered by the two companies. DOJ determined that the merger would not give Whirlpool excessive market power in the sale of its products and that any attempt to raise prices would likely be unsuccessful. In support of this claim, DOJ noted that (1) other U.S. brands, including Kenmore, GE, and Frigidaire, are well established; (2) foreign manufacturers, including LG and Samsung, are gaining market share; (3) existing U.S. manufacturers are below production capacity; (4) the large home appliance retailers have alternatives available to resist price increase attempts; and (5) Whirlpool and Maytag substantiated large cost savings and other efficiencies that would benefit consumers.[12]

Whirlpool and Maytag completed the merger on March 31, 2006. This large merger follows several other mergers and acquisitions in the home appliance industry. For example, Maytag acquired Jenn-Air Corporation (Jenn-Air) in 1982, Magic Chef, Inc. (Magic Chef) in 1986, and Amana Appliances (Amana) in 2001. Whirlpool acquired the KitchenAid division of Hobart Corporation (KitchenAid) in 1986. White Consolidated Industries (WCI) acquired the Frigidaire division of General Motors Corporation in 1979, and AB Electrolux acquired WCI (and therefore Frigidaire) in 1986.

3.6.3 Small Business Impacts

DOE considers the possibility of small businesses being impacted by the promulgation of energy conservation standards for residential clothes washers. The Small Business Association considers an entity to be a small business if, together with its affiliates, it employs less than a threshold number of workers specified in 13 CFR part 121, which relies on size standards and codes established by the NAICS. The threshold number for NAICS classification for 335224, which applies to household laundry equipment manufacturers and includes clothes washer manufacturers, is 1,000 employees. At this time, DOE is aware of one small manufacturer of residential clothes washers who would be impacted by a minimum efficiency standard. For this small manufacturers, DOE will study the potential impacts on the small businesses in greater detail during the manufacturer impact analysis (MIA).

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 clothes washers from publicly available sources. This section contains distribution channel information for residential appliances.

For residential appliances, including residential clothes washers, the majority of consumers purchase their appliances directly from retailers. Table 3.6.3 identifies the types of retail stores through which major appliances, including residential clothes washers, are sold based on data from the AHAM *Fact Book* 2005.[13]

Table 3.6.3 Major Appliance Sales by Channel (Purchased between 2001 and 2005)[14]

Type of Store	Appliance Purchases (*%*)
Department Store (such as Sears or Kohls)	34.7
Appliance Store or Consumer Electronics Store	30.9
Home Improvement Store (such as Lowe's or Home Depot)	23.8
Discount Store (such as Wal-Mart or K-Mart)	2.0
Membership Warehouse Club/Store (such as Sam's or Costco)	1.8
Another type of store	6.8

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.[15] A 2000 Consortium for Energy Efficiency (CEE) report determined that 5–10 percent of major appliance sales were made to commercial consumers such as builders, contractors, government sales, and property managers through distributors or wholesalers.[16]

3.7 REGULATORY PROGRAMS

The following section details current regulatory programs mandating energy conservation standards for residential clothes washers. Section 3.7.1 discusses Federal energy conservation standards prior to EISA 2007; section 3.7.2 reviews new standards issued by EISA 2007; section 3.7.3 provides an overview of existing State standards; sections 3.7.4 and 3.7.5 review standards in Canada and Mexico, respectively, that may impact the companies servicing the North American market; section 3.7.6 reviews international energy performance standards for residential clothes washers; and section 3.7.7 reviews foreign regulatory programs for standby power.

3.7.1 Federal Energy Conservation Standards Prior to EISA 2007

The National Appliance Energy Conservation Act of 1978 (NAECA) amended EPCA to establish the first prescriptive standards for residential clothes washers, requiring that all rinse cycles of clothes washers manufactured after January 1, 1988, shall include an unheated water option, but may have a heated water rinse option, and further required that DOE conduct two cycles of rulemakings to determine if more stringent standards are justified.[d] (42 U.S.C. 6295 (g)(2) and (4)) On May 14, 1991, DOE published a final rule in the *Federal Register* (FR) establishing the first set of performance standards for residential clothes washers; the new standards became effective on May 14, 1994 (hereafter, the "May 1991 Final Rule".) 56 FR 22279. DOE conducted a second standards rulemaking for residential clothes washers, publishing the January 2001 Final Rule revising the energy conservation standards; the revised standards became effective in two phases, on January 1, 2004 and January 1, 2007. 66 FR 3314. Table 3.7.1 provides energy conservation standards for residential clothes washers established by the January 2001 Final Rule.

[d] DOE defines "clothes washer" under EPCA as "a consumer product designed to clean clothes, utilizing a water solution of soap and/or detergent and mechanical agitation or other movement, and must be one of the following classes: automatic clothes washers, semi-automatic clothes washers, and other clothes washers." 10 CFR 430.2.

Table 3.7.1 Energy Conservation Standards for Residential Clothes Washers Established by the January 2001 Final Rule

Clothes Washer Product Class	Standards Effective Date	
	January 1, 2004	**January 1, 2007**
Top-loading standard and front-loading	1.04 MEF*	1.26 MEF
Top-loading compact	0.65 MEF	-

*The Modified Energy Factor (MEF) is a measure of how many kilowatt-hours (kWh) are required to wash each cubic foot (ft^3) of washer capacity. It measures the total energy consumption of the washer and also accounts for the amount of energy required to dry clothes based on the remaining moisture content of the clothes.

3.7.2 Energy Independence and Security Act of 2007

The Energy Independence and Security Act of 2007 (EISA 2007), Pub. L. No. 110-142, revised the energy conservation standards for residential clothes washers; the revised standards become effective on January 1, 2011. EISA 2007 further required that DOE publish a final rule no later than December 31, 2011 determining whether to amend the standards in effect for clothes washers manufactured on or after January 1, 2015. (42 U.S.C. 6295 (g)(9)) Table 3.7.2 provides the energy conservation standards for residential clothes washers established by EISA 2007.

Table 3.7.2 Energy Conservation Standards for Residential Clothes Washers Established by EISA 2007

. Clothes Washer Product Class	Standards Effective January 1, 2011	
	MEF (***ft^3/kWh/cycle***)	**WF*** (***gallons/ ft^3/cycle***)
Top-loading standard and front-loading	1.26	9.5

* Water Factor (WF) is measured in gallons of water required per cycle per cubic foot of washer capacity.

3.7.3 State Energy Conservation Standards

Federal standards, which preempt any State efficiency standards have existed for the energy consumption of residential clothes washers since 1994. However, no such standard existed for the water efficiency prior to those established by EISA 2007, which become effective January 1, 2011. On October 19, 2005, California issued minimum water conservation standards for residential clothes washers. On September 16, 2005, the California Energy Commission (CEC) issued a petition for an exemption from Federal preemption to seek to apply its own State regulation for residential clothes washer WF. DOE accepted written comments regarding this California petition until April 7, 2006. Table 3.7.3 provides the State's proposed residential clothes washer water conservation standards and their respective effective dates.

Table 3.7.3 California Water Conservation Standards for Residential Clothes Washers

Clothes Washer Classification	Maximum WF (*gallons/ ft^3/cycle*)	
	Effective January 1, 2007	**Effective January 1, 2010**
Top-loading	**8.5**	**6.0**
Front-loading	**8.5**	**6.0**

On December 28, 2006, DOE issued a decision denying the California petition. (71 FR at 78157) The denial of the petition was based on three factors. First, DOE determined that it does not have the statutory authority to prescribe a rule for California that would become effective by January 1, 2007, the first of two compliance dates contained in Title 20, section 1605.2(p)(1) of the California Code of Regulations. Second, DOE ruled that the CEC had not established by a preponderance of the evidence that the State of California has unusual and compelling water interests, a condition required by EPCA for DOE to grant California a waiver from Federal preemption. (42 USC 6297(d)(1)(B)) Finally, a preponderance of evidence showed that the California regulation would likely result in the unavailability of a class of residential clothes washers, specifically top-loading machines, in California.

The State submitted to DOE a Request for Reconsideration on January 29, 2007.[17] By failing to respond to the request by February 28, 2007, DOE effectively denied California's Request for Reconsideration.[18] On April 20, 2007, the CEC petitioned the US Court of Appeals for the Ninth Circuit for review of the Denial by the DOE.[19] In its decision on October 28, 2009, the Court of Appeals overturned DOE's denial of the waiver request and ordered DOE to reconsider its action, ruling that DOE's stated justifications [for denial] "demonstrate an arbitrary and capricious failure meaningfully to address the CEC's application for a waiver."[20]

3.7.4 Canadian Energy Conservation Standards

The Canadian government regulates the efficiency of residential clothes washers. This Regulation applies to standard or compact electrically operated household clothes washers that are top- or front-loaded, and that have an internal control system that regulates the water temperature without the need for user intervention subsequent to initiation of machine operation. Table 3.7.4 lists the current standards that went into effect January 1, 2007, along with the previous standards that went into effect January 1, 2004.

Table 3.7.4 Canadian Energy Conservation Standards for Residential Clothes Washers

Clothes Washer Classification	Minimum MEF (*L/kWh/cycle*)	
	January 1, 2004	**January 1, 2007**
Vertical-axis compact (< 45 liter capacity)	18.40	18.40
Vertical-axis standard (≥ 45 liter capacity)	29.45	35.68
Horizontal-axis*	29.45	35.68
Suds-saving*	NA	NA

* These product classes shall be equipped with an unheated rinse water option.

3.7.5 Mexican Energy Conservation Standards

The Mexican Official Standard (NOM-005-ENER-2000) establishes maximum energy consumption limits for residential clothes washers sold in Mexico. In effect since 2000, Maximum Energy Performance Standards are based on the assumption of 416 wash cycles per year and a water temperature of 20 °C ± 5 °C. Table 3.7.5 shows the mechanical energy used in the wash stages as specified for clothes washers sold in Mexico.[21]

Table 3.7.5 Mexican Energy Efficiency Standards for Residential Clothes Washers[22]

Washer Action	Washer Capacity (*pounds of clothes*)	Energy Consumption (*kWh/year*)
Impulsor	Less than 4	70
	4 to less than 6	70
	6 to less than 10	120
	Equal to or greater than 10	120
Agitator	Less than 4	100
	4 to less than 6	100
	6 to less than 8	175
	8 to less than 10	218
	Equal to or greater than 10	250
Drum	Less than 4	120
	4 to less than 6	150
	Equal to or greater than 6	200
Drum with heating element	Less than 4	360
	4 to less than 6	450
	Equal to or greater than 6	600

3.7.6 International Energy Performance Standards for Residential Clothes Washers

According to the Collaborative Labeling and Appliance Standards Program (CLASP), eight other countries outside of North America have mandatory minimum energy performance standards for residential clothes washers.[23] These standards, whether mandatory or voluntary, may be accompanied by a label. A mandatory label must include a washer's energy consumption under a specified test standard. Some countries require that manufacturers affix a performance label without requiring that they adhere to a minimum energy performance standard. Voluntary labels also exist for programs such as the ENERGY STAR program in Canada. Table 3.7.6 notes the presence of mandatory or voluntary performance standards and labeling programs where applicable.

Table 3.7.6 International Energy Efficiency Standards and Labels for Residential Clothes Washers[24]

Country	Minimum Energy Performance		Label	
	Mandatory	Voluntary	Mandatory	Voluntary
Algeria	X			
Argentina			X	
Australia			X	X
Austria				X
Brazil		X	X	X
Canada	X		X	X
Chile			X	
Colombia		X		X
Czech Republic				X
Egypt	X		X	
EU Member Countries		X	X	X
Germany				X
Hong Kong, China				X
Indonesia	X			
Iran			X	
Israel	X		X	
Jordan			X	
Malaysia	X			
Mexico	X		X	X
New Zealand			X	
Nordic Member Countries				X
People's Republic of China	X		X	
Peru	X		X	
Republic of Korea	X		X	
Russia		X		X
Singapore				X
Slovakia				X
South Africa				X
Switzerland		X	X	
Taipei				X
Thailand				X
Turkey			X	
UK				X
USA	X		X	X
Viet Nam				X

3.7.7 International Standby Power Regulatory Programs

The International Energy Agency (IEA) has raised awareness of standby power through publications, international conferences, and policy advice to governments. In 1999, the IEA developed the "1-Watt Plan," which proposed reducing standby power internationally in

electronic devices and which advocates that all countries harmonize energy policies and adopt the same definition and test procedure. The IEA has advocated a 1 watt (W) requirement for all consumer electrical products (unless specifically excluded) in standby mode. The IEA also stated that IEC 62301 provides an internationally sanctioned definition and test procedure for standby power which is now widely specified and used.[e]

A number of countries have implemented regulatory approaches to standby power in clothes washers. Australia has announced plans to implement a mandatory horizontal 1 W requirement for all consumer electrical products by 2012, including top loading and front loading clothes washers.[25] The Korea Energy Management Corporation developed their "e-standby" program, which currently has a mandatory labeling program for clothes washer standby power, as measured by IEC Standard 62301. The program is currently transitioning to a mandatory 1 W standard by the year 2010.[26]

The European Union passed the Ecodesign Directive in 2005 which calls for an implementing measure to reduce standby power for a specified list of energy using products, which include clothes washers. On December 18, 2008, the Commission of the European Communities published Commission Regulation (EC) No 1275/2008 containing Ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment. Table 3.7.7 presents the requirements for energy consumption in standby and off mode power.[27]

Table 3.7.7 Proposed EU Ecodesign requirements for standby and off mode

Mode	Maximum Power (*Watts*)
Tier 1 (effective January 07, 2010)	
Off (no function)	1.0 W
Standby (only reactivation function)	1.0 W
Standby (information or status display plus reactivation function)	2.0 W
Tier 2 (effective January 07, 2013)	
Off (no function)	0.5 W
Standby (only reactivation function)	0.5 W
Standby (information or status display plus reactivation function)	1.0 W

[e] For more information visit *http://www.iea.org/*.

3.8 VOLUNTARY PROGRAMS

DOE reviewed several voluntary programs promoting residential clothes washers in the United States. Many programs, including the CEE, ENERGY STAR, and FEMP, establish voluntary energy conservation standards for these products.

3.8.1 Consortium for Energy Efficiency

The CEE[f] develops initiatives for its North American members to promote the manufacture and purchase of energy efficient products and services. The goal of the organization is to induce lasting structural and behavioral changes in the marketplace, resulting in the increased adoption of energy efficient technologies. The CEE has a Residential Clothes Washer Initiative that encourages the purchase and use of energy and water efficient clothes washers. Table 3.8.1 shows the three CEE Tiers for residential clothes washers as of January 1, 2011.

Table 3.8.1 CEE Criteria for Residential Clothes Washers

Level	MEF	WF
Tier 1	2.00	6.0
Tier 2	2.20	4.5
Tier 3	2.40	4.0

3.8.2 ENERGY STAR

ENERGY STAR, a voluntary labeling program backed by the U.S. Environmental Protection Agency (EPA) and DOE, identifies energy efficient products through a qualification process.[g] To qualify, a product must exceed Federal minimum standards by a specified amount, or if no Federal standard exists, exhibit selected energy saving features. The ENERGY STAR program works to recognize the top quartile of products on the market, meaning that approximately 25 percent of products on the market meet or exceed the ENERGY STAR levels. ENERGY STAR specifications exist for several products, including residential clothes washers.

ENERGY STAR criteria exist for top- and front-loading residential clothes washers with capacities greater than 1.6 cubic feet. New ENERGY STAR criteria for residential clothes washers, which include energy and water consumption ratings, became effective January 1, 2011. Table 3.8.2 shows the previous and current ENERGY STAR criteria for residential clothes washers.

[f] For more information visit *http://www.cee1.org*.

[g] For more information visit *http://www.energystar.gov*.

Table 3.8.2 ENERGY STAR Criteria for Residential Clothes Washers

Clothes Washer Classification	Criteria Level				
	Jan. 1, 2001	Jan. 1, 2004	Jan. 1, 2007	July 1, 2009	Jan. 1, 2011 (Current)
Top- and front-loading clothes washers	MEF ≥ 1.26	MEF ≥ 1.42	MEF ≥ 1.72 WF ≥ 8.0	MEF ≥ 1.8 WF ≥ 7.5	MEF ≥ 2.0 WF ≥ 6.0

3.8.3 Federal Energy Management Program

DOE's FEMP[h] works to reduce the cost and environmental impact of the Federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at Federal sites. FEMP helps Federal buyers identify and purchase energy efficient equipment, including residential clothes washers.

The National Energy Conservation Act (P.L. 95-619), Executive Order 13423, and Federal Acquisition Regulations Subpart 23.2 and 53.223 require that Federal agencies purchase ENERGY STAR-qualified products. Table 3.8.3 presents the FEMP clothes washer recommendations as of January 1, 2011.

Table 3.8.3 FEMP Recommendations for Residential Clothes Washers

Clothes Washer Tub Volume	MEF	WF
1.6 cubic feet or greater	2.0 or more	6.0 or less

3.8.4 Manufacturer Tax Credits for Energy-Efficient Appliances

The Energy Policy Act of 2005 (EPACT 2005, Pub. L. 109-58) provides tax credits to manufacturers for energy-efficient residential clothes washers. These credits were intended to help manufacturers meet the costs of producing appliances that exceeded the Federal standards. The total credit for residential clothes washers is equal to the applicable credit amount multiplied by the eligible production, subject to credit limitations. For residential clothes washers manufactured in 2006 or 2007 that meet the requirements of the ENERGY STAR program which are in effect for clothes washers in 2007, the applicable amount is $100. The eligible production for residential clothes washers in a calendar year is the excess of the number of residential clothes washers which are produced by the taxpayer in the United States during such calendar year over the average number of residential clothes washers which were produced by the taxpayer (or any predecessor) in the United States during the preceding 3-calendar year period. (section 1334 of EPACT 2005; codified at 26 U.S.C. 42M)

[h] For more information visit *http://www.eere.energy.gov/femp*.

3.8.5 Consumer Tax Credits for Energy-Efficient Appliances

The Emergency Economic Stabilization Act of 2008 (Pub L. 110-343) provides tax credits for energy efficient appliances purchased in 2008, 2009, and 2010. The amount of the tax credit depends on the efficiency level of the clothes washer and the year of manufacture of the clothes washer. Table 3.8.4 lists the program requirements for the residential clothes washer tax credits. (26 U.S.C. 45M)

Table 3.8.4 Consumer Tax Credits Offered for Energy Efficient Clothes Washers

	Year of Manufacture		
Efficiency Level	**2008**	**2009**	**2010**
MEF 1.72 / WF 8.0	$75	-	-
MEF 1.8 / WF 7.5	$125	$125	-
MEF 2.0 / WF 6.0	$150	$150	$150
MEF 2.2 / WF 4.5	$250	$250	$250

3.8.6 Rebates for Highly Energy-Efficient Products

Electric utilities and other organizations promote the purchase of highly energy-efficient residential clothes washers through consumer rebates. Typically, these programs offer rebates for products meeting existing ENERGY STAR efficiency levels. Table 3.8.5 lists some rebates that were offered in 2008. Some utilities also offer incentives to retire old and inefficient appliances.

Table 3.8.5 Rebates Offered for Highly Energy-Efficient Clothes Washers in 2008[28]

Utility/Organization*	**Rebate Level**
Alliant Energy (Iowa and Minnesota)	$100 (ENERGY STAR)
Efficiency Vermont	$50 (ENERGY STAR)
Energy Trust of Oregon	$75 (2.0 – 2.19 MEF) $100 (2.2 MEF or higher)
Long Island Power Authority	$50 (2.2 MEF or higher, 4.5 WF or lower)
Pacific Gas and Electric Company (Northern California)	$35 (CEE Tier 2) $75 (CEE Tier 3)
Puget Sound Energy (Washington)	$50 (CEE Tier 1) $75 (CEE Tier 2) $100 (CEE Tier 3)
Sacramento Municipal Utility District (CA)	$100 (CEE Tier 1) $200 (CEE Tier 2 and 3) Additional $50-75 (WF 6.0 or lower)
Southern California Gas Company	$35 (ENERGY STAR)

* The table includes a survey of a limited number of rebate programs. Additional programs may exist.

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

3.9.1 New Home Starts

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

Table 3.9.1 and Figure 3.9.1 show the number of new single-family and multi-family housing units started in the United States from 1998–2010. Over the 5-year period from 2000–2005, single-family home starts increased 39 percent, to 1,716,000 units annually. However, between 2005 and 2009, single-family home starts decreased 74 percent, to 445,000 units annually. Multi-family unit starts remained relatively stable during the period 1998-2005 at around 350,000 units annually. Between 2005 and 2009, multi-family units decreased 30.8 percent to 109,000 units annually. Both single-family and multi-family housing starts increased by approximately six percent in 2010 compared to 2009.[29]

Table 3.9.1 New Privately Owned Single-Family and Multi-Family Housing Unit Starts in the United States from 1998–2010 [30]

Year	Single Unit (*1000*)	Multi-Unit (*1000*)
1998	1271	346
1999	1302	339
2000	1231	338
2001	1273	329
2002	1359	346
2003	1499	349
2004	1611	345
2005	1716	353
2006	1465	336
2007	1046	309
2008	622	284
2009	445	109
2010	471	116

Figure 3.9.1 Single-Family and Multi-Family Housing Unit Starts, 1998–2010

3.9.2 Unit Shipments

AHAM's *Fact Book 2003 and 2005* provide annual unit shipments for residential clothes washers from 1992 to 2005. Shipments for 2006 through 2010 were obtained from Appliance Magazine. Table 3.9.2 and Figure 3.9.2 below show the annual shipments of residential clothes washers for the period from 1992 to 2010. Shipments of residential clothes washers increased by 69 percent from 1992 to 2006. After an extended period of steady growth, residential clothes washer shipments declined in 2009 to around 7.9 million units, largely coinciding with the decrease in new housing starts.

Table 3.9.2 Industry Shipments of Residential Clothes Washers 1992–2010 (Domestic and Import, in Thousands of Units) [31,32]

Year	No. Clothes Washers (*Thousands*)
1992	5,632
1993	5,923
1994	6,161
1995	6,080
1996	6,225
1997	6,326
1998	6,835
1999	7,313
2000	7,495
2001	7,362
2002	7,745
2003	8,146
2004	8,832
2005	9,394
2006	9,500
2007	9,002
2008	8,292
2009	7,865
2010	7,999

Figure 3.9.2 Annual Shipments of Residential Clothes Washers, 1992–2010

Figure 3.9.3 shows the market share of top-loading and front-loading residential clothes washers from 2006–2008 according to data submitted by AHAM for this rulemaking.[33] The market share of top-loading clothes washers has dropped from 74.2 percent in 2006 to 63.6 percent in 2008, while the market share of front-loading clothes washers has risen from 25.8 percent in 2006 to 36.4 percent in 2008.

Figure 3.9.3 Market Share of Top-Loading and Front-Loading Residential Clothes Washers, 2006–2008

ENERGY STAR market share data are an indicator of the demand for highly energy-efficient appliances. Table 3.9.3 and Figure 3.9.4 show the ENERGY STAR-qualified clothes washer shipments and market share from 1998 to 2009 from the ENERGY STAR website.[34] Sales of ENERGY STAR-qualified clothes washers grew faster than the overall total sales of clothes washers during the period 1998–2006. However, sales of ENERGY STAR-qualified clothes washers decreased by almost 50 percent from 2006 to 2008, while total sales decreased by only 13 percent during the same period. Part of the disproportionate decrease may be due to the implementation of new ENERGY STAR criteria in 2007, which increased the MEF by 21 percent and added a new WF requirement. Under the new criteria, many previously qualified models, particularly traditional top-loading clothes washers, no longer qualified for the ENERGY STAR label. Part of the disproportionate decrease may also be due to the deteriorating U.S. economy during that period; consumers may have opted for lower-priced, less energy efficient clothes washer models. ENERGY STAR sales increased sharply in 2009 to 48 percent of total shipments.

Table 3.9.3 ENERGY STAR Clothes Washer Shipments and Market Share, 1998–2009 (Domestic and Import)[35, 36, 37]

		Shipments (*thousand units*)	
Year	**% ENERGY STAR**	**Total**	**No. ENERGY STAR**
1998	5.5%	6,835	376
1999	8.5%	7,313	622
2000	9.3%	7,495	697
2001[a]	10.3%	7,362	758
2002	16.3%	7,745	1,262
2003	23.1%	8,146	1,882
2004[b]	27.2%	8,832	2,402
2005	36.4%	9,394	3,419
2006	37.9%	9,500	3,601
2007[c]	41.6%	9,002	3,745
2008	23.7%	8,292	1,965
2009	48.3%	7,865	3,800

Figure 3.9.4 ENERGY STAR Clothes Washer Shipments and Market Share, 1998–2009

a) Energy Star criteria changed to MEF ≥ 1.26.
b) Energy Star criteria changed to MEF ≥ 1.42.
c) Energy Star criteria changed to MEF ≥ 1.72 and WF ≥ 8.0.
d) According to ENERGY STAR, the validity of the clothes washer data for quarter one and quarter three in 2007 is questionable. It is expected that the incorrect coding of previously qualified units for these two quarters resulted in a higher than actual market share projection. Actual ENERGY STAR shipments are expected to have been closer to 30%, as indicated by the dashed line in the graph.

3.9.3 Value of Shipments

Table 3.9.4 and Figure 3.9.5 provide the annual shipment value for the NAICS product class for household laundry (product class code 335224), which includes residential clothes washers and clothes dryer shipments, from 2004 to 2010 based upon data from the U.S. Census Bureau's *Current Industrial Reports (CIR)*[i] and *Annual Survey of Manufacturers (ASM)*[j]. The U.S. Census Bureau shipment values are expressed in nominal dollars; *i.e.*, 2010 data are expressed in 2010 dollars, and 2007 data are expressed in 2007 dollars. DOE converted each year's value of shipments to 2010 dollars using producer price index (PPI) data from the Bureau of Labor and Statistics for NAICS 335224: Household laundry equipment manufacturing[k].

[i] Available online at http://www.census.gov/manufacturing/cir/index.html
[j] Available online at http://www.census.gov/manufacturing/asm/index.html
[k] PPI data available at http://www.bls.gov/ppi/

Table 3.9.4 Annual Value of Shipments of Household Laundry Equipment[38]

	Annual Shipment Value *($ millions)*	
Year	**Nominal Dollars**	**2010 Dollars**
2004	5,030.7	5,752.7
2005	5,268.2	5,829.8
2006	5,184.4	5,556.0
2007	5,231.6	5,446.3
2008	5,834.8	5,944.4
2009	4,820.0	4,865.9
2010	4,656.8	4,656.8

Figure 3.9.5 Annual Shipment Value of Household Laundry Appliances, 2004–2010

3.9.4 Imports and Exports

Each month AHAM publishes import and export data for certain home appliances, which includes year-to-date annual summaries. Figure 3.9.6 shows selected import/export data from AHAM's *Import/Export Trade Reports* for December 2005–2010.[39] Imports increased in 2006 compared to 2005, and then decreased substantially during 2007 through 2010. Exports increased from 2005 to 2007 and decreased through 2010.

Figure 3.9.6 Imports and Exports of Residential Clothes Washers, 2005–2010[40]

3.10 HISTORICAL EFFICIENCIES

The average efficiency of new residential clothes washers has increased greatly since 1990. Table 3.10.1 and Figure 3.10.1 show the shipment-weighted trends in tub volume, energy consumption, and energy efficiency from 1990–2008. The data indicate the changes in efficiency resulting from Federal energy conservation standards that took effect in 1994 and 2004.

Table 3.10.1 Residential Clothes Washer Tub Volume, Energy Consumption, and Energy Efficiency Trends (Shipment Weighted Averages)[41]

Year	Tub Volume (ft^3)	Energy Consumption (*kWh/cycle*)	Energy Factor
2008	3.22	0.80	1.67
2007	3.16	0.82	1.66
2006	3.13	1.18	1.42
2005	3.08	1.13	1.37
2004*	3.05	1.22	1.35*
2003	3.01	1.97	1.83
2002	2.96	2.13	1.64
2001	2.96	2.19	1.55
2000	2.92	2.20	1.47
1999	2.89	2.17	1.47
1998	2.85	2.27	1.41
1997	2.83	2.21	1.34
1996	2.80	2.24	1.26
1995	2.72	2.22	1.23
1994	2.69	2.23	1.21
1993	2.71	2.71	1.00
1992	2.71	2.67	1.02
1991	2.72	2.68	1.01
1990	2.63	2.67	0.99

Figure 3.10.1 Tub Volume, Energy Consumption, and Energy Efficiency Trends for Residential Clothes Washers, 1990–2008

*2004 energy descriptor changed from EF to MEF; cannot be compared with previous years.

3.11 MARKET SATURATION

Appliance Magazine's annual *Portrait of the Appliance Industry* presents the market saturation for major appliances, including clothes washers. Table 3.11.1 presents the clothes washer saturation rate from 2000 to 2008 as reported in the September 2008–2009 editions of Appliance Magazine.[42] According to the data, the saturation rate of clothes washers has remained fairly constant at around 95 percent during this period.

Table 3.11.1 Clothes Washer Saturation Rate for U.S. Households, 2000–2008[43]

Product	2000	2001	2002	2003	2004	2005	2006	2007	2008
Clothes Washers	93%	94%	94%	94%	95%	93%	95%	95%	95%

3.12 PRODUCT RETAIL PRICES

Table 3.12.1 presents the average retail prices (in nominal dollars) of residential clothes washers and the Consumer Price Index (CPI) of each year (1982–84 = 100). Although prices for automatic clothes washers increased from 1980 to 2002, the increase was at a much slower rate than the annual rate of inflation. Since 2002, the average retail price has decreased, resulting in a net decrease in average retail price between 1980 and 2005.

Table 3.12.1 Residential Appliance Retail Prices [44]

Product	Average Retail Prices (*Nominal $*)				Percent Change
	1980	1994	2002	2005	1980–2005
Automatic Clothes Washers	386	394	426	359	-7.0%
*Consumer Price Index**	*82.4*	*148.2*	*179.9*	*195.3*	*137.0%*

* U.S. Department of Labor, Bureau of Labor Statistics, Consumer Price Index: U.S. city average. 1982–84 = 100.

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DOE conducted an in-depth survey of consumer retail prices for residential clothes washers in December 2009. DOE aggregated consumer prices from three major appliance retailers: Sears, Home Depot, and AJMadison.com websites. The Sears and Home Depot websites were used for this search. DOE identified a total of 174 models (74 standard-size top-loading clothes washers, 100 front-loading clothes washers), which encompassed 20 different brands. For models that were available in multiple colors, or at multiple retailers, DOE used the least expensive full price, not including retail discounts. DOE used the CEC[l] and ENERGY STAR[m] databases to match MEF and WF data with each clothes washer model. Figure 3.12.1 and Figure 3.12.2 summarize the data collected by DOE. The figure shows that retail price is generally a function of location of access (*i.e.*, top-loading or front-loading) and efficiency, although there is a significant overlap of retail prices for higher-efficiency top-loading and lower-efficiency front-loading clothes washers. The consumer retail prices for top-loading ranged from $319 to $1,259, with an average of $636. The consumer retail prices for front-loading ranged from $519 to $2,449, with an average of $1,041. If the four top-loading outliers are removed, the average front-loading price is $993. Note that these do not represent shipment-weighted averages.

[l] CEC appliance efficiency database available online at: http://www.energy.ca.gov/appliances/database/. Data collected did not include retail prices for combination washer/dryer units.
[m] ENERGY STAR database available at http://www.energystar.gov/index.cfm?fuseaction=clotheswash.search_clotheswashers

Figure 3.12.1 Residential Clothes Washer Retail Price as a Function of MEF, December 2009

Figure 3.12.2 Residential Clothes Washer Retail Prices as a Function of Location of Access, December 2009

As discussed further in Chapter 8 of the TSD, DOE used manufacturing costs developed for specific standard levels in combination with manufacturer and distributor markups, sales taxes, and installation costs to establish the total installed cost differences between baseline and more efficient residential clothes washers. DOE used the above range in current retail price differences between top-loading and front-loading clothes washers as an indication of the reasonableness of the total installed cost estimates that it developed for residential clothes washers.

3.13 INDUSTRY COST STRUCTURE

DOE developed the household appliance industry cost structure from publicly available information from the ASM and Economic Census, (Table 3.13.1 through Table 3.13.4) and the U.S. Securities and Exchange Commission (SEC) 10-K reports filed by publicly owned manufacturers (summarized in Table 3.13.5).

Table 3.13.1 and Figure 3.13.1 present the major appliance manufacturing industry (NAICS code 33522) employment levels and earnings from 1999-2009. The statistics illustrate a steady decline in the number of production and non-production workers in the industry. DOE converted the payroll data to constant 2009 dollars using the Gross Domestic Product Implicit Price Deflator published by the U.S. Bureau of Economic Analysis[n]. Table 3.13.1 shows that as industry employment levels decline, the industry payroll in constant 2009 dollars is also decreasing. The percent decrease in total industry employees tracks closely with the percent decrease in payroll for all employees.

Table 3.13.1 Major Appliance Manufacturing Industry Employment and Earnings [45]

Year	Production Workers	All Employees	Payroll for All Employees (*2009 $ Mil*)
2009	32,875	37,905	1,511.3
2008	39,208	45,152	1,791.4
2007	46,572	53,162	1,969.4
2006	49,360	56,174	2,144.3
2005	54,586	63,535	2,232.3
2004	57,660	68,213	2,362.4
2003	58,289	68,593	2,328.3
2002	59,234	70,013	2,387.3
2001	60,669	70,938	2,417.5
2000	64,417	75,055	2,533.8
1999	64,066	73,884	2,435.7

Figure 3.13.1 Major Appliance Industry Employment and Earnings, 1999–2009

Table 3.13.2 and Figure 3.13.2 present the employments levels and payroll for just the household laundry portion of the major appliance industry. Statistics for both employment levels and payroll show steady declines over the 10-year period, with payroll and employment levels again showing a positive correlation.

[n] Available online at http://www.bea.gov/national/nipaweb/SelectTable.asp

Table 3.13.2 Household Laundry Industry Employment and Earnings[46]

Year	Production Workers	All Employees	Payroll for All Employees (*2009 $ Mil*)
2009	7,326	7,927	315.6
2008	8,895	9,579	366.9
2007	10,864	11,741	440.6
2006	11,669	13,298	544.9
2005	12,590	14,468	517.1
2004	12,853	15,140	552.9
2003	13,137	15,510	572.1
2002	13,460	15,878	617.3
2001	12,833	14,918	541.0
2000	13,259	15,503	568.9
1999	14,034	15,915	554.1

Figure 3.13.2 Household Laundry Industry Employment and Earnings, 1999–2009

Table 3.13.3 and Figure 3.13.3 present the cost of materials and industry payroll as a percentage of value of shipments from 1999–2009. Payroll data is indicated for production workers as well as all employees, which includes production workers. The cost of materials as a percentage of value of shipments has declined from 55.7 percent to 58.8 percent over the 10-year period, with minor fluctuations. The cost of payroll for production workers as a percentage of value of shipments has declined from 10.7 percent to 6.4 percent over the 10-year period. Similarly, the cost of total payroll as a percentage of value of shipments has declined from 13.9 percent in 1999 to 8.3 percent in 2009.

Table 3.13.3 Major Appliance Manufacturing Industry Materials and Wages Cost[47]

	Cost as a Percentage of Value of Shipments (%)		
Year	**Materials**	**Payroll for Production Workers**	**Payroll for All Employees[a]**
2009	44.7%	6.4%	8.3%
2008	56.3%	7.4%	9.5%
2007	58.8%	8.1%	10.1%
2006	58.7%	8.5%	10.6%
2005	57.7%	8.5%	10.7%
2004	58.3%	9.3%	12.0%
2003	56.8%	9.5%	12.4%
2002	57.0%	10.2%	13.5%
2001	58.5%	10.7%	14.0%
2000	57.3%	10.8%	14.2%
1999	55.7%	10.7%	13.9%

Figure 3.13.3 Materials and Wages Cost as a Percentage of Shipments Value for Major Appliances, 1999–2009

a) Payroll for All Employees includes payroll for Production Workers

Table 3.13.4 and Figure 3.13.4 show the cost of materials and industry payroll as a percentage of value of shipments for the household laundry industry from 1999–2009. Material prices as a percentage of value of shipments have fluctuated over the 10-year period, decreasing from 53.9 percent in 1999 to 42.2 percent in 2009. DOE notes that fluctuations in raw material costs are common from year to year. The cost of payroll for production workers as a percentage of value of shipments has as declined from 10.5 percent to 5.5 percent over the 10-year period. The cost of total payroll as a percentage of value of shipments has followed the same general trend, decreasing from 13.3 percent in 1999 to 6.5 percent in 2009.

Table 3.13.4 Household Laundry Industry Materials and Wages Cost [48]

	Cost as a Percentage of Value of Shipments (%)		
Year	**Materials**	**Payroll for Production Workers**	**Payroll for All Employees[a]**
2009	42.2%	5.5%	6.5%
2008	47.7%	5.4%	6.3%
2007	53.2%	7.3%	8.4%
2006	52.6%[b]	8.5%	10.5%
2005	52.1%	7.7%	9.8%
2004	52.1%	8.4%	11.0%
2003	54.7%	9.1%	12.0%
2002	55.9%	10.3%	14.0%
2001	58.3%	9.6%	12.3%
2000	56.3%	10.1%	13.4%
1999	53.9%	10.5%	13.3%

Figure 3.13.4 Materials and Wages Cost as a Percentage of Shipments Value for Household Laundry, 1999–2009

a) Payroll for All Employees includes payroll for Production Workers
b) Cost of Materials data not available for 2006; the average value from 2005 and 2007 was used as an estimate.

Table 3.13.5 presents the industry cost structure derived from SEC 10-K reports of publicly owned home appliance manufacturers. DOE averaged the financial data from 2005–2008 of U.S.-based appliance manufacturers to obtain an industry average. Each financial statement entry is presented as a percentage of total revenues.

Table 3.13.5 Industry Cost Structure Using SEC Data, Average 2005–2008

Financial Statement Entry	Percent of Revenues
Cost of sales	83.8%
Net income	2.7%
Selling, general and administrative	11.2%
Capital expenditure	3.1%
Research and development	2.3%
Depreciation and amortization	3.2%
Net plant, property and equipment	17.4%
Working capital	3.2%

Figure 3.13.5 presents the industry-average gross margin over the period from 2002–2008 for the same manufacturers from which the industry cost structure is derived. The slope of the curve indicates the downward cost pressure facing manufacturers.

Figure 3.13.5 Appliance Industry Average Gross Margin Derived from SEC Data

A detailed financial analysis is presented in the MIA (see chapter 13 of this TSD). This analysis identifies key financial inputs including cost of capital, working capital, depreciation, and capital expenditures.

3.14 INVENTORY LEVELS AND CAPACITY UTILIZATION RATES

Table 3.14.1 and Figure 3.14.1 show the year-end inventory for the major appliance manufacturing industry. Table 3.14.2 and Figure 3.14.2 show the year-end inventory for the household laundry manufacturing industry. DOE used annual data from the ASM and converted the inventory data to 2009 dollars using the PPI. Both in dollars and as a percentage of value of shipments, the end-of-year inventory for the major appliance industry steadily declined between 1999and 2005. Inventories increased beginning in 2006, corresponding to the deterioration of the U.S. economy during that period. Household laundry equipment manufacturing generally experienced this same trend, with the rise in inventories beginning in 2005.

Table 3.14.1 Major Appliance Manufacturing Industry Inventory Levels[49]

Year	End-of-Year Inventory (*2009 $ Mil*)	EOY Inventory as a Percentage of Value of Shipments (%)
2009	1,150	6.3%
2008	1,334	7.1%
2007	1,453	7.5%
2006	1,261	6.2%
2005	1,265	6.1%
2004	1,236	6.3%
2003	1,187	6.3%
2002	1,249	7.1%
2001	1,363	7.9%
2000	1,515	8.5%
1999	1,491	8.5%

Figure 3.14.1 Major Appliances Manufacturing End-of-Year Inventory, 1999–2009

Table 3.14.2 Household Laundry Industry Inventory Levels[50]

Year	End-of-Year Inventory (*2009 $ Mil*)	EOY Inventory as a Percentage of Value of Shipments (%)
2009	240	5.0%
2008	263	4.5%
2007	274	5.2%
2006	273	5.3%
2005	217	4.1%
2004	193	3.8%
2003	210	4.4%
2002	232	5.3%
2001	265	6.1%
2000	241	5.7%
1999	360	8.7%

Figure 3.14.2 Household Laundry Equipment Manufacturing End-of-Year Inventory, 1999–2009

DOE obtained full production capacity utilization rates from the U.S. Census Bureau, *Survey of Plant Capacity* from 1999–2010. Table 3.14.3 and Figure 3.14.3 present utilization rates for the household appliance industry. Full production capacity is defined as the maximum level of production an establishment could attain under normal operating conditions. In the *Survey of Plant Capacity* reports, the full production utilization rate is a ratio of the actual level of operations to the full production level. The full production capacity utilization rate for all household appliances shows fairly steady utilization between 70-78 percent from 1998–2007, with a significant decrease to less than 65 percent between 2008–2010.

Table 3.14.3 Full Production Capacity Utilization Rates[51]

Year	Plant Capacity Utilization Rates (%)
2010	64%
2009	59%
2008	69%
2007	76%
2006	77%
2005	74%
2004	76%
2003	78%
2002	72%
2001	70%
2000	70%
1999	75%
1998	73%

Figure 3.14.3 Plant Capacity Utilization, 1998–2010

3.15 TECHNOLOGY ASSESSMENT

This section provides a technology assessment for residential clothes washers. Contained in this technology assessment are details about product characteristics and operation (section 3.15.1), an examination of possible technological improvements for each product (section 3.15.2), and a characterization of the product efficiency levels currently residentially available (section 3.15.3).

3.15.1 Product Operations and Components

In preparation for the screening and engineering analyses, DOE prepared a brief description of the characteristics and operation of residential clothes washers. These descriptions provide a basis for understanding the technologies used to improve product efficiency.

Residential clothes washers are appliances designed to clean clothes using a solution of soap and/or detergent and water with mechanical agitation. Clothes washers use electricity to operate one or more pumps and to power an electric motor that agitates and spins the clothes. Clothes are washed, rinsed, and spun within a tub that is inside a cabinet. Because clothes washers require heated water for hot and warm water cycles, a separate water heater is typically needed to supply hot water. Most of the energy used by clothes washers is for water heating. Water is fed into the clothes washer through electrically operated water valves: one connected to a hot water supply line and a second connected to a cold water supply line.

Traditional top-loading clothes washers have an opening on the top of the cabinet, covered by a door, which gives access to the inner basket where the load to be washed is placed. The inner basket is typically perforated and is surrounded by a larger outer tub which holds the water when the machine is running. The inner basket typically contains an agitator along a vertical axis, which undergoes a reversing circular motion. The motion of the agitator, which is powered by an electric motor, circulates the clothes vertically from the bottom to the top of the basket. The spinning action of the inner basket and the drain pump are also powered by the motor. Traditional top-loading clothes washers use more water than other types of washers, and therefore, consume more energy during heated wash cycles. They also typically extract less water from laundry during the spin cycle, which results in longer drying time and greater energy consumption.

Non-agitator top-loading clothes washers may have a “wash plate” rather than an agitator to move the clothes within the basket. These top-loading clothes washers function by partially filling the tub with water for wash and rinse cycles and using very high spin speeds to extract rinse water from the clothes during the spin cycle. These top-loading clothes washers are more efficient in terms of water and energy than traditional top-loading clothes washers, but their high spin speeds that reduce drying time (and thus dryer energy consumption) may wrinkle clothing more than traditional top-loading clothes washer spin speeds. These machines work best with low-foaming, high efficiency detergent.

Front-loading clothes washers utilize a cylindrical tub or drum rotating on a horizontal or nearly-horizontal axis to wash clothes. Clothes are usually loaded along the axis of the cylindrical drum, which has led to this type of clothes washer to be called front-loading. The clothes are cleaned by tumbling them in the water (*i.e.*, clothes are lifted to the top of the drum by the rotation of the cylinder and then dropped into the water below.) The cylindrical drum is only partially filled with water for wash and rinse cycles. High spin speeds are used to extract the water from the clothes during the spin cycles. These clothes washers are typically more efficient in terms of water and energy than traditional top-loading clothe washers, but as for non-agitator top-loading clothes washers, their high spin speeds may wrinkle clothing.

Although most clothes washers using a horizontal-axis rotating drum are front-loading, they can be designed to be top-loading as well. In a top-loading horizontal-axis design, the cabinet has a door at the top that opens above the washer drum. Another door that slides or pivots open then provides access to the inner drum.

3.15.2 Technology Options

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

DOE considered technologies identified in its most recent analysis of amended energy conservation standards as well as from information published in recent trade publications, technical reports, and manufacturers' literature. Most of the technologies listed in Table 3.15.1—with exceptions noted below—are taken from a 1996 report prepared for DOE entitled *Design Options for Clothes Washers*.[52] Improved horizontal-axis-washer drum design was identified in the September 2005 edition of *Appliance Magazine*.[53] Plastic particle cleaning was indentified in the September 2008 edition of *Appliance Magazine*.[54] DOE has included spray rinse and advanced agitator technology options based on comments to the most recent standards rulemaking for commercial clothes washers. DOE believes that residential and commercial clothes washer platform designs and technologies are similar, with the main difference being that commercial clothes washers are built for more rugged and frequent use. Based on a review of the *International Standby Basket of Products Survey*[o], which showed a wide range of standby power for front-loading clothes washers surveyed in the United States, and a review of controller and display options available for all residential clothes washers currently available on the market, DOE added the low-standby-power design option. DOE also added hot water circulation loop based on a review of technical reports. Of the technologies listed below, the current DOE test procedure cannot measure the possible energy savings of adaptive control systems (other than adaptive-water-fill control systems).

[o] *International Basket of Products Survey*, Funded by the Asia-Pacific Partnership on Clean Development and Climate. Available online at: http://www.energyrating.gov.au/standbydata/app/Default.aspx

Table 3.15.1 Technology Options for Residential Clothes Washers

1. Adaptive control systems
2. Added insulation
3. Advanced agitation concepts for vertical-axis machines
4. Automatic fill control
5. Bubble action
6. Direct-drive motor
7. Electrolytic disassociation of water
8. Horizontal-axis design
9. Horizontal-axis design with recirculation
10. Hot water circulation loop
11. Improved fill control
12. Improved horizontal-axis-washer drum design
13. Improved water extraction to lower remaining moisture content
14. Increased motor efficiency
15. Low standby-power design
16. Ozonated laundering
17. Plastic particle cleaning
18. Reduced thermal mass
19. Silver ion injection
20. Spray rinse or similar water-reducing rinse technology
21. Thermostatically-controlled mixing valves
22. Tighter tub tolerance
23. Ultrasonic washing

As described in the 1996 report on *Design Options for Clothes Washers*, DOE at that time eliminated the following technologies from further analysis: bubble action, electric disassociation of water; ozonated laundering; reduced thermal mass; suds savings; and ultrasonic washing. DOE will re-examine whether the basis for eliminating these technologies from further analysis is still valid.

Adaptive control system

According to the current DOE test procedure (10 CFR part 430, subpart B, appendix J2), "an adaptive control system refers to a clothes washer control system which is capable of automatically adjusting washer operation or washing conditions based on characteristics of the clothes load placed in the clothes container, without allowing or requiring consumer intervention or actions." This technology option uses sensors to measure the soil load to adjust the wash temperature, agitation and/or tumble cycle time, number of rinse cycles, spin speed, and other parameters. Modular design also enables packaging multiple sensors into one probe, thereby reducing installation costs and decreasing the potential for leak points.[55] Water and energy use can then be tailored to the load, thereby avoiding washing the clothes more than necessary. Although the DOE test procedure does not provide a means for determining the energy consumption of a clothes washer with an adaptive control system, the test procedure does allow for specific field test procedures to measure energy consumption.

Residential clothes washers have used fuzzy logic to weigh laundry loads and regulate the length of the cycle, water level, number of rinses, and drying time.[56] Specific clothes washer designs have incorporated fuzzy logic to optimize the washing process while conserving water usage. The fuzzy-logic control determines the absorbency of the items being washed at the earliest stage possible after the start of the washing cycle. The system determines the correct water quantity for clear-water washing and subsequent rinsing.[57]

Added insulation

This technology option adds insulation around the outer wash tub. Because some heat energy is lost through the shell of the clothes washer, adding insulation around the outer tub slightly reduces the water temperature needed for a hot wash. However, since the wash cycle is relatively short and the thermal mass of the water is very high, there is very little change in water temperature from adding insulation. Computer simulations performed on a traditional top-loading vertical-axis clothes washer for a 20-minute wash cycle at 140 degrees Fahrenheit (°F) showed that adding 1 inch of fiberglass insulation relative to no insulation resulted in only a 1–2 °F increase in water temperature during parts of the wash.[58]

Advanced agitation concepts for vertical-axis machines

Advanced agitation concepts replace the standard agitator found in traditional top-loading vertical-axis machines with an alternative manipulator to agitate clothes and thus mechanically remove soil. In the residential clothes washer market, these alternatives to agitators have taken different forms, including nutating plates, rotating disks, and side-mounted agitators. In some instances, such agitation concepts allow a vertical-axis washer to avoid the need to cover all clothes completely with water, rotating them in and out of the water-filled portion of the basket, much like horizontal-axis washers. Haier manufacturers a clothes washer in which the tub and pulsator spin in one direction while the inner tub and agitator spin in the opposite direction. Whirlpool manufacturers a clothes washer with a washplate that can adjust the amount of motion based on fabric saturation levels. Advanced agitation systems add considerable complexity to a vertical-axis clothes washer, and residential clothes washers that feature these technologies are sold for prices comparable to horizontal-axis clothes washers.

Since the DOE test procedure captures the amount of water that a clothes washer consumes, the benefits of an advanced agitation concept washer can be directly measured and quantified via the WF. Potential energy savings are captured by the MEF as long as a portion of the washing cycle consumes heated water.

Automatic fill control

This technology option incorporates advanced control technologies to sense the clothes load and adjust the water level accordingly. For a traditional top-loading vertical-axis machine, this may mean setting the water level to just submerge the clothes load. This technology option can overcome the tendency of consumers to manually select a water level greater than required

for a given load. Different types of sensors are available for controlling water volume including liquid-level sensors, which measures water levels at the tub bottom, or thermal-based water flow sensors, which are also known as thermo-anemometers.[59]

The implementation of this feature varies. While this feature is inexpensive to implement in all horizontal-axis washers, vertical-axis washers do not benefit from the same advantages regarding drum geometry and rotation axis.[p] As a result, automatic fill control is typically only found in higher-end vertical-axis models that have electronic controls and proprietary designs, limiting adoption to a small percentage of the vertical-axis market. Energy is saved in either vertical- or horizontal-axis designs by reducing the amount of hot water used in the wash cycle.

Bubble action

Daewoo has developed an air-bubble washing machine. This machine uses a low-profile impeller typical in Asian-style vertical-axis washers and combines it with a six-winged, rotating pulsator shaped to direct water in four directions. This pulsator also distributes air bubbles in different directions. The bubbles are generated by a vibrating bellows, which is driven by an electromagnet. Bubbles are reported to increase the cleaning power of the washer in several ways: (1) by inducing a high-frequency pressure fluctuation near the clothes, (2) by increasing the dissolution of detergent, (3) by increasing the amount of dissolved oxygen which increases the activity of the detergent, and (4) by lowering the viscosity of the wash water.[60, 61] Daewoo washers that utilize air-bubble washing action are available in the European market, but are not available to U.S. consumers.[62]

Sharp also developed a bubble washer in which the bubble-generating device uses neuro-fuzzy-logic controls. From a nozzle located at the bottom of the washer, air bubbles are generated by a computer-controlled pulsator and circulated upward in vertical and horizontal swirling motions. The controls adjust the amount of water used, so that a single-tub design that washes the same load size as a conventional dual-tub (inner and outer) configuration uses only. 70 percent as much water and detergent.[63] Although it is mentioned on the manufacturer's website, this washer is not available in the United States.[64] Sanyo released a washer in Japan in 2002 that used an ultrasonic wave generator, along with electrodes on the side of the tub to electrolyze the water, as a bubble-generating device.[65] Standardized and independent tests have yet to be conducted on the performance of the bubble-action system; therefore, the energy savings potential and wash performance of the bubble-action technology option is unknown.

Although bubble washing has been incorporated into residential clothes washers in Europe and Asia, production is still extremely limited and further commercialization in the United States would require manufacturers to develop entirely new platforms.

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[p] Horizontal-axis washers can incorporate a fill switch in the sump to monitor water levels as the wash basket and its contents are rotated slowly at the beginning of the wash cycle. As dry clothes drop into the wash water, they absorb some of it and the water level in the sump drops. The fill switch then opens the fill valve(s) to raise the water level until the sump is full again. This approach does not work with vertical-axis washers because the clothes are always immersed in the water. Proprietary solutions have been implemented on some vertical-axis washers, however.

Direct-drive motor

This technology option is primarily intended for use in traditional top-loading vertical-axis machines. A traditional top-loading vertical-axis clothes washer uses an induction motor, a mechanical transmission, and sometimes a pulley belt. A direct-drive motor can replace this conventional motor/transmission system. Rather than using a belt and/or transmission, a motor could be directly connected to the agitator, thereby avoiding transmission (gearbox) losses. In the past, Eaton, a motor manufacturer, claimed that this will result in less mechanical energy required, *i.e.*, less energy needed to run the agitator motor. This is accomplished by using a brushless direct-current (BLDC) motor with electronic controls.

Potential differences in cleaning performance due to the direct-drive substitution were not measured by Eaton. In addition, other parameters such as cycle time or spin speed were not held constant in a comparison test with a conventional washer. For the machines tested, Eaton found savings of about 140 watt-hours (Wh) per cycle, or 64 percent of motor energy use. When adjusted for the direct-drive standby power, this difference drops to about 35 Wh per cycle, or 16 percent of motor energy use. The direct-drive standby power is the energy consumption when the machine is "off". In the "off" mode, the direct-drive motor system has a power drain of 4.78 W. While the current DOE test procedure does not account for standby and off mode power use, DOE has initiated a test procedure change in parallel with the current rulemaking to incorporate standby mode and off mode power.[66] Energy savings could be improved if the standby/off mode power loss was reduced.

In the past, some manufacturers have stated that a limiting performance factor for this technology option was physical size. However, GE, Haier, and Whirlpool use direct-drive motors on some of their vertical-axis washers.[67,68,69] Fisher & Paykel also manufactures four top-loading, vertical-axis direct-drive washing machines available in the U.S. market.[70] Some front-loading, horizontal-axis machines also use a direct-drive motor, including models manufactured by LG and Whirlpool.[71,72]

Electrolytic disassociation of water

The goal of electrolytic disassociation of water is to reduce hot water usage by substituting the electrolytic production of bleaching agents for the activation of bleaching chemical reactions in detergents by hot water. A prototype clothes washer with electrolytic disassociation of water has been successfully tested.[73] Although commercial detergents perform better at high temperatures, the same hypochlorite concentrations obtained by adding bleaching agents to water can be achieved at low temperatures if the agents are produced by electrolytic disassociation within the machine. The bleaching action is due to the chemical reaction of the oxygen (derived from the chemical decomposition of the hypochlorite) with the insoluble organic compounds that constitute the soil in the clothes. Together they make soluble compounds that are dissolved in the water.

Electrolytic disassociation was tested in a laboratory electrochemical cell. Medium-soiled clothes and white materials were used in the test. The washing cycle test compared the energy consumption of electrolytic cleaning versus conventional detergents. The first test cycle, utilizing electrolytic action, was performed by adding four grams per liter of salt to the room-temperature wash water in the machine. The second test cycle was run with a commercial detergent at a wash water temperature of 95 °F to 113 °F. For both wash methods, a normal cycle was run. Initial tests showed that energy use dropped from about 2.65 kWh/cycle for a typical washing machine to 1.35 kWh/cycle for the new electrochemical method. The Haier WasH2o is a detergentless washer that uses electrolysis to separate water into ions. It is only available in China and France and was released in 2008.

In the past, manufacturers have stated that electrolytic disassociation is not a workable approach. Primary concerns are negative effects on garments resulting from the bleaching process and poor consumer acceptance due to their inability to control the chemistry and temperature in the wash portion of the cycle.[74]

Horizontal-axis design

Front-loading horizontal-axis machines rotate the drum (wash basket) and clothes about a horizontal axis. With this design, the drum does not have to be filled with water to cover the top of the clothes. Therefore, horizontal-axis machines use much less water than traditional top-loading vertical-axis machines. At the beginning of each wash or rinse cycle, the washer is filled to a specified level and the drum then rotates a few times. As dry clothes absorb the water, a water level sensor and the washer controller add water and keep rotating the drum slowly until the water level no longer changes, which signals that all clothes are saturated with water.

Thus, the water level is matched to the laundry load. Washing performance appears to be equal to that of vertical-axis machines. In laboratory testing, horizontal-axis machines used on average 40 percent less energy and 25 percent less water than traditional vertical-axis washers when normalized to clothes container volume. The horizontal-axis machines also had greater soil removal effectiveness[75]. Although water savings are realized with horizontal-axis machines, DOE assumes that detergent use remains unchanged.[76] [77]

In the previous residential clothes washer rulemaking, AHAM submitted comments in which some manufacturers stated that factors limiting performance include: (1) soil removal, (2) consumer interface (ergonomics), (3) tangling, (4) cycle time, (5) rinsing and (6) suds sensitivity[78]. Although these performance-limiting factors may exist, every major manufacturer of clothes washers offers horizontal-axis machines for sale in the United States.

Horizontal-axis design with recirculation

This technology option is a variation on the horizontal-axis technology option, using a small pump to recirculate water out of the sump and spray it into the drum. The small amount of standing water in a standard horizontal-axis washer is thus further minimized. Less hot water is needed per wash cycle, thereby saving energy.

In the previous residential clothes washer rulemaking, manufacturers commented that they have not been able to verify that a savings exists with recirculation.[79] Limiting factors mentioned by these manufacturers include (1) soil removal, (2) tangling, (3) cycle time, (4) rinsing, and (5) suds sensitivity.

In the past, Electrolux had produced models that sprayed 8 liters per minute of water/detergent solution into the drum by means of a supply valve above the door.[80]

Hot water circulation loop

This technology option uses the hot water line running through a heat exchanger to heat cold water for use in a clothes washer. Prototype testing of machines that heat water using a hot water circulation loop used significantly less to no energy for heating if supply water was 65-70 degrees C. Previous studies have been done on clothes washers with a hot water circuit and tube heat exchanger built into to the bottom of the wash drum, which decreased electricity demand from 3.78 MJ to 0.83 MJ for a cycle. However, this design uses more water while decreasing energy demand. To avoid this extra water usage, a prototype was developed using a pipe in pipe exchanger that does not require extra water. Further improvements to this option could include heat recovery from wastewater, or developing detergents that clean at lower wash temperatures.[81]

Improved fill control

This technology option is defined as improving the tolerance on existing wash-water fill sensing, which can be accomplished by reducing tolerances of presently used pressure sensors or improving switch design. This technology option relates primarily to top-loading vertical-axis design washers, although it is sometimes applicable to front-loading horizontal-axis washers, depending on the fill control used on the washer design.

In a traditional top-loading vertical-axis washer, one end of an air hose is connected to an air chamber near the bottom of the washer tub and the other end is connected to a pressure switch. As water fills the tub, air in the hose and chamber is forced into a smaller volume, thereby increasing the air pressure. The air pressure increases until it activates a pressure switch, which in turn shuts off the water inlet valve. A more accurate water-level-setting system would avoid overfilling the wash tub, thereby reducing the amount of water and energy used. In the past, manufacturers have stated that they were not aware of any opportunity to reduce tolerances of pressure sensors, but were still able to provide cost and efficiency data for improving the fill control.[82]

Improved horizontal-axis-washer drum design

Manufacturers of horizontal-axis washers continue to research and modify existing drum designs to improve wash performance, reduce mass, and increase spin speeds. With each drum revision, manufacturers frequently make claims that their drum designs increase consumer utility

by being gentler on clothes or by reducing the cycle time through better agitation of the clothes in the washer. A reduction in cycle time would have a measurable impact on washer power consumption, just as drums that can sustain higher spin speeds can reduce the remaining moisture content (RMC) (see the *Improved water extraction* technology option below for the definition of RMC) and thus raise the MEF of a washer. Implementation of this technology option varies, with drums featuring special paddles, drum-wall textures, or similar enhancements.

Improved water extraction to lower remaining moisture content

RMC is defined as:

$$RMC = \frac{(WC - WI)}{WI}$$

where WC is the weight of the test cloth immediately after completion of the washer spin cycle, and WI is the "bone dry" weight of the test cloth. There are several ways to reduce the RMC, including (1) increasing the spin speed of the wash basket for the final spin cycle, (2) changing the direction of rotation to more evenly distribute clothes, (3) having a longer spin cycle, and (4) increasing the size or number of drainage holes in the washer drum. Since mechanical water removal is more energy efficient than using heat to dry, energy consumption for the combined wash and dry process is reduced.

The DOE test procedure assumes that the improved-water-extraction feature will not be used for 25 percent of all wash cycles. Since this feature can be consumer selectable, clothes subject to wrinkling can be washed with a conventional spin-cycle option to avoid a wrinkling problem. Some manufacturers in the past were doubtful that RMCs of 35 percent and 30 percent could be practically obtained.

At the time of the 2001 TSD, laboratory testing was conducted to ascertain RMCs on commercially available front-loading horizontal-axis clothes washers. Measured RMCs ranged from 49 percent to 36 percent with a 50/50 cotton/polyester cloth load. For the same test load, a vertical-axis machine had a 52-percent RMC. The washers for the above testing were loaded at 3 lb/ft^3 of basket capacity.[83] The DOE test procedure, however, specifies the test load as being closer to 4 lb/ft^3 of basket capacity. Since the size of the cloth test load has an effect on the RMC achieved, it is unknown whether the above laboratory-tested machines can achieve their stated RMC values under DOE test conditions. As of the 2001 TSD, clothes washers with a certified RMC of up to 40 percent were available.[84]

RMC data are no longer required to be published because the current test procedure requires the publication of only the MEF and WF for clothes washers. However, RMC data can be found in the CEC residential clothes washer database, but this database does not cover all residential clothes washers on the market. DOE observed RMC values as low as 30 and 35 percent for front-loading washers and top-loading washers, respectively, according to the DOE

test procedure. For front-loading washers, RMC values ranged from 30 to 47 percent, with an average RMC of 38 percent. For top-loading washers, RMC values ranged from 35 to 61 percent, with an average RMC of 50 percent.

Increased motor efficiency

About 10 percent of the total electrical energy consumed by a typical clothes washer is used by the electric motor. The typical washing machine has a ½ –⅔ horsepower motor. In the past, a residential clothes washer manufacturer stated that replacing a split-phase motor with a capacitor-start motor may increase the efficiency of the motor by 10 percent.[85] Permanent magnet motors offer even higher efficiencies, though the benefit of a higher efficiency motor has to be balanced with the higher cost and the relatively small contribution to the overall energy consumption per wash cycle from the motor itself.

Drive system efficiency can also be increased by using a buck-boost power factor correction circuit (PFC). This reduces inverter complexity and cost by controlling inverter output voltage through changing DC bus voltage without affecting performance. Using a PFC circuit can improve efficiency by more than 1.5 times from that of a single-phase induction motor.[86] Three-phase induction motors have also been shown to consume 50 percent less power than universal commutator motors through better control of motor slip.[87]

Low-standby-power electronic controls

Electronic controls may consume power even when the clothes washer is not performing its intended function. Depending on the implementation of the controller, standby power is required to enable the electronic controls to detect user input without the user first having to turn on a mechanical power switch or to enable displays, illuminate switches, etc. Reducing the standby power consumption of electronic controls would reduce the annual energy consumption of the clothes washer, but would not impact the energy consumption of the clothes washer during operation. Low-standby-loss electronic controls can be implemented in a wide variety of ways. DOE is unaware of any data demonstrating energy savings associated with low-standby-power designs for residential clothes washers.

Ozonated laundering

Ozonated laundering systems are available for large-scale commercial or institutional use. The ozone, manufactured from ambient air, is injected into the water. There is some debate as to how the process of the ozonated cleaning exactly works. Some claim the ozone reacts with soluble soils, making them insoluble, after which the mechanical action of the washing separates the soils from the fabric. One manufacturer proposed that the energy inherent in ozone reduces water tension, making the water a better solvent. Energy is saved with this system because the water is not heated for lightly to moderately soiled laundry. In fact, colder water retains a higher concentration of ozone for a longer time than warmer water. For heavily soiled laundry, temperatures of 100–110 °F are used, which are lower than the temperatures required in a conventional washer. Also, since fewer chemicals are used, the rinse time is minimized, thereby

reducing the total cycle time and water consumption. Economical ozone production is critical to the potential energy savings. One manufacturer estimates savings of 25 percent on "utility expenses" with installation of its system.[88] However, in addition to the ozone generator, a new or reprogrammed controller would be required, adding to the cost of this technology option.

Sanyo has developed a residential clothes washer which uses ozone to disinfect and clean water that is held in a storage tank and used in the final rinse. This allows water to be recycled and reduces the amount of water required for the wash cycle. Although this clothes washer is currently sold in Japan, it has not yet been marketed in the United States.[89]

Plastic particle cleaning

This technology option uses the absorbent properties of plastic to clean clothes. The clothes are tumbled in with polymer granules, which absorb the dirt, for up to 30 minutes. This technology is currently in development by Xeros Ltd. in the United Kingdom, which hoped to have the technology on the market as early as 2009.[q] Research conducted in the United Kingdom has shown that this technology would require less than 2 percent of the water used by a conventional washing machine. The design would still require about a cup of water and detergent to loosen the dirt or stain in clothing. Another feature of this technology option is that the clothes would emerge from the clothes washer almost dry, reducing the energy required for drying the clothes.[90]

Reduced thermal mass

This technology option uses a plastic tub specially designed to minimize the thermal mass that is heated by the water. Tests by manufacturers indicate that very little energy can be saved this way because the bulk of the thermal mass is contained in the hot water itself. One manufacturer compared the impact of both porcelain-enameled steel and polypropylene outer tubs on water temperature. Both machines were filled with 16 gallons of 140 °F water and agitated for 10 minutes. After 10 minutes, there was no significant difference in water temperature between the two machines. Calculations show that if there were no heat losses through the outer tub, the equilibrium temperature for the tested steel tub described above would be 138.9 °F. Therefore, there is little to be gained by decreasing the thermal mass of the outer tub.[91]

Plastic outer tubs are commonly used by manufacturers and can be considered as part of the baseline model. There is no practicable way to manufacture washing machines with plastic tubs with a lower thermal mass beyond the current practice.

Silver ion injection

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[q] For more information, visit http://www.xerosltd.com/.

Samsung offers silver ion injection as an alternative to the traditional hot water sanitization cycle in its SilverCare™ line of front-loading residential clothes washers. Silver is electrolyzed during the wash and rinse cycles, and, according to Samsung, the released silver ions penetrate into the fabric, killing bacteria and sanitizing the clothes. Samsung also states that the silver ions eradicate bacteria and mold from inside the clothes washer, disinfecting the drum and other internal parts.[92]

Because the silver ion injection feature can be used for sanitization in cold water, energy savings can be achieved compared to a hot water or steam sanitization cycle.[93] The sanitization of the machine may also eliminate the need for period self-cleaning cycles commonly recommended for front-loading clothes washers.

The long-term health effects of human and environmental exposure to nanoscale silver particles are unknown. In September 2007, the EPA issued a *Federal Register* notice in which it determined that clothes washers will be regulated as pesticides if the machines contain silver or other substances, and if they generate ions of those substances for express pesticidal purposes.[94] According to this decision, a manufacturer would be required to register a clothes washer with EPA as a pesticide if the product is marketed with claims that it will kill bacteria on clothing.

In May 2008, a group of advocacy organizations sued the EPA asking the agency to issue new rules regulating products containing nanoscale silver particles. The petition claimed that EPA failed to adequately regulate products containing or using nanoscale silver particles. The petition asks EPA to: (1) classify nanoscale silver as a new pesticide; (2) require detailed product registration and data submissions under the Federal Insecticide Fungicide and Rodenticide Act; and (3)analyze the potential environmental, health, and safety risks of nanoscale silver.[95]

Since EPA currently permits the sale of registered clothes washers using silver ion injection, DOE concludes that silver ion injection does not pose any significant adverse impacts on health or safety, and thus is eligible to be considered as a design option at this time.

Spray rinse or similar water-reducing rinse technology

Traditional vertical-axis clothes washers immerse the clothing completely in water during the wash and rinse phases of the cleaning cycle. Spray-rinse systems eliminate the immersion requirement by spraying rinse water into the drum while the wash basket is rotating. The centrifugal force of the rotating basket pins the clothes against the outer walls and subsequently forces the rinse liquid through the clothes. In the process, the rinsing liquid picks up remaining suds and transports them into the sump, from which they are drained. Since immersion or partial immersion is no longer necessary, less rinse water is required. When using hot rinse water, this reduces energy consumption by reducing the amount of hot water required for the rinse cycle.

AHAM may develop a rinse performance standard for clothes washers that could preclude the use of rinse-water reduction technologies. The current DOE test procedure, though, captures the benefit of this technology option, as any reduction in water consumption improves WF and any reduction in heated water consumption improves MEF.

Thermostatically controlled mixing valves

Thermostatically controlled water valves (TCWVs) are defined by the DOE test procedure as "clothes washer controls that have the ability to sense and adjust the hot and cold supply water." This technology option achieves energy savings by more accurately controlling inlet water temperature for hot and warm fills. In a typical non-thermostatically-controlled water inlet system, two solenoid valves are used; one valve opens for hot water fills while the other opens for cold water fills. Both solenoid valves are opened if a warm water setting is selected. In the warm wash mode, fixed fractions of hot and cold water are controlled by flow-control devices. For example, a manufacturer may decide to specify warm water as 50-percent hot water and 50-percent cold water. To reduce hot water energy use, some manufacturers have reduced the warm water temperature by using other ratios such as 40-percent hot and 60-percent cold.

Energy can be saved with a TCWV by either reducing the hot water temperature and/or reducing the warm water temperature. For example, the TCWV could be used to lower the hot wash temperature from 135 °F to 130 °F by mixing hot water (at 135 °F test inlet conditions) with cold water. Warm water temperature could be similarly reduced. The energy savings can vary widely depending on the test standard's specified inlet hot water temperature and the selected temperature of the warm water.

The TCWV technology option has the potential to overstate the real-world energy savings, depending on the proximity of the water heater to the installed clothes washer. When tested under laboratory conditions, the clothes washer is typically close to the hot water source, whereas this is generally not the case in a home laundry setting. As a result of the distance between the hot water source and the clothes washer, there is a temperature drop due to line losses. Because of these line losses, a clothes washer with a TCWV may use more hot water than predicted on the basis of laboratory testing. Similarly, in a real-world application, savings will also vary with the temperature of incoming cold water. The unheated water temperature will vary with both geographic location and time of year. More energy would likely be saved in cases of warmer "cold" supply water, as a TCWV would then reduce the amount of time a hot water valve is open. The amount of savings is also dependent on the set point of the TCWV, the water heater set point, the temperature selection of the wash (hot or warm cycle), and the location of the sensing thermostat controlling the inlet water valves. A limiting performance factor mentioned by more than one manufacturer is soil removal with lower wash temperatures.

Tighter tub tolerance

This technology option reduces the annular volume between the inner wash basket and the outer tub. This annulus fills with water, but does not add to the clothes washer capacity. Having less space between the inner wash basket and the outer tub reduces the amount of water required for a fill, thereby saving the energy required to heat that water. This option applies primarily to traditional top-loading vertical-axis washers. In a high-efficiency top-loading or horizontal-axis clothes washer, water only occupies the lower portion of the annulus. Since most

of the annulus in a high-efficiency top-loading or horizontal-axis clothes washer is filled with air, a smaller annulus does not yield significant energy savings.

Other considerations are also important in determining an appropriate clearance between basket and tub. In the past rulemaking, residential clothes washer manufacturers stated that if the annulus is too small there may be problems with "suds lock", where suds from the wash water remain between the inner wash basket and outer tub. Clearance is also needed to drain water during the spin-dry cycle and to allow for deflection of baskets with out-of-balance loads. Increasing the spin speed of the washer basket during the spin dry cycle may also require a larger space between tub and basket to allow for greater deflection at higher spin speeds. For this latter reason, tighter tub tolerance was not combined with the improved-water-extraction technology option. Other limiting performance factors mentioned by residential clothes washer manufacturers in the past include: (1) noise, (2) vibration, and (3) sand removal.

Ultrasonic washing

The addition of mechanical energy to the wash cycle can reduce the need for hot water (or chemical energy) in the cleaning action of clothes washers. One potential method of delivering the mechanical energy is through ultrasonic vibrations that loosen and remove some of the dirt on the soiled clothes. Such washing machines have been produced by a Japanese firm and were to be marketed in the United States. One U.S. clothes washer manufacturer investigated the Japanese product and found that it did not successfully clean clothes. The U.S. firm stated that the Japanese company is an excellent manufacturer of ultrasonic transducers, but does not have experience with clothes washing. In 2002, Sharp Corporation unveiled a clothes washer in Japan with a spot washing feature, which uses an ultrasonic generator, along with electrodes on the side of the tub to electrolyze the water, to generate tiny air bubbles to loosen dirt or remove stains.[96]

One of the problems with ultrasonic washing is that clothes are not uniformly exposed to the vibrations generated by the transducers, which means that some areas may remain soiled. Additionally, the wash solution and the submerged clothes appear to dissipate much of the energy without the clothes being cleaned.

3.15.3 Energy Efficiency

In preparation for the screening and engineering analyses, DOE gathered data on the energy efficiency of residential clothes washers available in the marketplace in December 2009. DOE conducted an in-depth search of residential clothes washers by gathering consumer data from three major appliance retailers: Sears, Home Depot, and AJMadison.com websites. These three sources are considered major retailers and are representative of the most important retail sales channels for residential clothes washers. DOE identified a total of 174 models (74 standard-size top-loading clothes washers, 100 front-loading clothes washers), which encompassed 20 different brands. For models that were available in multiple colors, or at multiple retailers, DOE used the least expensive full price, not including retail discounts. DOE used the CEC and ENERGY STAR databases to match MEF and WF data with each clothes washer model.

While this section is not intended to provide a complete characterization of the energy efficiency of all residential clothes washers currently available and in use, it does provide an overview of the vast majority of units available currently on the market. Figure 3.15.1 displays the distribution of standard-sized (capacity of 1.6 ft.^{3} or higher) residential clothes washers as a function of MEF. Figure 3.15.2 displays the distribution of standard-sized (capacity of 1.6 ft.^{3} or higher) residential clothes washers as a function of WF.

Figure 3.15.1 Standard-Sized Residential Clothes Washer MEFs from DOE Market Survey, December 2009

Figure 3.15.2 Standard-Sized Residential Clothes Washer WFs from DOE Market Survey, December 2009

Figure 3.15.1 illustrates the difference in MEF between top-loading and front-loading residential clothes washers. While the majority of top-loading units have an MEF below 1.80, there are an increasing number of high-efficiency top-loading units with MEFs between 1.80 and 2.29. All of the clothes washers with an MEF above 2.3 are front-loading units.

Figure 3.15.2 illustrates the difference in WF between top-loading and front-loading residential clothes washers. All of the residential clothes washers with a WF greater than 8.0 are top-loading units, whereas all of the clothes washers with a WF less than 4.0 are front-loading. The majority of clothes washers with a WF between 4.0 and 8.0 are front-loading.

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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 residential clothes washers (chapter 3 of this technical support document (TSD)). In the market and technology assessment, DOE presented an initial list of technology options that can be used to reduce energy consumption of residential clothes washers. The goal of the screening analysis is to identify any technologies that will be eliminated from further consideration in the rulemaking analyses.

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

4.2 DISCUSSION OF TECHNOLOGY OPTIONS

For residential clothes washers, the screening criteria specified in section 4.1 were applied to the technology options to either retain or eliminate each technology from the engineering analysis. DOE derived these by reviewing the technology options for residential clothes washers listed in chapter 3 of the 1997 *Technical Support Document for Clothes Washers* (1997 TSD). Steam washing and improved horizontal-axis-washer drum design were identified in the September 2005 edition of *Appliance Magazine*.[1] Silver ion injection was identified in the September 2007 edition of *Appliance Magazine*.[2] Plastic particle cleaning was indentified in the September 2008 edition of *Appliance Magazine*.[3] DOE has included spray rinse and advanced agitator technology options based on comments to the most recent standards rulemaking for commercial clothes washers.

4.2.1 Screened-Out Technology Options

The following section details the specific technology options that were screened out prior to the engineering analysis, along with the rationale for elimination.

The technologies identified in the market and technology assessment were evaluated pursuant to the criteria set out in EPCA. (42 U.S.C. 6291–6309) EPCA provides criteria for prescribing new or amended standards, which will achieve the maximum improvement in energy efficiency that the Secretary of Energy determines is technologically feasible. (42 U.S.C. 6295(o)(2)(A)) It also establishes guidelines for determining whether a standard is economically justified. (42 U.S.C. 6295(o)(2)(B)) In view of the EPCA requirements for determining whether a standard is technologically feasible and economically justified, appendix A to subpart C of Title 10 Code of Federal Regulations part 430 (10 CFR part 430), *Procedures, Interpretations and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products* (the Process Rule), sets forth procedures to guide DOE in the consideration and promulgation of new or revised product energy conservation standards under EPCA. These procedures elaborate on the statutory criteria provided in 42 U.S.C. 6295 and in part eliminate problematic technologies early in the process of revising an energy conservation standard. Under the guidelines, at the outset of a rulemaking, DOE eliminates from consideration technologies that present unacceptable problems with respect to the following four factors:

(1) Technological feasibility. If it is determined that a technology has not been incorporated in commercially available 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 commercially available 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 equipment to significant subgroups of consumers, or results in the unavailability of any covered equipment type with performance characteristics (including reliability), features, size, capacities, and volumes that are substantially the same as equipment generally available in the United States at the time, it will not be considered further.

(4) 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.

Based on these factors, DOE screened out added insulation, bubble action, electrolytic disassociation of water, ozonated laundering, plastic particle cleaning, and ultrasonic washing for the reasons that follow.

Added insulation

As described in chapter 3, adding insulation around the outer wash tub would have an insignificant effect on energy efficiency. Since the wash cycle is relatively short and the thermal mass of the water is very high, there is very little change in water temperature from adding insulation. Computer simulations performed on a traditional top-loading vertical-axis clothes washer for a 20-minute wash cycle at 140 degrees Fahrenheit (°F) showed that adding 1 inch of fiberglass insulation relative to no insulation resulted in only a 1–2 °F increase in water temperature during parts of the wash.[4] Furthermore, as water factor continues to decrease for residential clothes washers, the potential energy savings due to added insulation also decreases because of the lower quantity of hot water used during warm and hot cycles. Currently, DOE is unaware of any commercially available products that contain insulation around the outer wash tub.

Bubble action

Although bubble washing has been incorporated into commercially available residential clothes washers in Europe and Asia, production is extremely limited and further commercialization for the U.S. market would require manufacturers to develop entirely new platforms. Therefore, DOE does not believe that this technology would be practicable to manufacture, install, and service on the scale necessary to serve the relevant market at the time of the effective date of an amended standard.

Electrolytic disassociation of water

Electrolytic disassociation of water is in the research stage, 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 equipment utility to consumers or equipment availability, or any adverse impacts on consumers' health or safety.

Ozonated laundering

Although ozonated laundering is commercially available for residential clothes washers in extremely limited production in Asia, DOE believes that it would not be practicable to manufacture, install and service this technology on the scale necessary to serve the U.S. residential clothes washer market at the time of the effective date of an amended standard. Also, because implementation of this technology is so limited, it is not possible to assess whether it will have any adverse impacts on equipment utility to consumers or equipment availability, or any adverse impacts on consumers' health or safety.

Plastic particle cleaning

Plastic particle cleaning is still in the research stage, 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. In addition, the requirements for the potential purchase, handling, reusing, recycling, and/or disposal of the plastic particles are unknown, as is cleaning performance, and therefore the impacts on consumer utility cannot be evaluated.

Ultrasonic washing

Ultrasonic washing has been demonstrated in residential clothes washers, but the ultrasonic clothes washer did not adequately remove soil from the clothes and would therefore reduce consumer utility. In addition, bubble cavitations caused by standing ultrasonic waves could potentially damage some fragile clothing or clothing fasteners, further reducing consumer utility.

4.2.2 Remaining Design Options

Table 4.2.1 lists the technology options for residential clothes washers that were retained by DOE and subsequently designated as design options.

Table 4.2.1 Retained Design Options for Residential Clothes Washers

1.	Adaptive control systems
2.	Advanced agitation concepts for top-loading machines
3.	Automatic water fill control
4.	Direct-drive motor
5.	Horizontal-axis design
6.	Horizontal-axis design with recirculation
7.	Hot water circulation loop
8.	Improved fill control
9.	Improved horizontal-axis washer drum design
10.	Improved water extraction to lower remaining moisture content
11.	Increased motor efficiency
12.	Low standby-power electronic controls
13.	Reduced thermal mass
14.	Silver ion injection
15.	Spray rinse or similar water-reducing rinse technology
16.	Thermostatically controlled mixing valves
17.	Tighter tub tolerance

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CHAPTER 5. ENGINEERING ANALYSIS

5.1 INTRODUCTION

After conducting the screening analysis, the U.S. Department of Energy (DOE) performed an engineering analysis based on the remaining design options. The engineering analysis consists of estimating the energy and water consumption and costs of residential clothes washers at various levels of increased efficiency. This section provides an overview of the engineering analysis (section 5.1), considers technologies that are unable to be analyzed for this rulemaking (section 5.2), discusses product classes (section 5.3), establishes baseline and incremental efficiency levels (section 5.4), explains the methodology used during data gathering (section 5.5) and discusses the analysis and results (section 5.6).

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

DOE typically structures its engineering analysis around one of three methodologies. These are: (1) the design-option approach, which provides the incremental costs of adding to a baseline model design options that will improve its efficiency; (2) the efficiency-level approach, which provides the relative costs of achieving increases in energy efficiency levels, without regard to the particular design options used to achieve such increases; and (3) the cost-assessment (or reverse-engineering) approach, which provides "bottom-up" manufacturing cost assessments for achieving various levels of increased efficiency, based on detailed data regarding costs for parts and material, labor, shipping/packaging, and investment for models that operate at particular efficiency levels

DOE conducted the engineering analyses for the top-loading standard and front-loading standard product classes using a combination of the cost-assessment approach and the efficiency-level approach. The cost-assessment approach provides an accurate means for estimating a single manufacturer's incremental manufacturing costs for achieving various levels of increased efficiency. This approach involves physically disassembling commercially available products to develop cost-efficiency relationships for each manufacturer's product lines. Because each manufacturer may choose a different path to achieve higher levels of efficiency, an efficiency-

level approach produces an industry-wide cost-efficiency relationship for each product class. DOE developed cost-efficiency relationships for the top-loading standard and front-loading standard product classes by calculating the market-weighted average of the individual cost-efficiency relationships it developed for each manufacturer.

Because less data was available for the top-loading compact and front-loading compact product classes, DOE used the design-option approach to develop the cost-efficiency relationships for these product classes. For the top-loading compact product class, DOE developed the cost-efficiency relationship by estimating the incremental costs of adding specific design options to a baseline model that would provide sufficient improvement in efficiency to achieve the higher efficiency levels considered for the analysis. For the front-loading compact product class, DOE estimated the efficiency of a baseline product by extrapolating the rated efficiencies of front-loading clothes washers with capacities nearing those that delineate the compact product class (*i.e.*, 1.6 to 3.0 cubic feet). DOE then estimated the incremental cost of adding specific design options to this baseline model that would improve its efficiency enough to achieve the higher efficiency level considered for the analysis.

5.2 TECHNOLOGIES UNABLE TO BE INCLUDED IN THE PRELIMINARY ANALYSIS

In performing the engineering analysis, DOE did not consider certain technologies could not be evaluated for one or more of the following reasons: (1) data are not available to evaluate the energy efficiency characteristics of the technology; (2) available data suggested that the efficiency benefits of the technology would be negligible; and (3) certain technologies cannot be measured according to the conditions and methods specified in the DOE clothes washer test procedure (10 CFR 430, subpart B, appendix J2).

5.2.1 Adaptive Controls

In the notice of proposed rulemaking issued on September 21, 2010 (75 FR 57556) (hereinafter referred to as the September 2010 TP NOPR), DOE stated that it was aware of multiple clothes washer models available on the market that use adaptive control technologies to respond to measured or inferred load size and fabric mix. However, these models have since been discontinued, and DOE is unaware of any other clothes washers currently available on the market offering adaptive controls other than adaptive fill control. Adaptive controls could allow a clothes washer to sense the fabric mix and soil level of a wash load, for example, and then adjust wash parameters such as the number of rinses, cycle time, and water temperatures accordingly. Because of the lack of commercially available clothes washers with adaptive features, however, DOE did not amend the test procedure at appendix J2 to include provisions for measuring the energy consumption of clothes washers offering adaptive controls other than adaptive fill control. For this reasons, DOE did not include adaptive controls in its engineering analysis.

5.2.2 Improved Horizontal-Axis Washer Drum Design

Although several manufacturers have claimed improved wash performance and greater utility from improved drum designs for front-loading clothes washers, DOE is unaware of any publicly available data to corroborate a decrease in cycle time or energy or water consumption as a result of implementing this design option in residential clothes washers. Therefore, DOE did not analyze this design option for the final analysis.

5.2.3 Reduced Thermal Mass

Reduced thermal mass describes minimizing the amount of energy consumed by heating the wash tub to the temperature of the wash water. DOE research suggests that manufacturers typically already use tubs with low thermal mass for all clothes washers and that there is no practicable way to manufacture clothes washers with significantly lower thermal mass beyond the current practice. DOE is unaware of any data available regarding efficiency improvements related to further decreasing the thermal mass of wash tubs, and therefore did not consider this technology in its final analysis.

5.2.4 Silver Ion Injection

Silver ion injection provides an alternative to the traditional method of sanitizing clothes using a hot water wash. Silver ion injection works by electrolyzing pure silver during the wash and rinse cycles, and releasing the ions into the wash basket to sanitize the basket and wash load. While this technology option appears to offer an efficiency improvement by eliminating the need for high wash water temperatures, the current DOE test procedure does not capture this efficiency gain. Additionally, DOE lacks data on the reduction in warm and hot water cycles associated with silver ion injection and is not aware of any test procedures that could be used to measure any energy savings resulting from the use of silver ion injection. Because of this, DOE was unable to consider silver ion injection for further analysis

5.2.5 Tighter Tub Tolerance

The tighter tub tolerance technology option reduces the annular volume between the inner wash basket and the outer tub and hence reduces the total amount of water required for a fill cycle. As a result of discussions with manufacturers, DOE believes this technology option has reached its limit for efficiency gains. Decreasing the space between the wash basket and the tub any further could create problems such as “suds lock,” whereby suds remain between the wash basket and tub; improper draining during the spin cycle; noise; and vibration, thereby negatively impacting product utility. Therefore, DOE did not consider this design option in its engineering analysis.

Table 5.2.1 shows the final list of design options that DOE retained for the engineering analysis.

Table 5.2.1 Retained Design Options for Residential Clothes Washer Engineering Analysis

1. Advanced agitation concepts for top-loading machines
2. Automatic water fill control
3. Direct-drive motor
4. Horizontal-axis design
5. Horizontal-axis design with recirculation
6. Hot water circulation loop
7. Improved fill control
8. Improved water extraction to lower remaining moisture content
9. Increased motor efficiency
10. Low-standby-power electronic controls
11. Spray rinse or similar water-reducing rinse technology
12. Thermostatically controlled mixing valves

5.3 PRODUCT CLASSES ANALYZED

DOE separated residential clothes washers into product classes. In general, the criteria for separation into different classes are (1) type of energy used (natural gas or electricity), and (2) capacity or other performance-related features such as those that provide utility to the consumer, or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 U.S.C. 6295 (q)) As discussed in chapter 3 of this TSD, DOE has separated residential clothes washers into the following four product classes:

- Top-loading, compact (less than 1.6 cubic feet capacity);
- Top-loading, standard (1.6 cubic feet or greater capacity);
- Front-loading, compact (less than 1.6 cubic feet capacity); and
- Front-loading, standard (1.6 cubic feet or greater capacity).

5.4 EFFICIENCY LEVELS

For residential clothes washers, energy conservation standard levels are currently defined by two factors—modified energy factor (MEF) and water consumption factor (WF). MEF is calculated as the clothes container capacity in cubic feet divided by the sum, expressed in kilowatt-hours (kWh), of: (1) the total weighted per-cycle hot water energy consumption; (2) the total weighted per-cycle machine electrical energy consumption; and (3) the per-cycle energy consumption for removing moisture from a test load. WF is calculated as the weighted per-cycle water consumption of the cold wash/cold rinse cycle divided by the clothes container capacity in cubic feet.

For residential clothes washers, MEF and WF are calculated as follows:

$MEF=C/(HE_T + ME_T + D_E)$

where:

C= Clothes container capacity (ft^3)
HE_T = Total weighted per-cycle hot water energy consumption (kWh)
ME_T = Total weighted per-cycle machine electrical energy consumption (kWh)
D_E= Per-cycle energy consumption for removal of moisture from test load (kWh)

$WF=Q_T/ C$

where:

Q_T= Total weighted per-cycle water consumption (gallons)
C = Clothes container capacity (ft^3).

Section 310 of the Energy Independence and Security Act of 2007 (EISA 2007), Pub. L. 110-140, amended section 325 of the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 U.S.C. 6291–6309) to require that the test procedure for clothes washers be amended to include measurement of standby mode and off mode energy use, taking into consideration the most current versions of Standards 62301 and 62087 of the International Electrotechnical Commission (IEC)[a]. EPCA, as amended by EISA 2007, also required that any final rule establishing or revising a standard for a covered product, adopted after July 1, 2010, shall incorporate standby mode and off mode energy use into a single amended or new standard, if feasible. If not feasible, the Secretary shall prescribe within the final rule a separate standard for standby mode and off mode energy consumption. (42 U.S.C. 6295(gg))

DOE initiated a rulemaking in September 2010 to revise the test procedure for clothes washers to provide for measurement of standby mode and off mode energy use, as well as to address issues with the active mode provisions of the test procedure. In the subsequent final rule, DOE integrated standby and off mode energy use into the revised test procedure by establishing an "integrated modified energy factor" (IMEF), which also includes amended calculations of energy use in the active mode. The revised test procedure, designated as appendix J2, also establishes an "integrated water factor" (IWF), a metric that incorporates water usage from all cycles included in the energy test cycle rather than just the cold wash cycle. (10 CFR 430, subpart B, appendix J2)

[a] The most current version is IEC Standard 62301, "Household electrical appliances–Measurement of standby power", Second Edition, 2011. IEC Standard 62087, "Methods of measurement for the power consumption of audio, video, and related equipment," Second Edition, 2008-2010, is not applicable to this rulemaking. IEC standards may be purchased online at *www.iec.ch*.

Because current product ratings are based on the recently superseded test procedure at appendix J1 (10 CFR 430, subpart B, appendix J1), the definition of baseline units and incremental efficiency levels were established using the current efficiency metrics (MEF and WF) and an understanding of the typical energy use of the products in standby and off modes. As described in section 5.4.5, DOE then translated each MEF/WF efficiency level into a corresponding IMEF/IWF efficiency level, accounting for the impacts of new provisions in the amended test procedure (appendix J2). The revised energy conservation standards established in this final rule are based on the integrated metrics IMEF and IWF.

5.4.1 Baseline Units

DOE selected baseline units as reference points for each product class. The baseline unit in each product class represents the basic characteristics of equipment in that class. Typically, a baseline unit is a unit that just meets current energy conservation standards and provides basic consumer utility. DOE used the baseline units in the engineering analysis and the LCC and PBP analysis. To determine energy savings and changes in price, DOE compared each higher energy efficiency design option with the baseline unit.

DOE established the baseline level for the top-loading, standard product class based on the 1.26 MEF specified by current Federal energy conservation standards and the 9.5 water factor (WF) requirement established by the Energy Independence and Security Act of 2007 (EISA 2007), which became effective for residential clothes washers manufactured on or after January 1, 2011. For the front-loading, standard product class, DOE applied the former ENERGY STAR level, effective prior to July 2009, to characterize the baseline efficiency level. DOE understands that all commercially available front-loading standard clothes washers have efficiencies that meet or exceed the existing Federal standards and the former ENERGY STAR level of 1.72 MEF and 8.0 WF. For the top-loading, compact product class, DOE defined the baseline efficiency level as 0.77 MEF/14.0 WF based on a survey of products currently available on the market.

For the front-loading, compact product class, DOE defined a baseline efficiency level of 1.60 MEF/8.5 WF, based on an extrapolation of the rated efficiencies of front-loading clothes washers with capacities nearing those that delineate the compact product class (*i.e.*, 1.6 to 3.0 cubic feet). Unlike the other product classes, there are no front-loading, compact products currently on the market that DOE could analyze. A survey of MEF/WF data in the California Energy Commission (CEC) appliance efficiency database reveals that for front-loading clothes washers, unlike for top-loading clothes washers, the MEF relationship with capacity flattens out at capacities less than 3.0 cubic feet, as shown in Figure 5.4.1.

Figure 5.4.1 Relationship between MEF and Capacity for Front-Loading Clothes Washers

By examining the MEF of front-loading clothes washers with capacities just above 1.6 cubic feet, it is evident that the same MEF could likely be achieved for those just below 1.6 cubic feet. DOE believes that any front-loading compact product that might come to market would have a capacity just under 1.6 cubic feet. Among the front-loading clothes washers with capacities less than 3.0 cubic feet, the lowest MEF is 1.63. DOE extrapolated this relationship between MEF and capacity and defined a baseline MEF of 1.60 for the front-loading, compact product class.

DOE performed a similar analysis to define the baseline WF level. Figure 5.4.2 shows the relationship between WF and capacity for front-loading clothes washers.

Figure 5.4.2 Relationship between WF and Capacity for Front-Loading Clothes Washers

Unlike the correlation between MEF and capacity, the correlation between WF and capacity is not as strong for front-loading clothes washers less than 3.0 cubic feet. However, DOE noted that the clothes washer with the lowest capacity also has the highest WF (8.5 WF). DOE believes that the same 8.5 WF could be achieved for a front-loading clothes washer just below 1.6 cubic feet. Therefore, DOE defined a baseline WF of 8.5 for the front-loading, compact product class.

Table 5.4.1 lists the baseline active mode efficiencies DOE has selected for all four residential clothes washer product classes.

Table 5.4.1 Clothes Washer Baseline Unit Active Mode Efficiencies

Product Class	Baseline Efficiency Level Reference Source	Baseline Efficiency Level	
		MEF *(ft^3/kWh)*	**WF** *(gallons/ft^3)*
Top-Loading, Standard	DOE Standard (effective 2011)	1.26	9.5
Front-Loading, Standard	Former ENERGY STAR (pre-July 2009)	1.72	8.0
Top-Loading, Compact	Baseline product on the market	0.77	14.0
Front-Loading, Compact	DOE-estimated baseline level	1.60	8.5

5.4.2 Higher Efficiency Levels

For the top-loading standard and front-loading standard product classes, DOE considered efficiency levels higher than baseline levels based on specifications prescribed by ENERGY

STAR and CEE's Super-Efficient Home-Appliances Initiative. The highest efficiency levels were defined by the maximum available technology that DOE could identify on the market. Where the increments between adjacent efficiency levels were large, DOE added an intermediate "gap-fill" level.

For the top-loading compact product class and front-loading product class, DOE defined higher efficiency levels based on the standard levels proposed in a Joint Petition submitted by groups representing manufacturers and environmental advocates (hereafter referred to as the "Consensus Agreement"). The Consensus Agreement included a proposed set of tiered efficiency standards for top-loading compact clothes washers (effective in 2015 and 2018) and a proposed efficiency standard for front-loading compact clothes washers effective in 2015.

Table 5.4.2 through Table 5.4.5 provide the active mode efficiency levels and the reference source of each level for the four product classes under consideration.

Table 5.4.2 Top-Loading Standard Clothes Washer Active Mode Efficiency Levels, Based on MEF and WF

Level	Efficiency Level Reference Source	Efficiency Level	
		MEF *(ft^3/kWh/cycle)*	**WF** *(gal/cycle/ft^3)*
Baseline	DOE Standard	1.26	9.5
EL 1	Gap Fill	1.40	9.5
EL 2	Former ENERGY STAR (pre- 2009)	1.72	8.0
EL 3	Former ENERGY STAR (pre-2011)	1.80	7.5
EL 4	Current ENERGY STAR (Jan 2011)	2.00	6.0
EL 5	Previous Max Available (at time of Framework Document)	2.26	4.5
EL 6	Current Max Available	2.47	3.6

Table 5.4.3 Front-Loading Standard Clothes Washer Active Mode Efficiency Levels, Based on MEF and WF

Level	Efficiency Level Reference Source	Efficiency Level	
		MEF *(ft^3/kWh/cycle)*	**WF** *(gal/cycle/ft^3)*
Baseline	Former ENERGY STAR (pre-July 2009)	1.72	8.0
EL 1	Former ENERGY STAR (pre-Jan 2011)	1.80	7.5
EL 2	Current ENERGY STAR (Jan 2011), also CEE Tier 1	2.00	6.0
EL 3	CEE Tier 2	2.20	4.5
EL 4	Gap Fill, also CEE Tier 3*	2.40	4.2*
EL 5	Gap Fill	2.60	3.8
EL 6	Max Available	2.89	3.2

* CEE Tier 3 currently specifies a maximum water factor of 4.0. The water factor of 4.2 for this gap fill level was selected before the current CEE Tier 3 specification was announced.

Table 5.4.4 Efficiency Levels for Top-Loading Compact Residential Clothes Washer Final Analysis

Level	Efficiency Level Description	Efficiency Level	
		MEF *(ft^3/kWh/cycle)*	**WF** *(gal/cycle/ft^3)*
Baseline	Baseline product on the market	0.77	14.0
1	Consensus Agreement (2015 Proposed Standard)	1.26	14.0
2	Consensus Agreement (2018 Proposed Standard)	1.81	11.6

Table 5.4.5 Efficiency Levels for Front-Loading Compact Residential Clothes Washer Final Analysis

Level	Efficiency Level Description	Efficiency Level	
		MEF *(ft^3/kWh/cycle)*	**WF** *(gal/cycle/ft^3)*
Baseline	DOE-estimated baseline level	1.60	8.5
1	Consensus Agreement (2015 Proposed Standard)	1.72	8.0

For top-loading standard clothes washers, DOE analyzed six efficiency levels beyond the baseline, as listed in Table 5.4.2. These levels were based on the previous and current ENERGY STAR levels, some of which correspond to the Consortium for Energy Efficiency (CEE) Residential Clothes Washer Initiative efficiency tiers, and the maximum level that is currently commercially available (which DOE used as a proxy for max-tech) as determined from data contained within the California Energy Commission (CEC) and ENERGY STAR product databases. DOE also added a gap-fill level to span the large difference in efficiency between the baseline and former ENERGY STAR (pre-2009) level.

For front-loading standard residential clothes washers, DOE analyzed six efficiency levels beyond the baseline, as listed in Table 5.4.3. These levels were based on the former and current ENERGY STAR levels, the CEE Residential Clothes Washer Initiative efficiency tiers, and maximum levels that are currently commercially available. Two gap-fill levels were added between the CEE Tier 2 and the maximum available level. DOE determined the max-tech level based on an extensive market survey, which suggests that the max tech unit's combination of high MEF and low WF represents the best-in-class balance between MEF and WF.

As described above, DOE defined higher efficiency levels for the top-loading compact and front-loading product classes based on the standard levels proposed in the Consensus Agreement.

5.4.3 Maximum Technologically Feasible Efficiency Levels

Under EPCA, DOE is required to consider the maximum technologically feasible level ("max-tech"). DOE determines max-tech levels based on technologies that are either commercially available or have been demonstrated as working prototypes. If the max-tech design meets DOE's screening criteria, DOE considers the design in further analysis. DOE also

considers consumer utility and availability of features, which may be met by a niche product, as required by EPCA.

DOE identified the max-tech levels for top-loading standard and front-loading standard residential clothes washers based on the maximum performance of products currently on the market in the United States. DOE considered several models in each product class to determine max-tech values that best represent optimal performance of MEF and WF for clothes washers on the market. DOE determined, based on comments from interested parties, that a high MEF and low WF are not necessarily correlated, and therefore, a max-tech level based on the highest MEF and lowest WF is not realistic (*i.e.*, a residential clothes washer with the highest possible MEF may not achieve the lowest possible WF, and *vice versa*). Therefore, DOE selected residential clothes washers currently available on the market that exhibit a balance of high MEF and low WF to represent the max-tech levels.

For top-loading compact clothes washers, DOE used the 2018 standard level proposed in the Consensus Agreement as the max-tech level, as described previously. For front-loading compact clothes washers, DOE used the 2015 standard level proposed in the Consensus Agreement as the max-tech level. Based on energy and water consumption modeling using a design option approach, DOE believes that these max-tech levels correspond to the maximum technologically feasible efficiency levels for the top-loading compact and front-loading compact product classes.

Finally, DOE has observed that the max-tech units on the market use a combination of significantly reduced water volumes, reduced water temperatures, extended cycle times, and extremely high spin speeds. DOE is not aware of any additional design options that could be used to increase the efficiency beyond the max-tech levels without causing potential negative effects on consumer utility. Nor is DOE aware of any working prototype clothes washers that exceed the efficiency levels of the max-tech units on the market in the United States. Therefore, DOE believes the "max available" efficiency levels for residential clothes washers correspond to the maximum technologically feasible efficiency levels.

5.4.4 Standby Mode and Off Mode Power

DOE measured standby and off mode energy use of residential clothes washers in its sample of reverse-engineered units. The results of the standby and off mode measurements are shown in Table 5.4.6 below. DOE performed these tests according to the provisions in IEC Standard 62301 First Edition[b], including Section 5, Paragraph 5.1, note 1, which instructs to allow sufficient time for the product to reach the lower power state before proceeding with the test measurement. Some of clothes washers in the test sample with electromechanical controls did not consume any power when the units were plugged in and not in active mode, or once a

[b] IEC Standard 62301 First Edition was the most current version at the time the engineering analysis was conducted. The Second Edition was published January 27, 2011 and contains revisions affecting the definitions and measurement methodology of standby and off-mode power. However, DOE believes that the methodology of the Second Edition would produce nearly identical standby power consumption measurements.

wash cycle had completed. With no status or information displays activated and no reactivation possible by remote switch, internal sensor, or timer, such units meet the definition of operation in off mode. DOE also noted that for some units with electronic controls, after a period of user inactivity (generally between 5 and 10 minutes), the display turns off and the power consumption reverts to the power consumption seen in the plugged in and off condition. For this reason, DOE believes that the lowest power consumption state for units with electronic controls provides for the most representative standby/off mode energy use.

Table 5.4.6 Clothes Washer Standby and Off Mode Power Measurements

Product Class	Test Unit	Rated MEF *(ft^3/kWh)*	Control Type	Power Supply Type	Power Consumption *(W)*	Lowest Power Mode
Top-Loading, Standard	1	1.35	Electromechanical	N/A	0.00	Off
	2	1.48	Electromechanical	N/A	0.00	Off
	3	1.76	Electromechanical	N/A	0.05	Standby
	4	1.82	Electronic	Switch-mode	1.16	Standby
	5	2.11	Electronic	Switch-mode	1.15	Standby
	6	2.25	Electronic	Switch-mode	1.67	Standby
Front-Loading, Standard	7	1.82	Electronic	Switch-mode	0.77	Standby
	8	2.13	Electronic	Switch-mode	1.60	Standby
	9	2.2	Electronic	Transformerless	0.01	Standby
	10	2.2	Electronic	Switch-mode	0.44	Standby
	11	2.38	Electronic	Switch-mode	1.60	Standby
	12	2.44	Electronic	Transformerless	0.01	Standby
	13	2.64	Electronic	Switch-mode	1.65	Standby
	14	2.71	Electronic	Transformerless	0.08	Standby
	15	2.89	Electronic	Switch-mode	0.01	Standby

The models in this DOE test sample with electronic controls incorporated switch-mode and transformerless power supplies. The power consumption for units with switch-mode power supplies ranged from 0.44 to 1.67 W. The power consumption for units with transformerless power supplies ranged from 0.01 to 0.08 W.

None of the models in this test sample used a conventional linear power supply, which DOE believes would represent a baseline design option with higher power consumption than a switch-mode power supply. Based on tests that DOE performed on residential dryers with conventional linear power supplies, DOE believes a clothes washer with a conventional linear power supply would consume approximately 2.3 W in standby mode. DOE estimated this baseline power level by scaling the power consumption measured for a baseline dryer according to the size of the transformer required for a residential clothes washer. (5VA transformer for clothes dryers, and 30VA transformer for clothes washers).

Based on its limited testing, DOE defined three standby power levels for analysis, shown in Table 5.4.7. DOE observed that both top-loading clothes washers and front-loading clothes washers share many of the same hardware components within the electronic controls; therefore, DOE believes that these standby power levels are the same for both top-loading and front-

loading residential clothes washers. DOE defined each level based on the highest standby power consumption observed for each configuration.

Table 5.4.7 Residential Clothes Washer Standby Power Levels

Level	Standby Power Source	Power Input *(W)*
Baseline	DOE Test Data and Analysis	2.3
SL 1	DOE Test Data	1.7
SL 2	DOE Test Data (Max-Tech)	0.08

The baseline standby power level is associated with a linear regulated control board power supply. SL 1 is associated with changing from a conventional power supply to a switch-mode power supply. For SL 2, a transformerless drop-cap power supply applied to the baseline linear power supply enables a microcontroller to remain on at all times while disabling the main power supply whenever the clothes washer is "asleep". The control logic monitors the clothes washer for key-presses, door openings, etc., and when user activity is detected, the logic activates the main power supply.

DOE recognizes that many top-loading clothes washers that just meet the current Federal energy conservation standards for MEF use electromechanical controls, which consume no standby power. Baseline standby power of 2.3 W is incorporated at the first MEF level for which electronic controls are required in order to achieve higher efficiency. For front-loading clothes washers, virtually all units at the baseline efficiency level incorporate electronic controls, and thus the baseline standby power level of 2.3 W is incorporated at the baseline MEF level. At higher MEF levels for both product classes, DOE believes that standby power improvements would be used at the lowest efficiency level where they would be cost effective. A summary of the incremental costs, and the methodology used to determine them, can be found in section 5.6.4. Table 5.4.8 and Table 5.4.9 show the standby power levels associated with each MEF efficiency level for top-loading standard and front-loading standard clothes washers.

Table 5.4.8 Standby Power and Associated MEF Levels for Top-Loading Standard Clothes Washers

Level	Efficiency Level Description	MEF *(ft^3/kWh)*	WF *(gal/ft^3)*
Baseline	DOE Standard + 0 W Standby	1.26	9.5
EL 1	Gap Fill + 0 W Standby	1.40	9.5
EL 2	Former ENERGY STAR (pre- 2009) + 0 W Standby	1.72	8.0
EL 3	Former ENERGY STAR (pre-2011) + 2.3 W Standby	1.80	7.5
EL 4	Former ENERGY STAR (pre-2011) + 1.7 W Standby	1.80	7.5
EL 5	Former ENERGY STAR (pre-2011) + 0.08 W Standby	1.80	7.5
EL 6	Current ENERGY STAR (Jan 2011) + 0.08 W Standby	2.00	6.0
EL 7	Max Available (at time of Framework Document) + 0.08 W Standby	2.26	4.5
EL 8	Current Max Available + 0.08 W Standby	2.47	3.6

Table 5.4.9 Standby Power and Associated MEF Levels for Front-Loading Clothes Washers

Level	Efficiency Level Description	MEF (ft^3/kWh)	WF (gal/ft^3)
Baseline	Former ENERGY STAR (pre-2009) + 2.3 W Standby	1.72	8.0
EL 1	Former ENERGY STAR (pre-2009) + 1.7 W Standby	1.72	8.0
EL 2	Former ENERGY STAR (pre-2009) + 0.08 W Standby	1.72	8.0
EL 3	Former ENERGY STAR (pre-2011) + 0.08 W Standby	1.80	7.5
EL 4	Current ENERGY STAR (Jan 2011) + 0.08 W Standby	2.00	6.0
EL 5	CEE Tier 2 + 0.08 W Standby	2.20	4.5
EL 6	Gap Fill + 0.08 W Standby	2.40	4.2
EL 7	Gap Fill + 0.08 W Standby	2.60	3.8
EL 8	Max Available + 0.08 W Standby	2.89	3.2

Because DOE used the standard levels proposed in the Consensus Agreement as the basis for the higher efficiency levels for the top-loading compact and front-loading product classes, DOE did not associate standby power levels with any of the higher efficiency levels for these product classes.

5.4.5 Integrated Efficiency Metrics

As described earlier, the amended test procedure at appendix J2 incorporates standby and off mode power measurements as well as number of other revisions that affect the IMEF and IWF calculations. DOE translated each MEF/WF efficiency level into a corresponding IMEF/IWF efficiency level to account for the impacts of new provisions in appendix J2.

Table 5.4.10 shows the major revisions included in the amended test procedure that significantly affect the calculated efficiency metrics.

Table 5.4.10 Revisions to the Clothes Washer Test Procedure that Significantly Affect Efficiency Metrics

Factors Affecting MEF / IMEF	Appendix J1	Appendix J2
Capacity measurement	For top-loading clothes washers: Innermost diameter of the tub cover. (Defined as "Fill Level 3" in DOE guidance document[c])	For top-loading clothes washers: Uppermost edge of the rotating portion, including any balance ring. (Defined as "Fill Level 2" in DOE guidance document)
Temperature Use Factors (TUF)	"Warm Rinse" included as an incremental featured added to a Warm Wash / Cold Rinse cycle.	Warm Wash / Warm Rinse cycle included as a complete, unique cycle.
Remaining Moisture Content (RMC)	Calculation performed using maximum test load weight corresponding to "Fill Level 3" capacity	Calculation performed using maximum test load weight corresponding to "Fill Level 2" capacity
Dryer energy calculation	Based on Load Adjustment Factor (LAF) of 0.52 multiplied by maximum test load weight	Based on weighted average load size according to existing Load Usage Factors (LUF).
Dryer Usage Factor (DUF)	DUF = 0.84	DUF = 0.91
Standby and off mode power	Not included.	Included in calculation based on 8,465 hours in standby/off mode, apportioned over all active mode cycles.
Number of annual cycles	392; Not included in any test procedure calculations.	295; Included as the basis for standby/off mode hours.
Factors Affecting WF / IWF		
Capacity measurement	See above.	See above.
Water Consumption	Based on water usage of Cold Wash / Cold Rinse cycles only.	Based on weighted average of water usage of all Wash / Rinse temperature combinations

IMEF is calculated as the clothes washer capacity in cubic feet divided by the sum, expressed in kWh, of the total weighted per-cycle hot water energy consumption, the total weighted per-cycle machine electrical energy consumption, the per-cycle energy consumption for removing moisture from a test load, and the per-cycle standby and off mode energy consumption. IWF is calculated as the total weighted per-cycle water consumption for all wash cycles, expressed in gallons per cycle; divided by the clothes container capacity in cubic feet.

To perform the efficiency metric translations, DOE tested a wide range of top-loading and front-loading clothes washers according to both appendix J1 and appendix J2. Based on these tests, DOE developed conversion formulas to relate MEF to IMEF, and WF to IWF. The conversion formulas take into account all the changes to the test procedure listed in Table 5.4.10. Therefore, a clothes washer that currently meets a given MEF/WF level as tested under appendix J1 would subsequently meet the corresponding IMEF/IWF level as tested under appendix J2.

[c] DOE issued guidance in May 2010 on what is considered the clothes container for purposes of measuring clothes container capacity. The Interpretive Rule is available at the residential clothes washer rulemaking website, http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers.html

Because the IMEF calculation is affected by the measured standby power level, DOE developed separate conversion formulas for each of the standby power levels identified in Table 5.4.7. The appropriate conversion formula was then applied to each efficiency level in Table 5.4.8 and Table 5.4.9 according to the standby power associated with each level.

5.4.5.1 Top-Loading, Standard Product Class

Figure 5.4.3 and Figure 5.4.4 show the MEF/IMEF and WF/IWF linear correlation curves, respectively, from which the conversion formulas were derived for top-loading standard clothes washers. Each data point represents the test results for a single clothes washer in the test sample.

Figure 5.4.3 MEF to IMEF Conversion Curves for Top-Loading Standard Residential Clothes Washers

Figure 5.4.4 WF to IWF Conversion Curve for Top-Loading Standard Residential Clothes Washers

Table 5.4.11 shows the integrated efficiency levels used in the final analysis for top-loading standard clothes washers, based on these conversion formulas.

Table 5.4.11 Integrated Efficiency Levels for Top-Loading Standard Residential Clothes Washers

		Efficiency Level – Appendix J1		Integrated Efficiency Level – Appendix J2	
Level	**Efficiency Level Description**	**MEF** *(ft^3/kWh/ cycle)*	**WF** *(gal/cycle/ ft^3)*	**IMEF** *(ft^3/kWh/ cycle)*	**IWF** *(gal/cycle/ ft^3)*
Baseline	DOE Standard + 0 W Standby	1.26	9.5	0.84	9.9
EL 1	Gap Fill + 0 W Standby	1.40	9.5	0.98	9.9
EL 2	Former ENERGY STAR (pre- 2009) + 0 W Standby	1.72	8.0	1.29	8.4
EL 3	Former ENERGY STAR (pre-2011) + 2.3 W Standby	1.80	7.5	1.34	7.9
EL 4	Former ENERGY STAR (pre-2011) + 1.7 W Standby	1.80	7.5	1.34	7.9
EL 5	Former ENERGY STAR (pre-2011) + 0.08 W Standby	1.80	7.5	1.37	7.9
EL 6	Current ENERGY STAR (Jan 2011) + 0.08 W Standby	2.00	6.0	1.57	6.5
EL 7	Max Available (at time of Framework Document) + 0.08 W Standby	2.26	4.5	1.83	5.0
EL 8	Current Max Available + 0.08 W Standby	2.47	3.6	2.04	4.1

5.4.5.2 Front-Loading, Standard Product Class

Figure 5.4.5 and Figure 5.4.6 show the MEF/IMEF and WF/IWF linear correlation curves, respectively, from which the conversion formulas were derived for front-loading standard clothes washers. Each data point represents the test results for a single clothes washer in the test sample.

Figure 5.4.5 MEF to IMEF Conversion Curves for Front-Loading Standard Residential Clothes Washers

Figure 5.4.6 WF to IWF Conversion Curve for Front-Loading Standard Residential Clothes Washers

Table 5.4.12 shows the integrated efficiency levels used in the final analysis for front-loading standard clothes washers, based on these conversion formulas.

Table 5.4.12 Integrated Efficiency Levels for Front-Loading Standard Residential Clothes Washers

Level	Efficiency Level Description	Efficiency Level – Appendix J1		Integrated Efficiency Level – Appendix J2	
		MEF *(ft^3/kWh/ cycle)*	**WF** *(gal/cycle/ ft^3)*	**IMEF** *(ft^3/kWh/ cycle)*	**IWF** *(gal/cycle/ ft^3)*
Baseline	Former ENERGY STAR (pre- 2009) + 2.3 W Standby	1.72	8.0	1.37	8.3
EL 1	Former ENERGY STAR (pre- 2009) + 1.7 W Standby	1.72	8.0	1.39	8.3
EL 2	Former ENERGY STAR (pre- 2009) + 0.08 W Standby	1.72	8.0	1.41	8.3
EL 3	Former ENERGY STAR (pre-2011) + 0.08 W Standby	1.80	7.5	1.49	7.8
EL 4	Current ENERGY STAR (Jan 2011) + 0.08 W Standby	2.00	6.0	1.66	6.3
EL 5	CEE Tier 2 + 0.08 W Standby	2.20	4.5	1.84	4.7
EL 6	Gap Fill + 0.08 W Standby	2.40	4.2	2.02	4.4
EL 7	Gap Fill + 0.08 W Standby	2.60	3.8	2.20	4.0
EL 8	Max Available + 0.08 W Standby	2.89	3.2	2.46	3.4

5.4.5.3 Top-Loading, Compact Product Class

DOE conducted an alternate analysis for the top-loading compact product class because of the limited number of top-loading compact clothes washers available on the market for testing. DOE conducted testing on several compact top-loading clothes washers and determined the typical energy and water consumption characteristics of a baseline model. Then, using the design option approach supplemented with information obtained through manufacturer interviews, DOE modeled the energy and water savings that would be achieved by implementing specific design options required to achieve the higher efficiency levels. DOE modeled the energy and water consumption according to the provisions of both appendix J1 and appendix J2, and used these results to develop the MEF/IMEF and WF/IWF correlation curves.

Table 5.4.13 shows the results of the energy consumption modeling at each efficiency level using appendix J1. Table 5.4.14 shows the results of the energy consumption modeling at each efficiency level using appendix J2. Table 5.4.15 shows the results of the water consumption modeling at each efficiency level using appendix J1. Table 5.4.16 shows the results of the water consumption modeling at each efficiency level using appendix J2.

Table 5.4.13 Energy Consumption Modeling of Top-Loading Compact Product Class Using Appendix J1

Efficiency Level	Capacity (ft^3)	Electrical Energy (kWh/cycle)	Hot Water Energy (kWh/cycle)	Dryer Energy (kWh/cycle)	MEF (ft^3/kWh/cycle)
Baseline	1.50	0.30	0.89	0.76	0.77
Level 1	1.59	0.30	0.21	0.76	1.26
Level 2	1.59	0.11	0.19	0.58	1.81

Table 5.4.14 Energy Consumption Modeling of Top-Loading Compact Product Class Using Appendix J2

Efficiency Level	Capacity (ft^3)	Electrical Energy (kWh/cycle)	Hot Water Energy (kWh/cycle)	Dryer Energy (kWh/cycle)	Standby Energy (kWh/cycle)	IMEF (ft^3/kWh/ cycle)
Baseline	1.50	0.30	0.89	1.35	0.00	0.59
Level 1	1.59	0.30	0.19	1.37	0.00	0.86
Level 2	1.59	0.11	0.19	1.01	0.07	1.15

Table 5.4.15 Water Consumption Modeling of Top-Loading Compact Product Class Using Appendix J1

Efficiency Level	Capacity (ft^3)	Water Consumption (gal)	WF (gal/cycle/ft^3)
Baseline	1.50	21.0	14.0
Level 1	(same as Baseline)		14.0
Level 2	1.59	18.4	11.6

Table 5.4.16 Water Consumption Modeling of Top-Loading Compact Product Class Using Appendix J2

Efficiency Level	Capacity (ft^3)	Water Consumption (gal)	IWF (gal/ cycle/ft^3)
Baseline	1.50	22.4	14.9
Level 1	(same as Baseline)		14.9
Level 2	1.59	19.1	12.0

Table 5.4.17 shows the integrated efficiency levels used in the final analysis for top-loading compact clothes washers, based on the results of the energy and water consumption modeling.

Table 5.4.17 Integrated Efficiency Levels for Top-Loading Compact Residential Clothes Washers

		Efficiency Level – Appendix J1		Integrated Efficiency Level – Appendix J2	
Level	**Efficiency Level Description**	**MEF** *(ft^3/kWh/ cycle)*	**WF** *(gal/cycle/ ft^3)*	**IMEF** *(ft^3/kWh/ cycle)*	**IWF** *(gal/cycle/ ft^3)*
Baseline	Baseline product on the market	0.77	0.59	0.59	14.4
EL 1	Consensus Agreement (2015 Proposed Standard)	1.26	0.86	0.86	14.4
EL 2	Consensus Agreement (2018 Proposed Standard)	1.81	1.15	1.15	12.0

5.4.5.4 Front-Loading, Compact Product Class

DOE is unaware of any compact front-loading clothes washers currently on the market in the United States. Therefore, DOE estimated the IMEF conversion formula based on expected product and performance characteristics for baseline models within that product class. Table 5.4.18 lists the expected product characteristics of a baseline compact front-loading clothes washer.

Table 5.4.18 Expected Product Characteristics of a Baseline Compact Front-Loading Clothes Washer

Feature	Expected Product Characteristics
Capacity	1.5 – 1.59 ft^3
Remaining Moisture Content	45% –50%
Control System	Electronic controls with baseline-level standby power consumption
Fill Level Control	Automatic fill using mechanical pressure sensor
Warm Rinse	Unavailable

Based on the capacities of all clothes washers in the CEC database, DOE believes that 1.5 cubic feet is an approximate lower bound on capacity that can be expected for compact front-loading clothes washers.

DOE further believes that a remaining moisture content (RMC) of 45–50 percent conservatively represents an appropriate upper bound for compact front-loading clothes washers with 1.5–1.6 cubic feet of capacity. DOE derived this estimate from three independent sources of information First, a single compact front-loading unit tested by CSA International has an RMC of 46 percent according to the Canadian clothes washer test procedure, C360-03, which is largely

similar to the DOE clothes washer test procedure at appendix J1[d]. Second, a trend line of RMC versus capacity for clothes washers in the CEC database indicates that the maximum expected RMC for compact-size units lies within a range of 40–50 percent, as shown by the shaded circle in Figure 5.4.7. Third, an analysis by DOE of the tub geometry of a front-loading clothes washer with 1.5 cubic feet capacity indicates that the clothing inside the wash tub would experience a maximum of around 150 g's during the spin cycle. This would correspond to an RMC of approximately 45 to 50 percent.

Figure 5.4.7 RMC as a Function of Capacity for Front-Loading Clothes Washers in the CEC Database, 2008-2011

Similar to the analysis for the top-loading compact product class, DOE conducted an alternate analysis for the front-loading compact product class. Using a design option approach, and extrapolating test results from the front-loading standard product class, DOE modeled the energy and water savings that would be achieved by implementing specific design options required to achieve the higher efficiency levels. DOE modeled the energy and water consumption according to the provisions of both appendix J1 and appendix J2, and used these results to develop the MEF/IMEF and WF/IWF correlation curves.

Table 5.4.19 shows the results of the energy and water consumption modeling at each efficiency level using appendix J1. Table 5.4.20 shows the results of the energy and water consumption modeling at each efficiency level using appendix J2.

[d] RMC values were derived from reported values of capacity, MEF, and energy consumption. Test report from CSA International available at http://directories.csa-international.org/xml_transform.asp?xml=certxml\244824-8802-01.xml&xsl=xsl/certrec.xsl

Table 5.4.19 Energy and Water Consumption Modeling of Front-Loading Compact Product Class Using Appendix J1

Efficiency Level	Capacity (ft^3)	Electrical Energy (kWh/cycle)	Hot Water Energy (kWh/cycle)	Dryer Energy (kWh/cycle)	Water Consumption (gal/cycle)	MEF (ft^3/kWh/cycle)	WF (gal/cycle/ft^3)
Baseline	1.50	0.10	0.27	0.57	12.8	1.60	8.8
Level 1	1.50	0.10	0.20	0.57	12.0	1.72	8.0

Table 5.4.20 Energy Consumption Modeling of Front-Loading Compact Product Class Using Appendix J2

Efficiency Level	Capacity (ft^3)	Electrical Energy (kWh/cycle)	Hot Water Energy (kWh/cycle)	Dryer Energy (kWh/cycle)	Standby Energy (kWh/cycle)	Water Consumption (gal/cycle)	IMEF (ft^3/kWh/ cycle)	IWF (gal/cycle/ ft^3)
Baseline	1.50	0.10	0.27	1.02	0.07	13.2	1.03	8.8
Level 1	1.50	0.10	0.20	1.02	0.00	12.5	1.13	8.3

Table 5.4.21 shows the integrated efficiency levels used in the final analysis for front-loading compact clothes washers, based on the results of the energy and water consumption modeling.

Table 5.4.21 Integrated Efficiency Levels for Front-Loading Compact Residential Clothes Washers

		Efficiency Level – Appendix J1		Integrated Efficiency Level – Appendix J2	
Level	**Efficiency Level Description**	**MEF** *(ft^3/kWh/ cycle)*	**WF** *(gal/cycle/ ft^3)*	**IMEF** *(ft^3/kWh/ cycle)*	**IWF** *(gal/cycle/ ft^3)*
Baseline	DOE-estimated baseline level	1.60	8.5	1.03	8.8
EL 1	Consensus Agreement (2015 Proposed Standard)	1.72	8.0	1.13	8.3

5.5 METHODOLOGY OVERVIEW

DOE used data submitted by AHAM (see appendix 5-A and 5-B of this TSD) as one source of cost information for the engineering analysis. AHAM provided DOE with aggregated incremental manufacturing cost data from its member companies. DOE conducted an independent review of the AHAM data using several methods and data sources. To gain a better understanding of the data submitted by member companies and to be able to relate the costs of improving efficiency to discrete or system-level technologies, DOE reviewed the TSD from the previous rulemaking and conducted interviews with residential clothes washer manufacturers. DOE also performed detailed product teardowns and cost modeling on multiple clothes washer models spanning a range of efficiencies to generate cost-efficiency curves. These cost-efficiency relationships were compared to the AHAM data for validation. Finally, DOE conducted standby power testing, as well as detailed energy performance testing at an independent laboratory and internally to gain insights into energy performance in active, standby, and off modes.

5.5.1 AHAM Data Request

In support of this rulemaking effort, DOE requested incremental cost data from AHAM for residential clothes washers. The data represent the average incremental production cost to improve a baseline unit to a specified efficiency level. In addition, DOE requested shipments, shipment-weighted average efficiency, and market share efficiency data. A discussion of the data provided by AHAM is included in section 5.6.1.

5.5.2 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 clothes washer efficiency, and their associated manufacturing costs. Sample questions asked during the interviews are contained in appendix 5-C.

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

5.5.3 Product Teardown Methodology

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

5.5.3.1 Selection of Units

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

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

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

5.5.3.2 Generation of Bill of Materials

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

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

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

5.5.3.3 Cost Structure of the Spreadsheet Models

The manufacturing cost assessment methodology used is a detailed, component-focused technique for rigorously calculating the manufacturing cost of a product (direct materials, direct labor and some overhead costs). Figure 5.5.1 shows the three major steps in generating the manufacturing cost.

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

Figure 5.5.1 Manufacturing Cost Assessment Stages

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

Following the development of a detailed BOM, the major manufacturing processes were identified and developed for the spreadsheet model. Some of these processes are listed in Table 5.5.1.

Table 5.5.1 Major Manufacturing Processes

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

Fabrication process cycle times for each part made in-house were estimated and entered into the BOM. Based on estimated assembly and fabrication time requirements, the labor content of each appliance could be estimated. For this analysis, $25.60 per hour was used as the average fully-burdened labor rate based on typical annual wages and benefits of industry employees.

Cycle requirements for fabrication steps were similarly aggregated by fabrication machine type while accounting for dedicated vs. non-dedicated machinery and/or change-over times (die swaps in a press, for example). Once the cost estimate for each teardown unit was finalized, a detailed summary was prepared for relevant components, subassemblies and processes. The BOM thus details all aspects of unit costs: material, labor, and overhead.

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

5.5.3.4 **Cost Model and Definitions**

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

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

Cost Definitions

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

- Direct material: Purchased parts (out-sourced) plus manufactured parts (made in-house from raw materials).
- Indirect material: Material used during manufacturing (*e.g.*, welding rods, adhesives).
- Fabrication labor: Labor associated with in-house piece manufacturing.
- Assembly labor: Labor associated with final assembly.
- Supervisory labor: Labor associated with fabrication and assembly basis. Assigned on a span basis (x number of employees per supervisor) that depends on the industry.
- Indirect labor: Labor costs that scale with fabrication and assembly labor. These included the cost of technicians, manufacturing engineering support, stocking, *etc*. that are proportional to all other labor.
- Equipment depreciation: Money allocated to pay for initial equipment installation and replacement as the production equipment is amortized. All depreciation is assigned in a linear fashion and affected equipment life depends on the type of equipment.
- Tooling depreciation: Cost for initial tooling (including non-recurring engineering and debugging of the tools) and tooling replacement as it wears out or is rendered obsolete.
- Building depreciation: Money allocated to pay for the building space and the conveyors that feed and/or make up the assembly line.
- Utilities: Electricity, gas, telephones, etc.
- Maintenance: Annual money spent on maintaining tooling and equipment.
- Insurance: Appropriated as a function of unit cost.
- Property Tax: Appropriated as a function of unit cost.

5.5.3.5 **Cost Model Assumptions**

As discussed in the previous section, assumptions about manufacturer practices and cost structure played an important role in estimating the final product cost. In converting physical information about the product into cost information, DOE reconstructed manufacturing processes

for each component using internal expertise and knowledge of the methods used by the industry. Site visits allowed DOE to confirm its cost model assumptions through direct observation of the manufacturing plant, as well as through manufacturer interviews, reviews of current Bureau of Labor Statistics data, etc.

5.5.4 Review of Previous Technical Support Documents and Models

DOE reviewed previous rulemaking TSDs to assess their applicability to the current standard setting process for residential clothes washers. These previous rulemaking TSDs served as a source for design options and energy consumption analysis, in addition to other sources.

5.5.5 Product Testing Methodology

Much of the analysis in this chapter relies on data from publicly available sources such as the CEC and ENERGY STAR databases. However, DOE also conducted its own limited performance testing according to the DOE test procedure for the following purposes:

- Verify performance trends that are apparent in the publicly available data;
- Develop a better understanding of the design options and product features currently available on the market;
- Develop a better understanding of the operational characteristics of residential clothes washers; and
- Evaluate possible active, standby, and off modes; the energy use in these modes; and the strategies manufacturers may take to reduce standby power.

As described further in section 5.6.2, DOE's testing generally confirmed the trends apparent in the publicly available data.

5.6 ANALYSIS AND RESULTS

5.6.1 AHAM Data

To support the DOE rulemaking, AHAM collected shipment and incremental manufacturing cost data from its member companies. At the time of the AHAM data collection, DOE was considering the same product classes defined in the current energy conservation standards (*i.e.*, top-loading standard, top-loading compact, top-loading semi-automatic, front-loading, and suds-saving.) For reasons of product availability and number of manufacturers, AHAM did not provide disaggregated data for top-loading compact, top-loading semi-automatic, and suds-saving clothes washers. Table 5.6.1 compiles unit shipment data for residential clothes washers from 2006–2008. AHAM began differentiating front-load and top-load shipments in 2006, so data broken down by method of loading prior to that year is unavailable. Note also that

AHAM did not specify whether the top-load category includes compact as well as standard-size units.

Table 5.6.1 AHAM Residential Clothes Washer Shipments Data Submittal

Year	Total Shipments	Front-Loading	Top-Loading
2006*	9,500,000	2,212,859	6,460,866
2007	8,825,000	2,883,828	5,941,197
2008	8,292,000	3,022,077	5,269,625

*Note: Front-load and top-load shipments do not sum to total domestic shipments in 2006 because the data baseline differs for both analyzed product types.

Table 5.6.2 reproduces AHAM's data submittal for the shipment-weighted average efficiency levels for top-loading and front-loading residential clothes washers. The data show the shipment-weighted MEF and WF for both product types. Again, AHAM did not indicate whether compact top-loading clothes washers were included in the top-load data; however, the small market share for these units would likely have a negligible effect on the weighted values.

Table 5.6.2 AHAM Residential Clothes Washer Shipment-Weighted Average Efficiency Data Submittal

	Front-Loading		Top-Loading	
Year	**Weighted MEF**	**Weighted WF**	**Weighted MEF**	**Weighted WF**
2006	1.99	5.12	1.24	11.38
2007	2.28	4.28	1.39	11.35
2008	2.26	4.23	1.44	10.88

AHAM provided market share efficiency data for top-loading (which specifically includes compact and standard-size) and front-loading residential clothes washers for 2006 to 2008, as shown in Table 5.6.3. All AHAM data are based on active mode efficiency levels. For some entries, market share data are provided combining multiple efficiency levels. In these cases, AHAM has combined the efficiency levels to maintain manufacturer confidentiality. The submitted values represent the market shares for clothes washers up to the listed efficiency levels. For example, the front-load efficiency level 3 market share for 2008 represents the front-loading clothes washers available with MEF from 2.2 to 2.4. This explains the large market share values reported at the max-tech efficiency levels.

Table 5.6.3 AHAM Residential Clothes Washer Market Share Efficiency Data Submittal

Efficiency Level MEF (Front/Top-Load)	Front-Loading (Standard)			Top-Loading (Compact and Standard)		
	2006	**2007**	**2008**	**2006**	**2007**	**2008**
Current Baseline (1.72/1.26)	10.7%	3.8%		93.7%	91.4%	87.2%
2011 Baseline (1.80/1.40)				0.0%		
Level 1 (2.00/1.72)	32.9%	8.3%	4.3%	1.1%	1.2%	3.7%
Level 2 (2.20/1.80)	51.1%	19.7%	24.0%	0.0%		
Level 3 (2.40/2.00)	5.3%	37.9%	48.9%	5.2%	7.3%	9.1%
Level 4 (2.89/2.25)		30.4%	22.8%	0.0%		

AHAM provided incremental manufacturing cost data for both top-loading standard and front-loading standard clothes washers, as shown in Table 5.6.4 and Table 5.6.5. DOE converted these to 2010 dollars to make the AHAM data consistent with the downstream analysis, which was conducted in 2010 dollars. To perform the conversion, DOE scaled the costs using the producer price index (PPI) data from the Bureau of Labor and Statistics for NAICS 335224: Household laundry equipment manufacturing.

At the time DOE requested data from AHAM, the efficiency levels of interest were specified as those in the framework document for this rulemaking, which were based on MEF. Thus, the AHAM cost data are presented at the original values of MEF to which the aggregated data correspond. However, as DOE finalized the analysis, it determined that the efficiency levels would be based on IMEF, and also identified the need for an additional gap-fill efficiency level for front-loading clothes washers. Therefore, DOE's cost estimates and subsequent analyses are presented for the updated IMEF levels.

Table 5.6.4 AHAM Top-Loading Standard Clothes Washer Incremental Cost Data Submittal

Efficiency Level	MEF *(ft^3/kWh)*	Incremental Manufacturing Cost *($2009)*	Incremental Manufacturing Cost *($2010)*[f]
Baseline	1.26	$ -	$ -
EL 1	1.40	$3.10	$3.11
EL 2	1.72	$8.40	$8.44
EL 3	1.80	$13.00	$13.06
EL 4	2.00	$24.00	$24.11
EL 5	2.26	$59.20	$59.47

Table 5.6.5 AHAM Front-Loading Standard Clothes Washer Incremental Cost Data Submittal

Efficiency Level	MEF *(ft^3/kWh)*	Incremental Manufacturing Cost *($2009)*	Incremental Manufacturing Cost *($2010)*[f]
Baseline	1.72	$ -	$ -
EL 1	1.80	$ 2.00	$2.01
EL 2	2.00	$ 5.00	$5.02
EL 3	2.20	$ 16.00	$16.07
EL 4	2.40	$ 39.00	$39.18
EL 5	2.89	$ 72.00	$72.33

Figure 5.6.1 plots the incremental costs submitted by AHAM at the listed MEF efficiency levels for both the top-loading standard and front-loading residential clothes washer product classes. The lowest point on the graph indicates the baseline level and therefore has a cost increment of $0.

[f] DOE scaled AHAM's manufacturing costs to 2010 dollars based on PPI data available at http://www.bls.gov/ppi/.

Figure 5.6.1 AHAM Residential Clothes Washer Incremental Cost Data Submittal

5.6.2 Product Testing Results

DOE tested a total of 23 clothes washer models in support of this rulemaking: eight top-loading standard units, two top-loading compact units, and 13 front-loading standard units. DOE also conducted teardowns on 23 clothes washer models: ten top-loading standard units, two top-loading compact units, and 11 front-loading standard units. DOE selected clothes washer models for testing and teardowns based on the proposed efficiency levels and the range of product efficiencies available on the market. Table 5.6.6 lists the major features of the top-loading standard clothes washers observed at each efficiency level. Table 5.6.7 and Table 5.6.8 list the major features of front-loading standard clothes washers observed at each efficiency level. As these tables indicate, manufacturers of front-loading standard clothes washers may choose different design option paths to achieve higher efficiency levels in their product lines. Table 5.6.9 lists the major features of the top-loading compact clothes washers in DOE's test sample.

Table 5.6.6 Top-Loading Standard Clothes Washer Test Unit Features

Feature	Top-Loading Clothes Washer Test Unit Efficiency Level						
	Baseline	**EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**	**EL 6**
Efficiency Level MEF *(ft^3/kWh)*	1.26	1.40	1.72	1.80	2.00	2.26	2.47
Efficiency Level WF *(gal/ ft^3)*	9.5	9.5	8.0	7.5	6.0	4.5	3.6
Rated Drum Capacity *(ft^3)*	3.2	3.5	3.5	3.9	4.0	4.1	4.5
Rated RMC *(%)*	51.9	53.6	48.8	37.9	36.6	36.6	34.8
Control Type	Electro-mechanical	Electro-mechanical	Electro-mechanical	Electronic	Electronic	Electronic	Electronic
Motor Type	PSC 1-Speed	PSC 2-Speed	PSC 2-Speed	Variable Speed PMM	Variable Speed PMM	Variable Speed PMM	Variable Speed PMM
Temperature Control	Thermal Switch	Thermistor	Thermistor	Thermistor	Thermistor	Thermistor	Thermistor
Fill Control	Electro-mechanical	Electro-mechanical	Electronic (auto)	Electronic (auto)	Electronic (auto)	Electronic (auto)	Electronic (auto)
Max RPM	640	640	640	950	1000	1000	1100
Wash Basket Material	Enameled Steel	Enameled Steel	Enameled Steel	Stainless Steel	Stainless Steel	Stainless Steel	Stainless Steel
Water Control Scheme	2-Way Solenoid	2-Way Solenoid	2-Way w/ Flowmeter	6-Way Solenoid	6-Way Solenoid	7-Way Solenoid	7-Way Solenoid
Fabric Softener Option	No	No	Yes	Yes	Yes	Yes	Yes
Spray Rinse	No	No	Yes	Yes	Yes	Yes	Yes
Agitator Type	Standard	Standard	Standard	Standard	Low-Profile	Low-Profile	Low-Profile
Internal Heater	No	No	No	No	No	Yes	No
Power Supply	Standard	Standard	Standard	Switch Mode	Switch Mode	Switch Mode	Switch Mode

Table 5.6.7 Front-Loading Standard Clothes Washer Test Unit Features

Feature	Front-Loading Clothes Washer Test Unit Efficiency Level				
	EL 1	**EL 2**	**EL 3**	**EL 3**	**EL 3**
EL MEF *(ft^3/kWh)*	1.80	2.0	2.2	2.2	2.2
EL WF *(gal/ ft^3)*	7.5	6.0	4.5	4.5	4.5
Rated Drum Capacity *(ft^3)*	3.0	3.3	3.2	3.5	3.5
Rated RMC *(%)*	41.4	41.6	40.4	34.4	39
Drive Type	Standard	Standard	Direct Drive	Standard	Standard
Temperature Sensors	0	1	1	1	2
Fill Control	Electro-mechanical	Electro-mechanical	Electro-mechanical	Electro-mechanical	Electronic
Max RPM	950	1050	1050	1100	1050
Water Control Scheme	3-Way Solenoid	2-Way Solenoid	4-Way Solenoid	2-Way Solenoid	3-Way w/ Flowmeter
Internal Heater	No	Yes	No	Yes	Yes
Recirculation	No	No	No	No	No
Power Supply	Switch Mode	Switch Mode	Transformerless	Switch Mode	Switch Mode

Table 5.6.8 Front-Loading Standard Clothes Washer Test Unit Features (continued)

Feature	Front-Loading Clothes Washer Test Unit Efficiency Level			
	EL 4	**EL 5**	**EL 5**	**EL 6**
EL MEF *(ft^3/kWh)*	2.4	2.6	2.6	2.89
EL WF *(gal/ ft^3)*	4.2	3.8	3.8	3.36
Rated Drum Capacity *(ft^3)*	3.6	3.8	3.9	3.6
Rated RMC *(%)*	38.7	36.3	36	33.1
Drive Type	Direct Drive	Standard	Direct Drive	Direct Drive
Temperature Sensors	1	2	1	1
Fill Control	Electro-mechanical	Electronic	Electro-mechanical	Electro-mechanical
Max RPM	1200	1300	1300	1200
Water Control Scheme	4-Way Solenoid	3-Way w/ Flowmeter	5-Way Solenoid	4-Way Solenoid
Internal Heater	Yes	Yes	Yes	Yes
Recirculation	No	no	Yes	No
Power Supply	Transformerless	Switch Mode	Transformerless	Transformerless

Table 5.6.9 Top-Loading Compact Clothes Washer Test Unit Features

Feature	Top-Loading Compact Clothes Washer Test Unit Efficiency Level		
	Baseline	**Baseline**	**Baseline**
Efficiency Level MEF *(ft^3/kWh)*	0.77	0.77	0.77
Efficiency Level WF *(gal/ ft^3)*	14.0	14.0	14.0
Rated Drum Capacity *(ft^3)*	1.5	1.5	1.3
Rated RMC *(%)*	58.4	N/A	N/A
Control Type	Electro-mechanical	Electro-mechanical	Electronic
Motor Type	PSC 2-Speed	PSC 1-Speed	N/A
Fill Control	Manual	Manual	Manual
Max RPM	640	400	690
Wash Basket Material	Enameled Steel	Stainless Steel	Stainless Steel
Water Control Scheme	2-Way Solenoid	2-way Solenoid	2-way Solenoid
Fabric Softener Option	No	No	No
Spray Rinse	No	N/A	N/A
Agitator Type	Standard	Low-Profile	Low-Profile
Internal Heater	No	No	No
Power Supply	Standard	Standard	Switch Mode

5.6.2.1 Active Mode Testing

Active mode clothes washer tests were first performed according to the current test procedure (appendix J1). The test procedure consists of running different load sizes of preconditioned test cloth in the clothes washer at various temperature settings. For all clothes washers, the minimum test load is 3 pounds of test cloth. Average and maximum load sizes are specified based on the clothes washer capacity. During the energy test cycles, the total kWh of electric energy consumed by the clothes washer is measured, in addition to the cold and hot water consumption. The measurements also include the "bone dry"[g] weight of the test load and the weight immediately after the completion of certain energy test cycles for the RMC calculation.

MEF is a function of capacity and per-cycle energy consumption, and WF is a function of capacity and per-cycle water consumption. DOE investigated the correlation between these variables and the efficiency metrics. These investigations helped DOE to determine the methods likely used by manufacturers to achieve higher efficiencies and the associated design options.

[g] "Bone dry" means a condition of a load of test clothes which has been dried in a dryer at maximum temperature for a minimum of 10 minutes, removed and weighed before cool down, and then dried again for 10-minute periods until the final weight change of the load is 1 percent or less.

Figure 5.6.2 shows the rated capacities and rated MEF values for the selected standard-size clothes washer test units. MEF is calculated as the capacity divided by energy use, so larger capacities should directly result in higher MEF ratings, all other variables held constant. The figure shows clear upward trends for both top-loading and front-loading clothes washers. DOE's informal tests confirmed these trends.

Figure 5.6.2 Rated MEF versus Rated Capacity

Figure 5.6.3 shows the rated per-cycle energy consumption and associated rated MEF for each test unit. Per-cycle energy consumption consists of machine electrical energy consumption and energy consumed to electrically heat the hot water used. Both top-loading and front-loading clothes washers show a downward trend between rated MEF and increasing per-cycle power consumption. DOE confirmed these trends through its testing.

Figure 5.6.3 Rated MEF versus Rated Per-Cycle Energy Consumption

The remaining component of MEF is the energy needed to remove moisture from the test load. This is calculated using the RMC of the test load, and assuming a typical clothes dryer energy consumption weighted by a clothes dryer use factor. Lower RMC values mean more water is removed during the clothes washer spin cycle, leaving less to be removed in a dryer. Figure 5.6.4 shows that clothes washers with lower RMC values generally achieve higher MEF ratings. DOE's testing verified this general trend.

Figure 5.6.4 Rated MEF versus Rated RMC

Figure 5.6.5 shows a trend of lower WFs at higher capacities for both top and front-loading clothes washers. DOE confirmed this trend through its testing.

Figure 5.6.5 Rated WF versus Rated Capacity

During the reverse-engineering analysis, DOE determined that two front-load test units employ the same design and construction but are rated at different MEFs. DOE investigated the active mode test data for these two units to determine which parameters might result in the different MEF ratings. Figure 5.6.6 shows the cumulative water consumption for both test units during an individual hot wash/cold rinse energy test cycle. Unit #2 is the test unit with a higher MEF rating. The hot water consumption for unit #2 is less than the hot water consumption for unit #1, but cold water consumption is greater. This implies that unit #2 likely has a lower wash water temperature set-point. The test data from all energy test cycles show that unit #2 has lower hot water consumption in seven of the nine test cycles that use hot water, and on a weighted per-cycle basis, unit #2 uses 33 percent less hot water than unit #1. Hot water consumption directly impacts total energy use, which is used to calculate MEF, so unit #2 may be achieving a higher MEF by using lower wash temperatures.

Figure 5.6.6 Cumulative Water Consumption versus Cycle Time

Also notable in Figure 5.6.6 is that unit #2 uses a longer wash cycle than unit #1. The two step increases in cold water consumption after 1500 seconds show the fills for cold water rinses. The flat period on the plot before the steps represents the wash cycle. For unit #2, the wash cycle lasts almost 2 minutes longer than the wash cycle in unit #1. Higher wash temperatures are generally associated with more effective cleaning, so unit #2 may compensate for a lower wash temperature by extending the length of the wash cycle.

Figure 5.6.7 shows the machine energy consumption for both test units over the same hot wash/cold rinse energy test cycle. Unit #2 consumes more electrical energy than unit #1 for the test cycle shown in the figure; on a weighted per-cycle basis, unit #2 uses about 5 percent more machine electrical energy than unit #1. Unit #2 is therefore likely achieving a higher MEF through means other than reduced machine electrical energy use.

Figure 5.6.7 Machine Cumulative Electrical Energy Consumption versus Cycle Time

The energy required to remove moisture from the test load is much lower for unit #2 than for unit #1—the result of a lower RMC value. Both units have the same construction and maximum spin speed, but the spin cycle duration for unit #2 is longer than for unit #1. The steeper sections of the plots at the end of the test cycle shown in Figure 5.6.7 represent the spin cycle. For this energy test cycle, the machine electrical energy consumption is greatest during the spin cycle, resulting in a steeper slope on the plot. Figure 5.6.7 shows that for this energy test cycle, unit #2 has a spin cycle lasting about 2 minutes longer than that of unit #1. This also likely contributes to the greater machine electrical energy consumption for unit #2.

DOE's test data show that unit #2 likely achieves a higher MEF than unit #1 by using less hot water and longer spin cycles to reach a lower RMC, despite the associated increase in machine electrical power consumption. While these changes do not have any associated design changes or incremental cost, they do impact consumer utility. The cycle times are longer for unit #2 due to longer wash and spin cycles. Additionally, consumers may not experience the same cleaning performance from these two clothes washers, due to differences in wash water temperature and overall water consumption.

To summarize key findings from the active mode testing of a sampling of residential clothes washers, DOE observed the following:

- DOE's testing generally confirmed the trends apparent in the publicly available data.
- Similar general trends are observed for top-loading and front-loading clothes washers.
- Manufacturers generally utilize a combination of improvements to multiple contributing parameters to achieve higher MEF and/or lower WF.
- Increases to MEF can be achieved with no corresponding mechanical design changes by adjusting control settings such as wash water temperature, wash cycle duration, and spin cycle duration; however, these changes may impact consumer utility.

5.6.2.2 **Standby and Off Mode Testing**

DOE measured standby and off mode power for all 15 clothes washers selected in the test sample, using the methodology provided in IEC Standard 62301 First Edition. The current version of this standard is IEC Standard 62301 Second Edition, which contains revisions affecting the definitions and measurement methodology of standby and off-mode power. However, DOE believes that the methodology of the Second Edition would produce nearly identical standby power consumption measurements. Data obtained from standby and off mode testing are presented in section 5.4.4.

5.6.3 Product Teardowns

As part of its reverse-engineering process, DOE conducted teardowns of clothes washers to identify design features and corresponding manufacturing costs that are associated with successively higher efficiency levels. The clothes washer teardown analysis performed for this analysis included 17 teardown units total from the top-loading standard, front-loading standard, and top-loading compact product classes.

DOE noted that all of the clothes washers it examined were constructed with an outer sheet metal assembly consisting of panels or an outer wrapper that had been formed by stamping. This assembly houses the cylindrical drum, drive motors, control systems, and the associated tubing and wiring. Details of these components and sub-assemblies are as follows.

5.6.3.1 **Baseline Construction: Top-Loading Standard Clothes Washer**

The baseline top-loading standard clothes washer is equipped with electromechanical controls that allow the user to select specific cycle settings. These include switches for wash temperature and load size. Temperature is controlled using a thermal cutout on the water inlet assembly, which consists of two solenoid valves. The baseline unit offers three wash temperature selections. The load size selector switch determines the fill level for a wash cycle, which is controlled by an electromechanical pressure switch. Three load size selections are available on the baseline unit.

The motor is a ½-horsepower permanent split capacitor (PSC) motor which drives the drum and the agitator. On some baseline models, this motor also drives the drain pump by reversing direction, while other manufacturers opt to include a dedicated drain pump instead. The baseline wash basket consists of an enameled steel cylinder with a circular plate attached to the bottom to form a drum. From the center of the bottom plate a smaller cylinder rises to guide the drive shaft into the impeller and to center the wash basket inside the tub. Snapped onto the top rim of the drum is a plastic balance ring, which is partially filled with a saline solution. Covering the balance ring is a plastic cover, often referred to as the tub cover, which typically includes a housing for bleach dispensing.

The outer wrapper of the baseline unit consists of stamped metal panels which may be made of pre-painted steel or coated post-fabrication with powder-coat paint. The top panel houses the lid, which is a smaller stamped piece of sheet metal on hinges. One of these hinges triggers a limit switch that cuts power to the motor when the lid is opened. The top panel and lid may be enameled on higher-end units.

Based upon product teardowns, DOE developed the following baseline production and materials cost distributions for a top-loading clothes washer. Table 5.6.10 and Figure 5.6.8 show the baseline production cost distributions; and Table 5.6.11 and Figure 5.6.9 show the baseline materials cost distribution. Depending on the manufacturer and the production volume, the depreciation costs may vary from those shown in the figures, which assume a “green-field” site.

Table 5.6.10 Baseline Top-Load Standard Clothes Washer Production Cost Distribution

Cost Category	Total Cost *($2010)*
Raw Materials	$98.92
Purchased Parts	$90.21
Assy Labor Cost	$9.88
Fab Labor Cost	$5.71
Indirect Labor Cost	$5.40
Supervision Cost	$0.81
Tooling Dep. Cost	$16.28
Indirect Process Costs	$2.77
Equipment Dep. Cost	$2.27
Building Dep. Cost	$1.50
Maintenance	$5.05
Utility Cost	$4.00
Property Tax	$2.87
Insurance	$1.97
Total	**$ 247.66**

Figure 5.6.8 Baseline Top-Load Standard Clothes Washer Production Cost Distribution

Table 5.6.11 Baseline Top-Load Standard Clothes Washer Materials Cost Distribution

Sub-Assembly	Total Materials Cost *($2010)*
Motor/Pump/Capacitor	$37.61
Controls	$31.85
Outer Wrapper	$24.32
Gearbox/Transmission	$26.53
Tub/Drum	$25.31
Suspension	$17.62
Packaging	$7.84
Wire Harness	$7.05
Water Temp Management	$2.83
Final Assy	$4.00
Door	$4.17
Total	**$ 189.13**

Figure 5.6.9 Baseline Top-Load Standard Clothes Washer Materials Cost Distribution

5.6.3.2 **Baseline Construction: Front-Loading Standard Clothes Washer**

DOE is unaware of any front-loading residential clothes washers currently available on the market that are at or above the baseline efficiency level but do not meet EL 1. For this reason, DOE established the baseline construction for a front-loading clothes washer at EL 1.

The baseline front-loading clothes washer is equipped with basic electronic controls that allow the user to select specific cycle settings. These include switches to select a wash cycle and wash temperature. Light-emitting diodes (LEDs) confirm the user selections, but there is no numerical display. Four wash temperatures can be selected, and the temperature is controlled using two water inlet solenoid valves combined with a third solenoid to control the flow of the mixed water. From the inlet solenoid assembly, the water flows through a detergent dispenser tray before entering the wash basket. There are no temperature sensors in the baseline unit, and the water fill level for a wash cycle is automatically controlled using an electromechanical pressure switch.

The internal tub/drum assembly of the baseline front-loading clothes washer is supported by four suspension legs attached to a plastic base plate. Two springs attached to the upper sides of the outer wrapper also support the tub/drum assembly from above. The tub/drum assembly consists of an internal rotating basket and a plastic wash tub. The basket is made of a stainless steel cylinder with an attached front ring and back plate. Attached to the back plate is a cast aluminum connector piece that secures the drive shaft. Molded into the back half of the tub is a cast iron hub that houses two bearings, which guide the drive shaft. A variable speed motor powers the drive shaft using a drive belt and drive wheel. The motor is attached to the plastic base plate. Also attached to the base plate is a drain pump.

The outer wrapper of the baseline unit consists of individual side, back, and top panels made of pre-painted stamped cold-rolled steel (PCRS) that are clinched together. The front panel, which is a smaller stamped piece of PCRS, houses the door assembly. A large piece of tempered glass with a plastic frame and handle make up the door assembly, which is attached to the front panel by a hinge. A door latch inside the front panel locks the door shut during the wash cycle. Attached to the front of the internal wash tub is a door seal gasket. This is a flexible ring that extends forward from the wash tub to create a water-tight seal when the door is shut.

Based on product teardowns, DOE production and materials cost distributions for the baseline front-loading clothes washer. Table 5.6.12 and Figure 5.6.10 show the total cost distribution, and Table 5.6.13 and Figure 5.6.11 show the materials cost distribution. Depending on the manufacturer and the production volume, the depreciation costs may vary from those shown in the figures, which assume a green-field site.

Table 5.6.12 Baseline Front-Load Clothes Washer Production Cost Distribution

Cost Category	Total Cost *($2010)*
Purchased Parts	$234.83
Raw Materials	$155.79
Assy Labor Cost	$27.73
Indirect Labor Cost	$14.42
Fab Labor Cost	$13.81
Supervision Cost	$2.16
Tooling Dep. Cost	$29.96
Indirect Process Costs	$10.40
Equipment Dep. Cost	$5.83
Building Dep. Cost	$1.85
Utility Costs	$8.42
Property Tax	$4.58
Maintenance Costs	$4.23
Insurance Costs	$4.11
Total	**$515.75**

Figure 5.6.10 Baseline Front-Load Standard Clothes Washer Production Cost Distribution

Table 5.6.13 Baseline Front-Load Clothes Washer Materials Cost Distribution

Sub-Assembly	Total Materials Cost *($2010)*
Tub/Drum	$107.49
Controls	$106.12
Motor/Pump/Capacitor	$58.94
Outer Wrapper	$46.85
Door	$16.88
Packaging	$14.91
Water Temp Management	$14.17
Wire Harness	$14.07
Final Assy	$6.39
Suspension	$4.80
Total	**$390.62**

Figure 5.6.11 Baseline Top-Load Standard Clothes Washer Materials Cost Distribution

5.6.3.3 Baseline Construction: Top-Loading Compact Clothes Washer

The baseline top-loading compact clothes washer is equipped with electromechanical controls that allow the user to select specific cycle settings. These include switches for wash temperature and load size. Temperature is controlled using a thermal cutout on the water inlet assembly, which consists of two solenoid valves. The baseline unit offers four wash temperature selections. The load size selector switch determines the fill level for a wash cycle, which is controlled by an electromechanical pressure switch. Three load size selections are available on the baseline unit.

The motor is a ½-horsepower permanent split capacitor (PSC) two-speed motor which drives the drum and the agitator. The baseline wash basket consists of an enameled steel cylinder with a circular plate attached to the bottom to form a drum. From the center of the bottom plate a smaller cylinder rises to guide the drive shaft into the impeller and to center the wash basket inside the tub. Snapped onto the top rim of the drum is a plastic cover, often referred to as the tub cover.

The outer wrapper of the baseline unit consists of stamped metal panels which may be made of pre-painted steel or coated post-fabrication with powder-coat paint. The top panel houses the lid, which is a smaller stamped piece of sheet metal on hinges. One of these hinges triggers a limit switch that cuts power to the motor when the lid is opened.

Due to the limited number of manufacturers of top-loading compact clothes washers, and the need to maintain manufacturer confidentiality, DOE is unable to show the baseline production and materials cost distributions for a baseline top-loading compact clothes washer. DOE observed, however, that the total cost of production for a compact top-loading clothes washer roughly equals the total cost of production for a standard-size top-loading clothes washer. Any reductions in materials cost due to the smaller size are mostly offset by higher costs for specialized parts, which are produced in much lower quantities for the compact product class.

5.6.3.4 Baseline Construction: Front-Loading Compact Clothes Washer

As described previously, currently no front-loading compact clothes washers exist in the United States market. Therefore, DOE was unable to perform a teardown analysis. Based on the observation for the top-loading compact class, DOE estimates that the baseline production cost for a compact front-loading clothes washer would roughly equal the total cost of production for a standard-size front-loading clothes washer.

5.6.3.5 Construction at Higher Efficiency Levels

Based on the design options retained from the screening analysis (see chapter 4 of this TSD), the reverse-engineering analyses, and discussions with manufacturers, summarized in

section 5.6.5, DOE developed manufacturing costs associated with various design features necessary to achieve higher efficiencies.

The following are the design changes DOE believes would be necessary to meet each active mode efficiency level, which were subsequently modeled to obtain incremental manufacturing cost estimates. Note that the efficiency levels listed here must be adjusted to obtain the integrated efficiency levels, which factor in standby power and other changes to the test procedure.

Top-Loading Standard Clothes Washers

MEF Efficiency Level 1

Based on characteristics of units selected for teardown and based on discussions with manufacturers, DOE research suggests that EL 1 is typically achieved in top-loading clothes washers through four changes:

1. Improved Temperature Control

Through its observations and discussions with manufacturers, DOE believes that in moving from the baseline level to EL 1, manufacturers would likely replace a thermal cutout with a thermistor in the inlet water solenoid assembly. A thermistor would allow for multiple temperature set-points, which could result in improved water temperature control. Eliminating excess hot water use would improve MEF.

2. Improved Fill Level Control

Improved fill level control reduces wash water consumption. Baseline and EL 1 clothes washers would both likely use an electromechanical pressure sensor to control the fill level. However, DOE expects manufacturers to use a pressure sensor at EL 1 with multiple fill level set-points. Multiple fill level options can reduce water consumption, if used properly.

3. Increased Capacity

Capacity is used directly in the calculations for MEF and WF, and an increase in capacity results in an improvement in both metrics. At EL 1, manufacturers would likely increase capacity from a baseline 3.2 ft^3 to around 3.5 ft^3.

4. Two-Speed Motor

DOE believes that manufacturers would likely switch from a single-speed motor at the baseline efficiency level to a two-speed motor at EL 1. The motors both have the same maximum speed, but the two-speed motor would allow for more flexibility throughout the cycle. Manufacturers may choose to use the lower spin speed during the wash cycle, consuming less electrical energy, but likely requiring longer spin duration.

MEF Efficiency Level 2

Through research and discussions with manufacturers, DOE believes that the EL 2 clothes washer would still use a two-speed motor, and would likely have the same capacity as an

EL 1 clothes washer. To reach EL 2, manufacturers would likely improve on the other design options used for EL 1, and would incorporate certain additional features:

1. Improved Temperature Control

To achieve EL 1, the temperature control scheme likely features a thermistor and four wash temperature set-points. A thermistor would also likely be used to reach EL 2, but with five temperature set-points instead of four. More temperature set-points would help to reduce excess hot water, improving efficiency.

2. Improved Fill Level Control

DOE believes manufacturers would likely offer automatic fill controls at EL 2. This includes switching to an electronic pressure transducer with embedded control logic, and adding a flowmeter. The electronic pressure sensor and control logic would allow the clothes washer to determine the load size based on the measured volume of water introduced to the clothes container and the transient water pressure measured at the bottom of the tub, which is affected by the load size. These controls would reduce excess water consumption by filling the wash basket with the minimum volume of water needed to soak the load. All other control components on an EL 2 clothes washer would likely remain electromechanical, as expected for the baseline and EL 1 efficiency level clothes washers.

3. Fabric Softener Option

The EL 2 clothes washer would likely feature a fabric softener option. Fabric softener requires a certain volume of water to dilute it and ensure it will not damage clothing. Without a fabric softener option, manufacturers must design the wash cycles to include this extra amount of water to maintain fabric quality. The fabric softener option allows the clothes washer to consume the added amount of water only when the consumer selects that option. Since the energy test cycle would not be tested with the fabric softener option activated, lower water usage would be achieved for the purposes of measuring MEF and WF.

4. Spray Rinse

Manufacturers would likely employ a spray rinse at EL 2. Spray rinse significantly decreases the volume of water used during the rinse cycle. The clothes washers at the baseline level and EL 1 typically use a deep rinse, during which the tub is filled with water to a level in which the clothes are submerged, agitated, and then drained to remove soap suds. A spray rinse uses high-pressure jets of water to rinse the load while the basket is spinning, without requiring the clothes to be immersed.

MEF Efficiency Level 3

DOE research suggests that manufacturers would likely significantly change the design of a top-loading standard-size clothes washer to reach EL 3. A clothes washer at EL 3 is likely to employ some of the same features as one at EL 2, such as load sensing, spray rinse, and a fabric softener option. The significant design changes are:

1. Electronic Controls

Manufacturers would likely use all electronic controls in an EL 3 clothes washer. This includes a control board for the user interface, with a numerical display, and a main control board.

2. Direct Drive Motor

A direct drive motor would likely replace the standard two-speed PSC motor to reach EL 3. A direct drive motor does not require a transmission or a drive system to power the drive shaft. The drive shaft is directly attached to the rotor, which allows the motor to fit below the wash tub. This design change is accompanied by a significant structural change: the tub and basket assembly is now always supported from the top of the outer wrapper assembly by four suspension rods, rather than from the bottom as in some lower efficiency washers. This motor implementation also requires a separate drain pump.

3. Improved Fill Level Control

Manufacturers would likely improve the automatic fill control at EL3. One implementation that DOE has observed used a floating wash basket design which allows the washer to detect when the clothes inside it have been saturated with water. The control scheme would be programmed to stop the inlet water flow after the basket begins to float.

4. Improved Water Flow Control

At EL 3, manufacturers would likely use a combination of electronically controlled thermistors and solenoid valves to achieve more precise water flow control. The thermistors sense the internal water temperatures, and the control system actively adjusts the solenoid valves to maintain the desired internal wash temperature.

5. Stainless Steel Wash Basket

Manufacturers would likely switch construction of the wash basket from enameled cold rolled steel to stainless steel at EL 3. According to interviews with manufacturers, stainless steel wash baskets are able to tolerate higher spin speeds, which yield lower RMC values. From baseline to EL 2, spin speeds would likely be around 640 RPM. Switching to a stainless steel wash basket, in addition to an improved motor and a lid-locking assembly, would allow clothes washers to reach spin speeds of up to 1100 RPM.

6. Increased Capacity

The direct-drive motor mentioned above eliminates the need for a gearbox, clutch, counterweight, and other accessories underneath the tub. Due to its low profile, it gives manufacturers the option to make the tubs and wash baskets deeper and hence more voluminous. At EL 3, manufacturers would likely increase capacity from 3.5 ft^3 to around 3.8 ft^3.

7. Water Recirculation

DOE believes that manufacturers would likely use a recirculation pump at EL 3 to decrease water consumption. Recirculation pumps take water from the bottom of the wash tub back to the top to help ensure effective washing throughout the wash basket.

MEF Efficiency Level 4

Based on torn-down units and discussions with manufacturers, DOE believes that to reach EL 4, manufacturers would likely employ similar features as those seen at EL 3. The EL 4 structural design is also likely largely the same design used at EL 3. DOE expects only two major design changes moving from EL 3 to EL 4:

1. Low-Profile Agitator Design

DOE believes manufacturers would likely move to a low-profile agitator design at EL 4. The low-profile agitator design consists of a rotating flat plate at the bottom of the wash basket, compared to the standard agitator, which is a finned cylinder that rises axially into the wash basket. The low-profile agitator results in more volume for clothes inside the wash basket, and therefore leads to a higher capacity rating which improves MEF and WF.

2. Multiple Spin Speeds

DOE expects manufacturers to offer multiple spin speed selections on top-loading clothes washers at EL 4. For EL 3, spin speed is determined only by wash cycle selection. The clothes washer at EL 4 would likely still default to a spin speed based on wash cycle selection, but would allow the user to change the setting.

MEF Efficiency Level 5

DOE believes that the design features used at EL 4 would also apply to EL 5. Manufacturers would likely make one additional change to the EL 4 design:

1. Increased Capacity

DOE believes that clothes washers at EL 5 would likely have a slightly larger capacity than those at EL 4. Manufacturers would likely produce top-loading clothes washers with capacities greater than 4 ft^3 to meet EL 5.

MEF Efficiency Level 6

Manufacturers would likely make two changes to the EL 5 design:

1. Increased Capacity

DOE believes that clothes washers at EL 6 would likely have a slightly larger capacity than those at EL 5. Manufacturers would likely produce top-loading clothes washers with capacities as high as 4.5 ft^3 to meet EL 6.

2. Increased Spin Speed

DOE believes that clothes washers at EL 6 would likely have slightly higher spin speeds than those at EL 5, resulting in lower RMC values.

Front-Loading Standard Clothes Washers

For front-loading clothes washers, DOE observed that manufacturers employ unique designs and different technology options to reach higher efficiencies. No single manufacturer

produces units at all efficiency levels, so it is difficult to associate incremental design changes to specific active mode efficiency levels. The following sections describe the general technology options DOE observed at each efficiency level. DOE does not expect that a manufacturer would use all technology options listed to reach a certain efficiency level, but would choose some combination of the observed features.

MEF Efficiency Level 1

As described previously in this section, DOE is unaware of any front-loading clothes washers available on the market that meet or exceed the baseline efficiency, but do not meet EL 1. Therefore, the EL 1 unit has the same construction and design features as the previously described baseline front-loading clothes washer.

MEF Efficiency Level 2

Through teardowns and discussion with manufacturers, DOE believes that manufacturers would likely rely on some or all of the following design options to reach EL 2:

1. Increased Capacity

Manufacturers would likely use a slight increase in capacity to raise efficiency from EL 1 to EL 2. DOE observed roughly a 10-percent increase in capacity. The increase in capacity also requires a larger frame and outer wrapper.

2. Internal Water Heating

A front-loading clothes washer at EL 1 would most likely not include an internal heater. At EL 2, manufacturers would likely add a rod heater to the bottom of the tub assembly. DOE expects internal water heating to be more efficient than external water heating for achieving the extra-hot temperature settings offered on many front-loading models at EL 2.

3. Improved Temperature Control

DOE believes that manufacturers would likely add a thermistor to the EL 2 front-loading clothes washer to improve temperature control. The EL 1 unit uses only two solenoid valves to control the flow of hot and cold water to regulate temperature. A thermistor provides feedback to adjust the solenoid valves as needed, and to control operation of the internal water heater.

4. Increased Maximum Spin Speed

Manufacturers would likely increase the maximum spin speed for a front-loading clothes washer at EL 2. DOE believes the spin speed would be increased by roughly 100 RPM at EL 2. This results in a lower RMC and higher MEF. To achieve higher spin speeds, the clothes washer at EL 2 also requires an improved motor.

MEF Efficiency Level 3

DOE observed through teardowns and learned from discussions with manufacturers that the following design options would likely be used to move from EL 2 to EL 3:

1. Increased Capacity

DOE believes that manufacturers would likely increase capacity somewhat further to raise efficiency from EL 2 to EL 3.

2. Improved Fill Level Control

As seen for top-loading clothes washers, one method used to improve water flow control is to incorporate an electronic pressure sensor and a flowmeter. All of the front-loading clothes washers DOE analyzed incorporate automatic fill control, but not all use electronic pressure sensors. DOE believes that some manufacturers would employ an electronic pressure sensor and a flowmeter at EL 3 to improve water fill level control.

3. Improved Control Scheme

DOE believes that some manufacturers would likely adjust control parameters to improve efficiency at EL 3. Through its active mode testing, DOE observed that longer spin cycles and lower wash temperature set-points correspond to lower RMC values and less hot water consumption, respectively. Neither of these changes is associated with any physical design change to the clothes washer, but they may impact consumer utility, as described in section 5.6.2.

4. Direct Drive Motor

Certain manufacturers would likely use a direct drive motor on their front-loading clothes washers at EL 3. This would replace the standard variable-speed motor, drive belt, and drive wheel used on the clothes washers at lower efficiency levels.

5. Improved Internal Water Heating

DOE observed that some manufacturers use multiple heating rods at EL3. DOE believes that using multiple heating rods may enable more precise hot water temperature control.

MEF Efficiency Level 4

To increase efficiency from EL 3 to EL 4, manufacturers would likely use three design options, which are an extension of the options used to reach the previous efficiency levels:

1. Increased Capacity

Manufacturers would likely incorporate another slight increase in capacity to improve MEF and WF from EL 3 to EL 4.

2. Improved Control Scheme

DOE believes that some manufacturers would rely on longer spin cycles and lower wash temperature set-points to reach EL 4.

3. Increased Maximum Spin Speed

Manufacturers would likely increase the maximum spin speed for a front-loading clothes washer at EL 4. DOE believes the spin speed would be roughly 100 RPM higher than the spin speed at EL 2 and EL 3. To achieve higher spin speeds, the EL 4 clothes washer requires an improved motor.

MEF Efficiency Level 5

DOE believes manufacturers would likely use three design options to increase efficiency from EL 4 to EL 5:

1. Increased Capacity

DOE observed front-loading clothes washer capacities at EL 5 approaching 4 ft^3 as compared to 3 ft^3 at the baseline. For the units DOE tore down at this efficiency level, the capacity increase does not require a different frame or outer wrapper assembly, which limits the associated incremental cost. However, other manufacturers may require a larger frame and outer wrapper to reach such large capacities.

2. Increased Maximum Spin Speed

DOE expects that manufacturers would likely increase the maximum published spin speed to around 1300 RPM at EL 5. During its active mode testing, DOE observed that the EL 5 test units use a shorter spin cycle than the lower efficiency units from the same manufacturers. Despite the shorter spin cycle, the EL 5 units have lower RMC ratings, likely because of the increased spin speeds.

3. Water Recirculation

DOE believes that certain manufacturers would likely use a recirculation pump at EL 5 to decrease water consumption.

MEF Efficiency Level 6

DOE believes that manufacturers would likely use two design options to increase efficiency from EL 5 to EL 6:

1. Increased Capacity

DOE believes capacities at EL 6 would exceed 4 ft^3.

2. Longer Spin Cycle

DOE expects that EL 6 units would also have a maximum spin speed of 1300 RPM and up. The EL 6 unit would likely have longer spin cycle duration than the EL 5 unit. During its active mode testing, DOE observed that the EL 6 test units have lower RMC values than EL 5 units.

Through its teardown analysis and active mode testing, DOE believes that manufacturers may alternatively achieve EL 6 from EL 4 or EL 5 via an improved control scheme alone. The EL 6 unit likely could employ the same design features as an EL 4 or EL 5 unit, but would use a longer spin cycle duration, and a lower wash temperature set-point. DOE observed the longest spin cycles and lowest wash water temperatures in the EL 6 unit in its test sample, and noted that these were the only functional changes from lower efficiency levels. However, DOE believes that manufacturers may choose to use a combination of increased capacity and higher spin speeds, as seen at EL 5, in conjunction with less dramatic changes to the control scheme, to reach EL 6. From information gained through discussions with manufacturers, DOE believes that

certain manufacturers would resist changing the control scheme so drastically because of the potential effects on wash performance and consumer utility.

Consumer utility at the higher efficiency levels may also be affected by overall cycle time. DOE investigated the relationship between cycle time and efficiency level, using data collected during its testing, supplemented with additional cycle times published by manufacturers in product literature. Figure 5.6.12 and Figure 5.6.13 present the average times for the normal cycle for both top-loading and front-loading clothes washers. The data are shown in terms of MEF and WF in order to provide a consistent basis of comparison between published information and DOE's results. It can be observed generally that front-loading clothes washers require longer cycle times than top-loading models, and that the top-loading cycle times are relatively constant regardless of the efficiency level. For front-loading clothes washers, however, it can be seen that cycle time increases at the highest efficiency levels, particularly as water consumption is reduced, as indicated by WFs of 4 gal/ft^3 or below (*i.e.*, front-loading MEF Efficiency Level 5 or higher).

Figure 5.6.12 Cycle Time as a Function of MEF

Figure 5.6.13 Cycle Time as a Function of WF

Top-Loading Compact Clothes Washers

MEF Efficiency Level 1

Based on energy and water consumption modeling using the design option approach and discussions with manufacturers, DOE believes that EL 1 could be achieved with the following changes:

1. Spray Rinse

Manufacturers would likely employ a spray rinse at EL 1. Spray rinse significantly decreases the volume of water used during the rinse cycle. The clothes washers at the baseline level use a deep rinse, during which the tub is filled with water to a level in which the clothes are submerged, agitated, and then drained to remove soap suds. A spray rinse uses high-pressure jets of water to rinse the load while the basket is spinning, without requiring the clothes to be immersed in water.

2. Increased Capacity

Unlike the top-loading standard product class, manufacturers have limited opportunity to increase capacity on top-loading compact units because they are limited, by definition, to an upper bound of 1.6 cubic feet. However, DOE believes that minor changes to the tub geometry could be made to increase capacity to 1.59 cubic feet.

3. Eliminate Warm Rinse

DOE believes that manufacturers are likely to eliminate the warm rinse feature at EL 1 in order to achieve the required MEF.

4. Reduced Water Temperatures

DOE believes that manufacturers would likely reduce the hot and warm wash temperatures at EL 1. DOE observed that in general, the baseline compact top-loading clothes washer uses hot and warm wash temperatures much higher than the baseline standard-size top-loading clothes washer. DOE believes that manufacturers could reduce the hot and warm wash temperatures to the same temperatures used by standard-size clothes washers without negatively affecting wash performance or consumer utility.

MEF Efficiency Level 2

Based on energy and water consumption modeling using the design option approach and discussions with manufacturers, DOE believes that EL 2 could be achieved with the following changes:

1. Electronic Controls

Manufacturers would likely use all electronic controls in an EL 2 clothes washer. This includes a control board for the user interface, with a numerical display, and a main control board. Electronic controls would likely be required as a prerequisite for the additional design options used at this efficiency level.

2. Improved Fill Level Control

DOE believes manufacturers would likely offer automatic fill controls at EL 2. This includes switching to an electronic pressure transducer with embedded control logic, and adding a flowmeter. The electronic pressure sensor and control logic would allow the clothes washer to determine the load size based on the measured volume of water introduced to the clothes container and the transient water pressure measured at the bottom of the tub, which is affected by the load size. These controls would reduce excess water consumption by filling the wash basket with the minimum volume of water needed to soak the load.

3. Improved Temperature Control

To achieve EL 2, the temperature control scheme likely features a thermistor and four or five wash temperature set-points. More temperature set-points would help to reduce excess hot water, improving efficiency.

4. More Efficient Motor

A more efficient motor would likely replace the standard two-speed PSC motor. A motor that is roughly three times more efficient than the motor used in the baseline model would likely be required to achieve the required MEF at EL 2. The motor would also be required to support significantly higher spin speeds.

5. Stainless Steel Wash Basket

Manufacturers would likely switch construction of the wash basket from enameled cold rolled steel to stainless steel at EL 2. According to interviews with manufacturers, stainless steel wash baskets are able to tolerate higher spin speeds, which yield lower RMC values. Switching

to a stainless steel wash basket, in addition to an improved motor and a lid-locking assembly, would allow clothes washers to reach spin speeds of up to 1000 RPM.

6. Water Recirculation

DOE believes that manufacturers would likely use a recirculation pump at EL 2 to decrease water consumption. Recirculation pumps take water from the bottom of the wash tub back to the top to help ensure effective washing throughout the wash basket.

Front-Loading Compact Clothes Washers

MEF Efficiency Level 1

Based on energy and water consumption modeling using the design option approach, DOE believes that EL 1 could be achieved with the following changes:

1. Improved Fill Level Control

As seen for front-loading standard clothes washers, one method used to improve water flow control is to incorporate an electronic pressure sensor. DOE believes that an electronic pressure sensor would be used to improve water fill level control at EL 1.

2. Low Standby Power Control Board

To achieve additional low-cost improvement in efficiency, manufacturers would likely use a switch mode power or transformerless power supply on the control board. These design options are described in more detail in the following section.

5.6.3.6 Standby Mode Construction

As part of the reverse-engineering analysis, DOE investigated the design options and incremental manufacturing costs for decreasing standby power consumption. DOE developed the following design pathways for the standby levels identified in section 5.4.4.

DOE's analysis suggests that SL 1 can be achieved by implementing a switch-mode power supply in place of a conventional linear regulated control board power supply. DOE observed a number of clothes washers that incorporated switch-mode power supplies. DOE's analysis also suggests that SL 2 can be achieved by implementing a transformerless power supply along with a conventional power supply. Such a power supply design, incorporated with a "soft" power pushbutton and electromechanical relay, would provide just enough power through the transformerless power supply to maintain the microcontroller chip while the clothes washer is not powered on. When the power button is pressed, the control logic enables a Triode for Alternating Current (Triac) to enable power to the transformer of the linear power supply. Hence, the Triac isolates the linear power supply from the mains until it is needed to power relays, the user interface, etc. Through this means, the standby power issues typically associated with linear power supplies can be nearly eliminated.

5.6.4 Cost-Efficiency Curves

5.6.4.1 Active Mode Incremental Costs

Based upon product teardowns and cost modeling, DOE developed the following active mode cost-efficiency relationships for top-loading standard and front-loading residential clothes washers. DOE used these curves to supplement and validate the incremental cost information provided by AHAM, as discussed in section 5.6.1. The corresponding cost-efficiency curves are shown as follows.

Top-Loading Standard

For top-loading standard clothes washers, DOE developed incremental manufacturing costs by tearing down units, and creating a cost model at each efficiency level. DOE started with the baseline unit cost model, and at each higher efficiency level, added in the observed changes associated with improving efficiency. By doing this, DOE excluded the costs of any non-efficiency related components from the more efficient units. The more efficient units are generally sold at a higher price point, and sometimes include more complex displays or other user interface features that are not necessarily efficiency-related. Table 5.6.14 and Figure 5.6.14 show the incremental manufacturing costs from DOE's reverse-engineering analysis and from the AHAM data submittal. These costs do not include costs related to reducing standby power consumption, which are discussed in the next section. The AHAM data submittal for top-loading clothes washers did not include EL 6 because EL 5 was the max-tech level on the market at the time the data was submitted.

Table 5.6.14 Top-Loading Standard Clothes Washer Incremental Manufacturing Costs Based on MEF

Efficiency Level (MEF, ft^3/kWh)	Incremental Costs *($2010)*	
	AHAM	DOE
Baseline (1.26)	-	-
EL 1 (1.40)	$3.10	$4.43
EL 2 (1.72)	$8.40	$23.79
EL 3 (1.80)	$13.00	$71.67
EL 4 (2.00)	$24.00	$66.23
EL 5 (2.26)	$59.20	$80.05
EL 6 (2.47)	N/A	$68.30

Figure 5.6.14 Top-Loading Standard Clothes Washer Cost-Efficiency Curves Based on MEF

Table 5.6.14 and Figure 5.6.14 clearly show that the DOE incremental costs are generally higher than the AHAM-submitted costs. DOE is confident in its estimates of the incremental costs for the units it torn down. However, DOE is aware that these values are only representative

of the small number of units torn down, and do not necessarily characterize the entire top-loading residential clothes washer market nor the expected typical costs at the time of the effective date of new standards. The AHAM data is aggregated from multiple manufacturers, and DOE believes this provides a better representation of the actual incremental costs manufacturers would experience. Because the AHAM incremental costs are generally lower than the DOE-developed costs, DOE believes manufacturers may be aware of additional methods to increase efficiency at a lower cost than the technology options observed in the reverse engineering analysis. For these reasons, DOE chose to use the AHAM-submitted incremental costs, adjusted to be expressed in terms of IMEF, as the basis for the subsequent top-loading analyses described in the later chapters of this TSD. Because the AHAM data submittal did not include an incremental cost figure for EL 6, DOE used the incremental cost derived from its teardown of the max-tech unit for the EL 6 data point.

Front-Loading Standard

For front-loading clothes washers, DOE tore down units at all efficiency levels, except for the baseline because DOE is unaware of any front-loading clothes washers available at that level.

DOE observed that manufacturers each have unique baseline units depending on their segment of the market. For example, manufacturers producing models only at higher efficiency levels will tend to have a higher efficiency baseline unit; an incremental cost compared to the overall baseline unit is therefore not representative of the actual incremental costs that such a manufacturer would expect. To account for this, DOE developed incremental cost curves for each manufacturer according to their respective baseline units. For a manufacturer only producing front-loading clothes washers at higher efficiency levels, the incremental costs associated with the efficiency levels below that manufacturer's baseline is assumed to be zero. A single cost-efficiency curve was then calculated from a market share-weighted average of the individual curves. The DOE incremental costs shown in Table 5.6.15 and Figure 5.6.15 show the market share-weighted average of the incremental cost curves.

Table 5.6.15 Front-Loading Clothes Washer Incremental Manufacturing Costs Based on MEF

Efficiency Level (MEF, ft^3/kWh)	Incremental Costs *($2010)*	
	AHAM	DOE
Baseline (1.72)	-	-
EL 1 (1.80)	$2.01	$0.00
EL 2 (2.00)	$5.02	$3.88
EL 3 (2.20)	$16.07	$23.53
EL 4 (2.40)	$39.18	$35.48
EL 5 (2.60)	N/A*	$51.44
EL 6 (2.89)	$72.33	$63.73 (MEF = 2.82**)

Figure 5.6.15 Front-Loading Standard Clothes Washer Cost-Efficiency Curves Based on MEF

*The AHAM data submittal did not include an incremental cost for EL 5 because DOE did not propose an efficiency level at 2.6 MEF in the August 2009 Framework Document.
**At the time DOE conducted its teardowns, the highest-efficiency clothes washer that was commercially available for purchase had MEF=2.82.

Table 5.6.15 and Figure 5.6.15 show that the DOE incremental cost estimates closely match the AHAM-submitted values. Therefore, DOE believes the AHAM data points provide an accurate representation of the incremental costs manufacturers would likely incur to reach the different efficiency levels. For these reasons, DOE based its front-loading analyses described in the later chapters of this TSD on the AHAM-submitted incremental costs, adjusted to be expressed as IMEF.

Top-Loading Compact

For top-loading compact clothes washers, DOE used a design option approach to model the cost of the design options that would likely be required to achieve each higher efficiency level. DOE started with the baseline unit cost model, which it developed during the teardown analysis, and added in estimates of the likely changes associated with improving efficiency. Table 5.6.16 and Figure 5.6.16 show the incremental manufacturing costs from DOE's design option analysis.

Table 5.6.16 Top-Loading Compact Clothes Washer Incremental Manufacturing Costs Based on MEF

Efficiency Level (MEF, ft^3/kWh)	Incremental Costs *($2010)*
	DOE
Baseline (0.77)	-
EL 1 (1.26)	$5
EL 2 (1.81)	$45

Figure 5.6.16 Top-Loading Compact Clothes Washer Cost-Efficiency Curves Based on MEF

Front-Loading Compact

For front-loading compact clothes washers, DOE used a design option approach to model the cost of the design options that would likely be required to achieve the higher efficiency level. DOE started with a baseline cost equivalent to the baseline cost for the front-loading standard product class and added in estimates of the likely changes associated with improving efficiency. Table 5.6.17 and Figure 5.6.17 show the incremental manufacturing costs from DOE's design option analysis.

Table 5.6.17 Front-Loading Compact Clothes Washer Incremental Manufacturing Costs Based on MEF

Efficiency Level (MEF, ft^3/kWh)	Incremental Costs *($2010)*
	DOE
Baseline (1.60)	-
EL 1 (1.72)	$3

Figure 5.6.17 Front-Loading Compact Clothes Washer Cost-Efficiency Curves Based on MEF

5.6.4.2 Standby Mode Incremental Costs

Based upon the product teardowns and cost modeling, DOE developed the incremental costs associated with decreasing standby power consumption, shown in Table 5.6.18. DOE did not receive data from AHAM regarding the incremental costs associated with the different standby power levels. These incremental costs are atypical because the highest efficiency level (SL2) is less expensive than SL1. This occurs because the switch-mode power supply used in SL1 is more expensive than the additional transformerless drop-cap power supply added to the traditional linear power supply in SL2.

Table 5.6.18 Standby Power Incremental Manufacturing Cost

Standby Power Level *(W)*	**Description**	**Incremental Cost** *($2009)*	**Incremental Cost** *($2010)*
Baseline (2.3)	Traditional linear power supply	$0	$0
SL 1 (1.7)	Switch-mode power supply	$3.90	$3.92
SL 2 (0.08)	Traditional linear power supply with additional transformerless drop-cap power supply and microcontroller	$1.17	$1.17

5.6.4.3 IMEF Incremental Costs

DOE subsequently developed cost-efficiency relationships based on IMEF. As noted in section 5.4.5, DOE developed conversion formulas to translate MEF efficiency levels into IMEF efficiency levels, taking into consideration all the significant amendments in the test procedure. The IMEF cost-efficiency curves also incorporate standby power options into the MEF efficiency levels where DOE determined them to be most cost effective. Table 5.6.19 and Figure 5.6.18 present DOE's estimates of the incremental manufacturing cost associated with improving IMEF above the baseline for top-loading standard-size clothes washers. These curves are derived from the AHAM data submittal and incorporate the additional costs in Table 5.6.18 associated with standby power reduction.

DOE used the AHAM-derived incremental manufacturing costs at the calculated IMEF efficiency levels as described in Table 5.6.19 and Table 5.6.20 in its subsequent analyses detailed in this TSD.

Table 5.6.19 Top-Loading Standard Clothes Washer Incremental Manufacturing Costs Based on IMEF

Integrated Efficiency Level	MEF (ft^3/kWh)	IMEF (ft^3/kWh)	Incremental Costs *($2010)*
Baseline	1.26	0.84	$0
EL 1	1.40	0.98	$3.11
EL 2	1.72	1.29	$8.44
EL 3	1.80	1.34	$13.06
EL 4	1.80	1.34	$16.98
EL 5	1.80	1.37	$14.24
EL 6	2.00	1.57	$25.29
EL 7	2.26	1.83	$60.65
EL 8	2.47	2.04	$69.79

Figure 5.6.18 Top-Loading Standard Clothes Washer Cost-Efficiency Curves Based on IMEF

Table 5.6.20 and Figure 5.6.19 present DOE's estimates of the incremental manufacturing cost associated with improving IMEF above the baseline for front-loading standard-size clothes washers. Like the top-loading curves, these curves are derived from the AHAM data submittal and incorporate the additional costs in Table 5.6.18 due to standby power reduction.

Table 5.6.20 Front-Loading Standard Clothes Washer Incremental Manufacturing Costs Based on IMEF

Integrated Efficiency Level	MEF (ft^3/kWh)	IMEF (ft^3/kWh)	Incremental Costs *($2010)*
Baseline	1.72	1.37	$0
EL 1	1.72	1.39	$3.92
EL 2	1.72	1.41	$1.18
EL 3	1.80	1.49	$3.18
EL 4	2.00	1.66	$6.20
EL 5	2.20	1.84	$17.25
EL 6	2.40	2.02	$40.36
EL 7	2.60	2.20	$53.88
EL 8	2.89	2.46	$73.51

Figure 5.6.19 Front-Loading Standard Clothes Washer Cost-Efficiency Curves Based on IMEF

Table 5.6.21 and Figure 5.6.20 present DOE's estimates of the incremental manufacturing cost associated with improving IMEF above the baseline for top-loading compact-size clothes washers.

Table 5.6.21 Top-Loading Compact Clothes Washer Incremental Manufacturing Costs Based on IMEF

Integrated Efficiency Level	MEF (ft^3/kWh)	IMEF (ft^3/kWh)	Incremental Costs *($2010)*
Baseline	0.77	0.59	-
EL 1	1.26	0.86	$5
EL 2	1.81	1.15	$45

Figure 5.6.20 Top-Loading Compact Clothes Washer Cost-Efficiency Curves Based on IMEF

Table 5.6.22 and Figure 5.6.21 present DOE's estimates of the incremental manufacturing cost associated with improving IMEF above the baseline for front-loading compact-size clothes washers.

Table 5.6.22 Front-Loading Compact Clothes Washer Incremental Manufacturing Costs Based on IMEF

Integrated Efficiency Level	MEF (ft^3/kWh)	IMEF (ft^3/kWh)	Incremental Costs *($2010)*
Baseline	1.60	1.03	-
EL 1	1.72	1.13	$3

Figure 5.6.21 Front-Loading Compact Clothes Washer Cost-Efficiency Curves Based on IMEF

5.6.5 Manufacturer Interviews

DOE conducted interviews with residential clothes washer manufacturers to develop a better understanding of current product features and the technologies used to improve energy efficiency. The questionnaires used to conduct these interviews are contained in appendix 5-C of this TSD. The manufacturers interviewed represent a wide range of U.S. market share and included both domestic and international companies that sell residential clothes washers in the United States. During these interviews, DOE asked manufacturers questions about the following topics:

- Product classes
- Design features of current baseline products
- Proposed incremental efficiency levels
- Design options required to meet each efficiency level
- Technical details about each design option
- Installation and repair costs as a function of efficiency
- Relationship between MEF and WF
- Test procedure issues

The discussion helped DOE understand what proposed design options have already been implemented and what additional design options DOE should consider. In addition, DOE conducted discussions regarding issues with the DOE clothes washer test procedure. The discussion below represents a consolidation of the responses.

5.6.5.1 **Product Classes**

All manufacturers supported the elimination of the top-loading semi-automatic and suds-saving product class categories because these products no longer exist in the marketplace.

Manufacturers were divided on whether to retain the distinction between top-loading standard and front-loading product classes and whether the same distinctions should apply to compact clothes washers.

5.6.5.2 **Design Features of Current Baseline Products**

Manufacturers identified the following features that are typically found in baseline top-loading and front-loading clothes washers, shown in shown in Table 5.6.23.

Table 5.6.23 Features Typically Found in Baseline Units

Top-Loading	Front-Loading
Electromechanical controls	Electronic controls
Single-speed motor	Variable-speed motor
Transmission	Belt & pulley drive system
Wash basket (enameled steel)	Wash basket (stainless steel)
Outer tub (plastic)	Outer tub (plastic)
Traditional agitator	Wash basket paddles
Simple ratio valves for hot/cold water	Simple ratio valves for hot/cold water
Drain pump	Drain pump
Pressure switch allowing 3-5 water levels	Simple pressure switch
Deep water fill	Front door and bellows assembly
Deep water rinse	Counterbalance mass
Moderate spin speeds	

5.6.5.3 Active Mode Efficiency Levels

DOE asked manufacturers to comment on the proposed active mode efficiency levels presented in the framework document for top-loading standard and front-loading product classes. Manufacturers were asked to comment on the appropriateness of each incremental efficiency level, including the gap-fill levels and the max-tech levels. In general, the responses from manufacturers were consistent with the comments received after the framework meeting.

5.6.5.4 Design Options Required to Meet each Active Mode Efficiency Level

DOE asked manufacturers to describe the changes associated with each active mode efficiency level relative to the baseline units in each product class. Table 5.6.24 presents a list of technologies that manufacturers currently use or are considering using to achieve each incremental active mode efficiency level in top-loading residential clothes washers. At the time the interviews were conducted, the max-tech level for top-loading clothes washers corresponded to EL 5. Therefore, no details were provided by manufacturers for EL 6.

Table 5.6.24 Design Options Required To Meet Top-Loading Standard Efficiency Levels

Efficiency Level	MEF	WF	Technology Options
EL 1	1.40	9.5	Adaptive fill technology Bi-metal temperature control Flow-control water valves Motor efficiency improvement Spray rinse
EL 2	1.72	8.0	Agitator modification Basket shape modification Electronic controls Higher spin speeds Larger capacity Load-size sensors More advanced water inlets Spray rinse Stainless steel basket Variable-speed drive Water temperature sensors (thermistors)
EL 3	1.80	7.5	Higher spin speeds Larger capacity Pressure switch accuracy improvement Stronger basket
EL 4	2.00	6.0	Adaptive fill technology Agitator replaced by impeller High suspension Higher spin speeds Larger capacity Longer cycle times Lower water temperatures More mechanical action More sensing technology More sophisticated electronic control Out-of-balance detection Recirculation pumps Stainless steel basket
EL 5	2.26	4.48	Absorption sensors Accelerometers Better motor Better temperature control Gray-water rinse Higher capacity Higher chemical concentration Highest spin speeds Load-composition sensors Longer cycle times More mechanical action More robust suspension system Most sophisticated load detection Tachometer Water flow meters
EL 6	2.47	3.60	No information provided by manufacturers

Table 5.6.25 presents a list of technologies that manufacturers currently use or are considering using to achieve each incremental active mode efficiency level in front-loading residential clothes washers. No information was provided by manufacturers for EL 5 because DOE was not considering that efficiency level at the time the manufacturer interviews were conducted.

Table 5.6.25 Design Options Required to Meet Front-Loading Standard Efficiency Levels

Efficiency Level	MEF	WF	Technology Options
EL 1	1.80	7.5	No changes necessary
EL 2	2.00	6.0	Electronic user interface
EL 3	2.20	4.5	Sophisticated damping system Analog pressure sensors Water flow meter Higher spin speeds Longer cycle time Reinforced structure Larger capacity
EL 4	2.40	4.2	Larger capacity Recirculation pump Better control technology
EL 5	2.60	2.20	No information provided by manufacturers
EL 6	2.89	3.20	More precise dispensing of chemicals Load-size sensors Fuzzy logic

5.6.5.5 Technical Details About Each Design Option

DOE asked manufacturers to provide technical details on each design option identified in the framework document. This included estimating the energy efficiency improvement potential of each design option. The sections below summarize the manufacturers' comments on each design option.

Adaptive Control Systems

The use of adaptive control systems varied among manufacturers. Some manufacturers reported no use of adaptive control systems. Others reported limited use, such as water temperature feedback. A small number of manufacturers reported using sophisticated adaptive control systems to perform functions such as sensing load size and composition. Sensors commonly used for these functions include thermistors, Hall-effect sensors, pressure sensors, water flow meters, electrodes, and feedback from the motor. Parameters that are adjusted based on sensor input include water level, wash profile, length of wash, and rinse type.

Turbidity sensors, commonly used in dishwashers to sense water clarity, are not used by any manufacturers interviewed in residential clothes washers. All manufacturers indicated that turbidity sensors are ineffective because of the level of suds commonly present in U.S. clothes

washers. Also, if a only single garment has a strong stain while the rest of the load is relatively clean, the wash water will appear also clean even though the stain has not been completely removed. In this case the turbidity sensor would incorrectly make the clothes washer select a cycle that may not result in the stain being lifted.

Added Insulation

All manufacturers stated that there is no significant potential efficiency improvement from adding insulation to the outer tub. The vast majority of residential clothes washers for sale in the United States incorporate a plastic tub, which has a low thermal mass. In the United States, most hot water is pre-heated outside the clothes washer, and the internal heat loss is negligible. Additionally, in most washers the proportion of hot wash water cycles is relatively small, while most cycles use either cold or lukewarm wash and/or rinse cycles, resulting in very little or no benefit for insulation.

Advanced agitation concepts for vertical-axis machines

Several manufacturers use low-profile agitators, nutating plates, or impellers, in their high efficiency vertical-axis top-loading machines. Using a low-profile agitator increases the usable capacity of a clothes washer and hence can significantly improve both MEF and WF.

Automatic Fill Control

Every manufacturer interviewed uses some type of automatic fill control in at least some of their units. These are used in both top-loading and front-loading clothes washers. Low-end systems use simple on/off switches. More advanced systems use pressure transducers, which cost more than the simple on/off pressure switch.

Bubble Action

The large majority of manufacturers have not considered this technology. Bubble action washers rely on generating bubbles to assist the mechanical agitation, reduce water consumption, and to more evenly distribute detergent throughout the clothing. No manufacturer currently ships a bubble-action clothes washer in the United States, and manufacturers were divided regarding the actual energy efficiency benefits of bubble-action clothes washers.

Direct Drive Motor

Approximately half of the manufacturers interviewed use direct-drive motors on some or all of their clothes washer models. Manufacturers currently use, or stated they would use in the future, brushless direct current (BLDC) and brushless permanent magnet (BPM) direct-drive motors. Direct-drive motors can have an almost infinite amount of wash profiles, which can help provide efficiency improvements

Electrolytic disassociation of water

None of the manufacturers currently use this technology in the United States. One manufacturer noted that this technology is used in Japan and Korea. Several manufacturers have considered this technology, but have determined that potential efficiency savings are not worth the added cost.

Horizontal-axis design

All manufacturers of horizontal-axis clothes washers generally agreed with DOE's estimate that horizontal-axis machines use on average 40 percent less energy and 25 percent less water than traditional vertical-axis washers.

Horizontal-axis design with recirculation

Recirculation may or may not offer much if any benefit according to the manufacturers queried. Vertical-axis clothes washers typically have a larger sump and hence may benefit more from recirculating water from the sump into the wash basket.

Hot water circulation loop

All manufacturers agreed that implementing a hot water circulation loop, which would involve a heat exchanger, may be technically possible but would provide little if any efficiency gains and would be prohibitively expensive.

Improved fill control

Improved fill control would require a high-end pressure switch or a more expensive pressure transducer, which would require an electronic controller to interpret the analog signal being sent by the transducer.

Improved horizontal-axis washer drum design

Manufacturers generally agreed that there is little room for efficiency improvements by changing the design of the washer drum.

Improved water extraction to lower remaining moisture content

The manufacturers interviewed currently have RMC values ranging from 39–55 percent for top-loading clothes washers and 30–40 percent for front-loading clothes washers. One manufacturer stated that 30-percent RMC is considered the lowest possible value that does not significantly increase the risk of laundry damage due to the higher spin speeds necessary.

Multiple manufacturers stated that increasing the spin speed offers the greatest potential for energy efficiency improvements. Current top-load spin speeds range from 350–1100 RPM. Current front-load spin speeds range from 1150–1600 RPM. Several manufacturers stated that

increasing spin speeds would require stronger motors, better off-balance detection and prevention, and stronger structural support. Containing catastrophic failures of wash baskets during the spin cycle may also require additional reinforcements to the existing exterior wrapper structure.

Multiple manufacturers stated that that longer spin cycles offer decreasing returns on improving energy efficiency.

Multiple manufacturers stated that changing the direction of rotation of the spin cycle does not have any significant effect on the energy efficiency of either top-loading clothes washers or front-loading clothes washers. All manufacturers generally agreed that there is little, if any, potential efficiency gains to be made by adjusting the number or size of holes in the wash basket. However, hole diameters in the wash basket have to be kept small enough to prevent clothes from being extruded through them during the spin cycle.

Increased motor efficiency

Two manufacturers stated that a direct-drive motor with newer drive train technologies could decrease motor energy usage by 50 percent, which would correspond to roughly 5-percent increase in overall efficiency. Other manufacturers stated that motor efficiency improvements would be less, ranging from 10–40 percent of motor energy usage. The cost estimates for a more advanced motor ranges from $5–30 over a traditional motor. One manufacturer stated that switching motors would require $1 million in capital expenses for new drive electronics and upgrades to the existing mounting system.

Low standby power design

All manufacturers stated that standby power is consumed by electronic components including displays, sensors, microprocessors, noise filters, and the internal power supply.

Manufacturers stated that they use a variety of electronic display types, including LEDs, graphic LEDs, and liquid crystal display (LCD) screens. Standby power for electronic displays ranges from 1.0 to 5.0 W, depending on the type of display. Several manufacturers dim the electronic displays after a period of non-use. Some manufacturers also turn off the displays completely during non-use, which reduces standby power to near zero.

One option for reducing standby power is to use a switch-mode power supply rather than a traditional linear power supply. The large majority of manufacturers interviewed currently use switch-mode power supplies. Manufacturers were uncertain about the standby power savings or costs associated with using switch-mode power supplies.

Ozonated laundering

Multiple manufacturers noted that this technology has been used in Japan, Korea, and Europe. One manufacturer stated that ozone does kill bacteria, so this technology could be used instead of hot water or steam for sanitization. However, manufacturers generally agreed that

ozone has the potential to degrade certain materials, particularly plastics and rubber gaskets, so materials in clothes washers would have to be upgraded to better handle ozone exposure.

Plastic particle cleaning

None of the manufacturers interviewed have considered plastic particle cleaning as a viable option. One manufacturer stated that the cleaning performance of this technology has not been proven, and the technology would require consumers to purchase and dispose of plastic pellets. The supply chain to support the technology does not exist today and would have to be developed. Consumer education would be another hurdle to implementation.

Reduced thermal mass

Most manufacturers interviewed currently use plastic wash tubs. Manufacturers generally agreed that there was no more room for improvement with reducing the thermal mass of the wash tub.

Spray rinse or similar water-reducing rinse technology

All the manufacturers that sell top-loading clothes washers reported using spray rinse technology in at least some of their top-loading clothes washers. One manufacturer stated that spray rinse uses one-third the water of a typical deep rinse, at essentially zero cost. Manufacturers stated that improvements in WF range from 0.4 to 2.0. Spray rinse is not used on front-loading clothes washers and there may be some consumer acceptance/education hurdles to overcome.

Thermostatically controlled mixing valves

Several manufacturers reported using implementations that emulate thermostatically controlled water valves using standard solenoid-activated water valves. In general, the electronic controller cycles the valves based on water temperatures measured either inside the washer or within the water valve assembly. Thermostatically controlled mixing valves have the potential to save hot water based on the temperature of the hot water inlet. The tolerance on these valves ranges from ± 2 to ± 5 degrees Fahrenheit. These savings are unlikely to be realized under DOE test conditions since incoming water temperatures are strictly controlled.

Tighter tub tolerance

Manufacturers generally agreed that tub tolerances have been tightened significantly and are close to their practical limits. Suds lock is one of the factors limiting further decreases in the annulus between the wash basket and the wash tub. Another limiting factor is the tolerance that must be provided to accommodate any flexing of the wash basket that can occur during the spin cycle, especially with out-of-balance loads. Front-load washers also require enough clearance for an internal water heater, if equipped.

5.6.5.6 **Installation and Repair Costs as a Function of Efficiency**

Manufacturers' responses differed with respect to whether installation and repair costs vary as a function of clothes washer efficiency. Multiple manufacturers stated that neither installation nor repair costs varied as a function of efficiency. Multiple manufacturers stated that maintenance and repair costs may increase as efficiency increases, since higher efficiency machines tend to have more complex parts, with higher failure rates and higher replacement costs. Multiple manufacturers stated that installation costs may increase as a function of efficiency, as high efficiency machines have higher spin speeds, which may require the user to reinforce the floor or to install the washer on a pedestal.

Relationship between MEF and WF

Multiple manufacturers stated that the main shared characteristic between MEF and WF is the impact on both due to the drum capacity. Multiple manufacturers also stated that hot water consumption affects both MEF and WF; cold water consumption affects only WF; and spin speed affects only MEF. One manufacturer noted that in general, as MEF increases, WF decreases, but not linearly.

Test procedure issues

DOE asked manufacturers a number of questions regarding the current clothes washer test procedure. Their responses were considered in the recent test procedure rulemaking. Some of the comments received include the following:

- Capacity – Manufacturers expressed the need for DOE to clarify the capacity measurement technique for both top-loading and front-loading clothes washers. Also, the test procedure should be modified to accommodate capacities up to 5 ft^3.
- Test cloth – Several manufacturers reported inconsistencies between lots of the test cloth. They recommended that DOE pursue ways of ensuring the consistency of future lots of test cloth.
- Performance – Several manufacturers stated that clothes washer standards have progressed to the point where they may start to have a negative impact on product performance. Some manufacturers suggested incorporating a measure of cleaning and rinsing performance into the standard.

CHAPTER 6. MARKUPS FOR EQUIPMENT PRICE DETERMINATION

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CHAPTER 6. MARKUPS FOR EQUIPMENT PRICE DETERMINATION

6.1 INTRODUCTION

To carry out its analyses, DOE needed to determine the cost to the consumer of baseline products and the cost of more-efficient units. As discussed in chapter 8, DOE developed retail prices for baseline products using proprietary retail price data collected by The NPD Group. For products with higher-than-baseline efficiency, DOE estimated the consumer prices by applying appropriate markups to the incremental manufacturing costs estimated in the engineering analysis.

6.1.1 Distribution Channels

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

Data from the Association of Home Appliance Manufacturers (AHAM) [(1)] indicate that an overwhelming majority of residential appliances are sold through retail outlets. Because DOE is not aware of any other distribution channel that plays a significant role for residential clothes washers, DOE assumed that all of the clothes washers are purchased by consumers from retail outlets. DOE did not include a separate distribution channel for clothes washers products included as part of a new home, as it did not have information on the extent to which these products are "pre-installed" by builders in new homes.

6.1.2 Markup Calculation Procedure

As just discussed, at each point in the distribution channel, companies mark up the price of the equipment to cover their business costs and profit margin. In financial statements, gross margin is the difference between the company revenue and the company cost of sales or cost of goods sold (*CGS*). The gross margin includes the expenses of companies in the distribution channel—including overhead costs (sales, general, and administration); research and development (R&D) and interest expenses; depreciation, and taxes—and company profits. 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. In developing markups for manufacturers and retailers, DOE obtained data about the revenue, *CGS*, and expenses of firms that produce and sell the products of interest.

6.2 MANUFACTURER MARKUPS

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

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

where:

MU_{MFG} = Manufacturer markup,
CGS_{MFG} = Manufacturer's cost of goods sold or Manufacturer Production Cost (*MPC*), and
GM_{MFG} = Manufacturer's gross margin.

The manufacturer's *CGS* (or *MPC)* plus its *GM* equals the manufacturer selling price (*MSP*).

DOE developed an average manufacturer markup by examining the annual Securities and Exchange Commission (SEC) 10-K reports filed by four publicly-traded manufacturers primarily engaged in appliance manufacturing and whose combined product range includes residential clothes washers. [(2)] The four manufacturers represent an over 70 percent market share for major appliances. Because these companies are typically diversified, producing a range of different appliances, an industry average markup was assumed by DOE to be representative for the manufacture of clothes washers. DOE evaluated markups for the years 2004-2009. Table 6.2.1 lists the average corporate gross margin during the years 2004-2009, and corresponding markups, for each of the four manufacturers.

Table 6.2.1 Major Appliance Manufacturer Gross Margins and Markups

	Mfr A	Mfr B	Mfr C	Mfr D
Average Net Revenues (Million)	$373	$15,503	$16,839	$2,402
Average Cost of Goods Sold	$279	$12,092	$14,373	$2,068
Markup	1.34	1.28	1.17	1.16

Source: SEC 10-K reports (2009-2004)

The weighted average markup values based on these four companies is 1.22; therefore DOE used the 1.22 markup for both front-loading and top-loading washers.

6.3 RETAILER MARKUP

6.3.1 Approach for Retailer Markups

DOE based the retailer markups for residential clothes washers on financial data for Electronics and Appliance Stores from the 2002 U.S. Census Business Expenditure Survey (BES), which is the most recent available survey. [(3)] DOE organized the financial data into statements that break down cost components incurred by firms in this category. 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 most accurate available indication of expenses for selling home appliances.

The BES data provided for Electronics and Appliance Stores only contain total sales and detailed operating expenses. In order to construct a complete data set to estimate markups, DOE needed to estimate CGS and gross margin. The 1997 Business Expenses Survey provides total sales, gross margin and detailed operating expenses of Household Appliance Stores. The CGS and gross margin account for around 70% and 30% of the total sales, respectively. DOE found that gross margin as percent of sales has been roughly constant in this category from 1993 to 2007.[a] Therefore, DOE assumed that the fractions of CGS and gross margin as percent of sales in 2002 are the same as in 1997. Following this assumption, DOE calculated the CGS, gross margin and net profit for Electronics and Appliance Stores in the 2002 BES.

6.3.1.1 Baseline Retailer Markup

The baseline markup relates the manufacturer sales price of baseline products to the retailer sales price. DOE considers baseline models to be equipment sold under existing market conditions (*i.e.*, without new energy efficiency standards). DOE calculated the baseline markup (MU_{BASE}) for retailers as an average markup using the following equation:

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

where:

MU_{BASE} = Baseline retailer markup,
CGS_{RTL} = Retailer's cost of goods sold,
GM_{RTL} = Retailer's gross margin,

Table 6.3.1 shows the calculation of the baseline retailer markup.

[a] U.S. Census, 2007 Annual Retail Trade Report: Electronics and Appliance Stores Sales and Gross Margin

Table 6.3.1 Data for Baseline Markup Calculation: Electronics and Appliance Stores (2002)

Kind of business item	Amount (*$1,000*)
Sales	$83,896,811
Cost of Goods Sold (CGS)	$57,888,800
Gross Margin (GM)	$26,008,011
Baseline Markup = (CGS+GM)/CGS	**1.45**

Source: U.S. Census, 2002 Business Expenses Survey (for Sales) and 1997 Business Expenses Survey (for CGS and GM shares)

6.3.1.2 Incremental Retailer Markup

Incremental markups are coefficients that relate the change in the manufacturer sales price of higher-efficiency models to the change in the retailer sales price. DOE considers higher-efficiency models to be equipment sold under market conditions with new efficiency standards. The incremental markup reflects a situation in which the retailer faces an increase in CGS for a particular product due to new or amended standards.

Unfortunately, empirical evidence regarding appliance retailer markup practices when a product increases in cost (due to increased efficiency or other factors) is lacking. DOE understands that real-world markup practices will vary depending on the market conditions faced by retailers, on the magnitude of the change in CGS associated with an efficiency increase and on any associated changes in retail costs. Pricing in retail stores may also involve rules of thumb that are difficult to know and to incorporate into DOE's analysis.

Given the uncertainty about actual markup practices in appliance retailing, DOE uses an approach that reflects the following key concepts:

1. Changes in the efficiency of the goods sold are not expected to increase economic profits. Thus, DOE calculates markups/gross margins to allow cost recovery for retail companies in the distribution chain (including changes in the cost of capital) without changes in company profits.

2. Efficiency improvements impact some distribution costs but not others. DOE sets markups and retail prices to cover the distribution costs expected to change with efficiency but not the distribution costs that are not expected to change with efficiency.

The incremental markup approach is described in more detail in Dale et al. (2004). [(4)]

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 fixed costs to include labor and occupancy expenses 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:

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

where:

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

Table 6.3.2 shows the breakdown of operating expenses using the 2002 BES data. The incremental markup is calculated as 1.17.

Table 6.3.2 Data for Incremental Markup Calculation: Electronics and Appliance Stores (2002)

Input Data for Incremental Markup Calculation	Amount *($1,000)*
Sales	$83,896,811
Cost of Goods Sold (CGS)	*$57,888,800*
Gross Margin (GM)	*$26,008,011*
Labor & Occupancy Expenses ("Fixed")	
Annual payroll	$10,267,605
Employer costs for fringe benefit	$1,407,970
Contract labor costs including temporary help	$160,094
Purchased utilities, total	$427,809
Cost of purchased repair and maintenance services	$308,789
Cost of purchased management consulting administrative services and other professional services	$300,548
Purchased communication services	$400,598
Lease and rental payments	$2,655,286
Taxes and license fees (mostly income taxes)	$385,538
Subtotal:	$16,314,237
Other Operating Expenses & Profit ("Variable")	
Expensed computer related supplies	$86,751
Cost of purchased packaging and containers	$41,866
Other materials and supplies not for resale	$611,361
Cost of purchased transportation, shipping and warehousing services	$500,233
Cost of purchased printing services	$285,012
Cost of purchased advertising and promotional services	$1,840,898
Cost of purchased legal services	$90,020
Cost of purchased accounting, auditing, and bookkeeping services	$86,292
Cost of purchased custom coded original software (expensed) including adaption of off-the-shelf software	$18,944
Cost of system support design and services including web design	$35,748
Cost of insurance	$393,201
Cost of data processing and other purchased computer services, except communications	$41,056
Depreciation and amortization charges	$1,229,110
Commissions paid	$106,061
Other operating expenses	$2,929,906
Cost of contract work	$21,955
Net profit before taxes	*$1,375,360*
Subtotal:	$9,693,774
Incremental Markup = (CGS+Total Other Operating Expenses and Profit)/CGS	**1.17**

Source: U.S. Census, 2002 Business Expenses Survey

By dividing expenses into fixed and variable components, the incremental markup approach envisions that retailers cover costs without changing profits. Although retailers may be able to reap higher profits for a time, DOE's approach assumes that competition in the appliance retail market will tend to pressure retail margins back down.

To measure the degree of competition in appliance retailing, DOE estimated the four firm concentration ratio (FFCR) of major appliance sales in three retail channels: Electronics and Appliance Stores, Building and Material and Supplies Dealers, and General Merchandise Stores. The FFCR represents the market share of the four largest firms in the relevant industry. Generally, an FFCR of less than 40% indicates that the industry is not concentrated and an FFCR of more than 70% indicates that an industry is highly concentrated.[b] [c]

The FFCR of major appliance sales is equal to the sector FFCR times the percent of total sales within each sector accounted for by major appliances. As shown in Table 6.3.3, the results indicate that appliance sales in Electronics and Appliance Stores, Household Appliance Stores, Building Material Supplies Dealers and General Merchandise Stores have a FFCR well under the 40% threshold. Moreover, the Electronics and Appliance Stores sector includes "Household Appliance Stores" as a subsector. Because there are many stores in this subsector, it has a FFCR of only 16.8%.

Table 6.3.3 Electronics and Appliance Stores, Concentration by Four Large Firms

Sector	**Four Firm Concentration Ratio** (Percent of Sector Sales)	**Percent of Sales Accounted for by Major Appliances**	**Four Firm Concentration Ratio** (Percent of Major Appliance Sales)
Electronics and Appliance Stores	43.9	39.4	17.3
Household Appliance Stores subsector	16.8	-	-
Building Material and Supplies Dealers	41.7	15.7	6.5
General Merchandise Stores	65.1	35.4	23.0

Source: U.S. Economic Census, Establishment and Firm Size: (Including Legal Form of Organization), 1997, 2002.
*Note: The assumption used here is that major appliance sales are uniformly distributed within all firms in each sector.

[b] University of Maryland University College
http://info.umuc.edu/mba/public/AMBA607/IndustryStructure.html
[c] Quick MBA
http://www.quickmba.com/econ/micro/indcon.shtml

6.4 SALES TAXES

The sales tax represents state and local sales taxes that are applied to the consumer equipment price. The sales tax is a multiplicative factor that increases the consumer equipment price.

DOE derived state and local taxes from data provided by the Sales Tax Clearinghouse. [5] DOE derived population-weighted average tax values for each Census division and large state, as shown in Table 6.4.1 below.

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

Census Division/State	Tax Rate (2009)
New England	5.55%
Mid Atlantic	6.62%
East North Central	6.94%
West North Central	6.86%
South Atlantic	6.44%
East South Central	7.90%
West South Central	8.42%
Mountain	6.50%
Pacific	5.21%
New York State	8.45%
California	9.15%
Texas	8.05%
Florida	6.70%

DOE then derived U.S. average tax values for each product (as shown in Table 6.4.2 below) based on the product's saturation within each Census division and large state. It determined the saturations from the DOE Energy Information Administration (EIA)'s 2005 Residential Energy Consumption Survey. [6]

Table 6.4.2 Average Sales Tax Rates

Product	Tax Rate
Top-Loading Clothes Washers	7.17%
Front-Loading Clothes Washers	7.06%

6.5 SUMMARY OF MARKUPS

Table 6.5.1 summarizes the markups at each stage in the distribution channel and the average sales tax.

Table 6.5.1 Summary of Markups

	Top-Loading		**Front-Loading**	
Markup	**Baseline**	**Incremental**	**Baseline**	**Incremental**
Manufacturer	1.22		1.22	
Retailer	1.45	1.17	1.45	1.17
Sales Tax	1.0717		1.0706	
Overall	1.90	1.53	1.89	1.53

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CHAPTER 7. ENERGY AND WATER USE DETERMINATION

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CHAPTER 7. ENERGY AND WATER USE DETERMINATION

7.1 INTRODUCTION

To perform the life-cycle cost (LCC) and payback period (PBP) calculations described in Chapter 8, DOE had to determine the savings in operating costs that consumers would derive from higher efficiency standards for clothes washers. DOE used consumer energy and water use data, along with energy and water prices, to develop the most significant component of consumer operating costs in the LCC and PBP analyses[*]. This chapter describes how DOE established the annual energy and water consumption of residential clothes washers.

7.2 PER-CYCLE ENERGY AND WATER CONSUMPTION BY EFFICIENCY LEVEL

DOE establishes the annual energy and water consumption of clothes washers by multiplying the per-cycle energy and water use by the number of cycles per year. The per-cycle energy consumption associated with a given clothes washer has three components: energy used for heating the water, operating the machine, and drying the clothes. DOE adopted test procedures for clothes washers in a final rule published on October 18, 2005.[1] That DOE test procedure provides the following equations to calculate total per-cycle energy consumption of clothes washers.

$$CW_{CYCLE} = \frac{HE_T}{e} + ME_T + D_E$$

Where:

CW_{CYCLE} =	total (without off-mode energy use) per-cycle energy consumption of clothes washer,
HE_T =	per-cycle energy consumption for heating water [kilowatt-hours (kWh)/cycle)],
e =	efficiency of electric water heater (100%) or gas water heater (75%),
ME_T =	per-cycle machine energy consumption for operating washer (kWh/cycle), and
D_E =	per-cycle energy consumption for removing moisture from test load [*i.e.*, dryer energy consumption (kWh/cycle)].

The following equation from the current DOE test procedure calculates the per-cycle energy consumption for removing moisture:

[*] Maintenance and repair costs are the other contributors.

$$D_E = \left(\left(LUF_{\max} \times W_{\max}\right) + \left(LUF_{avg} \times W_{avg}\right) + \left(LUF_{\min} \times W_{\min}\right)\right) \times \left(RMC - 4\%\right) \times DEF \times DUF$$

Where:

LUF = load usage factor,
W = weight of test load [pounds (lb)/cycle],
RMC = moisture content that remains after washing (lb),
DEF = nominal energy required for a clothes dryer to remove moisture from clothes (0.5kWh/lb), and
DUF = dryer usage factor, a percentage of washer loads dried in a clothes dryer (0.91).

For clothes washers with manual fill control systems, only the LUF_{max} and LUF_{min} terms are used. For clothes washers with adaptive fill control systems, all three terms are included. The values of W and LUF can be found in the current test procedure.

When considering gas drying, DOE multiplies the dryer energy consumption by a gas correction factor to account for the additional energy a gas dryer requires relative to an electric dryer. The following equation determines per-cycle energy consumption for gas drying.

$$\boldsymbol{D_G = GCF \times D_E}$$

Where:

D_G = per-cycle energy consumption for gas dryer to remove moisture from test load, *i.e.*, dryer energy consumption (kWh/cycle), and
GCF = gas correction factor = 1.12.[2]

DOE previously used a modified energy factor (MEF) and a water factor (WF) to establish the energy and water efficiencies of clothes washers. The following equations determine the MEF and WF:

$$\boldsymbol{MEF = \frac{C}{CW_{CYCLE}}}$$

$$\boldsymbol{WF = \frac{Q_T}{C}}$$

Where:

C = container capacity [cubic feet (cu ft)], and
Q_T = per-cycle water consumption for cold wash/cold/rinse [gallons (gal)/cycle].

The previous test procedure was revised to include non-active mode energy use.[3] This analysis takes those revisions into account by using the revised integrated energy and water factors defined below.

$$IMEF = C / (CW_{cycle} + \text{cyclic off-mode energy})$$

The cyclic off-mode energy is expressed in units of kWh/cycle and obtained by dividing the annual off-mode energy use by the number of wash cycles per year.

The integrated water factor is defined below.

$$IWF = Qt / C$$

Where:
Qt = Total weighted per-cycle water consumption for all wash cycles
C = Capacity

As discussed in the Engineering Chapter, DOE analyzed specific energy efficiency levels for top- and front-loading standard-capacity and compact residential clothes washers. Tables 7.2.1 and 7.2.2 show the efficiency levels for standard-capacity residential clothes washers and their corresponding per-cycle energy and water use. Since the capacity varies with efficiency level there is a column including that volume variable ("*Vol. ft*^{3}"). Both MEF and IMEF are also listed. The MEF can be used to calculate kWh/cycle without inclusion of non-active and self clean modes. For example, in the table for top-loading washers the volume of 3.86 cubic feet divided by an MEF of 2, representing the baseline, results in a kWh/cycle of 1.93 kWh which also equals the sum of machine, dryer and water heating energy per cycle. The same procedure using the IMEF of 1.57 would yield a total kWh per cycle of 2.46 kWh per cycle which includes non-active energy use. Most of the difference between these two measures of total cyclic energy use is a result of the different algorithm in the current test procedure to quantify dryer energy use. Tables 7.2.3 and 7.2.4 show the efficiency levels and the corresponding per cycle energy and water use for the two compact product classes.

Per-cycle energy use is disaggregated into energy used for heating the water, operating the machine, and drying the clothes. DOE determined the per-cycle clothes drying energy use by using RMC values contained in the cost/efficiency data from the engineering analysis. DOE obtained the per-cycle machine energy use from the cost/efficiency data set. After obtaining the per-cycle energy use for drying the clothes and operating the machine, DOE determined the per-cycle water-heating energy use. First DOE determined the total per-cycle energy use (the washer container volume divided by the IMEF) and then subtracted from it the per-cycle clothes-drying, standby, and machine energy use. The water-heating energy use assumes the use of an electric water heater. DOE determined the per-cycle hot water use by dividing the per-cycle water-heating energy use by an assumed temperature rise of 75 ºF (21.1 ºC) and a specific heat of

0.0024 kWh/gal-ºF (4.186 joule/gram-ºC). DOE determined the total water use by multiplying the IWF by the washer container volume.

Some of the variables in the following four tables were calculated using average values. These average values are not used in the LCC analysis described in Chapter 8. The IMEF includes off-mode energy use and requires using an average value for washer usage (295 cycles/year). An average dryer usage factor of 0.91 is used to calculate dryer energy use and this also impacts the calculation of water heater energy use; therefore, average values for these two quantities are shown in the two tables. When carrying out the LCC analysis, washer usage is selected from households in RECS. This methodology is described in Chapter 8.

Table 7.2.1 Top-loading Standard-Capacity Residential Clothes Washers: Per-Cycle Energy and Water Use by Efficiency Level

Level	Vol (ft^3)	Watts	MEF*	IMEF*	IWF (gal/cu ft)	RMC (%)	Energy Use (kWh/cycle)			
							Machine	Dryer	Water Heat+	Hot Water gal/cycle
Baseline	3.09	0.00	1.26	0.84	9.92	51.9%	0.279	2.16	1.24	6.90
1	3.38	0.00	1.40	0.98	9.92	53.6%	0.281	2.43	0.74	4.13
2	3.38	0.00	1.72	1.29	8.44	48.8%	0.228	1.69	0.69	3.85
3	3.76	2.30	1.80	1.34	7.95	37.9%	0.082	1.41	1.26	7.02
4	3.76	1.70	1.80	1.34	7.95	37.9%	0.082	1.41	1.26	7.02
5	3.76	0.08	1.80	1.37	7.95	37.9%	0.082	1.41	0125	4.92
6	3.86	0.08	2.00	1.57	6.47	36.6%	0.082	1.38	0.99	5.50
7	3.96	0.08	2.26	1.83	4.96	36.6%	0.077	1.41	0.67	3.74
8	4.34	0.08	2.47	2.04	4.10	34.8%	0.082	1.39	0.66	3.67

* cubic feet/kWh/cycle + based on use of electric water heater

Table 7.2.2 Front-loading Standard-Capacity Residential Clothes Washers: Per-Cycle Energy and Water Use by Efficiency Level

Level	Vol (ft^3)	Watts	MEF*	IMEF*	IWF (gal/cu ft)	RMC (%)	Energy Use (kWh/cycle)			
							Machine	Dryer	Water Heat§	Hot Water gal/cycle
Baseline	3.00	2.30	1.72	1.37	8.31	41.4%	0.113	1.31	0.69	3.86
1	3.00	1.70	1.72	1.39	8.31	41.4%	0.113	1.31	0.69	3.82
2	3.00	0.08	1.72	1.41	8.31	41.4%	0.113	1.31	0.70	3.88
3	3.00	0.08	1.80	1.49	7.80	41.4%	0.113	1.31	0.60	3.31
4	3.30	0.08	2.00	1.66	6.26	41.6%	0.163	1.42	0.40	2.22
5	3.41	0.08	2.20	1.84	4.73	38.6%	0.154	1.34	0.36	1.99
6	3.60	0.08	2.40	2.02	4.42	38.7%	0.164	1.41	0.20	1.13
7	3.83	0.08	2.60	2.20	4.01	36.2%	0.167	1.37	0.21	1.14
8	3.90	0.08	2.89	2.46	3.39	35.9%	0.155	1.38	0.04	0.25

Table 7.2.3 Top-loading Compact Residential Clothes Washers: Per-Cycle Energy and Water Use by Efficiency Level

Level	Vol (ft^3)	Watts	MEF*	IMEF*	IWF (gal/cu ft)	RMC (%)	Energy Use (kWh/cycle)			
							Machine	Dryer	Water Heat§	Hot Water gal/cycle
Baseline	1.50	0.0	0.77	0.59	14.4	58	0.30	1.35	0. 90	4.98
1	1.59	0.0	1. 62	0.86	14.4	58	0.10	1.35	0.40	2.24
2	1.59	2.3	1.81	1.15	12.0	45	0.10	0.87	0.34	1.90

Table 7.2.4 Front-loading Compact Residential Clothes Washers: Per-Cycle Energy and Water Use by Efficiency Level

Level	Vol (ft^3)	Watts	MEF*	IMEF*	IWF (gal/cu ft)	RMC (%)	Energy Use (kWh/cycle)			
							Machine	Dryer	Water Heat§	Hot Water gal/cycle
Baseline	1.5	2.30	1.60	1.03	8.8	45	0.10	1.02	0.27	1.49
1	1.5	0.08	1.72	1.13	8.3	45	0.10	1.02	0.20	1.13

7.3 AVERAGE ANNUAL ENERGY AND WATER CONSUMPTION BY EFFICIENCY LEVEL

To determine the average annual energy and water consumption for a clothes washer, DOE multiplies the per-cycle energy and water consumption by the number of cycles per year. Because the predominant application of residential clothes washers is single-family housing units, including condominiums and mobile units, DOE considered only those applications in determining the number of clothes washer cycles per year. Other applications may include lodging establishments (*e.g.*, some hotels and motels), but those are a minor part of the market compared to single-family housing units. DOE therefore believes it is not necessary for the analysis to accurately characterize residential clothes washer usage for applications other than single-family and multi-family housing units. In the LCC analysis, rather than using national averages, DOE determines clothes washer use by using a distinct value from RECS for each household.

DOE uses the following equation to calculate the annual energy consumption in each RECS household that is attributable to residential clothes washers.

$$\boldsymbol{CW_{ANNUAL} = CW_{CYCLE} \times N}$$

Where:

CW_{ANNUAL} = total annual energy consumption by clothes washers,
CW_{CYCLE} = total per-cycle energy consumption by clothes washers (C/IMEF), and
N = individual household annual clothes washer use (loads per year).

DOE used the following equation to calculate the annual water consumption of residential clothes washers.

$$\boldsymbol{CW_{ANNUAL\ WATER} = CW_{CYCLE\ WATER} \times N}$$

Where:

$CW_{ANNUAL\ WATER}$ = total annual water consumption by residential clothes washers, and
$CW_{CYCLE\ WATER}$ = total per-cycle water consumption by residential clothes washers.

The average annual energy and water consumption shown in Tables 7.3.1 through 7.3.4 reflect an annual usage of 295 cycles per year. This is the average usage obtained from RECS 2005. The total annual energy consumption reflects the use of an electric dryer and electric water heater. Total annual energy use equals *Volume* divided by *IMEF* multiplied by 295. This includes the non-active mode energy use. To convert electric water heating energy to gas or oil water heating energy use first convert kWh to Btu then divide by 0.75 to account for the efficiency of the water heater.

Table 7.3.1 Top-loading Standard-Capacity Residential Clothes Washers: Annual Energy and Water Use by Efficiency Level

Level	IMEF*	IWF (gal/cu ft)	Annual Energy Use				Annual Water Use
			Total (kWh)	Machine (kWh)	Dryer (kWh)	Water Heat (kWh)	(1000 gal.)
Baseline	0.84	9.92	1085	82	637	366	9.04
1	0.98	9.92	1019	83	717	219	9.89
2	1.29	8.44	770	67	499	204	8.41
3	1.34	7.95	831	24	416	372	8.82
4	1.34	7.95	826	24	416	367	8.82
5	1.37	7.95	808	24	416	368	8.82
6	1.57	6.47	725	24	407	294	7.36
7	1.83	4.96	639	23	416	200	5.79
8	2.04	4.10	629	24	410	195	5.25

Table 7.3.2 Front-loading Standard-Capacity Residential Clothes Washers: Annual Energy and Water Use by Efficiency Level

Level	IMEF*	IWF (gal/cu ft)	Annual Energy Use				Annual Water Use
			Total (kWh)	Machine (kWh)	Dryer (kWh)	Water Heat (kWh)	(1000 gal.)
Baseline	1.37	8.31	644	33	386	205	7.36
1	1.39	8.31	637	33	386	203	7.36
2	1.41	8.31	626	33	386	207	7.36
3	1.49	7.80	596	33	386	177	6.90
4	1.66	6.26	585	48	419	118	6.10
5	1.84	4.73	546	45	395	106	4.76
6	2.02	4.42	525	48	416	61	4.69
7	2.20	4.01	513	49	404	60	4.53
8	2.46	3.39	467	46	407	14	3.91

Table 7.3.4 Top-loading Compact Residential Clothes Washers: Annual Energy and Water Use by Efficiency Level

Level	IMEF*	IWF (gal/cu ft)	Annual Energy Use				Annual Water Use
			Total (kWh)	Machine (kWh)	Dryer (kWh)	Water Heat (kWh)	(1000 gal.)
Baseline	0.59	14.4	750	90	398	262	6.37
1	0.86	14.4	545	30	398	117	6.76
2	1.15	12.0	408	30	257	102	5.63

Table 7.3.3 Front-loading Compact Residential Clothes Washers: Annual Energy and Water Use by Efficiency Level

Level	IMEF*	IWF (gal/cu ft)	Annual Energy Use				Annual Water Use
			Total (kWh)	Machine (kWh)	Dryer (kWh)	Water Heat (kWh)	(1000 gal.)
Baseline	1.03	8.8	430	30	301	80	3.89
1	1.13	8.3	392	30	301	61	3.63

7.4 VARIABILITY IN ANNUAL ENERGY AND WATER CONSUMPTION: WASHER CAPACITY AND USAGE TRENDS

Clothes washer usage measured in cycles per year varies from one household to another and therefore, so do energy and water use. The magnitude of the annual usage has been decreasing while the average capacity of washers has been increasing. Figure 7.4.1 shows washer capacity using AHAM data plotted with usage data. Capacity has increased by about 14% from 1993 to 2005 while usage has decreased by about 17%[4] (RECS data) over the same time period. Assuming that any given household washes a fixed volume of clothes each year, this decrease in usage indicates that on average, larger amounts of clothes are being washed in each load.

The test procedure provides measurement methods for washers with and without load sensors. For washers with load sensors the test procedure gives the greatest weighting to a measurement with average loads (which means averaging maximum and minimum water fill results). This approach might result in calculated water and energy use that is unrealistically low if larger capacity washers tend to be filled with near maximum loads rather than average loads.

Figure 7.4.1 also shows washer usage decreasing over time. DOE has plotted results from analysis of RECS data and also market survey data. Both data sets show declining usage. The most recent average usage values from RECS 2005 and the market survey data show 295 and 309 cycles per year, respectively. Each study has an advantage and a disadvantage in how they were conducted. The market survey study has actual point values for the weekly washes whereas the RECS study uses intervals. On the other hand, the market survey study household size distribution does not match the Census values for household size as well as the RECS study. Household size affects washer usage. The market survey data set has fewer single-person households and more multiple-person households. That can lead to a higher average usage value as is the case for market survey data relative to RECS 2005. The RECS 2005 household size distribution is close to that for the latest Census Bureau sampling and the American Housing Survey (AHS).

Figure 7.4.1 Trends in Washer Usage and Capacity

DOE used RECS 2005 to determine the clothes washer usage in cycles per year for each household sampled in the LCC analysis. Figures 7.4.2 and 7.4.3 show the probability distribution of annual wash cycles for each product class. The average weighted usage is 295 cycles per year for top-loading clothes washers and 320 cycles per year for front-loading washers.

Figure 7.4.2 Annual Usage Distribution for Top-Loading Clothes Washers

Figure 7.4.3 Annual Usage Distribution for Front-Loading Clothes Washers

DOE also used RECS 2005 to determine the probability distribution of the dryer usage factors (DUF) for each household sampled. Figures 7.4.4 and 7.4.5 show the probability distribution of DUFs for both product classes. The vast majority of households use their dryers after every wash load.

Figure 7.4.4 Dryer usage for Households with Top-loading Clothes Washers

Figure 7.4.5 Dryer usage for Households with Front-loading Clothes Washers

DOE used the RECS household samples with their associated annual energy usage and DUF to conduct the LCC and PBP analyses. See chapter 8 for more details on the LCC and PBP analysis.

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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 describes the method the U.S. Department of Energy (DOE) used to analyze the economic impacts on individual consumers of potential energy efficiency standards for clothes washers. Impacts include a change in operating costs (usually a decrease) and a change in purchase price (usually an increase). This chapter describes three metrics DOE used in analyzing the effect of standards on individual consumers who purchase residential clothes washers.

- *Life-cycle cost* (LCC) is the total consumer expense over the life of an appliance, including purchase price and operating costs (including energy and water 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 a more energy efficient product through lower operating costs.
- *Rebuttable payback period* is a special case of the PBP. Although LCC and PBP are estimated for a range of inputs that reflect real-world conditions, rebuttable payback period is based on laboratory conditions, specifically those representative of the DOE test procedure.

DOE examined the life-cycle cost, payback period, and rebuttable payback period of all potential efficiency standards for four product classes of residential clothes washers. Inputs to the LCC and to the PBP are discussed in sections 8.2 and 8.3, respectively, of this chapter. Results of the LCC and PBP analysis are presented in section 8.4. The rebuttable PBP is discussed in section 8.5. Key variables and calculations are presented for each of the three metrics described above. DOE performed the calculations discussed here using a series of Microsoft Excel spreadsheets that are accessible on the Internet (www1.eere.energy.gov/buildings/appliance_standards/). Appendix 8A provides details and instructions pertaining to the spreadsheets.

In addition to conducting an LCC and PBP analysis to evaluate the effects of potential standards on individual consumers who purchase residential clothes washers, DOE conducted a panel regression analysis to assess the impacts on consumer welfare of the clothes washer standards that required compliance in 2007. This retrospective analysis, which is described in appendix 8-F, provides insight into how the standards being analyzed in the current rulemaking may affect consumer welfare in the future.

8.1.1 Approach

Recognizing that several inputs to the analysis of consumer LCC and PBP are either variable or uncertain, DOE used Monte Carlo simulation and probability distributions to define

inputs when appropriate. Appendix 8B provides a detailed explanation of the application of Monte Carlo simulation and probability distributions. The LCC and PBP spreadsheet models DOE developed incorporate both Monte Carlo simulation and probability distributions via Microsoft Excel spreadsheets combined with Crystal Ball (a commercially available add-in software program).

In addition to using probability distributions to characterize several inputs to the analysis, DOE developed samples of individual households that use one of the product classes of clothes washers. As described in chapter 7, DOE used the Energy Information Administration (EIA)'s 2005 Residential Energy Consumption Survey (RECS) to develop household samples for each product class.[1] The RECS surveys a sample of housing units nationwide to collect statistical information on each housing unit's consumption of and expenditures for energy. RECS also collects data on the energy-related characteristics of the housing units and occupants. The 2005 RECS, which comprised 4,382 housing units, was constructed by EIA to be a national representation of the household population in the United States. The household sample sizes for clothes washers were: 299 for front-loading clothes washers and 3610 for top-loading washers. By performing LCC and PBP calculations for each household in each sample, DOE accounted for the variation in both energy and water consumption and prices in a wide range of households. Although the standard error of the subsamples is three times that of the size of the entire 2005 RECS, it is still less than 5 percent. DOE believes a standard error of less than 5 percent is small enough to yield meaningful results. Therefore, DOE believes the results generated from the household samples for residential clothes washers are representative of U.S. households that use those appliances.

In its LCC and PBP analysis, DOE used RECS to establish the variability in annual energy and water use and pricing. DOE assigned unique annual energy and water usages and prices to each household in each sample. The large number of households considered in the LCC and PBP analysis resulted in a large range in annual energy and water use and prices. The range in washer usage (which impacts energy and water consumption) is presented and discussed in chapter 7.) The variability in annual energy and water use and pricing across all households contributes to the range of LCCs and PBPs calculated for each standard level. As described later in this chapter, DOE characterized the variability and uncertainty in energy and water prices through regional differences.

DOE displays LCC and PBP results as distributions of impacts compared to baseline conditions. Results, presented in section 8.4, 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 and PBP for each standard level and product class.

8.1.2 Summary of Inputs

The LCC is the total consumer expense throughout the life of a product, including purchase price and operating costs (including energy and water costs). DOE discounts future operating costs to the time of purchase and sums them throughout the lifetime of the product. The PBP is calculated as the change in purchase price due to an increased efficiency standard divided by the change in annual operating cost that results from a standard. The PBP represents the number of years it will take a consumer to recover an increased purchase price through decreased operating costs.

Inputs to the LCC and PBP analysis include (1) inputs for establishing total installed cost, including purchase price, and (2) inputs for determining operating costs. The primary inputs for establishing total installed cost are described below.

- *Baseline manufacturer cost* is that incurred by the manufacturer to produce a baseline product (one that meets current minimum efficiency standards).
- *Standard-level manufacturer cost increases* represent the change in manufacturer cost associated with producing a product that meets a given efficiency standard.
- *Markups and sales tax* are costs associated with converting the manufacturer cost to a consumer product price. Markups and sale tax are described in detail in chapter 6.
- *Installation cost* is the cost to the consumer of installing a product after purchase. The installation cost includes labor, overhead, and any miscellaneous materials and parts. Total installed cost equals the consumer product price plus installation cost.

The primary inputs for calculating operating costs are described below.

- *Product energy and water consumption* has two parts, the site energy and water use associated with operating a product. Chapter 7, Energy and Water Use Characterization, details how DOE used various data sources to develop energy and water consumption for each product class.
- *Product efficiency* dictates the energy and water consumption associated with a standard-level product (a product having an efficiency greater than that of the baseline product). Chapter 7 details how energy and water consumption change with increasing product efficiency.
- *Energy and water prices* are the prices consumers pay for those commodities. DOE determined current energy prices based on data from the DOE–EIA and *Natural Gas Monthly* (see section 8.2.2.2). DOE determined water prices based on data from the Raftelis Financial Consultants and the American Water Works Association[2] (see section 8.2.2.2).
- *Energy and water price trends* are used to forecast future energy prices. For the analyses described in this chapter, DOE used the reference case in EIA's *Annual Energy Outlook 2010*. DOE forecasted the trend in water prices based on Bureau of Labor Statistics' consumer price index (CPI) data specific to water and sewerage services.

- *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 a product. Section 8.2.2.4 details DOE's method for estimating repair and maintenance costs.
- *Lifetime*: The age at which a product is retired from service. Section 8.2.3 describes the distribution DOE developed for product lifetimes.
- *Discount rate*: The rate at which DOE discounted future expenditures to establish their present value (7 percent and 3 percent).

Figure 8.1.1 depicts the relationships among inputs for installed cost and operating costs that DOE used to calculate LCC and PBP. In Figure 8.1.1, 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 for Calculation of Life-Cycle Cost and Payback Period

Table 8.1.1 summarizes the input values DOE used to calculate the LCC and PBP for the four classes of residential clothes washers. Inputs to calculating total installed and operating costs include the lifetime, discount rate, and energy and water price trends. DOE used single-point values to characterize all the inputs to total installed cost, but used probability distributions to capture the uncertainty and/or variability in several of the inputs to operating costs. For those inputs characterized using probability distributions, the values in Table 8.1.1 are average or typical values. Also listed in the table is the section of this preliminary technical support document (TSD) that contains more detailed information on each input

Table 8.1.1 Residential Clothes Washers: Summary of Inputs to Life-Cycle Cost and Payback Period

Input	Product Class	Value	Characterization	TSD Section
Inputs to Total Installed Cost				
Baseline Manufacturer Cost	Top-Loading	0.84 IMEF* + 0W† standby; 9.92 IWF‡: $247.65	Single-point value	8.2.1.1
	Front-Loading	1.37 IMEF + 2.3W standby; 8.31 IWF: $518.13		
	Top-Loading Compact	0.59 IMEF* + 0W† standby; 14.4 IWF‡: $250.68		
	Front-Loading Compact	1.03 IMEF* + 2.3W† standby; 8.8 IWF‡: $515.75		
Increase in Manufacturer Cost for Standard Levels	Top-Loading	CSL§ 1 (0.98 IMEF + 0W standby): $3.11 CSL 2 (1.29 IMEF + 0W standby): $8.44 CSL 3 (1.34 IMEF + 2.3W standby): $13.06 CSL 4 (1.34 IMEF + 1.7W standby): $16.98 CSL 5 (1.37 IMEF + 0.08W standby): $14.24 CSL 6 (1.57 IMEF + 0.08W standby): $25.29 CSL 7 (1.83 IMEF + 0.08W standby): $60.65 CSL 8 (2.04 IMEF + 0.08W standby): $69.79	Single-point value	8.2.1.1
	Front-Loading	CSL 1 (1.39 IMEF + 1.7W standby): $3.92 CSL 2 (1.41 IMEF + 0.08W standby): $1.18 CSL 3 (1.49 IMEF + 0.08W standby): $3.18 CSL 4 (1.66 IMEF + 0.08W standby): $6.20 CSL 5 (1.84 IMEF + 0.08W standby): $17.25 CSL 6 (2.02 IMEF + 0.08W standby): $40.36 CSL 7 (2.2 IMEF + 0.08W standby): $53.88 CSL 8 (2.46 IMEF + 0.08W standby): $73.51		
	Top-Loading Compact	CSL§ 1 (0.86 IMEF + 0W standby): $5.00		
		CSL 2 (1.15 IMEF + 2.3W standby): $45.00		
	Front-Loading Compact	CSL§ 1 (1.13 IMEF + 0.08W standby): $3.00		
Manufacturer Markup	Top-Loading	Top-loading 1.22	Single-point value	6.2
	Front-Loading	Front-loading 1.22	Single-point value	6.2
Retailer Markup	Both	Baseline: 1.45 Incremental: 1.17	Single-point value	6.3
Sales Tax	Both	Top-loading, average: 7.17% Front-loading, average: 7.06%	Variable based on location	6.5
Inputs to Operating Costs				
Energy Prices	Both	Electricity = 0.12 ¢/kWh Gas = 13.13 $/MMBtu Oil = 24.67 $/MMBtu	Variable based on location	8.2.2.2

Input	Product Class	Value	Characterization	TSD Section
Water and Wastewater Prices	Both	Water = 3.30 $/10^3 gallon Wastewater = 3.87 $/10^3 gallon	Variable based on location	8.2.2.2
Repair and Maintenance Costs	Both	No appreciable difference between baseline and efficiency level repair costs	0	8.2.2.4
Lifetime	Both	14.2	Weibull distribution	8.2.3
Discount Rate	Both	Top-loading, average: 4.84% Front-loading, average: 4.69%	Custom distribution	8.2.4
Energy Price Trend	Both	AEO 2010	AEO reference case	8.2.2.3
Water and Wastewater Price Trend	Both	Extrapolated based on growth from 1970–2009, Bureau of Labor Statistics: CPI for water and sewerage.	Single forecast	8.2.2.3

* IMEF = integrated modified energy factor. The higher the IMEF value, the more efficient the clothes washer.
† W = watts.
‡ IWF = integrated water factor.
§ CSL = candidate standard level; one of the efficiency levels DOE is considering for new standards for clothes washers.

8.2 INPUTS TO LIFE-CYCLE COST ANALYSIS

Life-cycle cost is the total consumer cost throughout the life of an appliance, including purchase price and operating costs such as energy and water costs. DOE discounts future operating costs to the time of purchase and sums them over the lifetime of the product. DOE defines LCC by the following equation.

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

Where:

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

The following sections discuss total installed cost, operating cost, product lifetimes, and discount rate. Because DOE gathered most of its data for the LCC and PBP analysis in 2010, DOE expresses dollar values in 2010$.

8.2.1 Inputs to Total Installed Cost

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

$$IC = EQP + INST$$

Where:

EQP =	product price (price the consumer pays for the product, including taxes), expressed in dollars, and
INST =	installation cost (cost to the consumer to install the product, including labor and materials), also in dollars.

As discussed in chapter 6, DOE developed markups and sales taxes for converting manufacturing costs into consumer product prices. Total installed cost include:

- The *baseline manufacturer cost* is the cost incurred by the manufacturer to produce a product that meets current minimum efficiency standards.
- The *standard-level manufacturer cost increases* are the changes in manufacturer cost associated with producing a product that meets a given efficiency standard.
- *Manufacturer and retailer, markups plus sales tax* convert the manufacturer cost to a consumer product price.
- The *installation cost,* which is the cost to the consumer to install a product, represents all costs other than the marked-up consumer product price. The installation cost includes labor, overhead, and any miscellaneous materials and parts.

Thus, total installed cost equals the consumer product price plus the installation cost. DOE calculated the total installed cost for baseline products based on the following equation.

$$\begin{aligned} IC_{BASE} &= EQP_{BASE} + INST_{BASE} \\ &= COST_{MFG} \times MU_{OVERALL_BASE} + INST_{BASE} \end{aligned}$$

Where:

IC_{BASE} =	total installed cost for baseline product,
EQP_{BASE} =	consumer product price for baseline product,
$INST_{BASE}$ =	installation cost for baseline product,
$COST_{MFG}$ =	manufacturer cost for baseline product, and

$MU_{OVERALL_BASE}$ = overall baseline markup (product of manufacturer markup, baseline retailer markup, and sales tax).

DOE calculated the total installed cost for standard-level products based on the following equation.

$$\begin{aligned} IC_{STD} &= EQP_{STD} + INST_{STD} \\ &= \left(PP_{BASE} + \Delta PP_{STD}\right) + \left(INST_{BASE} + \Delta INST_{STD}\right) \\ &= \left(PP_{BASE} + INST_{BASE}\right) + \left(\Delta PP_{STD} + \Delta INST_{STD}\right) \\ &= IC_{BASE} + \left(\Delta COST_{MFG} \times MU_{OVERALL_INCR} + \Delta INST_{STD}\right) \end{aligned}$$

Where:

IC_{STD} = total installed cost for standard-level product,
EQP_{STD} = consumer product price for standard-level product,
$INST_{STD}$ = installation cost for standard-level product,
PP_{BASE} = consumer product price for baseline product,
ΔPP_{STD} = change in product price for standard-level product,
$INST_{BASE}$ = installation cost for baseline product,
$\Delta INST_{STD}$ = change in installation cost for standard-level product,
IC_{BASE} = total installed cost for baseline product,
$\Delta COST_{MFG}$ = change in manufacturer cost for standard-level product, and
$MU_{OVERALL_INCR}$ = incremental overall markup (product of manufacturer markup, incremental retailer markup, and sales tax).

The remainder of this section describes in detail each input variable that DOE used to calculate total installed costs for residential clothes washers.

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.

In light of these data and DOE’s aim to improve the accuracy and robustness of its analyses, for this analysis DOE performed an exponential fit on historical Producer Price Index (PPI) data for household laundry equipment from the Bureau of Labor Statistics’ (BLS). (PPI data specific to residential clothes washers were not available.) The PPI data used cover the period 1991–2010. An inflation-adjusted price index for household laundry equipment was calculated by dividing the PPI series by the GDP price deflator for the same years.

DOE forecast a price factor index using this exponential model. The value for 2015 used in the LCC and PBP analysis is 0.882. Thus, product prices forecast for the LCC and PBP analysis are equal to 0.882 times the 2010 values for each efficiency level in each product class. The details of DOE's approach are described in Appendix 8-E.

8.2.1.2 Baseline Manufacturer Cost

DOE used data from AHAM to develop the baseline manufacturer costs for front-loading and top-loading clothes washers.[3] Based on a manufacturer markup of 1.22 for all clothes washers as determined in section 6.2 of chapter 6, DOE arrived at a baseline manufacturer cost of $518.13 for front-loading standard-size clothes washers, $247.65 for top-loading standard-size clothes washers, $250.68 for top-loading compact-size clothes washers, and $515.75 for front-loading compact-size clothes washers. Table 8.2.1 presents the baseline manufacturer costs along with the associated baseline modified energy factor, integrated modified energy factor, and water factor, for the four product classes of residential clothes washers.

Table 8.2.1 Baseline Manufacturer Costs

Product Class	Baseline MEF cu ft/kWh/cycle*	Baseline IMEF	Baseline IWF gallons/cu ft	Baseline Manufacturer Cost 2010$
Top-loading	1.26 MEF	0.84	9.92	247.65
Front-loading	1.72 MEF + 2.3 W standby	1.37	8.31	518.13
Top-loading compact	0.77 MEF	0.59	14.40	250.68
Front-loading compact	1.6 MEF	1.03	8.80	515.75

* Cubic feet per kilowatt-hour per cycle.
Source: AHAM 2010.

8.2.1.3 Increases in Manufacturer Costs

DOE used cost data submitted by AHAM, along with a reverse engineering analysis, to develop manufacturer cost increases associated with increases in standard levels for residential clothes washers. Refer to chapter 5 for details. Tables 8.2.2 through 8.2.5 present the standard-level manufacturer cost increases and associated modified energy factors and water factors for the four product classes.

Table 8.2.2 Top-Loading Clothes Washers: Standard-Level Manufacturer Cost Increases

Standard Level	MEF cu ft/kWh/cycle	IMEF	IWF gallons/cu ft	Manufacturer Cost Increase 2010$
Baseline	1.26	0.84	9.92	NA
1	1.40	0.98	9.92	$3.11
2	1.72	1.29	8.44	$8.44
3	1.80	1.34	7.95	$13.06
4	1.80	1.34	7.95	$16.98
5	1.80	1.37	7.95	$14.24
6	2.00	1.57	6.47	$25.29
7	2.26	1.83	4.96	$60.65
8	2.47	2.04	4.10	$69.79

Table 8.2.3 Front-Loading Clothes Washers: Standard-Level Manufacturer Cost Increases

Standard Level	MEF cu ft/kWh/cycle	IMEF	WF gallons/cu ft	Manufacturer Cost Increase 2010$
Baseline	1.72	1.37	8.31	NA
1	1.72	1.39	8.31	$3.92
2	1.72	1.41	8.31	$1.18
3	1.80	1.49	7.80	$3.18
4	2.00	1.66	6.26	$6.20
5	2.20	1.84	4.73	$17.25
6	2.40	2.02	4.42	$40.36
7	2.60	2.20	4.01	$53.88
8	2.89	2.46	3.39	$73.51

Table 8.2.4 Top-Loading Compact Clothes Washers: Standard-Level Manufacturer Cost Increases

Standard Level	MEF cu ft/kWh/cycle	IMEF	WF gallons/cu ft	Manufacturer Cost Increase 2010$
Baseline	0.77	0.59	14.40	NA
1	1.26	0.86	14.40	$5.00
2	1.81	1.15	12.00	$45.00

Table 8.2.5 Front-Loading Compact Clothes Washers: Standard-Level Manufacturer Cost Increases

Standard Level	MEF cu ft/kWh/cycle	IMEF	WF gallons/cu ft	Manufacturer Cost Increase 2010$
Baseline	1.60	1.03	8.80	NA
1	1.72	1.13	8.30	$3.00

8.2.1.4 Markup and Sales Tax

The overall markup is determined by multiplying the manufacturer markups, retailer markups, and sales tax together to arrive at a single markup value. Table 8.2.6 shows the overall baseline and incremental markups for residential clothes washers. Refer to chapter 6 for details.

Table 8.2.6 Overall Markup

	Front-Loading		Top-Loading	
Markup	**Baseline**	**Incremental**	**Baseline**	**Incremental**
Manufacturer	1.22		1.22	
Retailer	1.45	1.17[a]	1.45	1.17[a]
Sales Tax	7.06%		7.17%	
Overall	1.89	1.53	1.90	1.53

8.2.1.5 Total Installed Cost

Because the cost to install residential clothes washers does not change as efficiency increases, DOE did not incorporate installation costs in its analysis.

8.2.2 Inputs to Operating Costs

DOE uses the following equation to define the operating cost for an appliance.

$$OC = EC + WC + RC + MC$$

Where:

$OC =$ operating cost,

[a] The LCC analysis for the preliminary analysis was conducted prior to finalization of the new markup calculation described here. It used an interim value of 1.19. For the NOPR, DOE plans to use 1.17 for the incremental retail markup.

EC = energy cost associated with operating the product,
WC = water cost associated with operating the product,
RC = repair costs associated with component failure, and
MC = service costs for maintaining product operation.

The inputs for calculating operating costs also are needed to determine lifetime operating costs, which include trends in energy and water prices, product lifetimes, discount rate, and effective date of a new standard:

- The *annual energy consumption* is the site energy use associated with operating the product.
- The *annual water consumption* is the site water use associated with operating the product. Annual energy and water consumption change with product efficiency. That is, the energy and water consumption associated with a standard-level product (*i.e.*, a product having an efficiency greater than that of the baseline product) are less than those associated with a baseline product.
- *Energy and water prices* are the prices consumers pay for energy (electricity or gas) and water. Multiplying annual energy consumption by energy prices and water consumption by water prices yields the annual costs for energy and water.
- *Repair costs* are costs associated with repairing or replacing components that fail.
- *Maintenance costs* are costs associated with maintaining operation of the product.
- DOE used *energy and water price trends* to forecast prices into the future. DOE used those forecasts, along with the product lifetime and discount rate, to establish lifetime energy and water costs.
- The *product lifetime* is the age at which a product is retired from service.
- The *discount rate* is the rate at which DOE discounted future expenditures to establish their present value (7% and 3%).

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

$$\begin{aligned} OC_{BASE} &= EC_{BASE} + WC_{BASE} + RC_{BASE} + MC_{BASE} \\ &= AEC_{BASE} \times PRICE_{ENERGY} + AWC_{BASE} \times PRICE_{WATER} + RC_{BASE} + MC_{BASE} \end{aligned}$$

Where:

OC_{BASE} = operating cost for baseline product,
EC_{BASE} = energy cost associated with operating baseline product,
WC_{BASE} = water cost associated with operating baseline product,
RC_{BASE} = repair cost associated with component failure for baseline product,
MC_{BASE} = service cost for maintaining operation of baseline product,
AEC_{BASE} = annual energy consumption for baseline product,
$PRICE_{ENERGY}$ = energy price,
AWC_{BASE} = annual water consumption for baseline product, and

$PRICE_{WATER}$ = water price.

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

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

Where:

OC_{STD} = operating cost for standard-level product,
EC_{STD} = energy cost associated with operating standard-level product,
WC_{STD} = water cost associated with operating standard-level product,
RC_{STD} = repair cost associated with component failure for standard-level product,
MC_{STD} = service cost for maintaining operation of standard-level product,
AEC_{STD} = annual energy consumption for standard-level product,
$PRICE_{ENERGY}$ = energy price,
AWC_{STD} = annual water consumption for standard-level product,
$PRICE_{WATER}$ = water price,
ΔAEC_{STD} = change in annual energy consumption associated with standard level product,
ΔAWC_{STD} = change in annual water consumption associated with standard-level product,
ΔRC_{STD} = change in repair cost associated with standard-level product, and
ΔMC_{STD} = change in maintenance cost associated with standard-level product.

The rest of this section provides information about each of the input variables that DOE used to calculate operating costs for residential clothes washers.

8.2.2.1 Annual Energy and Water Consumption

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

As described in chapter 7 and section 8.1.1 of this chapter, DOE developed samples of individual households that use one of the product classes of clothes washer. By developing household samples, DOE was able to calculate the LCC and PBP for each household to account for the variability in the usage and price of both energy and water. DOE used EIA's 2005 RECS to develop the household samples and, in turn, to establish the variability both in annual energy and water consumption and in energy and water price. Refer to chapter 7 to review the variability of usage and therefore, annual energy consumption for residential clothes washers.

Tables 8.2.7 through 8.2.10 provide the per cycle energy and annual water consumption by efficiency level for the four product classes of residential clothes washers.The tables are similar to those in section 7.2 of chapter 7. Based on data from the RECS, 39.4 percent of single- and multi-family housing units use electric water heating, 57.2 percent use gas water heating, and 3.4 percent use oil. Refer to chapter 7, to review how DOE characterized the variability in clothes washer usage. Keep in mind that the tables present only average annual water consumption. DOE captured the variability in energy and water consumption when it conducted its LCC and PBP analysis.

Table 8.2.7 Top-Loading Clothes Washers: Energy and Water Use per Cycle by Efficiency Level

Standard Level	IMEF cu ft/ kWh/cycle	IWF gal./cu ft	Water Heating†			Dryer Heating		Machine kWh	Water Use gallon
			Elec kWh	Gas MMBtu	Oil MMBtu	Elec kWh	Gas MMBtu		
Baseline	0.84	9.92	1.24	0.0057	0.0057	2.16	0.0082	0.28	30.6
1	0.98	9.92	0.74	0.0034	0.0034	2.43	0.0093	0.28	33.5
2	1.29	8.44	0.69	0.0032	0.0032	1.69	0.0065	0.23	28.5
3	1.34	7.95	1.26	0.0057	0.0057	1.41	0.0054	0.08	29.9
4	1.34	7.95	1.26	0.0057	0.0057	1.41	0.0054	0.08	29.9
5	1.37	7.95	1.25	0.0057	0.0057	1.41	0.0054	0.08	29.3
6	1.57	6.47	0.99	0.0045	0.0045	1.38	0.0053	0.08	25.0
7	1.83	4.96	0.67	0.0031	0.0031	1.41	0.0054	0.08	19.6
8	2.04	4.10	0.66	0.0030	0.0030	1.39	0.0053	0.08	17.8

† Electric and gas water heating are based on water heater recovery efficiencies of 100% for electric, 75% for gas, and 75% for oil.

Table 8.2.8 Front-Loading Clothes Washers: Energy and Water Use per Cycle by Efficiency Level

Standard Level	IMEF cu ft/ kWh/cycle	IWF gal./cu ft	Water Heating† Elec kWh	Water Heating† Gas MMBtu	Water Heating† Oil MMBtu	Dryer Heating Elec kWh	Dryer Heating Gas MMBtu	Machine kWh	Water Use gallon
Baseline	1.37	8.31	0.69	0.0032	0.0032	1.31	0.0050	0.11	24.9
1	1.39	8.31	0.69	0.0031	0.0031	1.31	0.0050	0.11	24.9
2	1.41	8.31	0.70	0.0032	0.0032	1.31	0.0050	0.11	24.9
3	1.49	7.80	0.60	0.0027	0.0027	1.31	0.0050	0.11	23.4
4	1.66	6.26	0.40	0.0018	0.0018	1.42	0.0054	0.16	20.7
5	1.84	4.73	0.36	0.0016	0.0016	1.34	0.0051	0.15	16.1
6	2.02	4.42	0.20	0.0009	0.0009	1.41	0.0054	0.16	15.9
7	2.20	4.01	0.21	0.0009	0.0009	1.37	0.0052	0.17	15.4
8	2.46	3.39	0.04	0.0002	0.0002	1.51	0.0058	0.16	13.2

† Electric and gas water heating are based on water heater recovery efficiencies of 100% for electric, 75% for gas, and 75% for oil.

Table 8.2.9 Top-Loading Compact Clothes Washers: Energy and Water Use per Cycle by Efficiency Level

Standard Level	IMEF cu ft/ kWh/cycle	IWF gal./cu ft	Water Heating† Elec kWh	Water Heating† Gas MMBtu	Water Heating† Oil MMBtu	Dryer Heating Elec kWh	Dryer Heating Gas MMBtu	Machine kWh	Water Use gallon
Baseline	0.59	14.4	0.90	0.0041	0.0041	1.35	0.005	0.3	21.6
1	0.86	14.4	0.40	0.0018	0.0018	1.35	0.005	0.1	22.9
2	1.15	12.0	0.34	0.0016	0.0016	0.87	0.003	0.1	19.1

† Electric and gas water heating are based on water heater recovery efficiencies of 100% for electric, 75% for gas, and 75% for oil.

Table 8.2.10 Front-Loading Compact Clothes Washers: Energy and Water Use per Cycle by Efficiency Level

Standard Level	IMEF cu ft/ kWh/cycle	IWF gal./cu ft	Water Heating† Elec kWh	Water Heating† Gas MMBtu	Water Heating† Oil MMBtu	Dryer Heating Elec kWh	Dryer Heating Gas MMBtu	Machine kWh	Water Use gallon
Baseline	1.03	8.80	0.27	0.0012	0.0012	1.02	0.004	0.1	13.2
1	1.13	8.30	0.20	0.0009	0.0009	1.02	0.004	0.1	12.5

† Electric and gas water heating are based on water heater recovery efficiencies of 100% for electric, 75% for gas, and 75% for oil.

8.2.2.2 Energy and Water Prices

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

Electricity Prices

DOE derived average energy prices from data that are published annually based on EIA Form 861. Those data include, for every utility that serves final consumers, annual electricity sales in kilowatt-hours; revenues from electricity sales; and number of customers in the residential, commercial, and industrial sectors. DOE calculated prices for each of 13 geographic areas: the nine U.S. Census divisions plus four large states (New York, Florida, Texas, and California). For Census divisions that contain one of the large states, DOE removed the data for that state from the calculation of the regional average. The Pacific region average does not include California, for example, and the West South Central does not include Texas.

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

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

Table 8.2.11 shows results for the 13 geographic regions.

Table 8.2.11 Average Residential Electricity Prices

Geographic Area	Average Price 2010$/kWh
New England	$0.179
Middle Atlantic (excluding New York)	$0.133
East North Central	$0.107
West North Central	$0.090
South Atlantic (excluding Florida)	$0.104
East South Central	$0.094
West South Central (excluding Texas)	$0.098
Mountain	$0.100
Pacific (excluding California)	$0.107
New York	$0.194
Florida	$0.140
Texas	$0.132
California	$0.118

Source: EIA Form 861 for 2009.

Natural Gas Prices

DOE obtained data for calculating regional prices of natural gas from the EIA publication, *Natural Gas Navigator*.[4] This publication presents monthly volumes of natural gas deliveries and average prices by state for residential, commercial, and industrial customers. The Department used the complete annual data for 2009 to calculate an average annual price for each geographic area. The calculation of average prices proceeded in two steps.

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

The method used to calculate natural gas prices differs from that used to calculate electricity prices, because the EIA does not provide consumer- or utility-level data on gas consumption and prices. The prices in Table 8.2.12 are in dollars per thousand cubic feet ($/tcf).

Table 8.2.12 Average Residential Natural Gas Prices

Geographic Area	Average Price 2010$/tcf
New England	$16.64
Middle Atlantic (excluding New York)	$15.49
East North Central	$11.84
West North Central	$11.83
South Atlantic (excluding Florida)	$17.46
East South Central	$14.62
West South Central (excluding Texas)	$13.97
Mountain	$12.18
Pacific (excluding California)	$14.93
New York	$15.53
Florida	$9.21
Texas	$12.63
California	$21.35

Source: EIA *Natural Gas Monthly*, 2009

Because DOE conducted the LCC and PBP analysis in 2010, all natural gas prices are in 2010$.

Water Prices

DOE obtained data on water prices for 2010 from the *Water and Wastewater Rate Survey* conducted by Raftelis Financial Consultants and the American Water Works Association.[2] The survey covers approximately 308 water utilities and 228 wastewater utilities, analyzing each industry (water and wastewater) separately. The water survey includes, for each utility, the cost to consumers of a given volume of water. The total consumer cost is divided into fixed and volumetric charges. DOE's calculation of water prices uses only volumetric charges, because only those charges would be affected by a change in water consumption. Including the fixed charge in the average would lead to a slightly higher water price.

For wastewater utilities, the data format is similar, except that the price represents the cost to treat a given volume of wastewater. A sample of 308 or 228 utilities is too small to calculate regional prices for all U.S. Census divisions and large states (for comparison, data from EIA Form 861 cover more than 3,000 utilities). Therefore, DOE calculated regional costs for wastewater service at the level of Census regions only (Northeast, South, Midwest, and West). The calculation of average prices per unit volume proceeds in three steps.

1. For each water or wastewater utility, DOE calculated the price per unit volume by dividing the total volumetric cost by the volume delivered.

2. DOE calculated a state-level average price by weighting each utility in a given state by the number of residential customers it serves.
3. DOE calculated a regional average by combining the state-level averages, weighting each by the state's population. This third step helps reduce any bias in the sample that may result from the relative under-sampling of large states.

Table 8.2.13 presents the results of the calculation of costs for water and wastewater service. The price units in the table are 2010 dollars per thousand gallons (/tg).

Table 8.2.13 Average Water and Wastewater Prices per Unit Volume

Census Region	Water 2010$/tg	Wastewater 2010$/tg
Northeast	$4.07	$3.53
Midwest	$2.21	$2.77
South	$3.01	$4.68
West	$4.06	$3.96
National Average	$3.30	$3.87

8.2.2.3 Trends in Energy and Water Prices

DOE used EIA price forecasts to estimate the trends in natural gas and electricity prices. To arrive at prices in future years, it multiplied the average prices described in section 8.2.2.2 by the forecast of annual average price changes in EIA's *AEO 2010*.[5] To estimate the trends after 2035, DOE followed past guidelines provided to the Federal Energy Management Program by EIA and used the average rate of change during 2020–2035. For the LCC results presented in section 8.4, DOE used the energy price forecasts from the AEO reference case only.

Figure 8.2.1 Trends in Electricity Prices

Figure 8.2.2 Trends in Natural Gas Prices

To estimate the future trend for water and wastewater prices, DOE used data on the historic trend in the national water price index (U.S. city average) from 1970 through 2009.[6] DOE extrapolated the future trend based on the linear growth from 1970 to 2009. DOE used the extrapolated trend to forecast prices through 2044. Figure 8.2.3 shows historical and projected trends in water and sewerage prices. DOE used the forecasted data to estimate water and wastewater prices for residential clothes washer use.

Figure 8.2.3 Trend in Water and Sewerage Prices

8.2.2.4 Repair and Maintenance Costs

Typically, small changes in product efficiency produce no, or only slight, changes in repair and maintenance costs compared to baseline products. DOE assumes that for the efficiency levels of all product classes there is no appreciable change in repair costs.

8.2.3 Product Lifetimes

RECS records the presence of various appliances in each household, and places the age of each appliance into bins comprising several years. Data from the U.S. Census's *American Housing Survey* (AHS),[7] which surveys all housing including vacant and second homes, enabled DOE to adjust the RECS data to reflect some appliance use outside of primary residences. By combining the results of both surveys with the known history of appliance shipments (collected from *Appliance* magazine or directly from manufacturer trade associations), DOE estimated the percentage of appliances of a given age still in operation. This survival function, which DOE assumed has the form of a cumulative Weibull distribution, provides an average and a median appliance lifetime. DOE calculated the average lifetime all both product classes at 14.2 years.

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

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

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

Where:

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

[b] For reference on the Weibull distribution, see sections 1.3.6.6.8 and 8.4.1.3 of the *NIST/SEMATECH e-Handbook of Statistical Methods*, <www.itl.nist.gov/div898/handbook/>.

Figure 8.2.4 Weibull Retirement Function for Clothes Washers

Appendix 8C presents the Weibull distributions that DOE used in the LCC and PBP analysis.

8.2.4 Discount Rates

The discount rate is the rate at which DOE discounts future expenditures to establish their present value. DOE derived discount rates for the LCC and PBP analyses from estimates of the cost to finance the purchase of the considered products. Following financial theory, the financial cost of raising funds to purchase appliances can be interpreted as: (1) the financial cost of any debt incurred to purchase a product, or (2) the opportunity cost of any equity used to purchase a product.

8.2.4.1 Discount Rates for Residential Consumers

Households use various methods to finance the purchase of major appliances. In principle, one could estimate the interest rates on the actual financing vehicles used to purchase appliances. The frequency with which each financing vehicle is used to purchase an appliance is unknown, however.

DOE's approach involved identifying all possible debt or asset classes that might be used to purchase the considered appliances, including household assets that might be affected indirectly.[c] DOE excluded debt from primary mortgages and the equity of assets considered non-liquid (such as retirement accounts), because those are unlikely to be used to purchase

[c] An indirect effect would arise if a household sold assets in order to pay off a loan or credit card debt that might have been used to finance the appliance purchase.

appliances. DOE estimated the average percentage shares of the various types of debt and equity in the average U.S. household using data from the Federal Reserve Board's *Survey of Consumer Finances (SCF)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[8] Table 8.2.14 shows the average percentages of each considered type of debt or equity. DOE derived the mean percentages of each source of financing throughout the 7 years surveyed.

Table 8.2.14 Types of Household Debt and Equity by Percentage Shares

Type of Debt or Equity	1989 %	1992 %	1995 %	1998 %	2001 %	2004 %	2007 %	Mean %
Home equity loan	4.3	4.5	2.7	2.8	2.8	4.4	4.6	3.7
Credit card	1.6	2.1	2.6	2.2	1.7	2.0	2.4	2.1
Other installment loan	2.8	1.7	1.4	1.7	1.1	1.3	1.1	1.6
Other residential loan	4.4	6.9	5.2	4.3	3.1	5.8	7.1	5.3
Other line of credit	1.1	0.6	0.4	0.2	0.3	0.5	0.3	0.5
Checking account	5.8	4.7	4.9	3.9	3.6	4.2	3.4	4.4
Savings or money market account	19.2	18.8	14.0	12.8	14.2	15.1	13.0	15.3
Certificate of deposit	14.5	11.7	9.4	7.0	5.4	5.9	6.5	8.6
Savings bond	2.2	1.7	2.2	1.1	1.2	0.9	0.7	1.4
Bonds	13.8	12.3	10.5	7.0	7.9	8.4	6.7	9.5
Stocks	22.4	24.0	25.9	36.9	37.5	28.0	28.6	29.0
Mutual funds	8.0	11.1	20.9	20.1	21.3	23.4	25.5	18.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.

DOE estimated interest or return rates associated with each type of equity and debt. The source for interest rates for loans, credit cards, and lines of credit was the Federal Reserve Board's SCF for 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Table 8.2.15 shows the average nominal rates in each year and the inflation factors used to calculate real rates. DOE calculated effective interest rates for home equity loans in a similar manner as for mortgage rates, because interest on both such loans is tax deductible. Table 8.2.16 shows the 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, they are expected to be representative of rates that may be in effect in 2014.

Table 8.2.15 Average Nominal Interest Rates for Household Debt

Type of Debt	1989 %	1992 %	1995 %	1998 %	2001 %	2004 %	2007 %	Mean %
Home equity loan	11.5	9.6	9.6	9.8	8.7	5.7	6.3	7.9
Credit card*	-	-	14.2	14.5	14.2	11.7	7.9	9.0
Other installment loan	9.0	7.8	9.3	7.8	8.7	7.4	12.6	13.4
Other residential loan	8.8	7.6	7.7	7.7	7.5	6.0	10.4	8.6
Other line of credit	14.8	12.7	12.4	11.9	14.7	8.8	6.3	7.4
Inflation rate	4.82	3.01	2.83	1.56	2.85	2.66	2.85	

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.
* No data on interest rates available for credit cards in 1989 or 1992.

Table 8.2.16 Average Real Effective Interest Rates for Household Debt

Type of Debt	1989 %	1992 %	1995 %	1998 %	2001 %	2004 %	2007 %	Mean %
Home equity loan	3.8	4.3	4.4	5.8	3.8	1.9	2.1	3.0
Credit card*	-	-	11.0	12.7	11.1	9.1	3.3	3.9
Other installment loan	4.9	5.8	7.0	6.6	6.1	5.4	9.7	10.7
Other residential loan	4.0	4.7	4.8	6.0	4.6	3.3	5.8	6.0
Other line of credit	9.6	9.4	9.3	10.2	7.3	6.0	3.4	4.4

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.
* No data on interest rates available for credit cards in 1989 or 1992.

No similar rate data are available from the *SCF* for classes of assets, so the Department derived that information from national historical data. The interest rates associated with certificates of deposit,[9] savings bonds,[10] and bonds (AAA corporate bonds)[11] were collected from Federal Reserve Board time-series data for 1977–2009. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts came from Cost of Savings Index data covering 1984–2009.[12] The rates for stocks are the annual returns on the Standard and Poor's 500 for 1977–2009. [13] Rates for mutual funds are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year for 1977–2009. DOE adjusted the nominal rates to real rates using the annual inflation rate for each year. Average nominal and real interest rates for the classes of household assets are listed in Table 8.2.17. 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 2014.

Table 8.2.17 Average Nominal and Real Interest Rates for Household Equity

Type of Equity	Average Nominal Rate %	Average Real Rate %
Checking account	-	0.0
Savings and money market accounts	5.4	2.2
Certificate of deposit	6.6	2.3
Savings bond	7.7	3.3
Bonds	8.5	4.1
Stocks	11.6	7.1
Mutual funds	10.3	5.8

Table 8.2.18 summarizes the mean real effective rates of each type of equity or debt. DOE determined the average percentage of each type of debt and asset using *SCF* data for 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Each year of SCF data provides the percents of debts and assets for U.S. households. DOE averaged those percentages for the 7 years of survey data to arrive at the percentages shown in Table 8.2.15. The average rate across all types of household debt and equity, weighted by the percentages of each type, is 4.8 percent.

Table 8.2.18 Average Interest on Household Debt and Equity

Type of Debt or Equity	Average % of Household Debt plus Equity*	Mean Effective Real Rate %**
Home equity loan	3.7	3.9
Credit card	2.1	10.7
Other installment loan	1.6	6.0
Other residential loan	5.3	4.4
Other line of credit	0.5	8.8
Checking account	4.4	0.0
Savings and money market account	15.3	2.2
Certificate of deposit	8.6	2.3
Savings bond	1.4	3.3
Bonds	9.5	4.1
Stocks	29.0	7.1
Mutual funds	18.6	5.8
Total/weighted-average discount rate	100.0	4.8

* Not including primary mortgage or retirement accounts.

** Adjusted for inflation and, for home equity loans, tax deduction of interest.

8.2.4.2 Assignment of Discount Rates to Sample Households

To account for variations among households, DOE assigned each sampled RECS household a rate from a distribution of rates for each type of debt and equity. DOE developed a probability distribution of interest rates based on SCF data.

8.2.5 Compliance Date of Standard

The compliance date is the future date at which a new standard becomes operative. Based on DOE's implementation report on activities related to energy conservation standards, submitted pursuant to Section 141 of the Energy Policy Act of 2005, a final rule for clothes washers is scheduled for completion in December 2011.[14] The compliance date of any new energy efficiency standards for clothes washers will be three years after the final rule is published, or January 2015. The Department calculated the LCC for all consumers as if each would purchase a new clothes washer in 2015.

8.2.6 Energy Efficiency in the Base Case

In determining the LCC for clothes washers, DOE analyzed standard levels relative to a base case efficiency. Some consumers already purchase products that have efficiencies greater than baseline levels, however. To estimate accurately the percentage of consumers who would be affected by a particular standard level, DOE took into account the distribution of product

efficiencies currently in the marketplace. In other words, rather than analyzing the impacts of a particular standard assuming that all consumers currently purchase products that function at the baseline level, DOE conducted the analysis by accounting for the full breadth of product efficiencies that consumers purchase under the base case (*i.e.*, the case without new energy efficiency standards).

As noted in section 8.1.1, DOE's approach to conducting the LCC analysis for residential clothes washers relied on developing samples of households that use each product class. DOE used Monte Carlo simulation to calculate the LCC for the households in the sample. Using the current distribution of product efficiencies, DOE assigned each sampled household a unique product efficiency. Because it calculated the LCC on a household-by-household basis, DOE based the LCC for a particular candidate standard level (CSL) on the efficiency of the product assigned to each given household. For example, if a household was assigned a product efficiency greater than or equal to the efficiency of the CSL under consideration, the LCC calculation would reveal that the household would not be affected by an increase in product efficiency equal to the standard level. The distributions of product efficiencies that DOE used for the LCC analysis for clothes washers are discussed in detail below.

DOE relied on data submitted by AHAM to estimate the base-case efficiency distributions for each of the product classes that were analyzed in the LCC and PBP analysis. To project the efficiency distributions in 2015, DOE considered the 2006–2008 trends and the potential effect of programs such as ENERGY STAR.

For front-loading clothes washers, the data from AHAM show some increase in the share of higher efficiency levels between 2006 and 2008. However, by 2008 over 95 percent of the front-loading clothes washer market was already at or above the 2011 ENERGY STAR criteria (Efficiency Level 4). Therefore, DOE believes that the new ENERGY STAR qualification requirements are likely to have a limited impact in further expanding the market shares of higher efficiency front-loading clothes washers. Based on the above considerations, DOE assumed that these market shares would remain constant through 2015.

For top-loading clothes washers, the data from AHAM show an increase in the share of medium- and high-efficiency levels (2-8) from 6.3 percent in 2006 to 8.5 percent in 2008. DOE fit an exponential curve to the three data points, assuming that the growth in share would level off at around 20 percent. The estimated total share of the medium- and high-efficiency levels in 2015 is 19.2 percent. DOE then disaggregated this total share using the following breakdown: 14.5% to CSL 2, 4.8% each to CSLs 3-5, 47.4% to CSL 6, 23.7% to CSL 7, and 0.0% to CSL 8.

For the compact product classes, DOE estimated that the entire market would be at the baseline efficiency levels in 2015. There are currently no compact clothes washer models available that exceed the baseline level.

Tables 8.2.19 through 8.2.22 present the market shares of efficiency levels in the base case for the four product classes. The tables describe the efficiency levels of each product class that consumers would purchase in 2015 in the absence of new standards.

Table 8.2.19 Top-Loading Clothes Washers: Base-Case Market Shares

Standard Level	MEF	IMEF	IWF	Market Share %
Baseline	1.26	0.84	9.92	40.4
1	1.40	0.98	9.92	40.4
2	1.72	1.29	8.44	2.8
3	1.80	1.34	7.95	0.9
4	1.80	1.34	7.95	0.9
5	1.80	1.37	7.95	0.9
6	2.00	1.57	6.47	9.1
7	2.26	1.83	4.96	4.6
8	2.47	2.04	4.10	0.0

Table 8.2.20 Front-Loading Clothes Washers: Base-Case Market Shares

Standard Level	MEF	IMEF	IWF	Market Share %
Baseline	1.72	1.37	8.31	0.0
1	1.72	1.39	8.31	0.0
2	1.72	1.41	8.31	0.0
3	1.80	1.49	7.80	4.3
4	2.00	1.66	6.26	24.0
5	2.20	1.84	4.73	48.9
6	2.40	2.02	4.42	11.4
7	2.60	2.20	4.01	11.4
8	2.89	2.46	3.39	0.0

Table 8.2.21 Top-Loading Compact Clothes Washers: Base-Case Market Shares

Standard Level	MEF	IMEF	IWF	Market Share %
Baseline	0.77	0.59	14.40	100.0
1	1.26	0.86	14.40	0.0
2	1.81	1.15	12.00	0.0

Table 8.2.22 Front-Loading Compact Clothes Washers: Base-Case Market Shares

Standard Level	MEF	IMEF	IWF	Market Share %
Baseline	1.60	1.03	8.80	100.0
1	1.72	1.13	8.30	0.0

8.3 INPUTS TO PAYBACK PERIOD ANALYSIS

The payback period (PBP) is the amount of time it takes a consumer to recover, through lower operating costs, the assumed higher purchase price of a more energy efficient product. Numerically, the PBP is the ratio of the increase in purchase price (from a less efficient to more efficient design) to the decrease in annual operating costs. This type of calculation provides what is known as a simple payback period, because it does not take into account changes in operating costs over time or the time value of money. That is, the calculation is done at an effective discount rate of 0 percent.

The equation for PBP is:

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

Where:

ΔIC = difference in the total installed cost between the standard-level unit and the baseline unit, and

ΔOC = difference in annual operating costs.

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

The data inputs to PBP are the total installed cost of the product to the consumer for each efficiency level and the annual first-year operating costs for each CSL. The inputs to the total

installed cost are the product price and the installation cost. The inputs to the operating costs comprise the annual costs of energy and water, repair, and maintenance. The PBP uses the same inputs as the LCC analysis described in section 8.2, except that it does not require trends in energy and water prices or discount rates. Because the PBP is a simple payback, the energy and water prices are only for the year in which a new standard takes effect—in this case, 2015. The energy and water prices DOE used in the PBP calculation were the prices projected for that year.

8.4 RESULTS OF ANALYSES

This section presents the LCC and PBP results for residential clothes washers. As discussed in section 8.1.1, DOE's approach to conducting the LCC analysis relied on developing samples of households that use each product class. DOE also used probability distributions to characterize the uncertainty in many of the inputs. DOE applied a Monte Carlo simulation to calculate the LCC for the households in the sample. For each set of sample households using a particular product class, DOE calculated the average LCC and LCC savings and the median and average PBP for each CSL.

DOE calculated LCC savings and PBPs relative to the base-case product it assigned to the households. As discussed in section 8.2.6, DOE assigned some households a base-case product that was more efficient than some of the CSLs. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific CSL and the LCC of the baseline product.

LCC and PBP calculations were performed 10,000 times on the sample of households established for each product class. Each LCC and PBP calculation was performed on a single household selected from the sample. The selection of a household was based on its weight (*i.e.*, how representative a particular household 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.

DOE utilized results of the Monte Carlo simulation on 10,000 samples to calculate, for the base case and each CSL, the percent of households that would experience a net LCC benefit, a net LCC cost, or no impact. DOE considered a household to receive no impact at a given CSL if DOE assigned it a base-case product having an efficiency equal to or greater than the CSL. The following sections present figures showing the distribution of LCC impacts and of PBPs for each product class under the base case and each CSL. The figures are presented as frequency charts that show the distribution of LCCs, LCC impacts, and PBPs, along with their corresponding probability of occurrence.

8.4.1 Distributions of Life-Cycle Cost for Baseline Units

The figures below are presented as frequency charts that show the distribution of LCCs, LCC impacts, and PBPs with their corresponding probability of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples.

Figures 8.4.1 through 8.4.4 show frequency charts for the baseline LCC for the four product classes.

Figure 8.4.1 Top-Loading Clothes Washers: Distribution of Life-Cycle Cost for Baseline Unit

Figure 8.4.2 Front-Loading Clothes Washers: Distribution of Life-Cycle Cost for Baseline Unit

Figure 8.4.3 Top-Loading Compact Clothes Washers: Distribution of Life-Cycle Cost for Baseline Unit

Figure 8.4.4 Front-Loading Compact Clothes Washers: Distribution of Life-Cycle Cost for Baseline Unit

8.4.2 Distributions of Life-Cycle Cost Under New Standards

Figures 8.4.5 through 8.4.8 are examples of frequency charts showing the distribution of LCC savings for clothes washers at the CSL levels corresponding to TSL 3. DOE can generate frequency charts similar to those shown for every CSL.

Figure 8.4.5 Top-Loading Clothes Washers: Distribution of Impacts on Life-Cycle Cost for Candidate Standard Level 2

Figure 8.4.6 Front-Loading Clothes Washers: Distribution of Impacts on Life-Cycle Cost for Candidate Standard Level 5

Figure 8.4.7 Top-Loading Compact Clothes Washers: Distribution of Impacts on Life-Cycle Cost for Candidate Standard Level 1

Figure 8.4.8 Front-Loading Compact Clothes Washers: Distribution of Impacts on Life-Cycle Cost for Candidate Standard Level 1

8.4.3 Distributions of Payback Period Under New Standards

Figures 8.4.9 through 8.4.12 are examples of frequency charts showing the distribution of PBPs for clothes washers at the CSL levels corresponding to TSL 3. DOE can generate frequency charts similar to those shown for every standard level.

Figure 8.4.9 Top-Loading Clothes Washers: Distribution of Payback Period for Candidate Standard Level 2

Figure 8.4.10 Front-Loading Clothes Washers: Distribution of Payback Period for Candidate Standard Level 5

Figure 8.4.11 Top-Loading Compact Clothes Washers: Distribution of Payback Period for Candidate Standard Level 1

Figure 8.4.12 Front-Loading Compact Clothes Washers: Distribution of Payback Period for Candidate Standard Level 1

8.4.4 Life-Cycle Costs and Payback Periods

Tables 8.4.1 through 8.4.4 show the LCC and PBP results for the four product classes of residential clothes washers. In the case of front-loading washers, for example, CSL 5 shows an average LCC savings of $47. Note that for CSL 5, approximately 72 percent of consumers in 2015 in the base case are assumed to already be using a clothes washer at CSL 5 and thus have zero savings (no impact) from the standard. For level 5, 26% of household receive a net LCC benefit.

Table 8.4.1 Top-Loading Clothes Washers: Life-Cycle Cost and Payback Period Results

Standard Level	Life-Cycle Cost 2010$			Life-Cycle Cost Savings 2010$				Median Payback Period years
					Households Showing			
	Avg.* Installed Price	Avg. Operating Cost	Avg. LCC	Avg. Savings	Net Cost %	No Impact %	Net Benefit %	
Baseline	$414	$1,652	$2,066	NA	0%	100%	0%	NA
1	$418	$1,665	$2,083	-$7	30%	60%	11%	3.2
2	$425	$1,317	$1,743	$268	1%	19%	80%	0.4
3	$432	$1,379	$1,810	$211	9%	17%	74%	0.7
4	$437	$1,373	$1,810	$212	10%	16%	74%	1.0
5	$433	$1,340	$1,773	$243	6%	15%	79%	0.7
6	$448	$1,182	$1,630	$366	3%	14%	82%	0.9
7	$496	$1,003	$1,499	$491	8%	5%	87%	1.8
8	$508	$958	$1,466	$524	9%	0%	91%	1.9

Table 8.4.2 Front-Loading Clothes Washers: Life-Cycle Cost and Payback Period Results

Standard Level	Life-Cycle Cost 2010$			Life-Cycle Cost Savings 2010$				Median Payback Period years
					Households Showing			
	Avg.* Installed Price	Avg. Operating Cost	Avg. LCC	Avg. Savings	Net Cost %	No Impact %	Net Benefit %	
Baseline	$865	$1,236	$2,101	NA	0%	100%	0%	NA
1	$870	$1,228	$2,099	$0	0%	100%	0%	NA
2	$867	$1,214	$2,081	$0	0%	100%	0%	NA
3	$869	$1,151	$2,020	$0	0%	100%	0%	NA
4	$874	$1,088	$1,961	$2	0%	96%	4%	0.9
5	$888	$946	$1,835	$37	2%	72%	26%	1.3
6	$920	$924	$1,843	$30	42%	23%	35%	10.0
7	$938	$900	$1,838	$35	45%	12%	43%	9.2
8	$964	$807	$1,771	$102	30%	0%	70%	5.2

Table 8.4.3 Top-Loading Compact Clothes Washers: Life-Cycle Cost and Payback Period Results

Standard Level	Life-Cycle Cost 2010$			Life-Cycle Cost Savings 2010$				Median Payback Period years
					Households Showing			
	Avg.* Installed Price	Avg. Operating Cost	Avg. LCC	Avg. Savings	Net Cost %	No Impact %	Net Benefit %	
Baseline	$419	$1,154	$1,573	NA	0%	100%	0%	NA
1	$426	$988	$1,414	$159	2%	0%	98%	0.5
2	$480	$781	$1,261	$312	13%	0%	87%	2.1

Table 8.4.4 Front-Loading Compact Clothes Washers: Life-Cycle Cost and Payback Period Results

Standard Level	Life-Cycle Cost 2010$			Life-Cycle Cost Savings 2010$				Median Payback Period years
					Households Showing			
	Avg.* Installed Price	Avg. Operating Cost	Avg. LCC	Avg. Savings	Net Cost %	No Impact %	Net Benefit %	
Baseline	$861	$752	$1,613	NA	0%	100%	0%	NA
1	$865	$694	$1,559	$54	0%	0%	100%	0.8

Figures 8.4.13 through 8.4.16 show the range in LCC savings for all CSLs for the four product classes. For each CSL, the top and the bottom of the box in a figure indicate the 75th and 25th percentiles, respectively. The bar in the middle of the box indicates the median: under that CSL, 50 percent of the households have LCC savings that exceed 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 CSL.

Figure 8.4.13 Range of Life-Cycle Cost Savings for Top-Loading Clothes Washers

Figure 8.4.14 Range of Life-Cycle Cost Savings for Front-Loading Clothes Washers

Figure 8.4.15 Range of Life-Cycle Cost Savings for Top-Loading Compact Clothes Washers

Figure 8.4.16 Range of Life-Cycle Cost Savings for Front-Loading Compact Clothes Washers

Figures 8.4.17 through 8.4.20 show the range in PBPs for all CSLs for the four product classes. Households that are not affected by a new standard are not included-in the figures.

Figure 8.4.17 Range of Payback Periods for Top-Loading Clothes Washers

Figure 8.4.18 Range of Payback Periods for Front-Loading Clothes Washers

Figure 8.4.19 Range of Payback Periods for Top-Loading Compact Clothes Washers

Figure 8.4.20 Range of Payback Periods for Front-Loading Compact Clothes Washers

8.5 REBUTTABLE PAYBACK PERIOD

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

8.5.1 Metric

The basic equation for calculating rebuttable PBP is the same as that shown in section 8.3 for calculating the standard PBP. Unlike the analyses described in sections 8.2 and 8.3, however, the rebuttable PBP does not rely on household samples and probability distributions. Rather, the rebuttable PBP is based on discrete, single-point values. For example, although DOE uses a probability distribution of regional energy and water prices in analyzing PBP, it uses only the national average energy and water prices from the probability distribution to determine the rebuttable PBP.

Other than the use of single-point values, the most notable difference between the distributional and the rebuttable PBP is the latter's reliance on the DOE test procedure to determine a product's annual energy and water consumption. DOE based the values for annual energy and water consumption used to determine the rebuttable PBP for each product class of clothes washers on the number of wash cycles per year specified in the draft revised DOE test procedure. The draft test procedure for residential clothes washers assumes that the annual number of wash cycles is 295.

8.5.2 Inputs

As noted in section 8.5.1, the calculation of the rebuttable PBP differs from that of the general PBP in that the inputs are discrete values rather than distributions. For the general PBP, inputs for determining total installed cost were based on single-point values. However, the variability and/or uncertainty in the inputs for determining operating costs required using distributions to calculate the general PBP. DOE used the following single-point values in determining the rebuttable PBP.

- Manufacturing costs, markups, sales taxes, and installation costs were the same as the single-point values used in the general LCC and PBP analysis.
- As noted in section 8.5.1, annual energy and water consumption were based on the usage in the draft revised DOE test procedure.
- Energy and water prices were based on national average values for the year that new standards are assumed to take effect (2015).
- Neither an average discount rate nor a lifetime is required for calculating the rebuttable PBP.

8.5.3 Results

DOE calculated rebuttable PBPs for each CSL relative to the baseline efficiency levels. In other words, DOE did not determine the rebuttable PBP relative to the current distribution of product efficiencies determined for the base case.

Tables 8.5.1 through 8.5.4 present the rebuttable PBPs for the four product classes.

Table 8.5.1 Top-Loading Clothes Washers: Rebuttable Payback Periods

CSL	MEF	IMEF	IWF	Rebuttable PBP years
Baseline	1.26	0.84	9.92	NA
1	1.40	0.98	9.92	1.83
2	1.72	1.29	8.44	0.27
3	1.80	1.34	7.95	0.55
4	1.80	1.34	7.95	0.70
5	1.80	1.37	7.95	0.53
6	2.00	1.57	6.47	0.62
7	2.26	1.83	4.96	1.08
8	2.47	2.04	4.10	1.17

Table 8.5.2 Front-Loading Clothes Washers: Rebuttable Payback Periods

CSL	MEF	IMEF	IWF	Rebuttable PBP years
Baseline	1.72	1.37	8.31	NA
1	1.72	1.39	8.31	6.32
2	1.72	1.41	8.31	0.74
3	1.80	1.49	7.80	0.48
4	2.00	1.66	6.26	0.53
5	2.20	1.84	4.73	0.79
6	2.40	2.02	4.42	1.68
7	2.60	2.20	4.01	2.09
8	2.89	2.46	3.39	2.22

Table 8.5.3 Top-Loading Compact Clothes Washers: Rebuttable Payback Periods

CSL	MEF	IMEF	IWF	Rebuttable PBP years
Baseline	0.77	0.59	14.40	NA
1	1.26	0.86	14.40	0.30
2	1.81	1.15	12.00	1.31

Table 8.5.4 Front-Loading Compact Clothes Washers: Rebuttable Payback Periods

CSL	MEF	IMEF	IWF	Rebuttable PBP years
Baseline	1.60	1.03	8.80	NA
1	1.72	1.13	8.30	0.71

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CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

The U.S. Department of Energy (DOE) analyzes shipments of affected products as part of every rulemaking regarding new or amended energy efficiency standards for appliances. Estimates of product shipments are a necessary input for calculating national energy savings (NES) and net present value (NPV) of the investment, which are required to justify potential new energy efficiency standards. Shipments also are a necessary input to the manufacturer impact analysis, which DOE conducts to prepare its notices of proposed rulemakings. This chapter describes DOE's method and results of projecting annual shipments for front-loading and top-loading standard clothes washers under base- and standards-case efficiency levels.

DOE used a computer model to predict shipments of clothes washers. It calibrated the model against historical records of shipments. In estimating the effects of potential new standard levels on product shipments, the model accounts for the combined effects of increases in purchase price, decreases in annual operating costs, and household income on the consumer purchase decision.

In estimating shipments, the model considers specific market segments, the results for which are then aggregated to estimate total product shipments. DOE accounted for two market segments: (1) shipments to new construction; and (2) replacement shipments going into existing building. .

The shipments models are prepared as Microsoft Excel spreadsheets that are accessible on the Internet (www.eere.energy.gov/buildings/appliance_standards/). Appendix 9A discusses how to access the shipments model and other related spreadsheets and provides basic instructions for using them. The rest of this chapter explains the shipments model in more detail. Section 9.2 describes the methodology that underlies development of the model; section 9.3 describes the data inputs and model calibration; section 9.4 discusses the effects of changes in purchase price, operating costs, and household income on shipments; and section 9.5 discusses the affected stock of products. Section 9.6 presents the model results for the five efficiency levels for top-loading and front-loading residential clothes washers that have been identified as trial standard levels (TSLs) for this rulemaking.

9.2 METHODOLOGY

DOE developed a model of the national stock of in-service appliances for estimating annual shipments for this standards rulemaking. The model considers market segments as distinct inputs to the shipments forecast. As represented by the following equation, the two primary market segments are new installations and replacements.

$$Ship_{cw}(j) = Rpl_{cw}(j) + NI_{cw}(j)$$

Where:

$Ship_{cw}(j)$ = total shipments of clothes washers in year j,
$Rpl_{cw}(j)$ = clothes washer units retired and replaced in year j, and
$NI_{cw}(j)$ = number of new installations of clothes washers in year j.

DOE's shipments model takes an accounting approach, tracking market shares of each product class, the vintage of units in the existing stock, and expected construction trends. In principle, each market segment and product class responds differently to the demographic and economic trends in the base case (without new standards) than in any of the standards cases. Furthermore, retirements, and efficiency trends[a] are dynamic and can differ among product classes. Rather than simply extrapolating a current shipments trend, the analysis of the base case for each product class (*i.e.*, the case without new standards) uses input variables as drivers, including construction forecasts and product lifetime distributions, to forecast sales in each market segment.

To estimate shipments of replacement units, the model utilizes shipments data from previous years and assumptions about the lifetime of each product. Estimated shipments of replacement units in a given year are equal to the total stock of the appliance minus those units shipped in previous years that remain in the stock. DOE determined the useful service life of each product class to estimate how many years it is likely to remain in stock. The following equation shows how DOE estimated shipments of replacement units.

$$Rpl_{cw}(j) = Stock_{cw}(j-1) - \sum_{age=0}^{ageMax} \sum_{j=N}^{j-1} Ship_j \times prob_{Rtr}(age)$$

Where:

$Stock_{cw}(j-1)$ = total stock of clothes washers in year $j-1$,
$prob_{Rtr}(age)$ = probability that an appliance of a particular *age* will be retired, and
N = year in which the model begins its stock accounting.

Stock accounting provides an estimate of the age distribution of product stocks for all years, using product shipments, a retirement function, and initial product stock as inputs. The age distribution of product stocks is a key input to both the NES and NPV calculations because the operating costs for any year depend on the age distribution of the stock. Operating cost is dependent on the product age distribution under a standards case scenario that produces

[a] Efficiency trends affect shipments only in the standards case. A change in the efficiency distribution of the stock produces a change in purchase price and operating costs, which affects shipments. This effect is discussed further in section 9.4.

increasing efficiency over time, where older, less efficient units may have higher operating costs, while younger, more-efficient units will have lower operating costs. As units are added to the in-service stock, some older ones are retired and exit the stock.

DOE calculated total stock of each product by integrating historical shipments data beginning with a specific year. The start year depended on the historical data available for the product. As units are added to the 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 stocks. For new units, the equation is:

$$\boldsymbol{Stock(j, age = 1) = Ship(j - 1)}$$

Where:

Stock(j, age) = number of units of a particular age,
j = year for which the 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. Slightly more complicated equations, such as the following equation, describe how the model accounts for the existing stock of units.

$$\boldsymbol{Stock(j + 1, age + 1) = Stock(j, age) ? \left[1 - prob_{Rtr}(age)\right]}$$

In this equation, as the year is incremented from *j* to *j+1*, the age is also incremented from *age* to *age+1*. Over time, a fraction of the stock is removed; that fraction is determined by a retirement probability function, $prob_{Rtr}(age)$, which is described in section 8.3. 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 of those replacements occur when a unit wears out and fails.

9.3 DATA INPUTS AND MODEL CALIBRATION

As noted above, shipments are driven primarily by the two market segments of new construction and replacements.

DOE used two inputs to estimate shipments driven by new construction: new housing forecasts and saturation of the product in new housing. New housing includes newly constructed single- and multi-family units, termed “new housing completions,” and mobile home placements. For new housing completions and mobile home placements, DOE used recorded data through 2007, and adopted the projections from the DOE Energy Information Administration (EIA)’s

Annual Energy Outlook 2009 (*AEO2009*) for 2008–2030.[1] To determine new construction shipments for clothes washer shipments, DOE used forecasts of market saturations combined with forecasts of housing starts.

DOE estimated replacements using product retirement functions that it developed based on product lifetimes. The retirement function is described in detail in chapter 8.

DOE designed its shipments model for residential clothes washers by developing a single model for all washers and then disaggregating the shipments into its two product classes—front-loading and top-loading clothes washers. DOE developed a cross-price elasticity to estimate the market shares of the considered product classes through the forecast period. The Cross-Price elasticity is covered in Section 9.4.

9.3.1 Historical Shipments

DOE used data on historical shipments (domestic and imports) to calibrate its shipments model. It relied on two sources to establish historical shipments: (1) data AHAM provided for 2002–2005[2] and (2) data from *Appliance Magazine*[3] for 1988–1998. For 1999–2001, DOE interpolated between the shipments for 1998 and 2002. Table 9.3.1 summarizes the historical data regarding clothes washer shipments.

Table 9.3.1 Historical Shipments: Domestic plus Imports

Year	Shipments millions	Year	Shipments millions	Year	Shipments millions
1972	4.754	1985	5.182	1997	6.326
1973	5.158	1986	5.619	1998	6.835
1974	4.631	1987	5.750	1999	7.313
1975	3.944	1988	5.787	2000	7.495
1976	4.194	1989	5.610	2001	7.362
1977	4.639	1990	5.591	2002	7.745
1978	4.732	1991	5.415	2003	8.146
1979	4.667	1992	5.632	2004	8.832
1980	4.308	1993	5.923	2005	9.225
1981	4.136	1994	6.161	2006	9.500
1982	3.826	1995	6.080	2007	8.825
1983	4.431	1996	6.225	2008	8.292
1984	4.945				

Sources: 1972-2005: AHAM; 2006-08: AHAM data submittal, 2009.

9.3.2 Markets and Model Calibration

As described in section 9.2, the market for clothes washers comprises primarily replacement units for products that have been retired and units for new housing. Total clothes washers shipments are represented by the equation 9.2.1 as represented below:

$$Ship_{CW}(j) = Rpl_{CW}(j) + NI_{CW}(j)$$

The following sections discuss both the new housing and replacement markets in further detail.

9.3.2.1 New Housing

As described above, DOE forecasted shipments to the new construction market based on forecasts of housing starts coupled with data on the market saturation of clothes washers. DOE then multiplied the housing forecasts by the forecasted saturation of clothes washers for new housing units. DOE used historical and forecasted new housing starts to calibrate its model.

Table 9.3.2 presents historical and forecasted new housing starts based on EIA's *AEO2009* for 1990–2035.[1] *AEO2010* provides three scenarios for housing starts: a reference case plus cases for high and low economic growth. Table 9.3.2 shows quantities based on all three forecasts. DOE used only the forecasts from the reference case to estimate its shipments to new construction, however. For 2036−2045, DOE froze completions at the level in 2035.

Table 9.3.2 Historical and Forecasted Housing Starts millions

Year	Reference	High	Low	Year	Reference	High	Low
1990	1.38	1.38	1.38	2018	2.00	2.41	1.59
1991	1.18	1.18	1.18	2019	2.03	2.35	1.55
1992	1.41	1.41	1.41	2020	2.03	2.20	1.42
1993	1.54	1.54	1.54	2021	1.97	2.15	1.36
1994	1.76	1.76	1.76	2022	1.92	2.14	1.31
1995	1.69	1.69	1.69	2023	1.89	2.14	1.29
1996	1.82	1.82	1.82	2024	1.88	2.16	1.28
1997	1.49	1.49	1.49	2025	1.89	2.21	1.28
1998	1.54	1.54	1.54	2026	1.89	2.28	1.26
1999	1.64	1.64	1.64	2027	1.85	2.30	1.24
2000	1.70	1.70	1.70	2028	1.81	2.30	1.20
2001	1.72	1.72	1.72	2029	1.78	2.30	1.17
2002	1.75	1.75	1.75	2030	1.78	2.32	1.18
2003	1.79	1.79	1.79	2031	1.75	2.29	1.17
2004	1.80	1.80	1.80	2032	1.71	2.24	1.14
2005	2.22	2.22	2.22	2033	1.70	2.22	1.13
2006	1.15	1.92	1.92	2034	1.70	2.22	1.13
2007	1.26	1.26	1.26	2035	1.70	2.22	1.13
2008	1.36	1.33	1.33	2036	1.70	2.22	1.13
2009	1.22	1.40	1.40	2037	1.70	2.22	1.13
2010	1.75	2.21	1.62	2038	1.70	2.22	1.13
2011	1.49	1.78	1.28	2039	1.70	2.22	1.13
2012	1.72	2.06	1.47	2040	1.70	2.22	1.13
2013	1.79	2.15	1.51	2041	1.70	2.22	1.13
2014	1.81	2.20	1.53	2042	1.70	2.22	1.13
2015	1.88	2.33	1.56	2043	1.70	2.22	1.13
2016	1.95	2.38	1.59	2044	1.70	2.22	1.13
2017	1.97	2.38	1.60	2045	1.70	2.22	1.13

Source: Energy Information Administration. Annual Energy Outlook, 2010.

DOE used the RECS data on clothes washer ownership in new housing to determine the historical saturations. Table 9.3.3 shows the historical saturation of clothes washers in new housing units.

Table 9.3.3 Historical Saturation of Clothes Washers in New Housing Units

Year	Saturation %	Year	Saturation %
1990	75.1%	1998	88.7%
1991	75.1%	1999	87.5%
1992	75.1%	2000	86.2%
1993	87.0%	2001	85.0%
1994	87.7%	2002	86.5%
1995	88.5%	2003	87.9%
1996	89.2%	2004	89.5%
1997	90.0%	2005	91.0%

Figure 9.3.1 shows the historical variation in saturation in new housing units as well as the forecasted saturation after 2005.

Figure 9.3.1 Saturation of Clothes Washers in New Housing Units

9.3.2.2 Replacements

To determine shipments to the replacement market, DOE used an accounting method that tracks the total stock of units by vintage. DOE estimated a stock of clothes washers by vintage by integrating historical shipments starting from 1972. Over time, some units are retired and removed from the stock, triggering the shipment of a replacement unit. Depending on the

vintage, a certain percentage of units will fail and need to be replaced. To estimate how long a unit will function before failing, DOE used a survival function based on the distributions of product lifetime. The survival function that DOE used had an average lifetime of 14.2 years. For a more complete discussion of clothes washer lifetimes, refer to section 8.2.3 of chapter 8. Figure 9.3.2 shows the survival function DOE used to estimate replacement shipments.

Figure 9.3.2 Survival Function

9.3.2.3 Early Replacements

DOE also calibrated its shipments model through early replacements. In the historical backcast of the model, estimated shipments were more than those indicated by data for new housing and replacements through retirements. To calibrate estimated shipments with the historical data, DOE introduced into the model a function for the early replacement market. DOE assumed that early replacements occur at the rate of 2 and 4 percent of the surviving stock per year during 1989-2003 and 2004–2045, respectively. The differential early replacement rates match the observed clothes washer stock in new housing reported in the American Housing Surveys. The early replacement rate is distributed among products that range from 9 to 30 years old. DOE weighted those ages by their respective populations in the surviving stock. The following equation illustrates the calculations.

$$ER_{CW}(j) = \sum_{age=4}^{AgeMax-1} \frac{Stock(j-1, age)}{\sum_{age} Stock(j-1, age)} \times ERRate \times Stock(j-1)$$

Where:

$ER_{CW}(j)$ =	number of clothes washers replaced early in year *j*,
Stock (j-1, age) =	number of in-service units of a particular age in year *j-1*,
ERRate =	early replacement rate, and
AgeMax =	maximum age of units before they are retired.

9.3.3 Base-Case Shipments

Figure 9.3.3 shows the forecasted shipments of clothes washer in the base case (*i.e.*, the case without new energy efficiency standards) and the historical shipments DOE used to calibrate that forecast. All shipments of residential clothes washers are represented in Figure 9.3.33.

Figure 9.3.3 Historical and Forecasted Shipments for Base Case

9.3.4. Market Share Forecast

DOE forecasted the change in market share between the front-loading and top-loading units in the base case based on available data. For the standards case, both available data and cross-price elasticities were used to forecast market share changes. For the base case market share forecast, DOE fit a curve to estimate the front-loading market share on the basis of the data from NPD and the data submitted by AHAM. Although there are only three data points from AHAM on market share, the NPD dataset provides data for additional years. DOE fit an S-curve to the six NPD data points to adequately capture the change in market share, with the front-

loading share stabilizing over time, as shown in Figure 9.3.4. Two of the three AHAM points show a close fit with the S-curve based on the NPD data.

Figure 9.3.4 Market Share Estimation

DOE performed an analysis of the cross-price impacts on the market share of top-loading and front-loading clothes washers. Cross-price impacts measure the change in the market share of one washer configuration (*e.g.*, top loaders) caused by a change in the price of the other washer configuration (*e.g.*, front loaders).

The logistic regression model equation estimated in our clothes washer analysis:

$$\ln\left(\frac{Market\ Share_{Front}}{1 - Market\ Share_{Front}}\right) = -2.985386 + 0.0035452 \times Price_{Top} - 0.0049114 \times Price_{Front} + 4.24347 \times \frac{Size_{Front}}{Size_{Top}}$$

where:

$\frac{Market\ Share_{Front}}{1-Market\ Share_{Front}}$ = the relative probability of the market share of top- and front-loading clothes washers,

$Price_{Top}$= monthly sales-weighted average price of top-loaders,

$Price_{Front}$= monthly sales-weighted average price of front-loaders, and

$\frac{Size_{Fonrt}}{Size_{Top}}$= ratio of the monthly sales-weighted average of front-loaders tub volume to the monthly sales-weighted average of top-loaders tub volume.

The equation indicates that front loader market share is positively correlated with top loader price and size and negatively correlated with front loader price. These regression results were used to derive the cross price impact of a change in the front loading washer price on the top loading market share (and vice versa). For example, a 10% increase in the mean price of front loader washers in the data resulted in a 10.7 % increase in the top-loading market share. Thus, the cross-price elasticity on top-loading market share (percent change in top-loading market share over percent change in front-loading price) is 1.07.

The equation below shows how the shipments model implements the relationship between price and market share, the cross-price elasticity. See Appendix 9A for the development of the cross-price elasticities.

$$MS_{S_FL} = MS_{BC_FL}\left(1 + E_{pTL_qFL} \times \frac{EP_{S_TL} - EP_{BC_TL}}{EP_{BC_TL}}\right) - MS_{BC_TL}\left(E_{pFL_qTL} \times \frac{EP_{S_FL} - EP_{BC_FL}}{EP_{BC_FL}}\right)$$

Where:

MS_{S_FL} = market share in the standards case for front-loaders,
MS_{BC_FL} = market share in the base case for front-loaders,
E_{pTL_qFL} = cross-price elasticity of top-loader price on front-loader market share, which is estimated to be 1.07,
EP_{S_TL} = market share in the standards case for top-loaders,
EP_{BC_TL} = market share in the base case for top-loaders,
MS_{BC_TL} = market share in the base case for top-loaders,
E_{pFL_qTL} = cross-price elasticity of front-loader price on top-loader market share, which is estimated to be 1.07,
EP_{S_FL} = market share in the standards case for front loaders,
EP_{BC_FL} = market share in the base case for front loaders,

Figure 9.3.5 shows forecasted base and standards case market share of clothes washers disaggregated by the two product types. The figures show the standards case for top-loading and front-loading clothes washers, TSL 3. Given the direct correlation between price and market share, as long as the price changes the market share will also continue to change.

Figure 9.3.5 Forecast of Market Share in Base Case and Standards Case TSL3 for Front-Loading (CSL5) and for Top-Loading (CSL6)

9.4 EFFECTS OF PURCHASE PRICE, OPERATING COSTS, AND HOUSEHOLD INCOME

DOE conducted a literature review and an analysis of appliance price and efficiency data to estimate the combined effects on product shipments from increases in product purchase price, decreases in product operating costs, and changes to household income. Appendix 10A explains in detail the method DOE used to quantify the effects of the above variables.

DOE found only a few studies of appliance markets that are relevant to this analysis and identified no studies that use time-series data of product price and shipments data after 1980. The information that can be derived from the literature suggests that the demand for appliances is price-inelastic (*i.e.*, price does not affect demand). Other information in the literature suggests that appliances are a normal good, so that rising incomes increase the demand for them. Finally, the literature suggests that consumers use relatively high implicit discount rates[b] when comparing the price of an appliance to its operating costs. For this analysis, DOE did not consider the impacts of consumer rebate programs.

[b] A high implicit discount rate with regard to operating costs means that consumers place little economic value on the savings in operating costs realized from more efficient appliances. In other words, consumers are much more concerned with higher purchase prices than with lower operating costs.

DOE found too few data on product purchase price and operating costs to perform a thorough analysis of dynamic changes in the appliance market. Rather, it used purchase price and efficiency data specific to residential refrigerators, clothes washers, and dishwashers during 1980–2002 to evaluate broad market trends and conduct simple regression analyses. Those data indicate that during that period shipments of appliances increased while purchase price and operating costs declined. In addition, household income rose during that period. To simplify the analysis, DOE combined the available economic information into one variable, termed the *relative price*. DOE used that variable to analyze market trends, as well as to conduct a regression analysis. DOE used the following expression to define relative price.

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

Where:

RP = relative price,
TP = total price,
Income = household income,
PP = appliance purchase price, and
PVOC = present value of operating costs.

In the above equation, DOE used an implicit discount rate of 37 percent to determine the present value of operating costs.

DOE's analysis of market trends suggests that the demand for clothes washers is relatively price inelastic (that is, has an elasticity less than 1.0). DOE's regression analysis suggests that the relative price elasticity of demand is -0.34. Thus, for example, a relative price increase of 10 percent results in a 3.4-percent decrease in shipments. Note that, because the relative price elasticity incorporates the effects of three factors (purchase price, operating costs, and household income), the impact from any single effect is mitigated by changes in the other two effects. The relative price elasticity of -0.34 is consistent with estimates in the literature. DOE nevertheless stresses that the measure is based on applying simple statistical analysis to a small data set. More importantly, the measure is based on the assumption that economic variables, including purchase price, operating costs, and household income, explain most of the trend in appliances per household in the United States since 1980. Changes in appliance quality and consumer preferences may have occurred during this period, but DOE's analysis did not account for them. Despite the uncertainties, DOE believes that its estimate of the relative price elasticity of demand provides a reasonable assessment of the effect that purchase price, operating costs, and household income have on shipments of clothes washers.

Because DOE's forecasts of shipments and national impacts attributable to standards pertain to a 30-year period, it needed to consider how the relative price elasticity is affected after a new standard takes effect. DOE considered the relative price elasticity described above to be a

short-term value. It was unable to identify sources specific to household durable goods, such as appliances, to indicate how short- and long-term price elasticities differ. Therefore, to estimate how the relative price elasticity changes through time, DOE relied on a study pertaining to automobiles.[4] That study showed that the price elasticity of demand for automobiles changes in the years following a change in purchase price. As the number of years increases, the price elasticity decreases until it reaches a terminal value at about the 10th 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 of demand for residential clothes washers based on the relative change in the automobile price elasticity. For years not shown in Table 9.4.1, DOE performed a linear interpolation to obtain a relative price elasticity.

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

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

DOE used the following equation to estimate shipments under each standards case for the two product classes of clothes washers. The equation incorporates the effect of the relative price into the forecast of base-case shipments. In the equation, the relative price and the relative price elasticity are functions of the year, because both change with time.

$$Ship_{STD_p}(j) = \left(Rpl_{BASE_p}(j) + NI_{BASE_p}(j) + M_{BASE_p}(j)\right) \times \left(1 - e_{RP}(j) \times \Delta RP(j)\right)$$

Where:

$Ship_{STD_p}(j)$ = total shipments of product p in year j under a given standards case;
$Rpl_{BASE_p}(j)$ = units of product p retired and replaced in year j under the base case;
$NI_{BASE_p}(j)$ = number of new construction installations of product p in year j under the base case;
$M_{BASE_p}(j)$ = units of product p installed in market M in year j (M represents early replacements) under the base case;
$e_{RP}(j)$= relative price elasticity in year j (equals -0.34 for year 1); and
$\Delta RP(j)$= change in relative price due to the given standard in year j.

9.5 AFFECTED STOCK

The affected stock is the in-service stock of a product that is affected by a potential energy efficiency standard. In addition to the forecast of product shipments under both the base case and each trial standard level (TSL), a key output of DOE's shipments model is the affected

stock, which represents the difference in the stock under the base case and each TSL. DOE calculates the affected stock to quantify the effect attributable to a TSL that new product shipments have on the appliance stock. The affected stock therefore consists of those in-service units that are purchased in or after the year a standard takes 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 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 affected units (years), and
Std_yr =	effective date of the standard.

As the above equation shows, 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 would become effective in 2015. Thus, all appliances purchased beginning on the first day of 2015 would be affected by the standard level.

9.6 RESULTS

The following sections show the shipments forecasts for a selective set of TSL combinations for front- and top-loading washers of all the levels that DOE considered for each product class of clothes washers.

This section presents the shipments forecasts for the TSLs that DOE considered for each of the product classes of clothes washers. Table 9.6.1 shows a selective set of TSL combinations for both front-loading (FL) and top-loading (TL) clothes machines in both standard and compact sizes. For standard sizes, TSL 1 consists of the efficiency level at two levels from the base level. TSL 2 represents an intermediary point between the efficiency levels chosen for TSL 1 and the efficiency levels recommended in the Joint Petition. TSL 3 consists of the efficiency levels recommended in the Joint Petition. In the case of TSL 3, for top-loading standard clothes washers, one set of values would apply starting in 2015, and another set would apply starting in 2018. TSL 4 consists of the efficiency levels that are one level below the max-tech efficiency levels. TSL 5 consists of the max-tech efficiency levels. For top-loading compact size clothes washers, TSL 1 through TSL 3 consist of the efficiency level at one level from the base level, and TSL 4 and TSL 5 consist of the efficiency level at two levels form the base level. For front-loading compact size clothes washers, TSL 1 through TSL 5 consist of the efficiency level at one level from the base level.

TSL 3 represents the consensus agreement level and is a tiered efficiency level. Until 2018, the efficiency level for top-loading standard size clothes washers would have an IMEF of 1.29; from 2018 forward, the IMEF level would become 1.57. Table 9.6.2 shows the cumulative impacts on shipments during 2015–2044 from the selective set of TSL combinations for front-loading and top-loading standard clothes washers. For all TSL combinations, shipments are forecasted to decrease; that is, the effects of an increased purchase price offsets the effects of decreased operating costs, resulting in a net decrease in shipments. The table provides the modified energy factor (MEF), the integrated modified energy factor (IMEF), which both are the cubic feet of washer capacity per kilowatt-hour per cycle, associated with each TSL. It also lists the integrated water factor (IWF), which stands for the gallons per cubic foot of washer capacity associated with each standard level.

Table 9.6.1 Front- and Top-loading Clothes Washers: TSL Combinations for Analysis

	Trial Standard Level			
	Standard Size		Compact Size	
TSL	Top-Loading Clothes Washer	Front-Loading Clothes Washer	Top-Loading Compact Clothes Washer	Front-Loading Compact Clothes Washer
1	2	2	1	1
2	4	5	1	1
3	5	2 until 2018 and then 6	1 until 2018 then 2	1
4	7	7	2	1
5	8	8	2	1

Table 9.6.2 Front- and Top-loading Clothes Washers: Cumulative Effects of Standards on Shipments, 2015–2044

	Standard Size		**Compact Size**		**Cumulative Shipments million**
	MEF/IMEF/IWF (cu.ft/kWh/cycle gal/cu.ft)				
TSL	**Top-Loading**	**Front-Loading**	**Top-Loading Compact**	**Front-Loading Compact**	
Base					330.3
1	1.72/1.29/8.44	1.72/1.41/8.31	1.26/0.86/14.40	1.72/1.13/8.30	330.1 (-0.1%)
2	1.80/1.37/7.95	2.00/1.66/6.26	1.26/0.86/14.40	1.72/1.13/8.30	329.6 (-0.2%)
3	2.00/1.57/6.47	2.20/1.84/4.73	1.26/0.86/14.40	1.72/1.13/8.30	328.8 (-0.5%)
4	2.26/1.83/4.96	2.60/2.20/4.01	1.81/1.15/12.00	1.72/1.13/8.30	325.0 (-1.6%)
5	2.47/2.04/4.10	2.89/2.46/3.39	1.81/1.15/12.00	1.72/1.13/8.30	323.6 (-2.0%)

Note: Figures in parenthesis indicate % change in cumulative shipments from the base case.

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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 trail standard levels (TSLs) for two product classes of clothes washers: front-loading and top-loading standard. DOE evaluated the following impacts: (1) national energy and water savings (NES) attributable to each possible standard, (2) monetary value of those energy savings to consumers of the considered products, (3) increased total installed cost of the products because of standards, and (4) net present value (NPV) of energy and water savings (the difference between the operational savings and increased total installed cost).

DOE determined both the NES and NPV for all the efficiency levels considered for new standards for residential clothes washers. DOE performed all calculations for each considered product using a Microsoft Excel spreadsheet model, which is accessible on the Internet. <www.eere.energy.gov/buildings/appliance_standards/> The spreadsheets, which implement the National Impact Analysis (NIA) model, combine the calculations for determining the NES and NPV for each considered product with input from the appropriate shipments model. Details and instructions for using the NIA model are provided in appendix 10-A.

Chapter 9 provides a detailed description of the shipments models that DOE used to forecast future purchases of the considered products. Chapter 9 includes detailed descriptions of consumers' sensitivities to total installed cost, operating cost, and income, and how DOE captured those sensitivities within the model.

To estimate the national impacts of new standards for all the product classes considered in this rulemaking, DOE allocated the product cost and annual energy consumption of each representative product class to all product classes within its category.

10.2 FORECASTED EFFICIENCIES FOR BASE AND STANDARDS CASES

This section describes the method DOE used to forecast the energy efficiencies of considered products under the base case and each of the potential standards cases. It provides efficiency distributions for both product classes of clothes washers.

10.2.1 Method and Assumptions

A key factor in estimating NES and NPV is the trend in energy efficiency forecasted for the base case (without new standards) and each of the standards cases. In calculating the NES, per-unit annual energy consumption is a direct function of product efficiency. For the NPV, two

inputs, the per-unit total installed cost and the per-unit annual operating cost, depend on efficiency. The first input, the per-unit total installed cost, is a direct function of efficiency. The per-unit annual operating cost, because it is a function of the per-unit annual consumption, is indirectly dependent on product efficiency.

Chapter 8 described how DOE developed a base-case energy efficiency distribution (which yields a shipment-weighted average efficiency) for each of the considered product classes for the first year of the forecast period. To project the trend in efficiency over the entire forecast period, DOE considered recent trends and the potential effect of programs such as ENERGY STAR. As discussed in chapter 8, DOE did not find a basis for projecting an increase in the average efficiency of front-loading clothes washers. For top-loading clothes washers, DOE assumed that the growth in share of the medium- and high-efficiency levels would level off at around 20 percent. Although there is room for the shares of the higher efficiency levels to grow, DOE believes that the growth will be constrained by the likelihood that consumers with a strong interest in energy efficiency will purchase front-loading clothes washers instead of top-loading clothes washers.

Table 10.2.1 provides the base-case efficiency distributions for the three years in which AHAM provided data (2006-2008) as well as the years 2015 (the assumed effective date of new standards) and 2022. The year 2022 is identified because it is seven years after 2015, the time period between the year 2008 (the last year in which data was made available by AHAM) and 2015.

Table 10.2.1 Standard Clothes Washers: Base-Case Efficiency Distributions

	Front Loading					Top Loading				
Standard Level	2006	2007	2008	**Base Case**		2006	2007	2008	**Base Case**	
				2015	2022				2015	2022
Baseline	10.60%	3.80%	0.10%	0.0%	0.0%	46.9%	45.7%	43.6%	40.4%	40.0%
1	10.97%	2.77%	1.4%	0.0%	0.0%	46.9%	45.7%	43.6%	40.4%	40.0%
2	10.97%	2.77%	1.4%	0.0%	0.0%	0.55%	0.6%	1.9%	2.8%	2.9%
3	10.97%	2.77%	1.4%	4.3%	4.3%	0.18%	0.2%	0.6%	0.9%	1.0%
4	51.10%	19.70%	24%	24.0%	24.0%	0.18%	0.2%	0.6%	0.9%	1.0%
5	2.7%	37.90%	48.90%	48.9%	48.9%	0.18%	0.2%	0.6%	0.9%	1.0%
6	1.3%	15.20%	11.40%	11.4%	11.4%	2.60%	3.7%	4.6%	9.1%	9.5%
7	1.3%	15.20%	11.40%	11.4%	11.4%	2.60%	3.7%	4.6%	4.6%	4.7%
8	0%	0%	0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SWMEF	**1.91**	**2.20**	**2.20**	**2.20**	**2.20**	**1.38**	**1.39**	**1.42**	**1.46**	**1.46**
SWIMEF	**1.57**	**1.84**	**1.84**	**1.85**	**1.85**	**0.95**	**0.97**	**1.00**	**1.03**	**1.04**
SWIWF	**8.37**	**7.41**	**7.48**	**5.11**	**5.11**	**9.69**	**9.59**	**9.48**	**9.28**	**9.69**

SWMEF Shipment weighted modified energy factor
SWIMEF Shipment weighted integrated modified energy factor
SWIWF Shipment weighted integrated water factor

To determine efficiency distributions for cases in which a candidate standard applies, DOE used a “roll-up” scenario for 2015, the year that compliance with any revised standards

would be required. DOE assumed that product efficiencies in the base case that did not meet the standard under consideration would roll up to meet the new standard in 2015. However, because ENERY STAR criteria in 2011 consist of an MEF ≥ 2.00 and a WF ≤ 6.0, DOE also assumed that the ENERGY STAR program would not affect the front-loader or top-loader market for any new standards set at efficiency levels below the future ENERGY STAR requirements. As a result, for top-loader efficiency levels 1 through 5 and front-loader efficiency levels 1 through 3, DOE estimated that efficiency distributions would remain unchanged from 2015 through 2044 (the end of the analysis period). For any new standards set at efficiency levels above the 2011 ENERGY requirements, DOE assumed that the market share of efficiency levels beyond the standard increased. The level of increase was set equal to the market share change from 2006 to 2008 for the efficiency level directly preceding the standard. Using the above criteria, DOE assumed that from 2015 to 2022 the shipment weighted integrated modified energy factor (SWIMEF) market share would grow linearly. As noted earlier in the discussion of base-case efficiency distributions, DOE chose a year of 2022 because it is it is seven years after 2015, the time period between the year 2008 (the last year in which data was made available by AHAM) and 2015. Because of the difficulty in forecasting changes in the market beyond 2022, DOE refrained from speculation and simply assumed that after 2022 the market would remain unchanged through 2044.

Figure 10.2.1 is a graphical representation of DOE's approach. The figure shows a plot of the shipment-weighted integrated modified energy factor for Front-Loaders for the base case and each candidate standard level. Similar figure could be created for Top-Loading units as well.

Figure 10.2.1 Projected Shipment-Weighted Integrated Modified Energy Factors as a Function of Standard Level for Front-Loading Clothes Washers

10.3 NATIONAL ENERGY AND WATER SAVINGS

DOE calculated the national energy and water savings associated with the difference between the base case and the case associated with each potential standard for clothes washers. DOE calculated cumulative energy savings throughout the forecast period, which extends from 2015 to 2044. The equations shown calculate energy savings; DOE used similar equations to calculate water savings.

10.3.1 Definition

The following equation shows that DOE calculated annual national energy and water savings (NEWS) as the difference between two projections: a base case (without new standards) and a standards case. Positive values of NEWS represent energy savings (that is, national annual energy consumption (AEC) under a standard is less than in the base case).

$$\boldsymbol{NES_y = AEC_{BASE} - AEC_{STD}}$$

Cumulative energy and water savings are the sum of annual national energy and water savings throughout the forecast period, which extends from the assumed effective date of new standards (January 1, 2015) to 30 years after that date (December 31, 2044). The calculation is represented by the following equations for energy and water.

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

$$NWS_{cumulative} = \sum NWS_y$$

DOE calculated the national annual energy and water consumption by multiplying the number or stock of each product class (by vintage) by its unit energy and water consumption (UEC or UWC; also by vintage). The calculation of national annual energy consumption is represented by the following equation.

$$AEC_y = \sum STOCK_V \times UEC_V$$

DOE defined the quantities for the above expressions as follows.

AEC =	national annual energy consumption each year in quadrillion British thermal units (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 per product in kilowatt hours (kWh) [electricity consumption is converted from site energy to source energy (quads) by applying a time-dependent conversion factor];
V =	year in which the product was purchased as a new unit; and
y =	year in the forecast.

The stock of a product depends on annual shipments and the lifetime of the product. As described in chapter 9, DOE projected product shipments under the base case and standards cases. DOE projected that shipments under the standards cases would be slightly lower than under the base case, because of the higher purchase cost of more efficient products. In other words, DOE believes that the higher purchase cost would cause some consumers to forego purchasing new products.

To avoid including savings attributable to shipments displaced because of standards, DOE used the projected standards-case shipments and, in turn, the standards-case stock, to calculate the annual energy consumption for the base case.

10.3.2 Inputs

The inputs to the calculation of national energy savings (NES) are:

- Shipments;
- product stock ($STOCK_V$);
- annual energy consumption per unit (*UE*C);
- national annual energy consumption (*AEC*); and
- site-to-source conversion factor (*src_conv*).

10.3.2.1 Shipments

DOE forecasted shipments of each product class under the base case and all standards cases. Several factors affect forecasted shipments, including purchase cost, operating cost, and household income. As noted earlier, the increased cost of more efficient products causes some consumers to forego buying the products. Consequently, shipments forecasted under the standards cases are lower than under the base case. The method DOE used to calculate and generate the shipments forecasts for each considered product class is described in detail in Chapter 9, Shipments Analysis.

10.3.2.2 Equipment Stock

The equipment stock in a given year is the number of products shipped from earlier years that survive in that year. The NIA model tracks the number of the number of units shipped each year. DOE assumes that products have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is the survival function. Chapter 9 provides additional details on the survival functions that DOE used for each product class.

10.3.2.3 Annual Energy Consumption per Unit

DOE used the shipment-weighted integrated modified energy factors (SWIMEFs) presented in section 10.2 for the base case and standards cases, along with the data on annual energy consumption presented in chapters 7 and 8, to estimate the shipment-weighted average annual per-unit energy consumption under the base and standards cases. The average annual per-unit energy consumption projected for 2015 for each product category is shown in Table 10.3.1.

Table 10.3.1 Shipment-Weighted Average Annual Energy Consumption in 2015

	Base Case	Trial Standards Levels				
		1	2	3	4	5
Front-Loading Standard						
SWIMEF	1.85	1.85	1.85	1.91	2.20	2.46
Avg. Elec Use	246	246	246	241	234	214
Avg. Gas Use	1.20	1.20	1.19	1.17	1.09	0.97
Avg. Oil Use	0.04	0.04	0.04	0.04	0.04	0.04
Top-Loading Standard						
SWIMEF	1.03	1.35	1.41	1.35	1.83	2.04
Avg. Elec Use	431	335	322	335	264	261
Avg. Gas Use	2.21	1.69	1.90	1.69	1.49	1.46
Avg. Oil Use	0.08	0.06	0.06	0.06	0.05	0.05
Front-Loading Compact						
SWIMEF	1.03	1.13	1.13	1.13	1.13	1.13
Avg. Elec Use	199	173	173	173	173	173
Avg. Gas Use	0.90	0.85	0.85	0.85	0.85	0.85
Avg. Oil Use	0.04	0.03	0.03	0.03	0.03	0.03
Top-Loading Compact						
SWIMEF	0.59	0.86	0.86	0.86	1.15	1.15
Avg. Elec Use	346	233	233	233	190	190
Avg. Gas Use	1.62	1.23	1.23	1.23	0.86	0.86
Avg. Oil Use	0.06	0.04	0.04	0.04	0.03	0.03

10.3.2.4 National Annual Energy and Water Consumption

The national annual energy and water consumption (AEC) is the product of the annual energy and water consumption per unit and the number of units of each vintage. This method of calculation accounts for differences in unit energy consumption from year to year. The equation for determining the annual energy consumption, which was presented in section 10.3.1, is repeated here. As stated previously, the equations for water consumption are the same as the equations for energy consumption.

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

In determining national annual energy consumption, DOE first calculated annual energy consumption at the site, then applied a conversion factor, described below, to calculate primary energy consumption. Annual water consumption is calculated at the site only. No conversion factor was applied to water consumption.

10.3.2.5 Site-to-Source Conversion Factors

In determining national annual energy consumption, DOE initially calculated the annual energy consumption at the site (for electricity, the energy in kWh consumed at the household or establishment). It then used site energy consumption to calculate primary (source) energy consumption by applying a conversion factor to account for losses associated with the generation, transmission, and distribution of electricity. The site-to-source conversion factor is a multiplicative factor used to convert site energy consumption into primary or source energy consumption, expressed in quads (quadrillion Btus). DOE used annual site-to-source conversion factors based on the version of the National Energy Modeling System (NEMS)[a] that corresponds to EIA's *Annual Energy Outlook 2010* (AEO 2010).[1] The factors are marginal values, which represent the response of the system to an incremental decrease in consumption. For electricity, the conversion factors change over time in response to projected changes in generation sources (*i.e.*, the types of power plants projected to provide electricity to the Nation). Figure 10.3.1 shows the site-to-source conversion factors from 2005 to the end of the forecast period. DOE assumed that conversion factors remain at 2030 values throughout the rest of the forecast.

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[a] For more information on NEMS, please refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2000*, DOE/EIA-0581(2000), March 2000. EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on EIA assumptions, DOE refers to the model by the name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed). NEMS-BT was previously called NEMS-BRS.

Figure 10.3.1 Marginal Site-to-Source Conversion Factors for Electricity

10.4 NET PRESENT VALUE

DOE calculated the net present value (NPV) of the increased product cost and reduced operating cost associated with the difference between the base case and each potential standards case for the considered residential clothes washer product classes.

10.4.1 Definition

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

$$NPV = PVS - PVC$$

Where:

PVS = present value of savings in operating cost, and
PVC = present value of increased total product cost to consumers.

DOE determined the *PVS* and *PVC* according to the following expressions.

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

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

Where:

OCS = total annual savings in operating cost each year summed over vintages of the product stock, $STOCK_V$;
TIC = total annual increases in product cost each year summed over years of the product shipments, $SHIP_y$;
DF = discount factor in each year; and
y = year in the forecast.

DOE calculated the total annual consumer savings in operating cost by multiplying the number or stock of a given product class (by vintage) by its per-unit operating cost savings (also by vintage). DOE calculated the total annual increases in consumer product cost by multiplying the number or shipments of the given product class (by vintage) by its per-unit increase in consumer product cost (also by vintage). The calculation of total annual operating cost savings and total annual product cost increases is represented by the following equations.

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

$$TIC_y = \sum SHIP_y \times UTIC_y$$

Where:

$STOCK_V$ = stock of products of vintage *V* that survive in the year for which DOE calculated annual energy consumption;
$UOCS_V$ = annual per-unit savings in operating cost;
V = year in which the product was purchased as a new unit;
$SHIP_y$ = shipments of products in year *y*; and
$UTIC_y$ = annual per-unit increase in installed product cost in year *y*.

DOE determined the total increased product cost for each year from the effective date of a potential standard to 2044. DOE determined the present value of operating cost savings for each year from the effective date of the standard to the year when all units purchased by 2044 have been retired. DOE calculated costs and savings as the difference between a standards case and a base case without new standards.

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

10.4.2 Inputs

The inputs to calculation of the net present value (NPV) are:

- Average annual product cost;
- average annual savings in operating cost;
- total annual increases in product cost;
- total annual savings in operating cost;
- discount factor;
- present value of costs; and
- present value of savings.

The increase in total annual product cost is equal to the annual change in the average annual product cost (difference between base case and standards case) multiplied by the shipments forecasted in the standards case. As with the calculation of the NES, DOE did not calculate total annual product costs using base-case shipments. To avoid including savings due to displaced shipments (by consumers deciding not to buy higher-cost products), DOE used the standards-case projection of shipments and, in turn, the standards-case stock, to calculate product costs.

The total annual savings in operating cost savings are equal to the change in annual operating cost (difference between base case and standards case) per unit multiplied by the shipments forecasted in the standards case.

10.4.2.1 Average Annual Product Cost

The average annual product cost is directly dependent on efficiency. DOE therefore used the SWIMEFs presented in section 10.2 for the base case and each standards case, along with the product costs at various efficiency levels (presented in chapter 8), to estimate the shipment-weighted average annual product cost under the base and standards cases. Table 10.4.1 shows the shipment-weighted average consumer product cost based on the SWIMEFs that correspond to the base case and each standards case in 2015.

In the preliminary analysis, DOE followed its past practice and assumed that the manufacturer costs and retail prices of products meeting various efficiency levels remain fixed, in real terms, after 2010 (the year for which the engineering analysis estimated costs) and throughout the period of the analysis. As discussed in chapter 8, 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, over-estimate long-term appliance and equipment price trends.

For the direct final rule, DOE applied a price trend based on historical PPI data for household laundry equipment to forecast the price of clothes washers sold in each year in the forecast period (see chapter 8 for derivation and description of the price trend). DOE also investigated the impact of different product price forecasts on the consumer net present value (NPV) for the considered TSLs for residential clothes washers. DOE considered four product price forecast sensitivity cases: (1) a trend based on the experience curve approach;[b] (2) a trend based on the "chained price index--other consumer durable goods except ophthalmic" that was forecasted for *AEO2010*; (3) constant prices at 2010 levels. The approach used to forecast the price trends and the results of these sensitivity cases are described in appendix 10-D.

Table 10.4.1 Shipment-Weighted Average Product Cost in 2015 for Base and Trial Standards Levels

	Base Case	Trial Standards Levels				
		1	2	3	4	5
Front-Loading Standard						
SWIMEF	1.85	1.85	1.85	1.91	2.20	2.46
Avg. Product Cost *2010$*	$893	$893	$893	$898	$938	$964
Top-Loading Standard						
SWIMEF	1.03	1.35	1.41	1.35	1.83	2.04
Avg. Product Cost *2010$*	$447	$454	$461	$454	$523	$536
Front-Loading Compact						
SWIMEF	1.03	1.03	1.03	1.03	1.03	1.03
Avg. Product Cost *2010$*	$861	$865	$865	$865	$865	$865
Top-Loading Compact						
SWIMEF	1.03	1.03	1.03	1.03	1.03	1.03
Avg. Product Cost *2010$*	$419	$426	$426	$426	$480	$480

10.4.2.2 Annual Operating Cost Savings per Unit

The average annual operating cost includes the costs for energy, repair, and maintenance. As described in chapter 8, for all the considered products DOE assumed that potential standards would produce no increase in maintenance or repair costs. For both product classes, therefore,

[b] In the experience curve method, the real product price (or proxy thereof) is related to the cumulative production or "experience" with a product. As experience 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 or experience rate. In typical experience curve formulations, the experience rate parameter is derived using two historical data series: price (or cost) and cumulative production, which is a function of shipments during a long time span.

DOE determined the per-unit annual savings in operating cost based only on the savings in energy costs attributable to a standard. DOE determined the per-unit annual savings in operating cost by multiplying the per-unit annual savings in energy consumption developed for each product class by the appropriate energy price. As described in chapter 8, DOE forecasted energy prices based on EIA's *AEO 2010*.

10.4.2.3 Total Annual Increases in Product Cost

The total annual increase in product cost for any given standards case is the product of the average cost increase per unit due to the standard and the number of units of each vintage shipped. The equation for determining the total annual increase in product cost for a given standards case, which was shown in section 10.4.1, is repeated here.

$$TIC_y = \sum SHIP_y \times UTIC_y$$

10.4.2.4 Total Annual Savings in Operating Cost

The total annual savings in operating cost for any given standards case is the product of the annual savings in operating cost per unit attributable to the standard and the number of units of each vintage. This method accounts for differences in annual savings in operating cost from year to year. The equation for determining the total annual savings in operating cost for a given standards case, which was presented in section 10.4.1, is repeated here.

$$OCS = \sum STOCK_V \times UOCS_V$$

10.4.2.5 Discount Factor

DOE multiplied monetary values in future years by a discount factor to determine the present value. The discount factor (DF) is described by the equation:

$$\boldsymbol{DF} = \frac{1}{(1+\boldsymbol{r})^{(y-yp)}}$$

Where:

r = discount rate,
y = year in which the monetary value exists, and
y_P = year in which the present value is being determined.

Although DOE used consumer discount rates to determine the life-cycle cost of clothes washers (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 2011.

10.4.2.6 Present Value of Costs

The present value of increased product costs is the annual total cost increase in each year (the difference between a standards case and the base case), discounted to the present and summed throughout the period in which DOE is considering the installation of products (that is, from the effective date of standards, 2015 to 2044). DOE calculated annual increases in installed cost as the difference in total product cost for new appliances purchased each year, multiplied by the shipments in the standards case.

10.4.2.7 Present Value of Savings

The present value of savings in operating cost is the annual savings on operating cost (the difference between the base case and a standards case), discounted to the present and summed from the effective date to the time when the last unit installed by 2044 is retired from service. Savings are decreases in operating cost associated with the higher energy efficiency of products purchased in the standards case compared to the base case. Total annual savings in operating cost are the savings per unit multiplied by the number of units of each vintage that survive in a particular year.

10.5 RESULTS OF NES AND NPV CALCULATIONS

The National Impact Analysis (NIA) model produces estimates of the NES and NPV attributable to a given candidate standard level. The inputs to the NIA model were discussed in sections 10.3.2 (inputs to NES) and 10.4.2 (inputs to NPV). DOE generated the NES and NPV results using a Microsoft Excel spreadsheet, which is accessible on the Internet <www.eere.energy.gov/buildings/appliance_standards/> Details regarding and instructions for using the spreadsheet are provided in appendix 10-A.

10.5.1 Summary of Inputs

Table 10.5.1 summarizes the inputs to the NIA model. A brief description of the data is provided for each input.

Table 10.5.1 Inputs to Calculation of National Energy Savings and Net Present Value

Input	Description
Shipments	Annual shipments from shipments model. (See chapter 9.)
Effective date of standard	2015
Base-case forecasted efficiencies	See section 10.2.
Standards-case efficiencies	See section 10.2.
Annual energy consumption per unit	Annual weighted-average values are a function of SWEUF. (See section 10.3.2.1.)
Total installed cost per unit	Annual weighted-average values are a function of the efficiency distribution. (See section 10.4.2.1.)
Energy and water cost per unit	Annual weighted-average values are a function of annual energy and water consumption per unit and energy prices. (See chapter 8 for energy and water prices.)
Repair and maintenance costs per unit	No changes in repair and maintenance cost assumed at higher-than-baseline efficiency levels.
Forecast of installed cost per unit	Price forecast based on historical PPI data.
Forecast of energy and water prices	Energy prices: EIA *AEO2010* forecasts (to 2035) and extrapolation thereafter. (See chapter 8). Water prices: Bureau of Labor Statistics 2010 from 1953 and extrapolation thereafter. (See chapter 8).
Marginal energy site-to-source conversion factor	A time-series conversion factor that includes electric generation, transmission, and distribution losses. Conversion, which changes yearly, is generated by DOE-EIA's NEMS* program.
Discount rates	3% and 7% real.
Present year	Future expenses are discounted to 2011.

* Chapter 14, Utility Impact Analysis, provides more detail on the National Energy Modeling System (NEMS).

10.5.2 Results of National Energy and Water Savings Calculations

The following sections provide NES calculation results for the efficiency levels analyzed for the considered products. NES results, which are cumulative from 2015 through 2044, are primary energy savings and site water 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 as in the life-cycle cost and payback period analyses. Results are presented for each TSL which represent specific efficiency level combinations for front- and top-loading clothes washers. Efficiency level combinations are necessary to account for the effect of the cross-price elasticity of demand observed between the two product classes, *i.e.*, the interplay between price

increase and market share between the two product classes. The cross-price elasticity between top- and front-loading units is described in greater detail in chapter 9.

Table 10.5.2 shows the NEWS results for the TSLs analyzed for standard-size front- and top-loading clothes washers. Table 10.5.3 shows the magnitude of the national energy savings (NES) if the savings are discounted at rates of 3 percent and 7 percent. Table 10.5.4 shows the magnitude of the national water savings (NWS) if the savings are similarly discounted.

Table 10.5.2 Cumulative (2015-2044) National Energy and Water Savings

TSL	Efficiency Level Combination				National Energy Savings (Quads)	National Water Savings (Trillion Gallons)
	Front-Loading Standard	Top-Loading Standard	Front-Loading Compact	Top-Loading Compact		
1	2	2	1	1	1.56	1.11
2	4	5	1	1	1.46	1.05
3	5	2, 6*	1	1, 2*	2.04	3.03
4	7	7	1	2	2.87	5.33
5	8	8	1	2	3.32	6.89

*Efficiency Level 2 from 2015 through 2017; Efficiency Level 6 after 2017

Table 10.5.3 Discounted Cumulative National Energy Savings

TSL	Efficiency Level Combination				Energy Savings discounted at 3% (Quads)	Energy Savings discounted at 7% (Quads)
	Front-Loading Standard	Top-Loading Standard	Front-Loading Compact	Top-Loading Compact		
1	2	2	1	1	0.85	0.42
2	4	5	1	1	0.80	0.39
3	5	2, 6*	1	1, 2*	1.10	0.54
4	7	7	1	2	1.56	0.77
5	8	8	1	2	1.81	0.89

*Efficiency Level 2 from 2015 through 2017; Efficiency Level 6 after 2017

Table 10.5.4 Discounted Cumulative National Water Savings

TSL	Efficiency Level Combination				Water Savings discounted at 3% (Trillion Gallons)	Water Savings discounted at 7% (Trillion Gallons)
	Front-Loading Standard	Top-Loading Standard	Front-Loading Compact	Top-Loading Compact		
1	2	2	1	1	0.61	0.30
2	4	5	1	1	0.57	0.27
3	5	2, 6*	1	1, 2*	1.62	0.77
4	7	7	1	2	2.90	1.42
5	8	8	1	2	3.75	1.84

*Efficiency Level 2 from 2015 through 2017; Efficiency Level 6 after 2017

10.5.3 Results of Net Present Value Calculations

This section provides net present value (NPV) calculation results for the potential efficiency standards for residential clothes washer product classes. Results, which are cumulative, are shown as the discounted value of the savings in dollar terms. Results are provided for each potential efficiency standard. DOE based the inputs to the NIA model on weighted-average values, yielding results that are discrete point values, rather than a distribution of values as in the life-cycle cost and payback period analysis.

The present value of increased total installed cost is the total annual increase in installed cost (the difference between the standards case and base case), discounted to the present and summed throughout the period for which DOE evaluated the impact of standards.

Savings are decreases in operating cost associated with the higher energy efficiency of products purchased in the standards case compared to the base case. Total savings in operating cost are the savings per unit multiplied by the number of units of each vintage (*i.e.*, year of manufacture) that survive in a particular year. For units purchased by 2044, the operating cost includes energy consumed until the last unit is retired from service.

Table 10.5.5 presents the NPV associated with the considered standards for clothes washers. Detailed results showing the breakdown of the NPV into national installed product cost and operating cost savings are provided in appendix 10-B. As with the NEWS results, NPV results are presented as a function of TSL.

Table 10.5.5 Discounted Cumulative Net Present Values

	Efficiency Level Combination				**Net Present Value, @ 3% Discount Rate (2010$ B)**	**Net Present Value, @ 7% Discount Rate (2010$ B)**
TSL	Front-Loading Standard	Top-Loading Standard	Front-Loading Compact	Top-Loading Compact		
1	2	2	1	1	20.18	8.73
2	4	5	1	1	18.47	7.77
3	5	2, 6*	1	1, 2*	31.29	13.01
4	7	7	1	2	41.60	16.42
5	8	8	1	2	50.48	19.92

*Efficiency Level 2 from 2015 through 2017; Efficiency Level 6 after 2017

10.6 ANNUALIZED NATIONAL COSTS AND BENEFITS

The benefits and costs of standards for residential dishwashers can be expressed in terms of annualized values over the analysis period. The annualized monetary values are the sum of (1) the annualized national economic value of the benefits from operating products that meet the proposed standards (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase costs, which is another way of representing consumer NPV),

and (2) the monetary value of the benefits of emission reductions, including CO_2 emission reductions. The emissions reductions for each TSL are described in chapter 15, and the derivation of the monetary value of the benefits of emission reductions is described in chapter 16 of this TSD. The value of the CO_2 reductions, otherwise known as the Social Cost of Carbon (SCC), is calculated using a range of values per metric ton of CO_2 developed by a recent interagency process. The derivation of the time series of SCC values is discussed in Appendix 16A of this TSD.

Although combining the values of operating savings and CO_2 reductions provides a useful perspective, two issues should be considered. First, the national operating savings are domestic U.S. consumer monetary savings that occur as a result of market transactions while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use quite different time frames for analysis. The national operating cost savings is measured for the lifetime of products shipped in the 30-year analysis period. The SCC values, on the other hand, reflect the present value of future climate-related impacts resulting from the emission of one ton of carbon dioxide in each year. These impacts go well beyond 2100.

10.6.1 Calculation Method

DOE uses a two-step calculation process to convert each time-series of costs and benefits into annualized values. First, DOE calculates a present value in the "present" year used in discounting the NPV of total consumer costs and savings.[c] For this calculation, DOE uses discount rates of three and seven percent for all costs and benefits except for the value of CO_2 reductions. For the latter, DOE uses the discount rate appropriate for each SCC time-series (see chapter 16 for discussion).

$$PV_x = \sum_{t=y_1,y_\mathrm{T}} (x(t) \cdot (1 + r_x)^{y_\mathrm{NPV} - t}) \qquad [1]$$

Where:

$x(t)$ = Time-series under evaluation,
PV_x = Present value of the time-series x,
y_1 = First year in the analysis period,
y_T = Last year in the analysis period,
y_NPV = Year to which the NPV of consumers' costs and savings are being discounted,
r_x = Discount rate used to discount the annual values of time-series x to year y_NPV.

[c] For the value of emissions reductions, DOE uses a time series that corresponds to the time period used in calculating the operating cost savings (*i.e.*, through the final year in which products shipped are still operating).

In the second step, DOE calculates, from the present values, the fixed annual payments over a 30-year period, starting in the first year of the analysis period (*i.e.*, the compliance year), which yields the same present values with discount rates of three and seven percent. This requires projecting the present values in the "present" year ahead to the compliance year. The fixed annual payments are the annualized values.

$$Ann_{x,r} = PV_x \cdot f_{y_1 - y_{\mathrm{NPV}},r} \cdot a_{30,r} = PV_x \cdot (1+r)^{y_1 - y_{\mathrm{NPV}}} \cdot \frac{r \cdot (1+r)^{30}}{(1+r)^{30} - 1} \qquad [2]$$

Where:

$Ann_{x,r}$ =	Annualized value of the time-series x,
$f_{n,r}$ =	Factor to project a value n years ahead[d] with r discount rate,
$a_{30,r}$ =	Factor to annualize present values over a 30-year period with r discount rate.

Although DOE calculates annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined would be a steady stream of payments.

10.6.2 Results for the Adopted Standards

The direct final rule associated with this TSD states that DOE is adopting amended energy conservation standards for residential clothes washers that correspond to TSL 3. Estimates of annualized benefits and costs for the adopted standards are shown in Table 10.6.1.

The Primary, Low Benefits, and High Benefits Estimates utilize forecasts of energy prices and housing starts from the AEO2010 Reference case, Low Economic Growth case, and High Economic Growth case, respectively. In addition, incremental product costs reflect a declining trend using the default product price trend in the Primary Estimate and the High Benefits Estimate, and constant product prices in the Low Benefits Estimate. See Appendix 10C for discussion of analyses using alternative economic growth scenarios. And see Appendix 8C and Appendix 10C for discussion of the product price trends.

[d] *n* is the number of years between the "present" year and the compliance year.

Table 10.6.1 Annualized Benefits and Costs of Amended Standards for Residential Clothes Washers for Products Sold in 2015–2044

	Discount Rate	Primary Estimate*	Low Net Benefits Estimate*	High Net Benefits Estimate*
		Monetized (million 2010$/year)		
Benefits				
Operating Cost Savings	7%	1234	1101	1379
	3%	1808	1587	2042
CO_2 Reduction at $4.9/t**	5%	34.5	31.7	37.4
CO_2 Reduction at $22.3/t**	3%	142	130	154
CO_2 Reduction at $36.5/t**	2.5%	226	207	246
CO_2 Reduction at $67.6/t**	3%	431	396	469
NO_X Reduction at $2,537/t**	7%	5.40	5.03	5.82
	3%	8.01	7.39	8.68
Total†	7% plus CO_2 range	1274 to 1671	1137 to 1502	1423 to 1854
	7%	1381	1236	1539
	3% plus CO_2 range	1851 to 2248	1626 to 1991	2089 to 2520
	3%	1958	1725	2205
Costs				
Incremental Product Costs	7%	185	258	200
	3%	212	309	230
Total Net Benefits				
Total†	7% plus CO_2 range	1088 to 1485	880 to 1244	1223 to 1654
	7%	1196	978	1339
	3% plus CO_2 range	1639 to 2036	1317 to 1682	1859 to 2291
	3%	1746	1416	1976

* The Primary, Low Benefits, and High Benefits Estimates utilize forecasts of energy prices and housing starts (which affect product shipments) from the AEO2010 Reference case, Low Economic Growth case, and High Economic Growth case, respectively. In addition, incremental product costs reflect a declining trend using the default product price trend in the Primary Estimate and the High Benefits Estimate, and constant product prices in the Low Benefits Estimate. Because product prices are constant in the Low Benefits Estimate, the incremental product costs are higher than in the other two estimates. Although the price trends in the Primary Estimate and the High Benefits Estimate are the same, the incremental product costs are higher in the High Benefits Estimate because this case assumes High Economic Growth and thus has more product shipments. The approach used for forecasting product prices is explained in section IV.F.1.

** The CO_2 values represent global values (in 2010$) of the social cost of CO_2 emissions in 2010 under several scenarios. The values of $4.9, $22.3, and $36.5 per ton are the averages of SCC distributions calculated using 5%, 3%, and 2.5% discount rates, respectively. The value of $67.6 per ton represents the 95th percentile of the SCC distribution calculated using a 3% discount rate. The value for NO_X (in 2010$) is the average of the low and high values used in DOE's analysis.

† Total Benefits for both the 3% and 7% cases are derived using the SCC value calculated at a 3% discount rate, which is $22.3/ton in 2010 (in 2010$). In the rows labeled as "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

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[2] Office of Management and Budget. *OMB Circular A-4, Regulatory Analysis*. 2003. OMB: Washington, D.C. September 17, 2003. <www.whitehouse.gov/omb/assets/omb/circulars/a004/a-4.pdf>

CHAPTER 11. LIFE-CYCLE COST SUBGROUP ANALYSIS

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CHAPTER 11. LIFE-CYCLE COST SUBGROUP ANALYSIS

11.1 INTRODUCTION

Chapter 8 describes the life-cycle cost (LCC) and payback period (PBP) analyses that examine impacts of energy conservation standards on the U.S. population. In analyzing the potential impact of new or amended standards on residential consumers, DOE further evaluates the impact on identifiable groups of consumers (*i.e.*, subgroups) that may be disproportionately affected by a national standard level. The LCC subgroup analysis evaluates impacts by analyzing the LCC and PBPs for subgroups of residential consumers.

For clothes washers, DOE identified two consumer subgroups that warranted further study: (a) households composed of people 65 years of age or older (senior-only); and (b) households at or below the poverty line (low-income). For the compact product classes, DOE identified multi-family households as an additional consumer subgroup.

DOE determined the impact on consumer subgroups for clothes washers using the LCC Spreadsheet Model, which allows for the examination of particular consumer subgroups. DOE has the ability to use the LCC Spreadsheet Model to analyze the LCC for any subgroup by sampling only the data that apply to that subgroup (Chapter 8 explains in detail the inputs to the model used in determining LCC and PBPs). As described in section 11.3, the energy use and energy price characteristics of the two subgroups (senior-only and low-income) are different than that for the general population. The occurrence of compact clothes washers is more likely in multi-family households.

This chapter describes the subgroup identification in further detail and gives the results of the LCC and PBP analyses for the considered subgroups.

11.2 SUBGROUPS DEFINITION

11.2.1 Senior-Only Households

Senior-only households have occupants who are all at least 65 years of age. Based on the DOE Energy Information Administration (EIA)'s Residential Energy Consumption Survey of 2005 (RECS), senior-only households comprise 17 percent of the country's households.[1]

11.2.2 Low-Income Households

As defined in the RECS survey, low-income households are considered to be those at or below the "poverty line." The "poverty line" varies with household size, head of household age, and family income. Table 11.2.1 summarizes the income level baselines for selecting low-income households from the RECS sample. The RECS survey classifies 15 percent of the country's households as low-income.

Table 11.2.1 RECS 2005 Definitions of Low-Income Households by Yearly Income

	Average Income in $		
Household Size	**48 Contiguous States and D.C.**	**Alaska**	**Hawaii**
1	9,570	11,950	11,010
2	12,830	16,030	14,760
3	16,090	20,100	18,510
4	19,350	24,190	22,260
5	22,610	28,270	26,010
6	25,870	32,350	29,760
7	29,130	36,430	33,510
8	32,390	40,510	37,260
9	35,650	44,590	41,010
10	38,910	48,670	44,760
11	42,170	52,750	48,510
12	45,430	56,830	52,260
13	48,690	60,910	56,010
14	51,950	64,990	59,760
15	55,210	69,070	63,510

11.2.3 Multi-Family Households

As defined in the RECS survey, multi-family households are considered to be structures with 2 or more housing units. The RECS survey classifies 11 percent of the country's households as multi-family.

11.3 INPUTS TO THE LIFE-CYCLE COST AND PAYBACK PERIOD SUBGROUP ANALYSIS

DOE performed the consumer subgroup analysis by analyzing the LCC and PBP of senior-only, low-income, multi-family, and manufactured households with the spreadsheet models used for the LCC and PBP analysis.

Table 11.3.1 and Table 11.3.2 summarize the household population for clothes washers, while Tables 11.3.3 through 11.3.6 summarize the weighted-average annual energy use for the households analyzed in the consumer subgroup analyses. These values are compared against the weighted-average values for the national sample.

Table 11.3.1 Household Population

	Top-Loading		Front-Loading	
	Count	Weight	Count	Weight
National	3311	84,104,261	299	7,687,965
Senior-Only	536	14,550,533	37	1,081,370
Senior-Only %	16%	17%	12%	14%
Low-Income	480	9,992,587	15	330,033
Low-Income %	14%	12%	5%	4%

Table 11.3.2 Household Population for Compact Clothes Washers

	Top-Loading		Front-Loading	
	Count	Weight	Count	Weight
Multi-Family	352	9,239,079	26	616,010
Multi-Family %	11%	11%	9%	8%

Table 11.3.3 Weighted-Average Annual Electricity Use for Top-Loading Clothes Washers

kWh/year	**All Households**	**Senior -Only**	**Low-Income**
Baseline	728	448	684
CSL 1	734	453	676
CSL 2	541	333	502
CSL 3	526	326	498
CSL 4	519	321	493
CSL 5	455	306	477
CSL 6	462	284	438
CSL 7	431	265	401
CSL 8	425	262	396

Table 11.3.4 Weighted-Average Annual Electricity Use for Front-Loading Clothes Washers

kWh/year	**All Households**	**Senior -Only**	**Low-Income**
Baseline	429	270	470
CSL 1	422	265	464
CSL 2	404	251	451
CSL 3	393	244	441
CSL 4	411	255	466
CSL 5	386	239	438
CSL 6	387	240	446
CSL 7	379	234	435
CSL 8	361	222	421

Table 11.3.5 Weighted-Average Annual Electricity Use for Top-Loading Compact Clothes Washers

kWh/year	All Households	Senior -Only	Low-Income	Multi-Family
Baseline	509	311	477	387
CSL 1	392	240	358	293
CSL 2	294	188	272	226

Table 11.3.6 Weighted-Average Annual Electricity Use for Front-Loading Compact Clothes Washers

kWh/year	All Households	Senior -Only	Low-Income	Multi-Family
Baseline	306	199	349	292
CSL 1	280	175	325	266

11.4 RESULTS

Tables 11.4.1 through 11.4.10 below summarize the LCC results for clothes washers. The LCC results provide the average installed price; average lifetime operating cost (discounted); average life-cycle cost; average life-cycle cost savings; the percentage of consumers that are burdened with net costs, realize net savings, or are not impacted; and the median payback period.

11.4.1 Senior-Only

Table 11.4.1 Top-Loading Clothes Washers: LCC and PBP Results for Senior-Only Households

CSL	Life-Cycle Cost *(2010$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2010$)*	Households with			Median *(years)*
					Net Cost	No Impact*	Net Benefit	
Baseline	$414	$1,021	$1,435	NA	0%	100%	0%	NA
1	$418	$1,026	$1,443	-$4	30%	60%	11%	4.3
2	$425	$812	$1,237	$163	2%	19%	79%	0.6
3	$431	$862	$1,293	$115	19%	17%	64%	1.2
4	$437	$856	$1,293	$116	19%	16%	65%	1.6
5	$433	$830	$1,263	$142	10%	15%	75%	1.1
6	$448	$731	$1,179	$214	8%	14%	77%	1.4
7	$495	$619	$1,115	$275	19%	5%	77%	2.8
8	$508	$592	$1,099	$291	21%	0%	79%	3.1

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.2 Front-Loading Clothes Washers: LCC and PBP Results for Senior-Only Households

CSL	Life-Cycle Cost *(2010$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2010$)*	Households with			Median *(years)*
					Net Cost	No Impact*	Net Benefit	
Baseline	$865	$785	$1,650	NA	0%	100%	0%	NA
1	$870	$778	$1,648	$0	0%	100%	0%	NA
2	$867	$762	$1,629	$0	0%	100%	0%	NA
3	$869	$722	$1,592	$0	0%	100%	0%	NA
4	$873	$683	$1,557	$1	0%	96%	4%	1.4
5	$888	$595	$1,483	$22	3%	72%	25%	2.2
6	$919	$580	$1,500	$9	52%	23%	25%	17.8
7	$938	$565	$1,503	$6	60%	12%	28%	15.7
8	$964	$506	$1,470	$38	48%	0%	52%	8.7

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.3 Compact Top-Loading Clothes Washers: LCC and PBP Results for Senior-Only Households

CSL	Life-Cycle Cost *(2010$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2010$)*	Households with			Median *(years)*
					Net Cost	No Impact*	Net Benefit	
Baseline	$419	$714	$1,132	NA	0%	100%	0%	NA
1	$425	$608	$1,034	$99	4%	0%	96%	0.8
2	$479	$490	$969	$163	27%	0%	73%	3.5

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.4 Compact Front-Loading Clothes Washers: LCC and PBP Results for Senior-Only Households

CSL	Life-Cycle Cost *(2010$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2010$)*	Households with			Median *(years)*
					Net Cost	No Impact*	Net Benefit	
Baseline	$861	$479	$1,340	NA	0%	100%	0%	NA
1	$865	$434	$1,299	$41	0%	0%	100%	1.1

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

11.4.2 Low-Income

Table 11.4.5 Top-Loading Clothes Washers: LCC and PBP Results for Low-Income Households

CSL	Life-Cycle Cost *(2010$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2010$)*	Households with			Median *(years)*
					Net Cost	No Impact*	Net Benefit	
Baseline	$414	$1,484	$1,898	NA	0%	100%	0%	NA
1	$418	$1,484	$1,902	-$1	25%	60%	16%	2.8
2	$425	$1,181	$1,607	$240	2%	19%	79%	0.5
3	$432	$1,255	$1,686	$173	18%	17%	66%	0.9
4	$437	$1,249	$1,686	$173	18%	16%	66%	1.3
5	$433	$1,218	$1,651	$203	10%	15%	75%	0.9
6	$448	$1,069	$1,517	$319	6%	14%	80%	1.2
7	$496	$898	$1,394	$437	12%	5%	84%	2.2
8	$508	$856	$1,365	$466	14%	0%	86%	2.4

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.6 Front-Loading Clothes Washers: LCC and PBP Results for Low-Income Households

CSL	Life-Cycle Cost *(2010$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2010$)*	Households with			Median *(years)*
					Net Cost	No Impact*	Net Benefit	
Baseline	$865	$1,240	$2,105	NA	0%	100%	0%	NA
1	$870	$1,231	$2,101	$0	0%	100%	0%	NA
2	$866	$1,216	$2,083	$0	0%	100%	0%	NA
3	$869	$1,150	$2,019	$0	0%	100%	0%	NA
4	$873	$1,079	$1,952	$3	0%	96%	4%	1.2
5	$888	$939	$1,827	$36	2%	72%	26%	1.9
6	$919	$910	$1,830	$34	47%	23%	30%	13.6
7	$937	$887	$1,824	$39	54%	12%	34%	14.4
8	$964	$789	$1,753	$109	40%	0%	60%	7.7

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.7 Compact Top-Loading Clothes Washers: LCC and PBP Results for Low-Income Households

CSL	Life-Cycle Cost *(2010$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2010$)*	Households with			Median *(years)*
					Net Cost	No Impact*	Net Benefit	
Baseline	$419	$1,040	$1,459	NA	0%	100%	0%	NA
1	$426	$884	$1,309	$150	3%	0%	97%	0.6
2	$480	$705	$1,184	$275	18%	0%	82%	2.7

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.8 Compact Front-Loading Clothes Washers: LCC and PBP Results for Low-Income Households

CSL	Life-Cycle Cost *(2010$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2010$)*	Households with			Median *(years)*
					Net Cost	No Impact*	Net Benefit	
Baseline	$861	$756	$1,617	NA	0%	100%	0%	NA
1	$865	$694	$1,559	$57	0%	0%	100%	0.9

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

11.4.3 Multi-Family

Table 11.4.9 Compact Top-Loading Clothes Washers: LCC and PBP Results for Multi-Family Households

CSL	Life-Cycle Cost *(2010$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2010$)*	Households with			Median *(years)*
					Net Cost	No Impact*	Net Benefit	
Baseline	$419	$909	$1,328	NA	0%	100%	0%	NA
1	$426	$776	$1,201	$127	2%	0%	98%	0.6
2	$480	$621	$1,101	$227	16%	0%	84%	2.6

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.10 Compact Front-Loading Clothes Washers: LCC and PBP Results for Multi-Family Households

CSL	Life-Cycle Cost *(2010$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2010$)*	Households with			Median *(years)*
					Net Cost	No Impact*	Net Benefit	
Baseline	$860	$644	$1,504	NA	0%	100%	0%	NA
1	$864	$592	$1,456	$48	0%	0%	100%	0.8

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

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[1] U.S. Department of Energy - Energy Information Administration, *Residential Energy Consumption Survey: 2005 Public Use Data Files*, 2005. <http://www.eia.doe.gov/emeu/recs/recspubuse05/pubuse05.html>

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 more stringent energy conservation standards on manufacturers of residential clothes washers, 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 each product in this rulemaking. The GRIM inputs include information on industry cost structure, shipments, and pricing strategies. The GRIM's key output is the industry net present value (INPV). The model estimates the financial impact of more stringent energy conservation standards by comparing changes in INPV between a base case and the various trial standard levels (TSLs) in the standards case. The qualitative part of the MIA addresses product characteristics, manufacturer characteristics, market and product trends, as well as the impact of standards on subgroups of manufacturers.

12.2 METHODOLOGY

DOE conducted the MIA in three phases. Phase I, "Industry Profile," consisted of preliminary research directed at characterizing the residential clothes washer industry. This research involved collecting data on market share, sales volumes and trends, pricing, employment, and the industry financial structure.

In Phase II, "Industry Cash Flow," DOE created a GRIM for residential clothes washers to model the economic impact of amended energy conservation standards to the residential clothes washer industry as a whole. The DOE also developed manufacturer interview guides to gather additional information on the potential impacts on manufacturers in Phase III.

In Phase III, "Subgroup Impact Analysis," DOE interviewed manufacturers representing over 85 percent of residential clothes washers. Interviewees included manufacturers with various market shares and product focus, providing a representative cross-section of the industries. During interviews, DOE discussed financial topics specific to each manufacturer and obtained each manufacturer's view of the industry. The interviews provided DOE with valuable

information for evaluating the impacts of amended energy conservation standards on manufacturer cash flows, investments, and employment.

12.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the residential clothes washer industry that built upon the market and technology assessment prepared for this rulemaking. (See chapter 3 of this Technical Support Document (TSD)). Before initiating the detailed impact studies, DOE collected information on the present and past market structure and characteristics of the industry tracking trends in market share, product attributes, product shipments, manufacturer markups, and the cost structure for various manufacturers.

The profile also included a top-down analysis of manufacturers in the industry using Security and Exchange Commission 10–K filings,[a] Standard & Poor's stock reports,[b] and corporate annual reports released by both public and privately held companies. DOE used this and other publicly available information to derive preliminary financial inputs for the GRIM (*e.g.* revenues, cost of goods sold; depreciation; selling, general and administrative expenses (SG&A); and research and development (R&D) expenses).

12.2.2 Phase II: Industry Cash-Flow Analysis and Interview Guide

Phase II focused on the financial impacts of amended energy conservation standards on the residential clothes washer industry as a whole. Amended energy conservation standards can affect manufacturer cash flows in three distinct ways: (1) by creating a need for increased investment, (2) by raising production costs per unit, and (3) by altering revenue due to higher per-unit prices and/or possible changes in sales volumes. DOE used the GRIM to model these effects in a cash-flow analysis for the residential clothes washer industry. In performing this analysis, DOE used the financial values derived during Phase 1 and the shipment assumptions from the NIA. In addition to the cash-flow analysis, DOE also prepared written guides for manufacturer interviews as part of Phase II.

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 amended energy conservation standards until several years after the standards' compliance date. These factors include annual expected revenues, costs of sales, SG&A, taxes, and capital expenditures related to the amended standards. Inputs to the GRIM include manufacturing costs, markups, and shipment forecasts developed in other analyses. DOE derived the manufacturing costs from the engineering analysis, information provided by the industry, publicly available financial reports, and interviews with manufacturers. DOE developed

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[a] Available online at www.sec.gov.

[b] Available online at www2.standardandpoors.com.

alternative markup scenarios for each GRIM based on discussions with manufacturers. DOE's shipments analysis, presented in chapter 10 of this TSD, provided the basis for the shipment projections in each GRIM. The financial parameters were developed using publicly available manufacturer data and were revised with information submitted confidentially during manufacturer interviews. DOE used the GRIM to compare in industry net present value (INPV) in the base case with INPV at various TSLs (the standards cases). The difference in INPV between the base and standards cases represents the financial impact of the amended standard on manufacturers.

12.2.2.2 Interview Guides

During Phase III of the MIA, DOE interviewed manufacturers to gather information on the effects of amended energy conservation on revenues and finances, direct employment, capital assets, and industry competitiveness. Before the interviews, DOE distributed interview guides for residential clothes washers. The interview guides provided a starting point to help identify relevant issues and understand the impacts of amended energy conservation standards on individual manufacturers or subgroups of manufacturers. Most of the information DOE received from these meetings is protected by non-disclosure agreements and resides with DOE's contractors. Before each telephone interview or site visit, DOE provided company representatives with an interview guide that included the topics for which DOE sought input. The MIA interview topics included (1) key issues to this rulemaking; (2) engineering and life cycle cost follow-up; (3) manufacturer markups and profitability; (4) financial parameters; and (5) conversion costs. The interview guides are presented in appendix 12-A.

12.2.3 Phase III: Subgroup Analysis

While conducting the MIA, DOE interviewed a representative cross-section of residential clothes washer manufacturers. The MIA interviews broadened the discussion to include business-related topics. DOE sought to obtain feedback from industry on the approaches used in the GRIM and to isolate key issues and concerns. During interviews, DOE did not identify any manufacturer subgroups that would warrant a subgroup analysis.

12.2.3.1 Manufacturing Interviews

The information gathered in Phase I and the cash-flow analysis performed in Phase II are supplemented with information gathered from manufacturer interviews in Phase III. The interview process provides an opportunity for interested parties to express their views on important issues privately, allowing confidential or sensitive information to be considered in the rulemaking process.

DOE used these interviews to tailor each GRIM to reflect unique financial characteristics of each product group. Within each manufacturer group, DOE contacted companies from its database of manufacturers. Companies with various market shares and product focus were

interviewed to provide a representation of the industry. Interviews were scheduled well in advance to provide every opportunity for key individuals to be available for comment. Although a written response to the questionnaire was acceptable, DOE sought interactive interviews, which help clarify responses and identify additional issues. The resulting information provides valuable inputs to the GRIM.

12.2.3.2 Revised Industry Cash-Flow Analysis

In Phase II of the MIA, DOE provided manufacturers with preliminary GRIM input financial figures for review and evaluation. During the interviews, DOE requested comments on the values it selected for the parameters. DOE revised its industry cash-flow models based on this feedback. Section 12.4.3 provides more information on how DOE calculated the parameters.

12.2.3.3 Manufacturer Subgroup Analysis

Using average cost assumptions to develop an industry cash flow estimate may not adequately assess differential impacts of amended energy conservation standards on manufacturer subgroups. For example, small businesses, manufacturers of niche products, or companies exhibiting a cost structure that differs significantly from the industry average could be more negatively affected. DOE uses the results of the industry characterization to group manufacturers exhibiting similar characteristics. During the interviews, DOE discussed the potential subgroups and subgroup members it identified for the analysis. DOE asked manufacturers and other interested parties to suggest what subgroups or characteristics are the most appropriate to analyze. As discussed below, since DOE only identified one small business manufacturer, DOE did not conduct a separate subgroup analysis of small business manufacturers.

12.2.3.4 Small-Business Manufacturer

DOE used the Small Business Administration (SBA) small business size standards published on August 22, 2008, 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 the rulemaking.[c] For the product classes 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.

[c] The size standards are available on the SBA's website at www.sba.gov/idc/groups/public/documents/sba_homepage/serv_sstd_tablepdf.pdf.

Table 12.2.1 SBA and NAICS Classification of Small Businesses Potentially Affected by This Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Household Laundry Equipment Manufacturing	N/A	1000	335224

DOE used the Association of Home Appliance Manufacturers (AHAM)[1] member directory as well as public certification databases including the Consortium of Energy Efficiency (CEE),[2] California Energy Commission (CEC),[3] and ENERGY STAR[4]to identify manufacturers of residential clothes washers. DOE then checked this list of clothes washer manufacturers against the employee limit for small businesses using reports from vendors such as Dun & Bradstreet. DOE also consulted publicly available data from the Small Business Association (SBA) to determine the presence of any additional small businesses in the industry. Further, DOE asked interested parties and industry representatives if they were aware of other small business manufacturers and checked any companies identified against the small business criteria.

During its research, DOE identified one small business that manufactures products covered by this rulemaking and meets the criteria as specified by the SBA. DOE conducted an analysis of potential impacts of increased energy efficiency standards on this manufacturer. Section 12.6 provides the details of this analysis.

12.2.3.5 Manufacturing Capacity Impact

One significant outcome of amended energy conservation standards could be the obsolescence of existing manufacturing assets, including tooling and production equipment. The manufacturer interview guides have a series of questions to help identify impacts of amended standards on manufacturing capacity, specifically capacity utilization and plant location decisions in the United States and North America, with and without amended standards; the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new requirements; the nature and value of any stranded assets; and estimates for any one-time changes to existing plant, property, and equipment (PPE). DOE's estimates of the one-time capital changes and stranded assets affect the cash flow estimates in the GRIMs. These estimates can be found in section 12.4.8; DOE's discussion of the capacity impact can be found in section 12.7.2.

12.2.3.6 Employment Impact

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. To assess how domestic direct employment patterns might be affected, the interviews explored current employment trends in the residential clothes washer industry. The interviews also solicited manufacturer views on changes in employment patterns that may result from more stringent standards. The employment impacts section of the interview guide focused on current employment levels associated with manufacturers at each production facility, expected future employment levels with and without amended energy

conservation standards, and differences in workforce skills and issues related to the retraining of employees. The employment impacts are reported in section 12.7.1.

12.2.3.7 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects on manufacturers due to amended energy conservation standards and other regulatory actions affecting the same products. DOE analyzed the impact on manufacturers of multiple, product-specific regulatory actions. Based on its own research and discussions with manufacturers, DOE identified regulations relevant to residential clothes washer manufacturers, such as State regulations and other Federal regulations that impact other products made by the same manufacturers. Discussion of the cumulative regulatory burden can be found in section 12.7.3.

12.3 MANUFACTURER IMPACT ANALYSIS KEY ISSUES

Each MIA interview starts by asking: "What are the key issues for your company regarding the energy conservation standard rulemaking?" This question prompts manufacturers to identify the issues they feel DOE should explore and discuss further during the interview. The following section describes key issues manufacturers mentioned for all product classes under review.

12.3.1 Potentially Large Conversion Costs

Manufacturers indicated that they were greatly concerned about the potential for this rulemaking to require significant product and capital conversion costs. Introducing new residential clothes washer platforms involves very large upfront costs. These capital and product development costs can be justified because a basic platform typically undergoes incremental changes over a number design cycles and the initial investment can be at least partially spread over all these shipments. Many of the existing residential clothes washer platforms have some designs options available that would only necessitate these incremental types of changes. However, substantially higher efficiencies could potentially necessitate a drum or cabinet capacity change. In this case, rather than altering the current platform, the required changes are more in line with designing a completely new platform. A new platform would require replacing most production equipment at a very large capital cost. Manufacturers also indicated that these initial costs for a new basic platform could result in a substantial shift in employment. Some manufacturers were also concerned that devoting resources to efficiency improvements could hurt their products in the market because these efforts could come at the expense of other features.

12.3.2 Product Classes

Manufacturers were divided on the need to retain top-loading and front-loading standard-size product classes. In general, manufacturers that produce top-loading clothes washers favored retaining the two distinct product classes. Manufacturers that produce only front-loading clothes washers were less concerned with maintaining the method of access as a product class distinction.

While all manufacturers agreed front-loading clothes washers are an important product offering, many manufacturers also stated that top-loading clothes washers are an important option for consumers because they offer the following benefits:

- Shorter cycle times
- Lower price points
- Lower installation costs because they do not require a pedestal
- Easier loading
- Easier access to add garments mid-cycle
- Less floor vibration

Some manufacturers in favor of maintaining the separate product classes also stated that eliminating top-loading clothes washers would harm lower-income customers who typically purchase baseline clothes washers. In addition, because front-loading clothes washers are mature in the marketplace, consumers are aware of the benefits of top-loading clothes washers, high efficiency top-loading products, and front-loading clothes washers and have the ability to choose higher efficiency products in either configuration.

12.3.3 Wash Performance

Manufacturers were concerned that efficiency gains over time have limited the potential to improve efficiency without possibly decreasing wash performance and negatively impacting consumer utility. Many manufacturers were concerned that a test procedure that did not take a minimum wash performance into consideration, coupled with a more stringent energy conservation standard, could force manufacturers to limit water consumption to a level that would harm consumers. For example, over-sudsing could be more commonplace. Also, water levels could be reduced to the point where cold water would no longer sufficiently clean clothes. Either one of these issues would result in lost energy savings as consumers either rewashed clothes or no longer selected cold water wash cycles. Consequently, many manufacturers supported adding a performance metric to the test procedure to ensure that consumers would genuinely benefit from improved efficiency.

12.3.4 Tub Capacity Measurement

Many manufacturers mentioned that different companies use inconsistent approaches in measuring tub capacity. While manufacturers offered slightly different suggestions for how to measure capacity, most were supportive of eliminating the ambiguity. Manufacturers hoped this issue would be resolved before the implementation of these amended energy conservation standards because both the modified energy factor and water factor calculations depend on measured capacity.

12.3.5 ENERGY STAR

One manufacturer mentioned an unwillingness to design new residential clothes washers that just meet the baseline compliance level. This manufacturer exclusively produces clothes washers that meet ENERGY STAR specifications. Because of their overall energy strategy, they must take into consideration ENERGY STAR levels when designing new clothes washers in order to remain competitive in that market segment. This manufacturer mentioned that the costs associated with designing new products to meet ENERGY STAR levels were not reflected in DOE's incremental cost tables.

Another manufacturer mentioned that ENERGY STAR compliance is an important purchasing factor, especially in the front-loading clothes washer market. The manufacturer expressed concern that standards that are too aggressive could jeopardize the future of the ENERGY STAR program for residential clothes washers. In turn, that could impact local rebates that enable manufacturers to offer products that meet the minimum efficiency standards.

12.4 GRIM INPUTS AND ASSUMPTIONS

The GRIM serves as the main tool for assessing the impacts on industry due to 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 an accounting model that calculates the industry cash flow both with and without amended energy conservation standards.

12.4.1 Overview of the GRIM

The basic structure of the GRIM, illustrated in Figure 12.4.1, is an annual cash flow analysis that uses manufacturer prices, manufacturing costs, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM spreadsheet uses a number of inputs to arrive at a series of annual cash flows, beginning with the base year of the analysis, 2011, and continuing to 2044. The model calculates the INPV by summing the stream of annual discounted cash flows during this period.[5]

Figure 12.4.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the base-case and the standard-case scenario induced by amended energy conservation standards. The difference in INPV between the base case and the standard case(s) represents the estimated financial impact of the amended energy conservation standard on manufacturers. Appendix 12-A provides more technical details and user information for the GRIM.

12.4.2 Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, U.S. Census data, credit ratings, the shipments model, the engineering analysis, and the manufacturer interviews.

12.4.2.1 Corporate Annual Reports

Corporate annual reports for publicly held companies are freely available to the general public through the SEC as filings of form 10-K. Additionally, some privately held companies publish annual financial reports which are regularly available on their corporate websites. DOE developed initial financial inputs to the GRIM by examining the publicly available annual reports of companies primarily engaged in the manufacture of home appliances and whose combined product range includes residential clothes washers. Because these companies produce a range of different products, DOE initially assumed that the industry average figures calculated for these companies were representative of manufacturing for residential clothes washers. Since these companies do not provide detailed information about their individual product lines, DOE used the financial information for the entire companies in developing its initial estimates of the financial parameters in both GRIM analyses. These figures were later revised using feedback from interviews to be representative of manufacturing for each product. DOE used corporate annual reports to derive the following initial inputs to the GRIM:

- Tax rate

- Working capital
- SG&A
- R&D
- Depreciation
- Capital expenditures
- Net PPE

12.4.2.2 Standard and Poor Credit Ratings

Standard and Poor (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 weighted average cost of capital.

12.4.2.3 Shipments Model

The GRIM used shipment projections derived from DOE's shipments model in the national impact analysis (NIA). The model relied on historical shipments data for residential clothes washers. Chapter 10 of the TSD describes the methodology and analytical model DOE used to forecast shipments.

12.4.2.4 Engineering Analysis

DOE conducted the engineering analyses for this rulemaking using the efficiency-level approach, combined with the cost-assessment approach, to develop a cost for each efficiency level for residential clothes washers. During this analysis, DOE used a manufacturing cost model to develop manufacturer production cost (MPC) estimates for residential clothes washers. The analysis yielded the labor, materials, overhead, and total production costs for products at each efficiency level. The engineering analysis also estimated a manufacturer markup to determine the manufacturer selling price (MSP) for each product at every efficiency level. Chapter 5 of this TSD describes the engineering analysis in detail.

12.4.2.5 Manufacturer Interviews

During the course of the MIA, DOE conducted interviews with a representative cross-section of manufacturers. DOE also interviewed manufacturers representing a significant portion of sales in every product class. During these discussions, DOE obtained information to determine and verify GRIM input assumptions in each industry. Key topics discussed during the interviews and reflected in the GRIM include:

- Capital conversion costs (one-time investments in PPE);
- Product conversion costs (one-time investments in research, product development, testing, and marketing);

- Product cost structure, or the portion of the MPCs related to materials, labor, overhead, and depreciation costs;
- Projected total shipment and shipment distribution mix; and
- MPCs estimated in the engineering analysis.

12.4.3 Financial Parameters

In the manufacturer interviews, DOE used the financial parameters from 2004 to 2009 for appliance manufacturers as a starting point for determining the residential clothes washer industry financial parameters. These initial estimates were used because many of the same white goods manufacturers produce a number of different product lines (including clothes washers, cooking products, clothes dryers, and room air conditioners) and no other publicly available SEC 10-K reports for residential clothes washer manufacturers were available. These financial parameters were determined by averaging the values in the annual reports of three publicly traded companies engaged in manufacturing and selling clothes washers over an 8-year period spanning from 1999 through 2006. Table 12.4.1 below shows the data used to determine the initial financial parameter estimates.

Table 12.4.1 GRIM Financial Parameters Based on 1999–2006 Weighted Company Financial Data

Parameter	Industry-Weighted Average	Manufacturer			
		A	B	C	D
Tax Rate *(% of Taxable Income)*	34.3	33.5	47.3	22.5	33.3
Working Capital *(% of Revenue)*	6.5	12.1	10.8	14.2	3.6
SG&A *(% of Revenue)*	11.3	13.7	17.9	9.8	10.0
R&D *(% of Revenues)*	2.2	2.3	1.9	1.0	2.3
Depreciation *(% of Revenues)*	4.7	2.9	22,5	2.8	3.0
Capital Expenditures *(% of Revenues)*	2.7	1.6	3.1	4.3	3.2
Net Property, Plant, and Equipment *(% of Revenues)*	17.7	16.7	14.9	24.9	17.4

During interviews, manufacturers were asked to provide their own figures for the parameters listed in Table 12.4.1. DOE adjusted the depreciation and capital expenditures according to the manufacturers' feedback.

12.4.4 Corporate Discount Rate

DOE used the weighted-average cost of capital (WACC) as the discount rate to calculate the INPV. A company's assets are financed by a combination of debt and equity. The WACC is the total cost of debt and equity weighted by their respective proportions in the capital structure of the industry. DOE estimated the WACC for the residential clothes washer industry based on several representative companies, using the following formula:

WACC = After-Tax Cost of Debt x (Debt Ratio) + Cost of Equity x (Equity Ratio) Eq. 1

The cost of equity is the rate of return that equity investors (including, potentially, the company) expect to earn on a company's stock. These expectations are reflected in the market price of the company's stock. The capital asset pricing model (CAPM) provides one widely used means to estimate the cost of equity. According to the CAPM, the cost of equity (expected return) is:

Cost of Equity = Riskless Rate of Return + β x Risk Premium Eq. 2

where:

Riskless rate of return is the rate of return on a "safe" benchmark investment, typically considered the short-term Treasury Bill (T-Bill) yield.

Risk premium is the difference between the expected return on stocks and the riskless rate.

Beta (β) is the correlation between the movement in the price of the stock and that of the broader market. In this case, Beta equals one if the stock is perfectly correlated with the S&P 500 market index. A Beta lower than one means the stock is less volatile than the market index.

DOE determined that the industry average cost of equity for the residential clothes washer industry is 20.6 percent (Table 12.4.2).

Table 12.4.2 Cost of Equity Calculation

Parameter	**Industry-Weighted Average %**	**Manufacturer**			
		A	B	C	D
(1) Average Beta (2002-2006 year)	1.79	1.0	1.46	1.80	1.99
(2) Yield on 10-Year T-Bill (1990-2007)	4.13	-	-	-	-
(3) Market Risk Premium (1926-1999)	9.2	-	-	-	-
Cost of Equity (2)+[(1)*(3)]	20.6	-	-	-	-
Equity/Total Capital	37.2	38,2	64.8	75.0	59.4

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 all three 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 4 percent, which is the average 10-year Treasury bond return between 1990 and 2007 (the analysis period used in the initial estimate for commercial clothes washers).

For the cost of debt, S&P's Credit Services provided the average spread of corporate bonds for the three public manufacturers between 2002 and 2006. As stated above, the representative data was taken from the commercial clothes washer final rule since several of the representative manufacturers are the same as in the residential clothes washer industry. DOE added the industry-weighted average spread to the average T-Bill yield over the same period. Since proceeds from debt issuance are tax deductible, DOE adjusted the gross cost of debt by the industry average tax rate to determine the net cost of debt for the industry. Table 12.4.3 presents the derivation of the cost of debt and the capital structure of the industry (*i.e.* the debt ratio (debt/total capital)).

Table 12.4.3 Cost of Debt Calculation

Parameter	**Industry-Weighted Average %**	**Manufacturer**			
		A	B	C	D
S&P Bond Rating	--	B	BBB	BB	B+
(1) Yield on 10-Year T-Bill (1990-2006)	4.3	-	-	-	-
(2) Gross Cost of Debt	8.6	9.78	6.63	7.78	8.63
(3) Tax Rate	34.3	33.5	47.3	22.5	33.3
Net Cost of Debt (2) x ((1)-(3))	5.7	-	-	-	-
Debt/Total Capital	32.9	38,2	64.8	75.0	59.4

Using public information for these three companies from the commercial clothes washer final rule, the initial estimate for the residential clothes washer industry's WACC was approximately 10.1 percent. Subtracting an inflation rate of 2.9 percent over the analysis period used in the initial estimate, the inflation-adjusted WACC and the initial estimate of the discount rate used in the straw-man GRIM is 8.0 percent. DOE also asked for feedback on the 8.0 percent discount during manufacturer interviews and slightly adjusted this figure for the residential clothes washers' GRIM.

12.4.5 Trial Standard Levels

DOE developed TSLs for residential clothes washers. For residential clothes washers, DOE analyzed four product classes – standard top-loading residential clothes washers, standard front-loading residential clothes washers, compact top-loading residential clothes washers, and compact front-loading residential clothes washers. Table 12.4.4 presents the TSLs and the

corresponding product class efficiency levels for residential clothes washers based on modified energy factor (MEF) and water factor (WF) according to the current test procedure (appendix J1). Table 12.4.5 presents the TSLs and the corresponding product class efficiency levels based on integrated modified energy factor (IMEF) and integrated water factor (WF) according to the revised test procedure (appendix J2) published in the *Federal Register* on March 7, 2012. 77 FR 13888.

TSL 1 consists of the efficiency levels that are two steps up in efficiency (EL 2) from the baseline levels for standard clothes washers, and one step up in efficiency (EL 1) from baseline levels for compact products. For standard clothes washers, TSL 2 represents an intermediary point between the efficiency levels chosen for TSL 1 and the efficiency levels recommended in the Joint Petition, and maintains the same efficiency levels for compact products as in TSL 1. TSL 3 consists of the efficiency levels recommended in a joint petition submitted by interested parties to DOE[d] ("Joint Petition"). The Joint Petition proposes energy efficiency standards for four residential clothes washer product classes. In the case of TSL 3, for top-loading standard clothes washers, a first tier of standards would apply starting in 2015, a second, more stringent tier would apply starting in 2018. TSL 4 consists of the efficiency levels that are one level below (EL 7) the max-tech efficiency levels (EL 8) for standard clothes washers, and the max-tech efficiency levels for both compact product classes. TSL 5 consists of the max-tech efficiency levels for all product classes.

Table 12.4.4 Trial Standard Levels for Residential Clothes Washers (Using Appendix J1)

Product Class		**Baseline**	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
Standard-Size Top-Loading	**MEF**	1.26	1.72	1.80	2.00	2.26	2.47
	WF	9.50	8.00	7.50	6.00	4.48	3.60
Standard-Size Front-Loading	**MEF**	1.72	1.72	2.00	2.20	2.60	2.89
	WF	8.00	8.00	6.00	4.50	3.80	3.20
Compact Top-Loading	**MEF**	0.77	1.26	1.26	1.81	1.81	1.81
	WF	14.0	14.0	14.0	11.6	11.6	11.6
Compact-Size Front-Loading	**MEF**	1.60	1.72	1.72	1.72	1.72	1.72
	WF	8.5	8.0	8.0	8.0	8.0	8.0

* See 10 CFR part 430 (31 October 2003), pp. 62198 – 62204

[d] "Agreement on Minimum Federal Efficiency Standards, Smart Appliances, Federal Incentives and Related Matters for Specified Appliances," DOE Docket No. EERE–2008–BT–STD–0019, Comment 32. DOE considered the Joint Petitioners' comments to supersede earlier comments by the listed parties regarding issues subsequently discussed in the Joint Petition.

Table 12.4.5 Trial Standard Levels for Residential Clothes Washers (Using Appendix J2)

Product Class		Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Standard-Size Top-Loading	**IMEF**	0.84	1.29	1.37	1.57	1.83	2.04
	IWF	9.92	8.44	7.95	6.47	4.96	4.10
Standard-Size Front-Loading	**IMEF**	1.37	1.41	1.66	1.84	2.20	2.46
	IWF	8.31	8.31	6.26	4.73	4.01	3.39
Compact Top-Loading	**IMEF**	0.59	0.86	0.86	1.15	1.15	1.15
	IWF	14.4	14.4	14.4	12.0	12.0	12.0
Compact-Size Front-Loading	**IMEF**	1.03	1.13	1.13	1.13	1.13	1.13
	IWF	8.8	8.3	8.3	8.3	8.3	8.3

* See 10 CFR part 430 (21 September 2010), pp. 57556 - 57595

12.4.6 NIA Shipments Forecast

The GRIM estimates manufacturer revenues based on total-unit-shipments forecasts and the distribution of these values by efficiency level. Changes in the efficiency mix at each standard level are a key driver of manufacturer finances. For this analysis, the GRIM used the NIA shipments forecasts from 2011 to 2044 for residential clothes washers. Chapter 10 of the TSD explains DOE's calculations of total shipments in detail. Table 12.4.6 shows total shipments forecasted in the shipments analysis for residential clothes washers in 2015.

Table 12.4.6 Total NIA Shipments Forecast in 2015 in the Reference NIA Shipment Scenario (Residential Clothes Washers)

Product Class	Total Industry Shipments
Standard-Size Top-Loading	4,324,091
Standard-Size Front-Loading	5,158,278
Compact-Size Top-Loading	95,984
Compact-Size Front-Loading	20,000

12.4.6.1 Base-Case Shipments Forecast

As part of the shipments analysis, DOE estimated the shipment distributions by efficiency level for residential clothes washers. DOE held the base-case energy efficiency distributions constant throughout the forecast period. Table 12.4.7 shows the base-case distributions of shipments by efficiency level estimated in the NIA for the residential clothes washer product classes.

Table 12.4.7 Base-Case Distributions of Efficiencies for Residential Clothes Washers in 2015

Product Class		Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7	EL 8
Standard-Size Top-Loading	IMEF	0.84	0.98	1.29	1.34	1.34	1.37	1.57	1.83	2.04
	% of the Market at EL	43.6	43.6	1.9	0.6	0.6	0.6	4.6	4.6	0.0
Standard-Size Front-Loading	IMEF	1.37	1.39	1.41	1.49	1.66	1.84	2.02	2.20	2.46
	% of the Market at EL	0.0	0.0	0.0	4.3	24.0	48.9	11.4	11.4	0.0
Compact-Size Top-Loading	IMEF	0.59	0.86	1.15						
	% of the Market at EL	100.0	0.0	0.0						
Compact-Size Front Loading	IMEF	1.03	1.13							
	% of the Market at EL	100.0	0.0							

12.4.6.2 Standards-Case Shipments Forecast

To examine the effects of amended energy conservation standards on shipments, which affect the INPV, DOE used the base-case shipments described in the previous section. For the standards case, DOE used the shipments developed in the NIA for residential clothes washers. DOE used a roll-up scenario to determine efficiency distributions for the standards case. In this scenario, products that fall below the amended energy conservation standard are assumed to "roll-up" to the new standard in 2015.

DOE also assumed there was relative price elasticity in the residential clothes washer market, meaning that amended energy conservation standards that increase the first cost of residential clothes washers would result in lower total shipments.

12.4.7 Production Costs

The changes in the MPCs of the analyzed products can affect revenues, gross margins, and cash flow of the industry, making these product cost data key GRIM inputs for DOE's analysis.DOE used the manufacturer production costs (MPCs) calculated in the engineering analysis for each efficiency level, as described in chapter 5 of the direct final rule TSD. DOE used the AHAM data submittal to determine the MPCs at most efficiency levels for top-loading and front-loading standard-size product classes. To supplement the AHAM submittal and calculate max-tech MPCs for these product classes, DOE also conducted product tear downs to generate MPCs using a manufacturing cost model. DOE also created separate cost curves for top-loading and front-loading compact product classes using a combination of tear-downs to develop baseline MPCs and the incremental costs for the standard product classes. The cost model also provided a breakdown of MPCs into material, labor, overhead, and depreciation that DOE applied to the AHAM-provided MPCs at each efficiency level. The top-loading standard clothes washer breakdown was also applied to the top-loading compact MPCs and the front-

loading standard clothes washer breakdown was used for the front-loading compact product class.

DOE used the AHAM data submittal to determine the MPCs at most efficiency levels. To supplement the AHAM submittal and calculate max-tech MPCs, DOE also conducted product teardowns to generate cost-efficiency curves for the top-loading standard and front-loading standard product classes. These cost-efficiency relationships were compared to AHAM data and manufacturer feedback for validation. The cost model provided a breakdown of MPCs into material, labor, overhead, and depreciation that DOE applied to the AHAM-provided MPCs at each efficiency level.

Manufacturing a higher-efficiency product is typically more costly than manufacturing a baseline product due to the use of more complex components and higher-cost raw materials. The changes in the MPCs of the analyzed products can affect revenues, gross margins, and cash flow of the industry, making these data a key GRIM input for DOE's analysis.

The GRIM also included DOE's estimate of the proportion of costs devoted to labor, materials, overhead, and depreciation that make up the full cost of production. For the MPC breakdown in the MIA, DOE used a depreciation value that is consistent with historical information in SEC 10-Ks. The remainder of total overhead was allocated to factory overhead. To calculate the incremental MPCs for products above the baseline, DOE added the incremental material, labor, and overhead costs from the engineering cost-efficiency curves to the baseline MPCs.

The MSP is comprised of production costs (the direct manufacturing costs or MPCs), non-production costs (indirect costs like SG&A), and profit. DOE calculated the MSPs for residential clothes washers by multiplying the MPCs by the appropriate manufacturer markup for that product. Table 12.4.8 through Table 12.4.11 show the production cost estimates used in the GRIM for the representative product classes for residential clothes washers.

Table 12.4.8 MPC Breakdown for Standard-Size Top-Loading Clothes Washers

TSL (Efficiency Level)	IMEF	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline	0.84	46.53	154.00	33.53	13.60	247.65	1.22	302.13
TSL 1 (EL 2)	1.29	47.93	160.37	33.73	14.06	256.09	1.22	312.43
TSL 2 (EL 5)	1.37	49.69	164.20	33.61	14.38	261.88	1.22	319.50
TSL 3 (EL 6)	1.57	52.14	172.13	33.68	14.98	272.93	1.26	343.90
TSL 4 (EL 7)	1.83	50.19	206.23	34.95	16.93	308.30	1.30	400.79
TSL 5 (EL 8)	2.04	34.19	234.62	31.20	17.43	317.44	1.30	412.67

Table 12.4.9 MPC Breakdown for Standard-Size Front-Loading Clothes Washers

TSL (Efficiency Level)	IMEF	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline	1.37	58.13	390.62	40.94	28.45	518.13	1.22	632.12
TSL 1 (EL 2)	1.46	58.13	391.80	40.87	28.51	519.31	1.22	633.55
TSL 2 (EL 4)	1.66	59.43	395.26	40.86	28.79	524.33	1.26	660.65
TSL 3 (EL 5)	1.84	60.54	404.34	41.11	29.39	535.38	1.30	695.99
TSL 4 (EL 7)	2.20	64.49	438.50	37.61	31.40	572.01	1.30	743.61
TSL 5 (EL 8)	2.46	66.95	449.70	42.51	32.48	591.64	1.30	769.13

Table 12.4.10 MPC Breakdown for Compact-Size Top-Loading Clothes Washers

TSL (Efficiency Level)	IMEF	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline	0.59	47.09	155.88	33.94	13.76	250.68	1.22	305.83
TSL 1 (EL 1)	0.86	47.97	159.42	34.26	14.04	255.68	1.22	311.93
TSL 2 (EL 1)	0.86	47.97	159.42	34.26	14.04	255.68	1.22	311.93
TSL 3 (EL 2)	1.15	55.34	185.17	38.94	16.23	295.68	1.22	360.73
TSL 4 (EL 2)	1.15	55.34	185.17	38.94	16.23	295.68	1.22	360.73
TSL 5 (EL 2)	1.15	55.34	185.17	38.94	16.23	295.68	1.22	360.73

Table 12.4.11 MPC Breakdown for Compact-Size Front-Loading Clothes Washers

TSL (Efficiency Level)	IMEF	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline	1.03	57.86	388.83	40.75	28.31	515.75	1.22	629.22
TSL 1 (EL 1)	1.13	57.76	392.05	40.46	28.48	518.75	1.22	632.88
TSL 2 (EL 1)	1.13	57.76	392.05	40.46	28.48	518.75	1.22	632.88
TSL 3 (EL 1)	1.13	57.76	392.05	40.46	28.48	518.75	1.22	632.88
TSL 4 (EL 1)	1.13	57.76	392.05	40.46	28.48	518.75	1.22	632.88
TSL 5 (EL 1)	1.13	57.76	392.05	40.46	28.48	518.75	1.22	632.88

12.4.8 Conversion Costs

Amended energy conservation standards typically cause manufacturers to incur one-time conversion costs to bring their production facilities and product designs into compliance with new regulations. For the MIA, DOE classified these one-time conversion costs into two major groups: capital conversion costs and product conversion costs. Capital conversion costs are one-time investments in PPE to adapt or change existing production facilities so that new product designs can be fabricated and assembled under the new regulation. Product conversion costs are one-time investments in research, development, testing, marketing and other costs to make product designs comply with amended energy conservation standards. The following sections describe the inputs DOE used in the GRIM in greater detail.

12.4.8.1 Residential Clothes Washer Product and Capital Conversion Costs

Amended energy conservation standards will cause manufacturers to incur conversion costs to bring their production facilities and product designs into compliance. For the MIA, DOE classified these costs into two major groups: (1) product conversion costs and (2) capital

conversion costs. Product conversion costs are investments in research, development, testing, marketing, and other non-capitalized costs focused on making product designs comply with the amended energy conservation standard. Capital conversion costs are investments in property, plant, and equipment to adapt or change existing production facilities so that new product designs can be fabricated and assembled.

DOE based its conversion cost estimates that would be required to meet each TSL on the AHAM data submittal. At each efficiency level, DOE matched the IMEF efficiency level to the corresponding MEF metric and used the aggregated total industry capital and product conversion cost from the May 2010 AHAM submittal. DOE multiplied each aggregated capital and product conversion total by 1.05 to account for the non-AHAM member shipments. For the new max-tech levels that were revised by DOE after the AHAM data submittal, DOE scaled the aggregated total conversion costs at the next lowest efficiency level by the same percentage increase in production costs. DOE did not increase the require product and capital conversion costs for efficiency levels that did not analyze changes to active mode efficiency. Using the AHAM data submittal for both the product and the capital conversion costs insures that the one-time costs required to meet amended energy conservation standards are consistent with the incremental costs to reach those efficiencies.

DOE took a number of steps to understand the conversion costs in the AHAM data submittal. DOE reviewed the AHAM conversion costs during manufacturer interviews to understand the magnitude and cost of the required conversions for individual manufacturers. DOE also reviewed public information in the CEC, ENERGY STAR, CEE product databases as well as manufacturer websites to understand which products manufacturers would upgrade at each efficiency level. DOE also reviewed the AHAM submittal in conjunction with the technology options and information learned during product teardowns for multiple product lines.

For the top-loading compact product class, DOE scaled the top-loading standard conversion costs for the same efficiency level by the relative number of compact platforms. DOE estimated the number of top-loading standard and compact platforms using publicly available information from manufacturer websites and product databases as well as insights gained in the engineering analysis. DOE did not include conversion costs for the front-loading compact product classes because the design options analyzed to improve efficiency would require minimal changes to baseline products.

Table 12.4.12 through Table 12.4.15 show DOE's estimates of the product and capital conversion costs necessary for each residential clothes washer product class at each TSL.

Table 12.4.12 Product and Capital Conversion Costs for Standard-Size Top-Loading Clothes Washers by TSL

TSL (Efficiency Level)	IMEF	Design Options Considered	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
Baseline	0.84		0.0	0.0
TSL 1 (EL 2)	1.29	Agitator modification Basket shape modification Electronic controls Higher spin speeds Larger capacity Load size sensors More advanced water inlets Spray rinse Stainless steel basket Variable speed drive Water temperature sensors (Thermistors)	21.2	79.7
TSL 2 (EL 5)	1.37	Higher spin speeds Larger capacity Pressure switch accuracy improvement Stronger basket	29.3	91.3
TSL 3 (EL 6)	1.57	Adaptive fill technology Agitator replaced by impeller High suspension Higher spin speeds Larger capacity Longer cycle times Lower water temperatures More mechanical action More sensing technology More sophisticated electronic control Out of balance detection Recirculation pumps Stainless steel basket	66.3	117.0
TSL 4 (EL 7)	1.83	Absorption sensors Accelerometers Better motor Better temperature control Gray water rinse Higher capacity Higher chemical concentration Highest spin speeds Load composition sensors Longer cycle times More mechanical action More robust suspension system Most sophisticated load detection Tachometer Water flow meters	92.1	185.0

TSL 5 (EL 8)	2.04	No information provided by manufacturers	94.8	190.5

Table 12.4.13 Product and Capital Conversion Costs for Standard-Size Front-Loading Clothes Washers by TSL

TSL (Efficiency Level)	IMEF	Design Options Considered	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
Baseline	1.37		0.0	0.0
TSL 1 (EL 2)	1.41	Electronic user interface	0.0	0.0
TSL 2 (EL 4)	1.66	Larger capacity Recirculation pump Better control technology	10.9	14.9
TSL 3 (EL 5)	1.84	Sophisticated damping system Analog pressure sensors Water flow meter Higher spin speeds Longer cycle time Reinforced structure Larger capacity	38.2	182.8
TSL 4 (EL 7)	2.20	Larger capacity Recirculation pump Better control technology	109.3	291.2
TSL 5 (EL 8)	2.46	More precise dispensing of chemicals Load size sensors Fuzzy logic	113.0	301.2

Table 12.4.14 Product and Capital Conversion Costs for Compact-Size Top-Loading Clothes Washers by TSL

TSL (Efficiency Level)	IMEF	Design Options Considered	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
Baseline	0.59		0.0	0.0
TSL 1 (EL 1)	0.86	Spray Rinse Larger Capacity Eliminate Warm Rinse Reduced Water Temperatures	1.4	1.5
TSL 2 (EL 1)	0.86	Spray Rinse Larger Capacity Eliminate Warm Rinse Reduced Water Temperatures	1.4	1.5
TSL 3 (EL 2)	1.15	Electronic Controls Improved Fill Level Control Improved Temperature Control More Efficient Motor Stainless Steel Wash basket Water Recirculation	3.0	11.2
TSL 4 (EL 2)	1.15	Electronic Controls Improved Fill Level Control Improved Temperature Control More Efficient Motor Stainless Steel Wash basket Water Recirculation	3.0	11.2
TSL 5 (EL 2)	1.15	Electronic Controls Improved Fill Level Control Improved Temperature Control More Efficient Motor Stainless Steel Wash basket Water Recirculation	3.0	11.2

Table 12.4.15 Product and Capital Conversion Costs for Compact-Size Front-Loading Clothes Washers by TSL

TSL (Efficiency Level)	IMEF	Design Options Considered	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
Baseline	1.03		0.0	0.0
TSL 1 (EL 1)	1.13	Improved Fill Level Control Low Standby Power Control Board	0.0	0.0
TSL 2 (EL 1)	1.13	Improved Fill Level Control Low Standby Power Control Board	0.0	0.0
TSL 3 (EL 1)	1.13	Improved Fill Level Control Low Standby Power Control Board	0.0	0.0
TSL 4 (EL 1)	1.13	Improved Fill Level Control Low Standby Power Control Board	0.0	0.0
TSL 5 (EL 1)	1.13	Improved Fill Level Control Low Standby Power Control Board	0.0	0.0

12.4.9 Markup Scenarios

DOE used several standards case markup scenarios to represent the uncertainty about the impacts of amended energy conservation standards on prices and profitability. In the base case, DOE used the same baseline markups calculated in the engineering analysis for all product classes. In the standards case, DOE modeled three markup scenarios to represent the uncertainty about the potential impacts on prices and profitability following the implementation of amended energy conservation standards: (1) a no commoditization markup scenario, (2) a tiered markup scenario, and (3) and a tiered markup with margin pressure scenario.. These scenarios lead to different markups values, which, when applied to the inputted MPCs, result in varying revenue and cash flow impacts.

MSP is equal to MPC times a manufacturer markup. The MSP includes direct manufacturing production costs (*i.e.*, labor, material, and overhead estimated in DOE's MPCs) and all non-production costs (*i.e.*, SG&A, R&D, and interest), along with profit.

To calculate the baseline manufacturer markup, DOE evaluated publicly available financial information for manufacturers of major household appliances whose product offerings include residential clothes washers. DOE also requested feedback on the 1.22 baseline manufacturer markup during manufacturer interviews. In the base case for all three GRIM markup scenarios, DOE assumed that the products that meet the January 2011 ENERGY STAR criteria earn a moderately higher manufacturer markup than "baseline" products that fall below those efficiencies. Additionally, products that meet the CEE Tier 2 and Tier 3 criteria earn an incrementally higher markup than those that meet the 2011 ENERGY STAR criteria.

For the MIA, DOE modeled three standards-case markup scenarios to represent the uncertainty regarding the potential impacts on prices and profitability for manufacturers

following the implementation of amended energy conservation standards: (1) a no commoditization markup scenario, (2) a tiered markup scenario, and (3) and a tiered markup with margin pressure scenario. Modifying these markups from the base case to the standards cases yields different sets of impacts on manufacturers' changing industry revenue and cash flow.

12.4.9.1 No Commoditization Scenario

The no commoditization scenario assumes that the base-case markup structure (with baseline, ENERGY STAR, and CEE Tier 2 and Tier 3 markups) is maintained in the standards case. This scenario represents the upper bound of industry profitability because manufacturers are able to fully pass through additional costs from amended standards to their customers. In addition to fully passing through higher production costs, manufacturers continue to earn premium markups after standards for products that are no longer differentiated by the ENERGY STAR and CEE programs.

12.4.9.2 Tiered Markup Scenario

The tiered markup scenario also starts with the three different product markups in the base case (baseline, ENERGY STAR, and CEE Tier 2 and Tier 3 markups). In the standards case, the tiered markup scenario considers the situation in which the breadth of a manufacturer's portfolio of products shrinks and amended standards result in higher-tier products moving to lower tiers. As a result, higher efficiency products that previously commanded the ENERGY STAR and CEE Tier 2 and Tier 3 markups are assigned the ENERGY STAR and baseline markups, respectively. This scenario models a reduction in markups that manufacturers may experience as standards increase and reflects one of the industry's key concerns about product commoditization at higher efficiency levels as efficiency differentiators are eliminated Table 12.4.16 through Table 12.4.19 list the products DOE analyzed with the corresponding markups at each TSL for residential clothes washers.

Table 12.4.16 Tiered Markups for Standard-Size Top-Loading Clothes Washers

EL (IMEF)	Markups by TSL					
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
Baseline (1.25)	1.220					
EL 1 (1.34)	1.220					
EL 2 (1.53)	1.220	1.220				
EL 3 (1.56)	1.220	1.220	1.220			
EL 4 (1.56)	1.220	1.220	1.220			
EL 5 (1.58)	1.220	1.220	1.220			
EL 6 (1.70)	1.260	1.260	1.260	1.220		
EL 7 (1.86)	1.300	1.300	1.300	1.260	1.220	
EL 8 (1.98)	1.300	1.300	1.300	1.260	1.260	1.220

Table 12.4.17 Tiered Markups for Standard-Size Front-Loading Clothes Washers

EL (IMEF)	Markups by TSL					
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
Baseline (1.55)	1.220					
EL 1 (1.59)	1.220					
EL 2 (1.63)	1.220	1.220				
EL 3 (1.70)	1.220	1.220				
EL 4 (1.87)	1.260	1.260	1.220			
EL 5 (2.03)	1.300	1.300	1.260	1.220		
EL 6 (2.20)	1.300	1.300	1.260	1.260		
EL 7 (2.37)	1.300	1.300	1.260	1.260	1.220	
EL 8 (2.61)	1.300	1.300	1.260	1.260	1.260	1.220

Table 12.4.18 Tiered Markups for Compact-Size Top-Loading Clothes Washers

EL (IMEF)	Markups by TSL					
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
Baseline (1.55)	1.220	1.220	1.220			
EL 1 (1.59)	1.220	1.220	1.220	1.220		
EL 2 (1.63)	1.220	1.220	1.220	1.220	1.220	1.220

Table 12.4.19 Tiered Markups for Compact-Size Front-Loading Clothes Washers

EL (IMEF)	Markups by TSL					
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
Baseline (1.55)	1.220	1.220	1.220			
EL 1 (1.59)	1.220	1.220	1.220	1.220	1.220	1.220

12.4.9.3 Tiered Markups with Margin Pressure Markup Scenario

DOE also modeled a lower bound profitability scenario. In the tiered markup with margin pressure scenario, the markups of products that exceed the minimum energy conservation standards similarly move to lower efficiency tiers as standards eliminate current efficiency differentiators. In this scenario, the manufacturer markups at the new minimum standard are also lowered. For both top-loading and front-loading clothes washers, manufacturers are able to maintain only the operating profit of the baseline product in absolute dollars. For products at the new minimum energy conservation standards, the higher production costs and the investments required to comply with the amended energy conservation standard do not yield additional operating profit. This scenario models concerns that higher production costs for minimally compliant products could greatly hurt manufacturer profitability because a large segment of the market is greatly impacted by increases in first costs and there would be tremendous pressure to keep entry level products close to today's prices.

Table 12.4.20 Tiered Markups with Margin Pressure Markup for Standard-Size Top-Loading Clothes Washers

EL (IMEF)	Markups by TSL					
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Baseline (1.25)	1.220					
EL 1 (1.34)	1.220					
EL 2 (1.53)	1.220	1.218				
EL 3 (1.56)	1.220	2.220				
EL 4 (1.56)	1.220	2.220				
EL 5 (1.58)	1.220	2.220	1.217			
EL 6 (1.70)	1.300	1.300	1.300	1.214		
EL 7 (1.86)	1.380	1.380	1.380	1.300	1.207	
EL 8 (1.98)	1.380	1.380	1.380	1.300	1.300	1.206

Table 12.4.21 Tiered Markups with Margin Pressure Markup for Standard-Size Front-Loading Clothes Washers

EL (IMEF)	Markups by TSL					
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Baseline (1.55)	1.220					
EL 1 (1.59)	1.220					
EL 2 (1.63)	1.220	1.220				
EL 3 (1.70)	1.220	1.220				
EL 4 (1.87)	1.300	1.300	1.219			
EL 5 (2.03)	1.380	1.380	1.300	1.218		
EL 6 (2.20)	1.380	1.380	1.300	1.300		
EL 7 (2.37)	1.380	1.380	1.300	1.300	1.214	
EL 8 (2.61)	1.380	1.380	1.300	1.300	1.300	1.212

Table 12.4.22 Tiered Markups with Margin Pressure Markup for Compact-Size Top-Loading Clothes Washers

EL (IMEF)	Markups by TSL					
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
Baseline (1.55)	1.220	1.220	1.220			
EL 1 (1.59)	1.220	1.220	1.220	1.220		
EL 2 (1.63)	1.220	1.220	1.220	1.220	1.220	1.220

Table 12.4.23 Tiered Markups with Margin Pressure Markup for Compact-Size Front-Loading Clothes Washers

EL (IMEF)	Markups by TSL					
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
Baseline (1.55)	1.220	1.220	1.220			
EL 1 (1.59)	1.220	1.220	1.220	1.220	1.220	1.220

12.5 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, the GRIM estimated indicators of financial impacts on the residential clothes washer industry. The main results of the MIA are also reported in this section. The MIA consists of two key financial metrics: INPV and annual cash flows.

12.5.1 Introduction

The INPV measures the industry value and is used in the MIA to compare the economic impacts of different TSLs in the standards case. The INPV is different from DOE's NPV, which is applied to the U.S. economy. The INPV is the sum of all net cash flows discounted at the industry's cost of capital, or discount rate. The residential clothes washer GRIM estimates cash flows from 2011 to 2044. This timeframe models both the short-term impacts on the industry from the announcement of the standard until the compliance date (2011 until an estimated compliance date of January 2015) and a long-term assessment over the 30-year analysis period used in the NIA (2015–2044).

In the MIA, DOE compares the INPV of the base case (no amended energy conservation standards) to that of each TSL in the standards case. The difference between the base case and a standards case INPV is an estimate of the economic impacts that implementing that particular TSL would have on the industry. For the residential clothes washer industry, DOE examined the three markup scenarios described above: the flat markup, the preservation of operating profit,

and the tiered markup. While INPV is useful for evaluating the long-term effects of 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 net cash flows, Figure 12.5.1 through Figure 12.5.3 below present the annual net or free cash flows from 2010 through 2025 for the base case and different TSLs in the standards case.

Annual cash flows are discounted to the base year, 2011. Between 2011 and the 2015 compliance date of the amended energy conservation standard, cash flows are driven by the level of conversion costs and the proportion of these investments spent every year. After the standard announcement date (*i.e.*, the publication date of the final rule), industry cash flows begin to decline as companies use their financial resources to prepare for the amended energy conservation standard. The more stringent the amended energy conservation standard, the greater the impact on industry cash flows in the years leading up to the compliance date, as product conversion costs lower cash inflows from operations and capital conversion costs increase cash outflows for capital expenditures.

Free cash flow in the year the amended energy conservation standards take effect is driven by two competing factors. In addition to capital and product conversion costs, amended energy conservation standards could create stranded assets, *i.e.*, tooling and equipment that would have enjoyed longer use if the energy conservation standard had not made them obsolete. In this year, manufacturers write down the remaining book value of existing tooling and equipment whose value is affected by the amended energy conservation standard. This one time write down acts as a tax shield that alleviates decreases in cash flow from operations in the year of the write-down. In this year, there is also an increase in working capital that reduces cash flow from operations. A large increase in working capital is needed due to more costly production components and materials, higher inventory carrying to sell more expensive products, and higher accounts receivable for more expensive products. Depending on these two competing factors, cash flow can either be positively or negatively affected in the year the standard takes effect.

In the years following the compliance date of the standard, the impact on cash flow depends on the operating revenue. More stringent TSLs typically have a positive impact on cash flows relative to the base case under the flat markup scenario because manufacturers are able to earner higher operating profit at each TSL in the standards case, which increases cash flow from operations. There is very little impact on cash flow from operations under the preservation of operating profit scenario because this scenario is calibrated to have the same operating income in the standards case at each TSL as the base case as in the year after the standard takes effect. In this scenario, the industry value is impacted because production costs increase, but operating profit remains approximately equal to the base case which decreases profit margins as a percentage of revenue.

12.5.2 Residential Clothes Washer Industry Financial Impacts

Table 12.5.1 through Table 12.5.3 provide the INPV estimates for the residential clothes washers. Figure 12.5.1 through Figure 12.5.3 present the annual net cash flows for residential clothes washers for each of the different markup scenarios.

Table 12.5.1 Manufacturer Impact Analysis for Residential Clothes Washers – No Commoditization Markup Scenario

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	*(2010$ millions)*	2,585.7	2,529.4	2,571.3	2,682.0	2,790.7	2,841.2
Change in INPV	*(2010$ millions)*	-	(56.3)	(14.3)	96.4	205.0	255.5
	(%)	-	-2.2%	-0.6%	3.7%	7.9%	9.9%

*For tables in section 0, values in parenthesis indicate negative numbers

Table 12.5.2 Manufacturer Impact Analysis for Residential Clothes Washers – Tiered Markup Scenario

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	*(2010$ millions)*	2,585.7	2,529.4	2,110.0	1,762.8	1,453.0	1,417.5
Change in INPV	*(2010$ millions)*	-	(56.3)	(475.7)	(822.9)	(1,132.7)	(1,168.1)
	(%)	-	-2.2%	-18.4%	-31.8%	-43.8%	-45.2%

Table 12.5.3 Manufacturer Impact Analysis for Residential Clothes Washers – Tiered Markup Scenario with Margin Impacts

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	*(2010$ millions)*	2,585.7	2,521.7	2,095.3	1,726.9	1,329.3	1,250.4
Change in INPV	*(2010$ millions)*	-	(64.0)	(490.3)	(858.8)	(1,256.4)	(1,335.3)
	(%)	-	-2.5%	-19.0%	-33.2%	-48.6%	-51.6%

Figure 12.5.1 Annual Industry Net Cash Flows for Residential Clothes Washers (No Commoditization Markup Scenario)

Figure 12.5.2 Annual Industry Net Cash Flows for Residential Clothes Washers (Tiered Markup Scenario)

Figure 12.5.3 Annual Industry Net Cash Flows for Residential Clothes Washers (Tiered Markup Scenario with Margin Impacts)

12.6 IMPACTS ON SMALL RESIDENTIAL CLOTHES WASHER MANUFACTURERS

To estimate the number of small businesses which could be impacted by the amended energy conservation standards, DOE conducted a market survey using all available public information to identify potential small manufacturers. DOE's research included the AHAM membership directory, product databases (CEE, CEC, and ENERGY STAR databases) and individual company websites to find potential small business manufacturers. DOE also asked stakeholders and industry representatives if they were aware of any other small business manufacturers during manufacturer interviews and at previous DOE public meetings. DOE reviewed all publicly available data and contacted various companies, as necessary, to determine whether they met the SBA's definition of a small business manufacturer of covered residential clothes dryers or room air conditioners. 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.

The majority of residential clothes washers are currently manufactured in the United States by one corporation that accounts for approximately 64 percent of the total market.

Together, this and three other major manufacturers that are not small business manufacturers comprise 92 percent of the residential clothes washer market. The small portion of the remaining residential clothes washer market (approximately 700,000 shipments) is supplied by a combination of 12 international and domestic companies, all of which have small market shares.

DOE identified only one manufacturer that is considered a small business under NAICS Code 335224. The one small business manufacturer has one product platform. It makes a standard-size top-loading residential clothes washer that meets a 1.85 MEF and a 6.75 WF. The product meets the 2015 energy conservation standards, but falls short of the 2018 standard. The unit does not offer warm rinse and has electromechanical controls, making it likely that three wash temperatures (hot, warm, cold) are available on all settings including Normal for test procedure purposes. Thus, it is likely the unit will have to undergo alterations to its basic design to meet the 2018 efficiency requirements.

This company appears to manufacturer its residential clothes washer with less automation and more labor than some of the larger competitors. In order to change the design of their current product to meet the 2018 efficiency standards, one available design pathway would be increasing the volume of the wash basket—assuming there is enough clearance within the cabinet. Increasing the drum's radius would only involve cutting slightly larger octagon-shaped pieces of metal but would not be a capital intensive solution. With this pathway, the assembly process and fabrication time would essentially remain the same. This solution would also prevent the small business manufacturer from bearing the cost of retrofitting their manufacturing process and could result in lower per unit conversion costs relative to larger manufacturers. Additionally, since the small business manufacturer already meets the 2015 energy conservation standards, it would have nine years from the announcement of today's direct final rule until it would have to make any changes to its current product in response to standards. Thus, DOE does not believe that this company would be disproportionately impacted by the standards established for residential clothes washers in today's final rule. DOE also notes that the small business manufacturer accounts for less than one percent of the total residential clothes washer market share.

12.7 OTHER IMPACTS

12.7.1 Employment

For residential clothes washers, DOE used the GRIM to estimate the domestic labor expenditures and number of domestic production workers in the base case and at each TSL from 2011 to 2044. DOE used statistical data from the most recent U.S. Census Bureau's 2009 Annual Survey of Manufacturers, the results of the engineering analysis, and interviews with manufacturers to determine the inputs necessary to calculate industry-wide labor expenditures and domestic employment levels. Labor expenditures for the manufacture of a product are a function of the labor intensity of the product, the sales volume, and an assumption that wages in real terms remain constant.

In the GRIM, DOE used the labor content of each product and the manufacturing production costs from the engineering analysis to estimate the annual labor expenditures in the residential clothes washer industry. DOE used Census data and interviews with manufacturers to estimate the portion of the total labor expenditures that is attributable to U.S. (*i.e.*, domestic) labor.

The production worker estimates in this section only cover workers up to the line-supervisor level who are directly involved in fabricating and assembling a product within an Original Equipment Manufacturer (OEM) facility. Workers performing services that are closely associated with production operations, such as material handing with a forklift, are also included as production labor. DOE's estimates only account for production workers who manufacture the specific products covered by this rulemaking.

The employment impacts shown in Table 12.7.1 represent the potential production employment that could result following amended energy conservation standards. The upper end of the results in this table estimates the maximum change in the number of production workers after amended energy conservation standards must be met. The upper end of the results assumes manufacturers would continue to produce the same scope of covered products in the same production facilities. The upper end of the range also assumes that domestic production does not shift to lower-labor-cost countries. Because there is a real risk of manufacturers evaluating sourcing decisions in response to amended energy conservation standards, the lower end of the range of employment results in Table 12.7.1 includes the estimated total number of U.S. production workers in the industry who could lose their jobs if all existing production were moved outside of the United States. While the results present a range of employment impacts following the compliance date of amended energy conservation standards, the discussion below also includes a qualitative discussion of the likelihood of negative employment impacts at the various TSLs. Finally, the employment impacts shown are independent of the employment impacts from the broader U.S. economy, which are documented in chapter 13, Employment Impact Analysis, of the direct final rule TSD.

The GRIM forecasts the residential clothes washer domestic labor expenditure for production labor in 2015 will be approximately $327.81 million. Using the $19.61 wage rate and 1,860 production hours per year per employee found in the 2009 ASM, the GRIM estimates there will be approximately 8,990 U.S. production employees involved in manufacturing residential clothes washers covered by this rulemaking. In addition, DOE estimates that 738 non-production employees in the United States will support residential clothes washer production.[e]

[e] As defined in the 2009 ASM, production workers number include "workers (up through the line-supervisor level) engaged in fabricating, processing, assembling, inspecting, receiving, storing, handling, packing, warehousing, shipping (but not delivering), maintenance, repair, janitorial and guard services, product development, auxiliary production for plant's own use (*e.g.*, power plant), recordkeeping, and other services closely associated with these production operations at the establishment covered by the report. Employees above the working-supervisor level are excluded from this item." Non-production workers are defined as "employees of the manufacturing establishment including those engaged in factory supervision above the line-supervisor level. It includes sales (including driver-

The employment spreadsheet of the residential clothes washer GRIM shows the annual domestic employment impacts in further detail. Approximately 70 percent of residential clothes washers sold in the United States are manufactured domestically.

Table 12.7.1 illustrates the range of potential impacts of amended energy conservation standards on domestic production employment levels at each TSL for the residential clothes washer market.

Table 12.7.1 Potential Changes in the Total Number of Domestic Residential Clothes Washer Production Workers in 2015

	Trial Standard Level					
	Baseline	1	2	3	4	5
Total Number of Domestic Production Workers in 2015 (without changes in production locations)	8,990	9,058	9,164	9,080	9,376	8,604
Potential Changes in Domestic Production Workers in 2015*	-	68 - (8,890)	174 - (8,890)	90 - (8,890)	386 - (8,890)	(386) - (8,890)

*DOE presents a range of potential employment impacts. Numbers in parentheses indicate negative numbers.

Figure 12.7.1 below shows total annual domestic employment levels for each TSL calculated by the GRIM.

salespersons), sales delivery (highway truck drivers and their helpers), advertising, credit, collection, installation and servicing of own products, clerical and routine office functions, executive, purchasing, financing, legal, personnel (including cafeteria, medical, etc.), professional, and technical employees. Also included are employees on the payroll of the manufacturing establishment engaged in the construction of major additions or alterations utilized as a separate work force."

Figure 12.7.1 Total Residential Clothes Washer Industry Domestic Employment by Year

All examined TSLs show relatively minor impacts on domestic employment levels relative to total industry employment. At all TSLs, most of the design options analyzed by DOE do not greatly alter the labor content of the final product. For example, more complex wash cycles or larger basket sizes involve one-time changes to the final product but do not significantly change the number of steps required for the final assembly of the clothes washer (which would add labor). Because many manufacturers have recently introduced high efficiency products in the United States that meet or exceed the standards in today's final rule, it is unlikely today's direct final rule would greatly impact the sourcing decisions of these manufacturers. However, at higher TSLs, some of the design options analyzed greatly impact the ability of manufacturers to make product changes within existing platforms. The very large upfront capital costs at these levels (especially for introducing new front-loading clothes washer platforms) could influence the decision of manufacturers to relocate some or all of the domestic production of these clothes washers to lower labor cost countries.

12.7.2 Production Capacity

Most shipments of top-loading residential clothes washers fall below the 2015 and 2018 amended energy conservation standards. However, in response to the EISA 2007 water factor requirements, multiple manufacturers have modified baseline products to comply with these more stringent regulations. These changes were incremental modifications to lower efficiency platforms. The 2015 efficiency requirements would also involve modifications to lower-end platforms for top-loading clothes washers for all manufacturers, but would similarly not require completely new platforms at a significantly higher upfront cost. In addition, multiple manufacturers have recently introduced new top-loading clothes washers that meet substantially higher efficiencies than lower-end products at the baseline efficiency today. The introduction of these platforms greatly mitigates the required capital conversion costs for the industry to meet the 2018 top-loading energy conservation standards. DOE believes that the mitigated capital

conversion costs for manufacturers that have already introduced high efficiency top-loading clothes washers in addition to the additional 3 years for all remaining manufacturers to meet the more aggressive standards for top-loading clothes washers in 2018 will allow the industry to meet demand and continue to offer a full range of products after the compliance date.

More than 70 percent of front-loading clothes washer shipments currently meet the front-loading energy conservation standards in today's direct final rule. In addition, every manufacturer that ships front-loading clothes washers offers products at the amended energy conservation standard. Since manufacturers will not have to make extensive platform changes but will need to increase the production of existing product by the 2015 compliance date, the experience of multiple front-loading clothes washer manufacturers that already produce standards-compliant front-loading clothes washers will allow the industry to meet the amended energy conservation standards proposed in the direct final rule.

12.7.3 Cumulative Regulatory Burden

While any one regulation may not impose a significant burden on manufacturers, the combined effects of several impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. For the cumulative regulatory burden analysis, DOE looks at other significant product-specific regulations that could affect residential clothes washer manufacturers that will take effect three years before or after the compliance date of amended energy conservation standards for these products.[f] In addition to the amended energy conservation regulations on residential clothes washers, several other Federal regulations apply to these products and other equipment produced by the same manufacturers. While the cumulative regulatory burden focuses on the impacts on manufacturers of other Federal requirements, DOE also has described a number of other regulations in section 12.7.3.3 and section 12.7.3.4 because it recognizes that these regulations also impact the products covered by this rulemaking.

Companies that produce a wide range of regulated products may be faced with more capital and product development expenditures than competitors with a narrower scope of products. Regulatory burdens can prompt companies to exit the market or reduce their product offerings, potentially reducing competition. Smaller companies in particular can be affected by regulatory costs since these companies have lower sales volumes over which they can amortize the costs of meeting new regulations. A proposed standard is not economically justified if it contributes to an unacceptable level of cumulative regulatory burden.

[f] The compliance date for residential clothes washers is 3 years from the date of publication of the final rule (approximately January 2015).

12.7.3.1 DOE Regulations for Other Products Produced by Residential Clothes Washer Manufacturers

In addition to the amended energy conservation standards on residential clothes washers, several other Federal regulations and pending regulations apply to other products produced by the same manufacturers. DOE recognizes that each regulation can significantly affect a manufacturer's financial operations. Multiple regulations affecting the same manufacturer can quickly strain manufacturers' profits and possibly cause an exit from the market. Table 12.7.2 lists the other DOE energy conservation standards that could also affect manufacturers of residential clothes washers in the 3 years leading up to and after the compliance date of amended energy conservation standards for these products.

Table 12.7.2 Other DOE and Federal Actions Affecting the Residential Clothes Washer Industry

Regulation	Approximate Compliance Date*	Number of Impacted Companies from the Market and Technology Assessment (MTA) (See Chapter 3)	Estimated Total Industry Conversion Costs
Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps	2012	4	$17.3 million (2007$)[g]
Cooking Products	2012	12	$22.6 million (2006$)[h]
General Service Fluorescent Lamps and Incandescent Reflector Lamps	2012	1	$363.1 million (2008$)[i]
Dehumidifiers	2012	4	N/A†
Commercial Clothes Washers	2013	7	$20.4 million (2008$)[j]
Battery Chargers and External Power Supplies	2013*	1	N/A††
ER, BR, and Small Diameter IRLs	2014*	1	N/A††
Residential Refrigerators and Freezers	2014*	13	N/A††
Room Air Conditioners	2014*	6	N/A††
Residential Clothes Dryers	2014*	16	N/A††
Fluorescent Lamp Ballasts	2014*	1	N/A††
Microwave Ovens	2014*	9	N/A††

[g]Estimated industry conversion expenses were published in the TSD for the October 2008 packaged terminal air conditioners and packaged terminal heat pumps final rule. 73 FR 58772. The TSD for the 2008 packaged terminal air conditioners and packaged terminal heat pumps final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/ptacs_pthps_final_tsd.html.

[h]Estimated industry conversion expenses were published in the TSD for the April 2009 residential cooking products final rule. 74 FR 16040. The TSD for the 2009 residential cooking products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/cooking_products_final_rule_tsd.html.

[i]Estimated industry conversion expenses were published in the TSD for the July 2009 general service fluorescent lamps and incandescent reflector lamps final rule. 74 FR 34080. The TSD for the 2009 lamps final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps_standards_final_rule_tsd.html.

[j]Estimated industry conversion expenses were published in the TSD for the January 2010 commercial clothes washers final rule. 75 FR 1122. The TSD for the 2010 commercial clothes washers final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_ecs_final_rule_tsd.html

Regulation	Approximate Compliance Date*	Number of Impacted Companies from the Market and Technology Assessment (MTA) (See Chapter 3)	Estimated Total Industry Conversion Costs
Metal Halide Lamp Fixtures	2015*	1	N/A††
Residential Clothes Washers	2015*	16	N/A††
Residential Water Heaters	2015	4	$95.9 million (2009$)[k]
Commercial Electric Motors	2015*	1	N/A††
Commercial Distribution Transformers	2015*	2	N/A††
Commercial Refrigeration Equipment	2016*	2	N/A††
High–Intensity Discharge Lamps	2017*	1	N/A††
Dishwashers	2018*	14	N/A††

*The dates listed are an approximation. The exact dates are pending final DOE action.
† For minimum performance requirements prescribed by the Energy Independence and Security Act of 2007 (EISA 2007), DOE did not estimate total industry conversion costs because an MIA was not completed as part of a rulemaking. Pub. L. 110-140. EISA 2007 made numerous amendments to the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 U.S.C. 6291–6309), which established an energy conservation program for major household appliances and industrial and commercial equipment.
†† For energy conservation standards for rulemakings awaiting DOE final action, DOE does not have a finalized estimated total industry conversion cost.

Some Federal DOE regulations have a more significant impact on manufacturers of residential clothes washers than others because manufacturers hold a significant market share in those covered products. Where market share and company financial data is available, DOE attempts to quantify the cumulative regulatory burden as measured by the fraction of corporate revenues that are derived from the manufacture of products covered by other standards rulemakings. Table 12.7.3 below shows the DOE energy conservation standards with compliance dates within four years of residential clothes washers where manufacturers are expected to be most impacted due to their market positions. For these rulemakings, residential clothes washer manufacturers would likely be burdened by a significant portion of the estimated industry conversion costs.

[k] Estimated industry conversion expenses were published in the TSD for the April 2010 heating products final rule. 75 FR 20112. The TSD for the 2010 heating products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_tsd.html.

Table 12.7.3 DOE Regulations on Products For Which Residential Clothes Washer Manufacturers Hold Significant Market Share

		GE		Whirlpool		Electrolux	
	Revenue	$150,211,000,000		$18,366,000,000		$16,492,000,000	
	Industry Sales	Market share	% of Revenue	Market share	% of Revenue	Market share	% of Revenue
Refrigerators and Freezers	$10,310,000,000	21.8%	1.5%	23.8%	13.3%	23.4%	14.7%
Residential Clothes Dryers	$2,486,248,000	14.2%	0.24%	71.2%	9.64%	7.1%	1.1%
Room Air Conditioners	$1,050,272,000			13%	0.74%	13%	0.85%
Residential Clothes Washers	$3,373,042,000	16.0%	0.36%	64%	11.75%	6.0%	1.23%
Dishwashers	$2,106,245,000	27.0%	0.38%	49%	5.6%	18.0%	2.3%
Cooking Products	$4,491,117,000	44.0%	1.3%			15.4%	4.2%
Dehumidifiers	$199,130,000			35%	0.38%	6.0%	0.07%
Microwave Ovens	1,376,667,000			4.0%	0.3%		
Totals			3.78%		41.8%		24.3%

		LG		Haier		Samsung	
	Revenue	$51,432,900,000		$42,500,000,000		$142,631,000,000	
	Industry Sales	Market share	% of Revenue	Market share	% of Revenue	Market share	% of Revenue
Refrigerators and Freezers	$10,310,000,000			9.4%	2.3%		
Residential Clothes Dryers	$2,486,248,000						
Room Air Conditioners	$1,050,272,000	32.0%	0.65%	8.0%	0.2%	5%	0.04%
Residential Clothes Washers	$3,373,042,000	6.0%	0.4%				
Dishwashers	$2,106,245,000						
Cooking Products	$4,491,117,000	27.4%	2.4%				
Dehumidifiers	$199,130,000	35.0%	0.14%			3.0%	0.004%
Microwave Ovens	1,376,667,000	35.0%	0.94%			12.0%	0.12%
Totals			4.5%		2.5%		0.16%

Where specific market share data was not available, DOE identified additional products manufacturers produced that are covered by additional efficiency standards as shown in Table 12.7.4.

Table 12.7.4 Other Covered Products For Which Residential Clothes Washer Manufacturer Market Share Data Is Unavailable.

Manufacturer	Other Products Manufactured
Alliance	Commercial clothes washers, residential clothes dryers
Asko	Commercial clothes washers, residential clothes dryers, dishwashers
Bosch-Siemens	Cooking products, residential clothes dryers, residential water heaters, dishwashers
Equator	Residential refrigerators and freezers, residential clothes dryers, dishwashers
Fagor	Cooking products, residential refrigerators and freezers, residential clothes dryers, dishwashers
Fisher & Paykel	Cooking products, residential clothes dryers, dishwashers
Haier	Cooking products, residential clothes dryers, room air conditioners
Indesit	Cooking products, residential refrigerators and freezers, residential clothes dryers, dishwashers
Miele	Cooking products, residential refrigerators and freezers, residential clothes dryers, dishwashers
Samsung	Cooking products, residential clothes dryers, room air conditioners
Staber	Residential clothes dryers
Summit	Residential refrigerators and freezers, residential clothes dryers, commercial refrigeration equipment, dishwashers

12.7.3.2 Other Federal Regulations

Potential Climate Change and Greenhouse Gas Legislation

Many manufacturers expressed concern about potential climate change legislation. One proposed regulation that would exacerbate the manufacturer burden caused by more stringent energy conservation standards on refrigeration products is H.R. 2454, the American Clean Energy and Security Act of 2009. This legislation would initiate a phase-down of hydrofluorocarbons (HFCs) and would make the amended energy conservation standard levels considered in this rulemaking more difficult to achieve. Manufacturers were particularly concerned that these regulations could impact U.S. heat pump clothes washer designs in the future.

12.7.3.3 UL Conversion Costs

In the clothes dryer rulemaking, DOE accounted for the conversion costs for manufacturers to comply with the revisions to UL 2158 as mentioned in the comments from interested parties. DOE notes that the UL 2157 and 2158 are not Federal regulations. In contrast to the RoHS Directive requirements discussed previously, UL certification is a de facto requirement for selling products in the United States because many local building codes require all installed products to meet safety regulations. DOE has included the UL certification costs for both UL 2157 and UL 2158 as a sensitivity scenario in the GRIM, but does not include the UL conversion costs in the main MIA results.

For this analysis, DOE scaled the UL conversion costs from the clothes dryer rulemaking by the relative number of shipments for residential clothes washers to arrive at a UL conversion cost for this rulemaking.

12.7.3.4 Other Regulations That Could Impact Residential Clothes Washer Manufacturers

While the cumulative regulatory burden focuses on the impacts on manufacturers of other Federal requirements, in this section DOE has described a number of other regulations below that could also impact the residential clothes washers covered by this rulemaking

State Energy Conservation Standards

Manufacturers indicated that California has several programs that are either already in place or are currently in development that affect manufacturers of residential clothes washers. Various building, electrical, mechanical, and plumbing codes in California affect clothes washers, and products are also subject to California's laws on the Restriction on the use of certain Hazardous Substances (RoHS). California's RoHS law took effect January 1, 2007 and was modeled after the EU's directive (described below), which bans certain hazardous substances from electrical and electronic equipment.

International Energy Conservation Standards

Residential clothes washer manufacturers that sell products outside of the United States are subject to several international energy conservation standards. In the EU, products are also subject to RoHS. This regulation bans the sale of new equipment in the EU that contains more than agreed levels of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and PBDE flame retardants. Waste Electrical and Electronic Equipment (WEEE) and the Registration, Evaluation, Authorization, and restriction of Chemicals (REACH) are additional regulations that create compliance costs for manufacturers that compete in Europe. REACH deals with chemicals and their safe use and has provisions that will be phased-in over eleven years, beginning June 1, 2007. The EU also sets limits for the amount of energy consumed by equipment when it is in standby mode and off mode. Additionally, HFCs are banned in refrigerants in several countries, such as Austria, Denmark, and Switzerland. Canada and several other foreign countries have regulations or have initiated regulations affecting clothes washer manufacturers.

12.8 CONCLUSION

The following sections summarize the different impacts for the scenarios DOE believes are most likely to capture the range of impacts on residential clothes washer manufacturers at each TSL in the standards case. While these scenarios bound the range of the most plausible

impacts on manufacturers, some circumstances could cause manufacturers to experience impacts outside this range.

12.8.1 Residential Clothes Washers

At TSL 1, DOE estimates impacts on INPV to range -$56.3 million to -$64.0 million, or a change in INPV of -2.2 percent to -2.5 percent. At this level, industry free cash flow is estimated to decrease by approximately 20.2 percent to $170.0 million, compared to the base-case value of $213.1 million in the year leading up to the amended energy conservation standards.

Because the top-loading and front-loading standard clothes washers comprise over 98 percent of the total residential clothes washer shipments, the vast majority of the INPV impacts come from the standard-size product classes. At TSL 1, most impacts on both INPV and free cash flow stem from the modest changes required for top-loading standard clothes washers because all of the front-loading standard residential clothes washers on the market today already meet standards at this level. For top-loading clothes washers, of which only 13 percent of the market currently meets standards proposed at TSL 1, the impacts on INPV and free cash flow arise from increases in upfront investment for product development and, to a lesser extent, the per-unit component costs required to achieve this efficiency level. TSL 1 would require investments in product redesign and improvements to facilities totaling approximately $103.9 million in an industry with base-case annual revenues of more than $4.4 billion in the year the standards go into effect.

Regarding increases in component costs, the design options used to meet standards at TSL 1 include component changes such as electronic controls, agitator modification, and basket modifications. For top-loading standard residential clothes washers, these changes contribute only $8.44 (3.4 percent) to arrive at a MPC of $256.09. In summation, the cumulative effect on INPV and free cash flow is minimal largely because all front-loading standard products and some top-loading standard products already meet the efficiencies required at TSL 1, and the design changes for the top-loading standard products that do not meet the efficiency required at TSL1 would impose minimal costs. Further, as the efficiencies required at TSL 1 are well below ENERGY STAR levels, manufacturers are likely to retain the premiums they currently see across the full range of product efficiencies.

At TSL 2, DOE estimates impacts on INPV to range -$14.3 million to -$490.3 million, or a change in INPV of -0.6 percent to -19.0 percent. At this level, industry free cash flow is estimated to decrease by approximately 28.4 percent to $152.6 million, compared to the base-case value of $213.1 million in the year leading up to the amended energy conservation standards.

Because the top-loading and front-loading standard clothes washers comprise over 98 percent of the total residential clothes washer shipments, the vast majority of the INPV impacts come from the standard-size product classes. At TSL 2, the impacts on INPV and free cash flow result from higher per-unit costs for both top-loading and front-loading standard-sized product

classes as well as increases in product and capital conversion costs for both of these product classes. The design options used to meet standards at TSL 2 for standard-size products include additional component changes to enable higher spin speeds and better control beyond the improvements to electronic controls and the agitator and basket associated with TSL 1. The resulting MPC for top-loading standard residential clothes washers is approximately $261.88 at TSL 2, a $14.23 (5.7 percent) increase over current baseline units and similar to the incremental costs at TSL 1. For front-loading standard residential clothes washers, the MPC is approximately $524.33, a $6.20 (1.2 percent) increase from the baseline. The product redesign and incorporation of these changes into manufacturing lines requires approximately $149.3 million in total conversion costs—a $45.4 million increase from TSL 1.

TSL 2 brings all front-loading standard clothes washers up to current ENERGY STAR standard levels. The most severe impact to INPV at TSL 2 is the result of margin compression on front-loading standard clothes washers as manufacturers forfeit premiums and cut into margins as they try to maintain a marginally compliant competitively priced entry level product. While only a small fraction of front-loading clothes washers (4 percent of shipments) would be impacted in the standards case at TSL2, in the tiered markup scenario with margin compression the profitability impacts on front-loading clothes washers has a disproportionately large negative impact on INPV because most of the market is ENERGY STAR compliant in the base case.

At TSL 3, DOE estimates impacts on INPV to range $96.4 million to -$858.8 million, or a change in INPV of 3.7 percent to -33.2 percent. At this level, industry free cash flow is estimated to decrease by approximately 3.6 percent to $205.5 million, compared to the base-case value of $213.1 million in the year leading up to the first tier of amended energy conservation standards in 2015.

At TSL3, the largest impacts to free cash flow and INPV stem from the substantial upfront investments required to achieve this efficiency level. While the efficiency requirements for top-loading standard clothes washers in 2015 require incremental changes to existing products, the 2018 efficiency requirements for top-loading standard clothes washers are more substantial. Because only 9 percent of current shipments of top-loading standard clothes washers meet the 2018 efficiency standards established at TSL 3, manufacturing products to meet the 2018 standards would require large investments in product redesign and conversion of facilities. Substantial investments would also be required for manufacturers to meet the 2015 front-loading standard. The total conversion cost required to meet the 2015 and 2018 standards at TSL 3 is approximately $418.5 million— a substantial fraction of overall industry value and $269.2 million higher than at TSL 2.

Less than 25 percent of the conversion costs associated with TSL 3 can be attributed to the 2015 compliance for top-loading standard products. This is a considerably smaller factor than at TSL 1 and TSL 2 at which 97 percent 81 percent of conversion costs can be attributed to standard top-loading compliance, respectively. The design options used to meet the 2015 front-loading and 2018 top-loading standards at TSL 3 include larger unit capacities, damping systems, and reinforced structural elements. Substantial changes to existing production facilities

would be required to manufacture products to incorporate the 2015 front-loading and 2018 top-loading design options. Several manufacturers have already introduced products that meet the 2015 front-loading standard and 2018 top-loading standard efficiency levels, which mitigates the required changes to production facilities for these manufacturers. The two-tiered compliance date of TSL 3 also mitigates the effect of the large conversion costs required to meet the 2018 top-loading standards, subjecting the impact on cash flows to greater discounting while also allowing manufactures to delay or spread out their conversion costs.

At TSL 3, the MPC for top-loading standard residential clothes washers is $256.09 to meet the 2015 energy conservation standard and $272.93 to meet the 2018 energy conservation standard. For front-loading standard residential clothes washers the MPC is approximately $535.38 to meet the 2015 energy conservation standard. For the 2015 standard this is an $8.44 (3.4 percent) increase for top-loading standard clothes washers and a $17.25 (3.3 percent) increase for front-loading standard residential clothes washers. For the 2018 energy conservation standard for top-loading standard clothes washers, this is a $25.28 (10.2 percent) increase. In the scenario in which manufacturers see no commoditization of higher efficiency clothes washers, the modest increases to MPC translate to higher margins sufficient to offset the initial capital investments and product design costs over the 30 year analysis period. In contrast in the tiered mark up scenario, because TSL 3 sets standards for top-loading standard clothes washers at current ENERGY STAR levels and standards for front-loading standard clothes washers above these levels, manufacturers lose their premium markup for high efficiency standard-size product classes leading to a substantial reduction in future revenues and subsequently in INPV.

At TSL 4, DOE estimates impacts on INPV to range $205.0 million to -$1,256.4 million, or a change in INPV of 7.9 percent to -48.6 percent. At this level, industry free cash flow is estimated to decrease by approximately 130.7 percent to -$65.5 million, compared to the base-case value of $213.1 million in the year leading up to the amended energy conservation standards.

Much like TSL 3, the impacts to INPV at TSL 4 result primarily from the substantial upfront investments required to achieve the amended efficiency levels for standard-size products, the incremental increases in per-unit costs, and the potential margin impacts. In contrast to TSL 3, TSL 4 has no tiered compliance dates for increased energy efficiency standards for top loading clothes washers. As such, manufacturers are required to cover the conversion costs for all products by 2015. Manufacturing products to meet standards for both standard-size product classes at TSL 4 may require a complete platform overhaul, resulting in significant investments in both product redesign and the conversion of facilities. The total conversion cost required to meet standards at TSL 4 is approximately $691.8 million—a $273.3 million increase from TSL 3. The design options used to meet standards at TSL 4 include changes such as larger capacity, accelerometers, and better control technology beyond what is required for TSL 3. The resulting MPC for top-loading standard residential clothes washers at TSL 4 is approximately $308.30, and approximately $572.01 for front-loading standard residential clothes washers. This is a $60.65 (24.5 percent) and a $53.88 (10.4 percent) increase from the baseline for top and front-

loading standard residential clothes washers, respectively. This increase in MPC translates to a 3.5 percent decrease in 2015 shipments.

The impact on INPV arising from a decrease in shipments from price elasticity is minor in comparison to that stemming from product commoditization and margin impacts as analyzed in the tiered markup scenario with margin impacts for standard-sized product classes. As TSL 4 brings standards for both front-loading and top-loading standard products above current ENERGY STAR levels, the fraction of products that are eligible for any additional markup above the baseline is further reduced as manufacturers sacrifice margins as they continue to seek to maintain a low-price-point basic product offering.

At TSL 5, DOE estimates impacts on INPV to range $255.5 million to -$1,335.3 million, or a change in INPV of 9.9 percent to -51.6 percent. At this level, industry free cash flow is estimated to decrease by approximately 134.9 percent to -$74.3 million, compared to the base-case value of $213.1 million in the year leading up to the amended energy conservation standards.

TSL 5 represents the max-tech efficiency level for both top and front-loading standard clothes washers. The effects on INPV result from similar sources as TSL 4, including the substantial upfront investments required to achieve the amended efficiency levels, the incremental increases in per-unit costs, and the potential margin impacts. These effects, however, are compounded by the higher upfront investments for facility improvements and product development, the additional increases to the MPC, and the collapse of manufacturer margins as analyzed in the tiered markup scenario with margin impacts. At present, the market share of commercially available residential clothes washers that conform to this standard is negligible. As such, standards will affect nearly all platforms and manufacturers will incur substantial conversion costs associated with total redesigns and improvements to all production facilities. The total conversion cost required to meet standards at TSL 5 is approximately $713.7 million—a $21.9 million increase from TSL 4. TSL 5 does not delay compliance for the more stringent standard either top-loading product class, so manufacturers will incur all product and capital conversion costs by 2015, leading to a larger negative impact on INPV.

The MPC for top-loading standard residential clothes washers is approximately $317.44 at TSL 5, and approximately $591.64 for front-loading standard residential clothes washers. This is a $69.79 (28.2 percent) and a $73.51 (14.2 percent) increase from the baseline for top and front-loading standard residential clothes washers, respectively. However, the increase in per-unit production costs at TSL 5 relative to those at TSL 4 is comparatively small and involves only minimal incremental design options such as changes to load size sensors and more precise dispensing of laundry detergent and additives. With the increase in MPCs, 2015 shipments are forecast to decrease by approximately 4.4 percent at TSL 5. However, the impact on INPV arising from a decrease in shipments from price elasticity is minor in comparison to that stemming from product commoditization and margin impacts as analyzed in the tiered markup scenario with margin impacts. Where TSL 4 still provided some room for markups above the most basic units, TSL 5 sets the standard for all products as high as technically feasible, leaving

manufacturers no ability to differentiate products by efficiency. Thus, all margins collapse to their lowest levels.

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CHAPTER 13. EMPLOYMENT IMPACT ANALYSIS

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CHAPTER 13. EMPLOYMENT IMPACT ANALYSIS

13.1 INTRODUCTION

DOE's employment impact analysis is designed to estimate indirect national job creation or elimination resulting from possible standards, due to reallocation of the associated expenditures for purchasing and operating clothes washers.

13.2 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 appliances, including the retail price plus sales tax, and increase installation costs.

Using an input/output econometric model of the U.S. economy, this analysis estimated the year-to-year 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 include a qualitative discussion of how labor markets are likely to respond in the longer term. In future rulemakings, DOE may consider the use of other modeling approaches for examining long run employment impacts.

13.3 METHODOLOGY

The Department based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 3.1.1[1] (Impact of Sector Energy Technologies) as a successor to ImBuild[2], a special-purpose version of the IMPLAN[3] national input/output model. ImSET estimates the employment and income effects of building energy technologies. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy-efficiency investments in buildings.

In an input/output model, the level of employment in an economy is determined by the relationship of different sectors of the economy and the spending flows among them. Different

sectors have different levels of labor intensity and so changes in the level of spending (*e.g.*, due to the effects of an efficiency standard) in one sector of the economy will affect flows in other sectors, which affects the overall level of employment.

ImSET uses a 187-sector model of the national economy to predict the economic effects of residential and commercial buildings technologies. ImSET collects estimates of initial investments, energy savings, and economic activity associated with spending the savings resulting from standards (*e.g.*, changes in final demand in personal consumption, business investment and spending, and government spending). It provides overall estimates of the change in national output for each input-output sector. The model applies estimates of employment and wage income per dollar of economic output for each sector and calculates impacts on national employment and wage income.

Energy-efficiency technology primarily affects the U.S. economy along three spending pathways. First, general investment funds are diverted to sectors that manufacture, install, and maintain energy-efficient appliances. The increased cost of appliances leads to higher employment in the appliance 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, electric utility sector investment funds are released for use in other sectors of the economy. When consumers use less energy, electric 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 clothes washer 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.

13.4 RESULTS

The results in this section refer to impacts of clothes washer standards relative to the base case. DOE disaggregated the impact of standards on employment into three component effects: increased capital investment costs, decreased energy and water costs, and changes in operations and maintenance costs. DOE presents the component effects and summary impact. No discernible change in non-energy operations and maintenance cost is anticipated.

Figure 13.4.1 summarizes the employment impacts of the increased investment and spending on higher-efficiency equipment for clothes washers. Clothes washer manufacturing is relatively capital intensive compared to other sectors of the economy, so the net result is a small loss of employment.

Figure 13.4.1 Clothes Washer Employment Impact of Increased Equipment Cost

Figure 13.4.2 shows the strongly positive employment impact of redirected spending made possible by appliance operating cost savings.

Figure 13.4.2 Clothes Washer Employment Impact of Operating Cost Savings

Figure 13.4.5 shows the estimated net national employment impacts of the clothes washer trial standard levels. For any given year, this figure shows the net change in the number of jobs in the economy relative to if there was no change in standards (and thus no resulting change in spending and cash flow patterns throughout the economy). This figure shows the combined effects of equipment cost, operations and maintenance cost, and energy use changes due to standards.

Figure 13.4.3 Clothes Washer Net National Change in Employment

Table 13.4.1 shows the net national employment impact in specific years for clothes washers, as well as the average annual employment impact over the 2015-2044 time period. The initial decrease in net employment is caused by the dominance of capital costs in early years, while the impacts of operating cost savings from reduced energy use build up slowly over time, resulting in a net positive impact on employment in later years.

Table 13.4.1 Clothes Washer Net National Change in Employment

Trial Standard Level	2015	2020	2030	2044	Average 2015-2044
1	0.05	2.78	5.52	7.02	4.59
2	-0.26	2.59	5.58	7.20	4.57
3	0.04	2.95	7.99	10.78	6.47
4	-3.06	2.82	9.45	13.45	7.34
5	-3.81	3.19	10.97	15.80	8.51

For context, OMB currently assumes that the office unemployment rate may decline to 6.9% in 2014 and drop further to 5.3% in 2017.[4] The unemployment rate in 2017 is projected to be close to "full employment." When an economy is at full employment any effects on net employment are likely to be transitory as workers change jobs, rather than enter or exit longer-term employment.

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CHAPTER 14. UTILITY IMPACT ANALYSIS

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CHAPTER 14. UTILITY IMPACT ANALYSIS

14.1 INTRODUCTION

DOE analyzed the effects of residential clothes washer standard levels on the electric utility industry using a variant 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 *AEO* for 2010 *(AEO2010)* forecasts energy supply and demand through 2035.[1] DOE used a variant of this model, referred to here as NEMS-BT,[b] to account for the impacts of clothes washer energy conservation standards. DOE's utility impact analysis consists of a comparison between model results for the *AEO2010* Reference Case and for cases in which standards are in place, and applies the same basic set of assumptions as the *AEO2010*. The *AEO2010* reference case corresponds to medium economic growth.

The utility impact analysis reports the changes in electric installed capacity and generation that result for each trial standard level (TSL) by plant type, as well as changes in residential natural gas consumption.

NEMS-BT has several advantages that have led to its adoption as the forecasting tool in the analysis of energy conservation standards. NEMS-BT uses a set of assumptions that are well known and fairly transparent, due to the exposure and scrutiny each *AEO* receives. In addition, the comprehensiveness of NEMS-BT permits the modeling of interactions among the various energy supply and demand sectors, producing a complete picture of the effects of energy conservation standards. Perhaps most importantly, NEMS-BT can be used to estimate marginal effects, which yield a better estimate of the actual impact of energy conservation standards than considering only average effects.

14.2 METHOD

The utility impact analysis uses the assumptions of the *AEO2010* and treats residential clothes washer conservation standards as variations in policy. The effects of the policy are calculated as the difference between the *AEO2010* Reference Case and each proposed standard case, which is described as a trial standard level (TSL).

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[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003), March, 2003.

[b] DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on DOE/EIA assumptions, DOE refers to it by the name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed). NEMS-BT was previously called NEMS-BRS.

DOE used the energy savings developed in the national impact analysis (chapter 10) for each TSL as input to NEMS-BT. The magnitude of the energy decrement that would be required for NEMS-BT to produce stable results out of the range of numerical noise is larger than the highest efficiency standard under consideration. Therefore, DOE estimated results corresponding to each TSL using interpolation. DOE ran higher energy use reduction levels in NEMS-BT, representing multipliers of each TSL, and used these outputs to linearly interpolate the results to estimate actual changes in generation and capacity due to the standard.

Policy runs are executed by reducing electricity and fossil fuel consumption in the NEMS-BT Residential Demand Module. These energy savings are decremented with the appropriate end use. The reductions are also divided amongst the nine U.S. Census divisions based upon the share of energy end use consumption in each division, as given in NEMS.

Although the current time horizon of NEMS-BT is 2035, other parts of the energy conservation standards analysis extend through the year 2044. It is not feasible to extend the forecast period of NEMS-BT for the purposes of this analysis, nor does DOE/EIA have an approved method for extrapolation of many outputs beyond 2035. While it might seem reasonable to make simple linear extrapolations of results, in practice this is not advisable because outputs could be contradictory. An analysis of various trends sufficiently detailed to guarantee consistency is beyond the scope of this work, and, in any case, would involve a great deal of uncertainty. Therefore, all extrapolations beyond 2035 are simple replications of year 2035 results. To emphasize the extrapolated results wherever they appear, they are shaded in gray to distinguish them from actual NEMS-BT results.

14.3 RESULTS

This utility impact analysis reports NEMS-BT forecasts for residential-sector electricity and natural gas consumption, total electricity generation by fuel type, and installed electricity generation capacity by fuel type. Results are presented in five-year increments to year 2035. Beyond year 2035, an extrapolation through 2044 for each proposed TSL represents a simple replication of the year 2035 results.

The results from the *AEO2010* Reference Case are shown in Table 14.3.1.

A set of five TSLs were modeled for residential clothes washers. The results for each of these TSLs are presented in Tables 14.3.2 through 14.3.6, Each table shows forecasts using interpolated results, as described in section 14.2, for total U.S. electricity generation and installed capacity as well as natural gas consumption.

The considered residential clothes washer TSLs reduce electricity and natural gas consumption compared to the *AEO2010* Reference Case. The electricity impacts predicted by the NIA Model for the considered clothes washer products reduce consumption from a range of 0.34 to 0.71 percent of total residential electricity consumption in the year 2035. The residential

natural gas consumption impacts range from a decrease of 0.42 percent to a decrease of 1.23 percent of total residential natural gas consumption in the year 2035.

Table 14.3.1 AEO2010 Reference Case Forecast

NEMS-BT Results: AEO2010 Reference							
	2005	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Residential Sector Energy Consumption [1]							
Electricity Sales (TWh)[2]	1,359	1,388	1,400	1,472	1,553	1,637	1,707
Total U.S. Electric Generation [3]							
Coal (TWh)	2,013	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	759	857	690	769	886	1,018	1,095
Petroleum (TWh)	122	45	46	47	48	48	49
Nuclear (TWh)	782	813	834	883	886	886	895
Renewables (TWh)	358	462	649	714	797	850	890
Total (TWh)[4]	4,034	4,005	4,257	4,503	4,746	5,012	5,234
Installed Generating Capacity [5]							
Coal (GW)	314	321	325	326	326	330	337
Other Fossil (GW)[6]	439	468	445	446	467	501	534
Nuclear (GW)	100	102	105	111	111	111	113
Renewables (GW)	99	133	171	177	186	196	209
Total (GW)[7]	952	1,024	1,046	1,059	1,091	1,138	1,192

[1] Comparable to Table A2 of AEO2010: Energy Consumption, Residential

[2] Comparable to Table A8 of AEO2010: Electricity Sales by Sector

[3] Comparable to Table A8 of AEO2010: Electric Generators and Cogenerators

[4] Excludes "Other Gaseous Fuels" cogenerators and "Other" cogenerators

[5] Comparable to Table A9 of AEO2010: Electric Generators and Cogenerators Capability

[6] Includes "Other Gaseous Fuels" cogenerators

[7] Excludes Pumped Storage and Fuel Cells

Table 14.3.2 Clothes Washer Trial Standard Level 1 Forecast

NEMS-BT Results:							Difference from AEO2010 Reference Case									
													Extrapolation		
	2010	2015	2020	2025	2030	2035		2010	2015	2020	2025	2030	2035	2040	2042	2044
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*									
Electricity Sales (TWh)	1,388	1,400	1,469	1,549	1,632	1,702	Electricity Sales (TWh)	0.00	-0.47	-2.78	-4.59	-5.39	-5.73	-5.97	-6.06	-6.15
Natural Gas (EJ)	5.22	5.11	5.22	5.29	5.28	5.26	Natural Gas (EJ)	0.000	-0.003	-0.016	-0.026	-0.031	-0.033	-0.034	-0.035	-0.035
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35	Other (EJ)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Natural Gas (Quads)	4.95	4.85	4.95	5.01	5.00	4.98	Natural Gas (Quads)	0.000	-0.003	-0.015	-0.025	-0.029	-0.031	-0.032	-0.033	-0.033
Other (Quads)	1.59	1.44	1.40	1.35	1.31	1.28	Other (Quads)	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Total U.S. Electric Generation							*Total U.S. Electric Generation*									
Coal (TWh)	1,828	2,038	2,090	2,130	2,208	2,304	Coal (TWh)	0.07	0.15	-0.73	-0.02	-1.06	-1.10	-1.10	-1.10	-1.10
Gas (TWh)	857	691	769	883	1,016	1,094	Gas (TWh)	0.16	1.08	-0.36	-3.02	-1.74	-1.11	-1.11	-1.11	-1.11
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.00	0.00	-0.02	-0.02	-0.03	-0.04	-0.04	-0.04	-0.04
Nuclear (TWh)	813	834	883	886	886	894	Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.32	-0.32	-0.32	-0.32
Renewables (TWh)	462	647	712	795	848	888	Renewables (TWh)	-0.22	-1.72	-1.51	-1.80	-1.89	-2.11	-2.11	-2.11	-2.11
Total (TWh)	4,005	4,257	4,500	4,741	5,007	5,229	Total (TWh)	0.00	-0.49	-2.62	-4.85	-4.72	-4.68	-4.68	-4.68	-4.68
Installed Generating Capacity							*Installed Generating Capacity*									
Coal (GW)	321	325	326	326	330	336	Coal (GW)	0.000	-0.036	-0.015	-0.015	-0.078	-0.070	-0.070	-0.070	-0.070
Other Fossil (GW)	468	445	446	467	501	534	Other Fossil (GW)	-0.001	-0.103	-0.137	-0.382	-0.226	-0.227	-0.227	-0.227	-0.227
Nuclear (GW)	102	105	111	111	111	112	Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	-0.042	-0.042	-0.042	-0.042
Renewables (GW)	133	171	176	186	195	209	Renewables (GW)	-0.063	-0.470	-0.460	-0.401	-0.432	-0.543	-0.543	-0.543	-0.543
Total (GW)	1,024	1,045	1,058	1,090	1,137	1,191	Total (GW)	-0.064	-0.609	-0.612	-0.798	-0.736	-0.882	-0.882	-0.882	-0.882

Table 14.3.3 Clothes Washer Trial Standard Level 2 Forecast

NEMS-BT Results:							Difference from AEO2010 Reference Case							Extrapolation		
	2010	2015	2020	2025	2030	2035		2010	2015	2020	2025	2030	2035	2040	2042	2044
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*									
Electricity Sales (TWh)	1,388	1,400	1,468	1,548	1,631	1,701	Electricity Sales (TWh)	0.00	-0.53	-3.16	-5.24	-6.19	-6.60	-6.87	-6.97	-7.08
Natural Gas (EJ)	5.22	5.11	5.23	5.30	5.29	5.27	Natural Gas (EJ)	0.000	-0.002	-0.010	-0.017	-0.021	-0.022	-0.023	-0.023	-0.024
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35	Other (EJ)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Natural Gas (Quads)	4.95	4.85	4.96	5.02	5.01	4.99	Natural Gas (Quads)	0.000	-0.002	-0.010	-0.016	-0.020	-0.021	-0.022	-0.022	-0.022
Other (Quads)	1.59	1.44	1.40	1.35	1.31	1.28	Other (Quads)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Total U.S. Electric Generation							*Total U.S. Electric Generation*									
Coal (TWh)	1,828	2,038	2,089	2,130	2,208	2,303	Coal (TWh)	0.08	0.17	-0.83	-0.03	-1.21	-1.26	-1.26	-1.26	-1.26
Gas (TWh)	857	692	769	882	1,016	1,094	Gas (TWh)	0.18	1.22	-0.41	-3.44	-1.99	-1.28	-1.28	-1.28	-1.28
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.00	0.00	-0.02	-0.02	-0.03	-0.04	-0.04	-0.04	-0.04
Nuclear (TWh)	813	834	883	886	886	894	Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.37	-0.37	-0.37	-0.37
Renewables (TWh)	462	647	712	795	848	888	Renewables (TWh)	-0.25	-1.94	-1.72	-2.05	-2.17	-2.43	-2.43	-2.43	-2.43
Total (TWh)	4,005	4,257	4,500	4,740	5,006	5,228	Total (TWh)	0.01	-0.55	-2.98	-5.54	-5.42	-5.38	-5.38	-5.38	-5.38
Installed Generating Capacity							*Installed Generating Capacity*									
Coal (GW)	321	325	326	326	330	336	Coal (GW)	0.00	-0.04	-0.02	-0.02	-0.09	-0.08	-0.08	-0.08	-0.08
Other Fossil (GW)	468	445	446	467	501	534	Other Fossil (GW)	0.00	-0.12	-0.16	-0.44	-0.26	-0.26	-0.26	-0.26	-0.26
Nuclear (GW)	102	105	111	111	111	112	Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.05	-0.05	-0.05	-0.05
Renewables (GW)	133	171	176	186	195	209	Renewables (GW)	-0.07	-0.53	-0.52	-0.46	-0.50	-0.62	-0.62	-0.62	-0.62
Total (GW)	1,024	1,045	1,058	1,090	1,137	1,191	Total (GW)	-0.07	-0.69	-0.69	-0.91	-0.84	-1.01	-1.01	-1.01	-1.01

Table 14.3.4 Clothes Washer Trial Standard Level 3 Forecast

NEMS-BT Results:							Difference from AEO2010 Reference Case									
													Extrapolation		
	2010	2015	2020	2025	2030	2035		2010	2015	2020	2025	2030	2035	2040	2042	2044
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*									
Electricity Sales (TWh)	1,388	1,400	1,468	1,547	1,629	1,699	Electricity Sales (TWh)	0.00	-0.49	-3.52	-6.35	-7.81	-8.43	-8.82	-8.95	-9.09
Natural Gas (EJ)	5.22	5.11	5.22	5.29	5.28	5.25	Natural Gas (EJ)	0.000	-0.003	-0.017	-0.029	-0.034	-0.036	-0.038	-0.038	-0.039
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35	Other (EJ)	0.000	0.000	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002
Natural Gas (Quads)	4.95	4.84	4.95	5.01	5.00	4.98	Natural Gas (Quads)	0.000	-0.003	-0.016	-0.027	-0.032	-0.034	-0.036	-0.036	-0.037
Other (Quads)	1.59	1.44	1.40	1.35	1.31	1.28	Other (Quads)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002
Total U.S. Electric Generation							*Total U.S. Electric Generation*									
Coal (TWh)	1,828	2,038	2,089	2,130	2,208	2,303	Coal (TWh)	0.07	0.15	-0.92	-0.03	-1.53	-1.62	-1.62	-1.62	-1.62
Gas (TWh)	857	691	769	881	1,016	1,093	Gas (TWh)	0.16	1.13	-0.45	-4.17	-2.51	-1.64	-1.64	-1.64	-1.64
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.00	0.00	-0.02	-0.02	-0.04	-0.05	-0.05	-0.05	-0.05
Nuclear (TWh)	813	834	883	886	886	894	Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.47	-0.47	-0.47	-0.47
Renewables (TWh)	462	647	712	794	847	887	Renewables (TWh)	-0.23	-1.79	-1.91	-2.48	-2.74	-3.10	-3.10	-3.10	-3.10
Total (TWh)	4,005	4,257	4,499	4,739	5,005	5,227	Total (TWh)	0.00	-0.51	-3.31	-6.70	-6.83	-6.88	-6.88	-6.88	-6.88
Installed Generating Capacity							*Installed Generating Capacity*									
Coal (GW)	321	325	326	326	330	336	Coal (GW)	0.00	-0.04	-0.02	-0.02	-0.11	-0.10	-0.10	-0.10	-0.10
Other Fossil (GW)	468	445	446	467	501	533	Other Fossil (GW)	0.00	-0.11	-0.17	-0.53	-0.33	-0.33	-0.33	-0.33	-0.33
Nuclear (GW)	102	105	111	111	111	112	Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.06	-0.06	-0.06	-0.06
Renewables (GW)	133	171	176	186	195	209	Renewables (GW)	-0.07	-0.49	-0.58	-0.55	-0.62	-0.80	-0.80	-0.80	-0.80
Total (GW)	1,024	1,045	1,058	1,090	1,137	1,191	Total (GW)	-0.07	-0.64	-0.77	-1.10	-1.07	-1.30	-1.30	-1.30	-1.30

Table 14.3.5 Clothes Washer Trial Standard Level 4 Forecast

NEMS-BT Results:							Difference from AEO2010 Reference Case								Extrapolation		
	2010	2015	2020	2025	2030	2035		2010	2015	2020	2025	2030	2035	2040	2042	2044
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*									
Electricity Sales (TWh)	1,388	1,399	1,467	1,545	1,627	1,697	Electricity Sales (TWh)	0.00	-0.85	-5.05	-8.38	-9.98	-10.68	-11.14	-11.31	-11.48
Natural Gas (EJ)	5.22	5.11	5.21	5.27	5.26	5.23	Natural Gas (EJ)	0.000	-0.004	-0.026	-0.043	-0.052	-0.056	-0.058	-0.059	-0.060
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35	Other (EJ)	0.000	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Natural Gas (Quads)	4.95	4.84	4.94	5.00	4.98	4.96	Natural Gas (Quads)	0.000	-0.004	-0.025	-0.041	-0.049	-0.053	-0.055	-0.056	-0.057
Other (Quads)	1.59	1.44	1.40	1.35	1.31	1.28	Other (Quads)	0.000	0.000	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002
Total U.S. Electric Generation							*Total U.S. Electric Generation*									
Coal (TWh)	1,828	2,038	2,089	2,130	2,207	2,303	Coal (TWh)	0.13	0.27	-1.33	-0.05	-1.96	-2.05	-2.05	-2.05	-2.05
Gas (TWh)	858	692	768	880	1,015	1,093	Gas (TWh)	0.28	1.95	-0.65	-5.51	-3.21	-2.07	-2.07	-2.07	-2.07
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.00	-0.01	-0.03	-0.03	-0.06	-0.07	-0.07	-0.07	-0.07
Nuclear (TWh)	813	834	883	886	886	894	Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.60	-0.60	-0.60	-0.60
Renewables (TWh)	462	645	711	794	847	886	Renewables (TWh)	-0.40	-3.09	-2.75	-3.28	-3.51	-3.93	-3.93	-3.93	-3.93
Total (TWh)	4,005	4,256	4,498	4,737	5,003	5,225	Total (TWh)	0.01	-0.88	-4.76	-8.86	-8.73	-8.71	-8.71	-8.71	-8.71
Installed Generating Capacity							*Installed Generating Capacity*									
Coal (GW)	321	325	326	326	330	336	Coal (GW)	0.00	-0.07	-0.03	-0.03	-0.14	-0.13	-0.13	-0.13	-0.13
Other Fossil (GW)	468	445	445	467	501	533	Other Fossil (GW)	0.00	-0.19	-0.25	-0.70	-0.42	-0.42	-0.42	-0.42	-0.42
Nuclear (GW)	102	105	111	111	111	112	Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.08	-0.08	-0.08	-0.08
Renewables (GW)	133	171	176	186	195	208	Renewables (GW)	-0.11	-0.85	-0.83	-0.73	-0.80	-1.01	-1.01	-1.01	-1.01
Total (GW)	1,024	1,045	1,058	1,089	1,137	1,191	Total (GW)	-0.12	-1.10	-1.11	-1.46	-1.36	-1.64	-1.64	-1.64	-1.64

Table 14.3.6 Clothes Washer Trial Standard Level 5 Forecast

NEMS-BT Results:							Difference from AEO2010 Reference Case								Extrapolation		
	2010	2015	2020	2025	2030	2035		2010	2015	2020	2025	2030	2035	2040	2042	2044
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*									
Electricity Sales (TWh)	1,388	1,399	1,466	1,544	1,626	1,695	Electricity Sales (TWh)	0.00	-0.96	-5.74	-9.51	-11.28	-12.08	-12.62	-12.82	-13.01
Natural Gas (EJ)	5.22	5.11	5.21	5.26	5.25	5.23	Natural Gas (EJ)	0.000	-0.005	-0.031	-0.051	-0.061	-0.065	-0.068	-0.069	-0.070
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35	Other (EJ)	0.000	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Natural Gas (Quads)	4.95	4.84	4.94	4.99	4.98	4.95	Natural Gas (Quads)	0.000	-0.005	-0.029	-0.048	-0.057	-0.062	-0.065	-0.066	-0.067
Other (Quads)	1.59	1.44	1.40	1.35	1.31	1.28	Other (Quads)	0.000	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Total U.S. Electric Generation							*Total U.S. Electric Generation*									
Coal (TWh)	1,828	2,038	2,089	2,130	2,207	2,302	Coal (TWh)	0.14	0.30	-1.51	-0.05	-2.21	-2.32	-2.32	-2.32	-2.32
Gas (TWh)	858	693	768	879	1,015	1,093	Gas (TWh)	0.32	2.21	-0.74	-6.25	-3.63	-2.34	-2.34	-2.34	-2.34
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.00	-0.01	-0.03	-0.03	-0.06	-0.07	-0.07	-0.07	-0.07
Nuclear (TWh)	813	834	883	886	886	894	Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.67	-0.67	-0.67	-0.67
Renewables (TWh)	462	645	711	793	846	886	Renewables (TWh)	-0.46	-3.51	-3.13	-3.72	-3.96	-4.45	-4.45	-4.45	-4.45
Total (TWh)	4,005	4,256	4,497	4,736	5,002	5,224	Total (TWh)	0.01	-1.00	-5.41	-10.05	-9.87	-9.86	-9.86	-9.86	-9.86
Installed Generating Capacity							*Installed Generating Capacity*									
Coal (GW)	321	325	326	326	330	336	Coal (GW)	0.00	-0.07	-0.03	-0.03	-0.16	-0.15	-0.15	-0.15	-0.15
Other Fossil (GW)	468	445	445	466	501	533	Other Fossil (GW)	0.00	-0.21	-0.28	-0.79	-0.47	-0.48	-0.48	-0.48	-0.48
Nuclear (GW)	102	105	111	111	111	112	Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.09	-0.09	-0.09	-0.09
Renewables (GW)	133	171	176	185	195	208	Renewables (GW)	-0.13	-0.96	-0.95	-0.83	-0.90	-1.14	-1.14	-1.14	-1.14
Total (GW)	1,024	1,045	1,058	1,089	1,137	1,190	Total (GW)	-0.13	-1.25	-1.26	-1.65	-1.54	-1.86	-1.86	-1.86	-1.86

14.4 IMPACT OF STANDARDS ON NATURAL GAS AND ELECTRICITY PRICES AND ASSOCIATED BENEFITS FOR CONSUMERS

Using the framework of the utility impact analysis, DOE analyzed the potential impact on electricity and natural gas prices resulting from proposed standards on clothes washer products. Associated benefits for all energy users in all sectors of the economy are then derived from these price impacts.

DOE's analysis of energy price impacts used NEMS-BT in a similar manner as described in section 14.2. Like other widely-used energy-economic models, NEMS uses elasticities to estimate the energy price change that would result from a change (increase or decrease) in energy demand. The elasticity of price to a decrease in demand is the "inverse price elasticity." The calculated inverse price elasticity based on NEMS-BT simulations differs throughout the forecast period in response to the dynamics of supply and demand for natural gas or electricity.

The average inverse gas price elasticity during 2015–2035 is 2.08 with TSL 3 (the proposed standard). A value of 2.08 means that, given a one-percent decrease in demand, the price of gas would decline by 2.08 percent.

In a review of such studies that used versions of NEMS to examine the impacts on natural gas prices resulting from reductions in natural gas demand, Wiser and Bollinger[2] examined analyses that reported the reductions in natural gas demand caused by certain energy policies, and the resulting decline in the average U.S. wellhead gas price. Wiser and Bollinger found that the average values of the inverse price elasticity throughout the forecast period in each study ranged from 0.7 to 4.7. The average inverse price elasticities in 13 of 19 analyses were between 0.8 and 2.0. The value from DOE's current analysis (2.08 for TSL 3) falls within the overall range.

Other widely used, complex energy demand/supply models produce price elasticities that are similar to those incorporated in NEMS. Table 14.4.1 compares the results of several studies that modeled the response of natural gas prices to changes in gas consumption. These results are summarized in a 2003 study by Stanford's Energy Modeling Forum (EMF).[3] Although the magnitude of the price response (as summarized by the inverse price elasticity) varies considerably among the models, they generally confirm a sizable price effect associated with changes in natural gas consumption.[c] It is worth noting that the NEMS average value determined by-the EMF study is smaller than that of most of the other models. Therefore, it is reasonable to conclude that the impacts estimated by NEMS are conservative.

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[c] The EMF scenarios modeled the effect of increased gas demand on price. Assuming a smooth supply curve over the long term, however, the elasticities implied by an increase in demand should be equivalent to those implied by a decrease in demand. For undetermined reasons, two of the models studied in the Wiser and Bollinger report (NANGAS and NARG) report somewhat anomalous inverse elasticities.

Table 14.4.1 Natural Gas Inverse Price Elasticity from Seven Energy Models

	2005	2010	2015	2020	Average
NEMS	1.8	2.2	0.53	0.11	1.2
POEMS	2.4	1.8	2.5	1.8	2.1
CRA	3.5	2.5	1.1	0.9	2.0
NANGAS	5.4	7.0	7.6	5.1	6.3
E2020	1.5	1.0	1.0	0.7	1.1
MARKAL	N/A	2.0	N/A	2.1	2.1
NARG	8.7	12.4	5.6	2.4	7.3

Source: Based on EMF, 2003.
NEMS (National Energy Modeling System, 2002); POEMS (Policy Office Electricity Modeling System); CRA (Charles River Associates); NANGAS (North American Natural Gas Analysis System), E2020 (Energy 2020); MARKAL (MARKet ALlocation); NARG (North American Regional Gas model).

In addition to the models listed above, studies have been conducted by the National Petroleum Council[4] and the National Commission on Energy Policy[5] that are based on the EEA model. The EEA model has higher inverse price elasticities (between 4.0 and 16.8) than those predicted by NEMS and most other national energy models, leading to larger natural gas price reductions for a given decrease in demand.

14.4.1 Impact on Natural Gas Prices

Figure 14.4.1 shows the annual change in U.S. natural gas consumption, relative to the base case which involves no new standards, for the proposed standard (TSL 3). Because standards may decrease electricity demand, and a significant percentage of electricity is generated using natural gas, the standards may reduce natural gas consumption in the utility sector as well as in the residential sector.

Figure 14.4.1 Change in U.S. Natural Gas Consumption Resulting From the Proposed Clothes Washer Product Energy Conservation Standard

As described in section 14.2, using NEMS-BT to analyze impacts of relatively small annual changes in energy consumption typically involves using higher-decrements to isolate the impacts of the standards from numerical noise (*i.e.*, larger energy savings quantities than those resulting from the considered standards). After generating results using higher decrements to gas and electricity consumption, DOE utilized a regressed interpolation toward the origin to derive the natural gas price effects resulting from energy savings at TSL 3, the proposed standard. Figure 14.4.2 shows the annual change in average U.S. wellhead price for natural gas, relative to the base case. The price reduction averages 1.3 cents per MMBtu (in 2010$), this is a reduction of 0.18 percent in wellhead prices.

Figure 14.4.2 Effects of the Proposed Clothes Washer Product Energy Conservation Standard on Average U.S. Wellhead Natural Gas Prices

14.4.2 Impact of Changes in Natural Gas Prices on Gas Users

Although NEMS indicates that amended standards for clothes washers reduce natural gas prices by only a small amount, the associated economy-wide savings in natural gas expenditures during the forecast period are substantial. For each TSL, DOE calculated the nominal savings in total natural gas expenditures in each year by multiplying the annual change in the average-user price for natural gas by the total annual U.S. natural gas consumption forecast by NEMS.[d] The amended standards would continue to reduce demand for natural gas after 2035 (which is the last year in the NEMS forecast). DOE's estimate for 2036–2045 (the period used to estimate the NPV of the national consumer benefits from amended standards) multiplied the average gas price reduction in 2015–2035 by estimated total annual gas consumption in 2036–2045.[e] DOE then discounted the stream of reduced expenditures to calculate a NPV.

Table 14.4.2 shows the calculated NPV of the economy-wide savings in natural gas expenditures for each considered TSL at 3-percent and 7-percent discount rates. The need to extrapolate price effects and gas consumption beyond 2035 suggests that one should interpret the

[d] The average user includes electric utilities. Presumably the decrease in expenditures of natural gas that they experience would largely be passed on to electricity consumers.

[e] The estimation of gas consumption after 2035 uses the average annual growth rate in 2031-2035 from the AEO 2010 Reference projection.

post-2035 results as a rough indication of the benefits to natural gas users in the post-2035 period.

Table 14.4.2 Cumulative NPV of the Economy-Wide Savings in Natural Gas Expenditures Due to the Projected Decline in Natural Gas Prices Resulting from the Proposed Standard for Clothes Washers*

Discount Rate	*billion $2010*
3 percent	4.937
7 percent	2.313

* Impacts for units sold from 2015 through 2045

14.4.3 Discussion of Savings in Natural Gas Expenditures

A decline in natural gas consumption may lower natural gas prices for two primary reasons. One reason is that decreasing consumption would lower the output of existing natural gas production capacity, leading to increased competition and downward pressure on prices. A second reason is that reduced consumption slows the depletion of low-cost gas reserves, lowers the future cost of finding and extracting natural gas resources, and dampens expectations for future prices.

When gas prices drop in response to a lower output of existing natural gas production capacity, consumers benefit, but producers suffer. In economic terms, the situation represents a benefits transfer to consumers (whose expenditures fall) from producers (whose revenue falls equally)[f]. When prices decrease because extraction costs decline, however, consumers and producers both benefit, and the change in natural gas prices represents a net gain to society. Consumers benefit from the lower prices, and producers, whose revenues and costs both fall, are made no worse off.

The short-term impact of lower consumption on natural gas price likely results from changes in the utilization of natural gas production and capacity. It is likely that reduced consumption has only a short-term impact on capacity utilization in the natural gas industry. Producers can adjust to changes in consumption in the long term by either increasing or decreasing investments in infrastructure to bring capacity utilization rates back to original levels.

The long-term impact on natural gas prices probably results from changes in extraction costs. Natural gas is an exhaustible resource, and conventional natural gas sources are limited. When those low-cost sources are depleted, producers must turn to higher-cost sources of natural gas, at which point extraction costs and wellhead prices will increase. Reduced demand creates

[f] Gas producers include domestic, other North American, and overseas LNG producers. The proportion of domestic producers is expected to decline in the future.

downward pressure on extraction costs and prices because it delays the depletion of low-cost reserves and forestalls a shift toward higher-cost sources.

Because the NEMS is a complex model, it is difficult to determine exactly how much of the model-estimated drop in natural gas price in any given year is explained by a decrease in utilization of capacity, and how much is explained by a decrease in extraction costs. One would expect, however, that most of the forecasted price decline after 2015 is caused by a decline in extraction costs. Supporting evidence for this conclusion derives from comparing the sources of natural gas drawn upon to supply consumers in the base case (without standards) and the standards cases of the model runs. The three principal sources of natural gas considered in NEMS for 2035 are termed conventional sources, unconventional sources, and imports. The imports are primarily of liquefied natural gas (LNG). Conventional sources are the lowest-cost, and imports are the highest-cost source of natural gas, as forecast by NEMS.

The effect of standards on extraction costs is revealed by comparing the rate of natural gas production from the three natural gas sources in model runs for the base case with the rates for the standards cases. As shown in DOE's furnace/boiler rulemaking (see the TSD, chapter 10), NEMS indicates that standards produce decreases in natural gas production from all three sources, but production from the higher-cost sources declines most of all. This result suggests that, based on the NEMS model, energy conservation standards decrease future costs for natural gas extraction because they result in decreased rates of depletion of low-cost natural gas supplies and decreased imports of high-cost LNG. This result further suggests that a significant part of the long-term decreases in wellhead prices forecasted by the NEMS represents both a benefit to consumers of natural gas and a net benefit to society.

14.4.4 Impact on Electricity Prices

DOE analyzed the electricity price effect of clothes washer products at TSL 3, the selected standard level. A single regression was made to calculate the total impacts at this standard level. Results were generated using higher decrements to energy consumption. A regressed interpolation toward the origin was then used to derive the price effects associated with the total energy savings.

Figure 14.4.3 shows the annual change in U.S. electricity sales for the proposed standard, relative to the base case which involves no new standards.

Figure 14.4.3 Change in U.S. Electricity Sales Associated with the Proposed Clothes Washer Product Energy Conservation Standard

Figure 14.4.4 shows the annual change in average U.S. price for electricity, relative to the Reference case, projected to result from the proposed standard. The price reduction averages 0.007 cents per kWh (in 2010$). This average price reduction equals 0.07 percent.

Figure 14.4.4 Effect of the Proposed Clothes Washer Product Energy Conservation Standard on Average U.S. Electricity Prices (All Users)

14.4.5 Impact of Changes in Electricity Price on Electricity Users

Using the estimated electricity price impacts, DOE calculated the nominal savings in total electricity expenditures in each year by multiplying the annual change in the average-user price for electricity by the total annual U.S. electricity sales forecast by NEMS, adjusted for the impact of the standards. The amended standards would continue to reduce demand for electricity after 2035 (which is the last year in the NEMS forecast). DOE's estimate for 2036–2045 (the period used to estimate the NPV of the national consumer benefits from amended standards) multiplied the average electricity price reduction in 2015–2035 by estimated total annual electricity sales in 2036–2045.[g] DOE then discounted the stream of reduced expenditures to calculate a NPV.

Table 14.4.3 shows the calculated NPV of the economy-wide savings in electricity expenditures for each considered TSL at 3-percent and 7-percent discount rates. The need to extrapolate price effects and electricity sales beyond 2035 suggests that one should interpret the post-2035 results as a rough indication of the benefits to electricity users in the post-2035 period.

[g] The estimation of electricity consumption after 2035 uses the average annual growth rate in 2031-2035 of total U.S. electricity consumption forecasted by NEMS. This forecast includes the impact of the standards.

Table 14.4.3 Cumulative NPV of the Economy Wide Savings in Electricity Expenditures Due to the Projected Decline in Electricity Prices Resulting from the Proposed Standard For Clothes Washers*

Discount Rate	*billion $2010*
3 percent	5.224
7 percent	2.471

* Impacts for units sold from 2015 through 2045

14.4.6 Discussion of Savings in Electricity Expenditures

Although the aggregate benefits for all electricity users are potentially large, there may be negative effects on the actors involved in electricity supply. The electric power industry is a complex mix of power plant providers, fuel suppliers, electricity generators, and electricity distributors. While the distribution of electricity is regulated everywhere, the institutional structure of the power sector varies, and has changed over time. For these reasons, an assessment of the impacts on the actors involved in electricity supply from the reduction in electricity demand associated with energy conservation standards is beyond the scope of this rulemaking.

In considering the potential benefits to electricity users, DOE takes under advisement the instruction provided by the Office of Management and Budget (OMB) to Federal agencies on the development of regulatory analysis (OMB Circular A-4 (Sept. 17, 2003), section E, “Identifying and Measuring Benefits and Costs”). Specifically, at page 38, Circular A-4 instructs that transfers should be excluded from the estimates of the benefits and costs of a regulation. DOE is continuing to investigate the extent to which a change in electricity prices that is projected to result from standards represents a net gain to society.

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[3] *Natural Gas, Fuel Diversity and North American Energy Markets*, September 2003. Energy Modeling Forum, Stanford University. Report No. EMF Report 20.

[4] *Balancing Natural Gas Policy - Fueling the Demands of a Growing Economy, Vol. I Summary of Findings and Recommendations*, September 25, 2003. National Petroleum Council.

[5] National Commission on Energy Policy, *Increasing U.S. Natural Gas Supplies: A Discussion Paper and Recommendations from the National Commission on Energy Policy*, October, 2003. <www.energycommission.org>

CHAPTER 15. EMISSIONS ANALYSIS

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CHAPTER 15. EMISSIONS ANALYSIS

15.1 INTRODUCTION

This chapter describes potential changes to emissions of carbon dioxide (CO_2) and three air pollutants that may result from energy conservation standards for residential clothes washers. The impacts on air emissions are largely driven by changes in power plant types and quantities of electricity generated under each of the considered standard levels. Changes in electricity generation are described in the utility impact analysis in chapter 14.

15.2 AIR EMISSIONS DESCRIPTIONS AND REGULATION

This analysis considers three pollutants: sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury (Hg). An air pollutant is any substance in the air that can cause harm to humans or the environment. Pollutants may be natural or man-made (*i.e.*, anthropogenic) and may take the form of solid particles (*i.e.*, particulates or particulate matter), liquid droplets, or gases.[a] DOE's analysis also considers carbon dioxide (CO_2).

Sulfur Dioxide. Sulfur dioxide, or SO_2, belongs to the family of sulfur oxide gases (SOx). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron. SOx gases are formed when fuel containing sulfur, such as coal and oil, is burned, and when gasoline is extracted from oil, or metals are extracted from ore. SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment.[1]

Nitrogen Oxides. Nitrogen oxides**,** or NO_X, is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2), along with particles in the air can often be seen as a reddish-brown layer over many urban areas. NO_2 is the specific form of NO_X reported in this document. NO_X is one of the main ingredients involved in the formation of ground-level ozone, which can trigger serious respiratory problems. It can contribute to the formation of acid rain, and can impair visibility in areas such as national parks. NO_X also contributes to the formation of fine particles that can impair human health.[2]

Nitrogen oxides form when fossil fuel is burned at high temperatures, as in a combustion process. The primary manmade sources of NO_X are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fossil fuels. NO_X can also be formed naturally. Electric utilities account for about 22 percent of NO_X emissions in the United States.[2]

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[a] More information on air pollution characteristics and regulations is available on the U.S. Environment Protection Agent (EPA)'s website at www.epa.gov.

Mercury. Coal-fired power plants emit mercury (Hg) found in coal during the burning process. While coal-fired power plants are the largest remaining source of human-generated Hg emissions in the United States, they contribute very little to the global Hg pool or to contamination of U.S. waters.[3] U.S. coal-fired power plants emit Hg in three different forms: oxidized Hg (likely to deposit within the United States); elemental Hg, which can travel thousands of miles before depositing to land and water; and Hg that is in particulate form. Atmospheric Hg is then deposited on land, lakes, rivers, and estuaries through rain, snow, and dry deposition. Once there, it can transform into methylmercury and accumulate in fish tissue through bioaccumulation.

Americans are exposed to methylmercury primarily by eating contaminated fish. Because the developing fetus is the most sensitive to the toxic effects of methylmercury, women of childbearing age are regarded as the population of greatest concern. Children exposed to methylmercury before birth may be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities, and verbal memory.[4]

Carbon Dioxide. Carbon dioxide (CO_2) is not a criteria pollutant (see below), but it is of interest because of its classification as a greenhouse gas (GHG). GHGs trap the sun's radiation inside the Earth's atmosphere and either occur naturally in the atmosphere or result from human activities. Naturally occurring GHGs include water vapor, CO_2, methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Human activities, however, add to the levels of most of these naturally occurring gases. For example, CO_2 is emitted to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), wood, and wood products are burned. In 2007, over 90 percent of anthropogenic (*i.e.*, human-made) CO_2 emissions resulted from burning fossil fuels.[5]

Concentrations of CO_2 in the atmosphere are naturally regulated by numerous processes, collectively known as the "carbon cycle." The movement of carbon between the atmosphere and the land and oceans is dominated by natural processes, such as plant photosynthesis. While these natural processes can absorb some of the anthropogenic CO_2 emissions produced each year, billions of metric tons are added to the atmosphere annually. In the United States, in 2007, CO_2 emissions from electricity generation accounted for 39 percent of total U.S. GHG emissions.[5]

Particulate Matter. Particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

PM impacts are of concern due to human exposures that can impact health. Particle pollution - especially fine particles - contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, for example; decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease.

DOE acknowledges that particulate matter (PM) exposure can impact human health. Power plant emissions can have either direct or indirect impacts on PM. A portion of the pollutants emitted by a power plant are in the form of particulates as they leave the smoke stack. These are direct, or primary, PM emissions. However, the great majority of PM emissions associated with power plants are in the form of secondary sulfates, which are produced at a significant distance from power plants by complex atmospheric chemical reactions that often involve the gaseous (non-particulate) emissions of power plants, mainly SO_2 and NO_X. The quantity of the secondary sulfates produced is determined by a very complex set of factors including the atmospheric quantities of SO_2 and NO_X, and other atmospheric constituents and conditions. Because these highly complex chemical reactions produce PM comprised of different constituents from different sources, EPA does not distinguish direct PM emissions from power plants from the secondary sulfate particulates in its ambient air quality requirements, PM monitoring of ambient air quality, or PM emissions inventories. For these reasons, it is not currently possible to determine how the amended standard impacts either direct or indirect PM emissions. Therefore, DOE is not planning to assess the impact of these standards on PM emissions. Further, as described below, it is uncertain whether efficiency standards will result in a net decrease in power plant emissions of SO_2, and of NO_X in many States, since those pollutants are now largely regulated by cap and trade systems.

Air Quality Regulation. The Clean Air Act Amendments of 1990 list 188 toxic air pollutants that EPA is required to control.[6] EPA has set national air quality standards for six common pollutants (also referred to as "criteria" pollutants), two of which are SO_2 and NO_X. Also, the Clean Air Act Amendments of 1990 gave EPA the authority to control acidification and to require operators of electric power plants to reduce emissions of SO_2 and NO_X. Title IV of the 1990 amendments established a cap-and-trade program for SO_2, in all 50 states and the District of Columbia (D.C.), intended to help control acid rain.[6] This cap-and-trade program serves as a model for more recent programs with similar features.

In 2005, EPA issued the Clean Air Interstate Rule (CAIR) under sections 110 and 111 of the Clean Air Act (40 CFR Parts 51, 96, and 97).[b] 70 FR 25162–25405 (May 12, 2005). CAIR limited emissions from 28 eastern States and D.C. by capping emissions and creating an allowance-based trading program. Although, CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit), (see North Carolina v. EPA, 550 F.3d 1176 (D.C. Cir. 2008),) it remained in effect temporarily, consistent with the D.C. Circuit's earlier opinion in North Carolina v. EPA, 531 F.3d 896 (D.C. Cir. 2008).

On July 6, 2010, EPA issued the Transport Rule proposal, a replacement for CAIR. 75 FR 45210 (Aug. 2, 2010). On July 6, 2011, EPA promulgated the final Transport Rule, entitled "Federal Implementation Plans: Interstate Transport of Fine Particulate Matter and Ozone and Correction of SIP Approvals," but commonly referred to as the Cross-State Air Pollution Rule or the Transport Rule. 76 FR 48208 (Aug. 8, 2011).

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[b] See http://www.epa.gov/cleanairinterstaterule/.

With respect to Hg emissions, in 2005, EPA issued the final rule entitled "Standards of Performance for New and Existing Stationary Sources: Electric Steam Generating Units," under sections 110 and 111 of the Clean Air Act (40 CFR Parts 60, 63, 72, and 75).[7] This rule, called the Clean Air Mercury Rule (CAMR), was closely related to the CAIR and established standards of performance for Hg emissions from new and existing coal-fired electric utility steam generating units. The CAMR regulated Hg emissions from coal-fired power plants. On February 8, 2008, the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) issued its decision in State of New Jersey, *et al.* v. Environmental Protection Agency,[c] in which the Court, among other actions, vacated the CAMR.

15.3 GLOBAL CLIMATE CHANGE

Climate change has evolved into a matter of global concern because it is expected to have widespread, adverse effects on natural resources and systems. A growing body of evidence points to anthropogenic sources of greenhouse gases, such as carbon dioxide (CO_2), as major contributors to climate change. Because this rule, if finalized, will likely decrease CO_2 emission rates from the fossil fuel sector in the United States, the Department here examines the impacts and causes of climate change and then the potential impact of the rule on CO_2 emissions and global warming.

Impacts of Climate Change on the Environment. Climate is usually defined as the average weather, over a period ranging from months to many years. Climate change refers to a change in the state of the climate, which is identifiable through changes in the mean and/or the variability of its properties (*e.g.*, temperature or precipitation) over an extended period, typically decades or longer.

The World Meteorological Organization and United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) to provide an objective source of information about climate change. According to the IPCC Fourth Assessment Report (IPCC Report), published in 2007, climate change is consistent with observed changes to the world's natural systems; the IPCC expects these changes to continue. [8]

Changes that are consistent with warming include warming of the world's oceans to a depth of 3000 meters; global average sea level rise at an average rate of 1.8 mm per year from 1961 to 2003; loss of annual average Arctic sea ice at a rate of 2.7 percent per decade, changes in wind patterns that affect extra-tropical storm tracks and temperature patterns, increases in intense precipitation in some parts of the world, as well as increased drought and more frequent heat waves in many locations worldwide, and numerous ecological changes.[8]

Looking forward, the IPCC describes continued global warming of about 0.2 °C per decade for the next two decades under a wide range of emission scenarios for carbon dioxide (CO_2), other greenhouse gases (GHGs), and aerosols. After that period, the rate of increase is less certain. The IPCC Report describes increases in average global temperatures of about 1.1 °C

[c] 517 F.3d 574, 583 (D.C. Cir. 2008).

to 6.4 °C at the end of the century relative to today. These increases vary depending on the model and emissions scenarios.[8]

The IPCC Report describes incremental impacts associated with the rise in temperature. At ranges of incremental increases to the global average temperature, IPCC reports, with either high or very high confidence, that there is likely to be an increasing degree of impacts such as coral reef bleaching, loss of wildlife habitat, loss to specific ecosystems, and negative yield impacts for major cereal crops in the tropics, but also projects that there likely will be some beneficial impacts on crop yields in temperate regions.

Causes of Climate Change. The IPCC Report states that the world has warmed by about 0.74 °C in the last 100 years. The IPCC Report finds that most of the temperature increase since the mid-20th century is very likely due to the increase in anthropogenic concentrations of CO_2 and other long-lived greenhouse gases such as methane and nitrous oxide in the atmosphere, rather than from natural causes.

Increasing the CO_2 concentration partially blocks the earth's re-radiation of captured solar energy in the infrared band, inhibits the radiant cooling of the earth, and thereby alters the energy balance of the planet, which gradually increases its average temperature. The IPCC Report estimates that currently, CO_2 makes up about 77 percent of the total CO_2-equivalent[d] global warming potential in GHGs emitted from human activities, with the vast majority (74 percent) of the CO_2 attributable to fossil fuel use.[9] For the future, the IPCC Report describes a wide range of GHG emissions scenarios, but under each scenario CO_2 would continue to comprise above 70 percent of the total global warming potential.[9]

Stabilization of CO_2 Concentrations. Unlike many traditional air pollutants, CO_2 mixes thoroughly in the entire atmosphere and is long-lived. The residence time of CO_2 in the atmosphere is long compared to the emission processes. Therefore, the global cumulative emissions of CO_2 over long periods determine CO_2 concentrations because it takes hundreds of years for natural processes to remove the CO_2. Globally, 49 billion metric tons of CO_2 – equivalent of anthropogenic (man-made) greenhouse gases are emitted every year.[e] Of this annual total, fossil fuels contribute about 29 billion metric tons of CO_2.[10]

Researchers have focused on considering atmospheric CO_2 concentrations that likely will result in some level of global climate stabilization, and the emission rates associated with achieving the "stabilizing" concentrations by particular dates. They associate these stabilized CO_2 concentrations with temperature increases that plateau in a defined range. For example, at the low end, the IPCC Report scenarios target CO_2 stabilized concentrations range between 350

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[d] GHGs differ in their warming influence (radiative forcing) on a global climate system due to their different radiative properties and lifetimes in the atmosphere. These warming influences may be expressed through a common metric based on the radiative forcing of CO_2, *i.e.*, CO_2-equivalent. CO_2 equivalent emission is the amount of CO_2 emission that would cause the same- time integrated radiative forcing, over a given time horizon, as an emitted amount of other long- lived GHG or mixture of GHGs.

[e] Other non-fossil fuel contributors include CO_2 emissions from deforestation and decay from agriculture biomass; agricultural and industrial emissions of methane; and emissions of nitrous oxide and fluorocarbons.

ppm and 400 ppm (essentially today's value)—because of climate inertia, concentrations in this low-end range would still result in temperatures projected to increase 2.0 °C to 2.4 °C above pre-industrial levels[f] (about 1.3 °C to 1.7 °C above today's levels). To achieve concentrations between 350 ppm to 400 ppm, the IPCC scenarios present that there would have to be a rapid downward trend in total annual global emissions of greenhouse gases to levels that are 50 to 85 percent below today's annual emission rates by no later than 2050. Since it is assumed that there would continue to be growth in global population and substantial increases in economic production, the scenarios identify required reductions in greenhouse gas emissions intensity (emissions per unit of output) of more than 90 percent. However, even at these rates, the scenarios describe some warming and some climate change is projected due to already accumulated CO_2 and GHGs in the atmosphere.[11]

The Beneficial Impact of the Rule on CO_2 Emissions. It is anticipated that the Rule will reduce energy-related CO_2 emissions, particularly those associated with energy consumption in buildings. The U.S. Energy Information Administration (EIA) reports in its 2011 *Annual Energy Outlook* (*AEO2011*)[12] that U.S. annual energy-related emissions of CO_2 in 2009 were about 5.4 billion metric tons, of which 1.2 billion tons were attributed to the residential buildings sector (including energy-using products such as residential clothes washers). Most of the greenhouse gas emissions attributed to residential buildings are emitted from fossil fuel-fired power plants that generate electricity used in this sector. In the *AEO2011* Reference Case, EIA projected that annual energy-related CO_2 emissions would grow from 5.4 billion metric tons in 2009 to 6.3 billion metric tons in 2035, an increase of 16 percent, while residential emissions would grow to from 1.17 billion metric tons to 1.23 billion metric tons, an increase of 5 percent.

The estimated cumulative CO_2 emission reductions from residential clothes washers energy conservation standards (shown as a range of alternative TSLs) during the 30-year analysis period are indicated in Table 15.3.1. Estimated CO_2 emission reductions in Table 15.3.1 come from power sector electricity generation and from site emissions resulting from the operation of these appliances. The estimated CO_2 emission reductions from electricity generation are calculated using the 2010 NEMS-BT model. Household emissions are calculated outside of the NEMS-BT model, using emissions factors for fuel combustion. For a complete description of the household emissions methodology, see appendix-15A. The considered TSLs each have a different composition level of both of these types of emissions

[f] IPCC Working Group 3 Table TS 2

Table 15.3.1 Reduction in Cumulative Energy-Related Emissions of CO_2 from 2015 through 2044 from Residential Clothes Washer Energy Conservation Standards

	Trial Standard Levels				
	TSL 1	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
	Million Metric Tons				
Power Plant Emissions	47.0	53.9	67.6	86.8	98.3
Household Emissions	40.7	28.1	45.3	68.7	80.5
Total	87.6	82.0	113	156	179
Percent of Total Cumulative Emissions Reduction compared with the *AEO2010* Reference Case in 2016-2046	0.117	0.109	0.151	0.208	0.239

The Incremental Impact of the Rule on Climate Change. It is difficult to correlate specific emission rates with atmospheric concentrations of CO_2 and specific atmospheric concentrations with future temperatures because the IPCC Report describes a clear lag in the climate system between any given concentration of CO_2 (even if maintained for long periods) and the subsequent average worldwide and regional temperature, precipitation, and extreme weather regimes. For example, a major determinant of climate response is "equilibrium climate sensitivity", a measure of the climate system response to sustained radioactive forcing. It is defined as the global average surface warming following a doubling of carbon dioxide concentrations. The IPCC Report describes its estimated, numeric value as about 3 °C, but the likely range of that value is 2 °C to 4.5 °C, with cloud feedbacks the largest source of uncertainty. Further, as illustrated above, the IPCC Report scenarios for stabilization rates are presented in terms of a range of concentrations, which then correlates to a range of temperature changes. Thus, climate sensitivity is a key uncertainty for CO_2 mitigation scenarios that aim to meet specific temperature levels.

Because of how complex global climate systems are, it is difficult to know to what extent and when particular CO_2 emissions reductions will impact global warming. However, as Table 15.3.1 indicates, the rule is expected to reduce CO_2 emissions associated with energy consumption in buildings.

15.4 ANALYTICAL METHODS FOR AIR EMISSIONS

For each of the considered TSLs, DOE calculated total power-sector emissions based on output from the NEMS-BT model (see chapter 14 for description of the model).

Coal-fired electric generation is the single largest source of electricity in the United States. Because the mix of coals used significantly affects the emissions produced, the model

includes a detailed representation of coal supply. The model considers the rank of the coal as well as the sulfur contents of the fuel used when determining optimal dispatch.

Within the NEMS-BT model, planning options for achieving emissions restrictions in the Clean Air Act Amendments include installing pollution control equipment on existing power plants and building new power plants with low emission rates. These methods for reducing emission are compared to dispatching options such as fuel switching and allowance trading. Environmental regulations also affect capacity expansion decisions. For instance, new plants are not allocated SO_2 emissions allowances according to the Clean Air Act Amendments. Consequently, the decision to build a particular capacity type must consider the cost (if any) of obtaining sufficient allowances. This could involve purchasing allowances or over-complying at an existing unit.

For this analysis, DOE used the version of NEMS-BT based on *AEO 2011*, which assumes the implementation of CAIR. Thus, DOE's analysis assumes the presence of nationwide emission caps on SO_2 and caps on NO_X emissions in the 28 States covered by CAIR. DOE expects that the NEMS-BT based on *AEO 2012* will incorporate implementation of the Transport Rule.

SO_2 emissions from affected Electric Generating Units (EGUs) are subject to nationwide and regional emissions cap and trading programs, and DOE has determined that these programs create uncertainty about the standards' impact on SO_2 emissions. The attainment of emissions caps is typically flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the imposition of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. However, if the standard resulted in a permanent increase in the quantity of unused emissions allowances, there would be an overall reduction in SO_2 emissions from the standards. While there remains some uncertainty about the ultimate effects of efficiency standards on SO_2 emissions covered by the existing cap and trade system, the NEMS-BT modeling system that DOE uses to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2.[g]

The CAIR established a cap on NO_X emissions in 28 eastern states and the District of Columbia. All these States and D.C. have elected to reduce their NO_X emissions by participating in cap-and-trade programs for EGUs. Therefore, energy conservation standards for residential clothes washers may have little or no physical effect on these emissions in the 28 eastern States and the D.C. for the same reasons that they may have little or no physical effect on SO_2 emissions.

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[g] In contrast to the modeling forecasts of NEMS-BT that SO_2 emissions will remain at the cap, during the years 2007 and 2008, SO_2 emissions were below the trading cap. This raises the possibility that standards could cause some reduction in SO_2 emissions. However, because DOE does not have a method to predict when emissions will be below the trading cap, it continues to reply on NEMS-BT and thus does not estimate SO_2 emissions reductions at this time.

With respect to Hg, in the absence of CAMR or another trading program, a DOE standard would likely reduce Hg emissions and DOE uses NEMS-BT to estimate these emission reductions. However, DOE continues to review the impact of rules that reduce energy consumption on Hg emissions, and may revise its assessment of Hg emission reductions in future rulemakings.

As noted in chapter 14, NEMS-BT model forecasts end in year 2035. Rather than extrapolate beyond this year, DOE assumes that emissions impacts beyond 2035 are equal to the impacts in 2035.

15.5 EFFECTS ON POWER PLANT EMISSIONS

Table 15.5.1 shows *AEO2010* reference case power plant emissions in selected years. The Reference Case emissions are the emissions shown by the NEMS-BT model to result if none of the TSLs are promulgated (the base case).

Table 15.5.1 Power Sector Emissions Forecast from *AEO2010* Reference Case

NEMS-BT Results	2010	2015	2020	2025	2030	2035
CO_2 (million metric tons)	2,218	2,278	2,341	2,421	2,534	2,636
NO_X (million tons)	2.24	2.06	2.02	2.03	2.06	2.07
Hg (tons)	40.6	30.6	30.1	30.0	30.2	30.3

Table 15.5.2 shows the estimated changes in power plant emissions of CO_2, NO_X, and Hg in selected years for each of the TSLs. As in Table 15.2.2, values for CO_2 are given in metric tons, while values for NO_X and Hg are given in short tons. “Mt” refers to “million metric tons.”

Table 15.5.2 Power Sector Emissions Impacts Forecasts for Residential Clothes Washer TSLs

NEMS-BT Results*	Difference from AEO2010 Reference Case									
							Extrapolation			Total
	2010	2015	2020	2025	2030	2035	2040	2042	2044	2015-2044
Standard Level 1										
CO_2 (Mt/yr)	0.18	1.01	-0.89	-2.42	-2.18	-1.72	-1.72	-1.72	-1.72	**-47.0**
NOx (kt/yr)	0.19	0.91	-0.77	-2.03	-1.77	-1.35	-1.35	-1.35	-1.35	**-38.0**
Hg (ton/yr)	0.003	-0.003	-0.018	-0.003	-0.005	-0.006	-0.006	-0.006	-0.006	**-0.198**
Standard Level 2										
CO_2 (Mt/yr)	0.21	1.14	-1.01	-2.76	-2.51	-1.97	-1.97	-1.97	-1.97	**-53.9**
NOx (1,000 tons/yr)	0.21	1.03	-0.87	-2.32	-2.04	-1.55	-1.55	-1.55	-1.55	**-43.6**
Hg (ton/yr)	0.003	-0.003	-0.020	-0.003	-0.006	-0.007	-0.007	-0.007	-0.007	**-0.226**
Sandard Level 3										
CO_2 (Mt/yr)	0.19	1.05	-1.13	-3.34	-3.16	-2.52	-2.52	-2.52	-2.52	**-67.6**
NOx (1,000 tons/yr)	0.19	0.95	-0.97	-2.80	-2.57	-1.98	-1.98	-1.98	-1.98	**-54.7**
Hg (ton/yr)	0.003	-0.003	-0.023	-0.004	-0.008	-0.009	-0.009	-0.009	-0.009	**-0.269**
Standard Level 4										
CO_2 (Mt/yr)	0.33	1.82	-1.62	-4.41	-4.04	-3.20	-3.20	-3.20	-3.20	**-86.8**
NOx (1,000 tons/yr)	0.34	1.64	-1.39	-3.71	-3.28	-2.51	-2.51	-2.51	-2.51	**-70.2**
Hg (ton/yr)	0.005	-0.005	-0.032	-0.005	-0.010	-0.012	-0.012	-0.012	-0.012	**-0.364**
Standard Level 5										
CO_2 (Mt/yr)	0.38	2.06	-1.84	-5.00	-4.57	-3.62	-3.62	-3.62	-3.62	**-98.3**
NOx (1,000 tons/yr)	0.38	1.86	-1.59	-4.20	-3.71	-2.84	-2.84	-2.84	-2.84	**-79.5**
Hg (ton/yr)	0.006	-0.005	-0.037	-0.006	-0.011	-0.013	-0.013	-0.013	-0.013	**-0.413**

*CO_2 results are in metric tons, NO_X and Hg results are in short tons.

15.6 EFFECTS ON HOUSEHOLD EMISSIONS

Table 15.6.1 shows the estimated changes in household emissions by TSL for residential clothes washers. The table displays changes in CO2, NO_X, and SO_2 in selected years for each of the TSLs.

Table 15.6.1 Household Emissions Impacts Forecasts for Residential Clothes Washer TSLs

NEMS-BT Results*	Difference from AEO2010 Reference Case									
							Extrapolation			Total
	2010	2015	2020	2025	2030	2035	2040	2042	2044	2015-2044
Standard Level 1										
CO_2 (Mt/yr)	0.00	-0.14	-0.84	-1.38	-1.63	-1.73	-1.73	-1.73	-1.73	**-40.7**
NOx (1,000 tons/yr)	0.00	-0.11	-0.66	-1.09	-1.29	-1.37	-1.37	-1.37	-1.37	**-32.2**
SO_2 (1,000 tons/yr)	0.00	-0.02	-0.11	-0.19	-0.22	-0.23	-0.23	-0.23	-0.23	**-5.50**
Standard Level 2										
CO_2 (Mt/yr)	0.00	-0.10	-0.57	-0.95	-1.12	-1.20	-1.20	-1.20	-1.20	**-28.1**
NOx (1,000 tons/yr)	0.00	-0.08	-0.45	-0.75	-0.89	-0.95	-0.95	-0.95	-0.95	**-22.2**
SO_2 (1,000 tons/yr)	0.00	-0.02	-0.13	-0.21	-0.25	-0.27	-0.27	-0.27	-0.27	**-6.31**
Sandard Level 3										
CO_2 (Mt/yr)	0.00	-0.15	-0.91	-1.52	-1.81	-1.94	-1.94	-1.94	-1.94	**-45.3**
NOx (1,000 tons/yr)	0.00	-0.12	-0.72	-1.21	-1.43	-1.54	-1.54	-1.54	-1.54	**-35.8**
SO_2 (1,000 tons/yr)	0.00	-0.02	-0.14	-0.26	-0.32	-0.34	-0.34	-0.34	-0.34	**-7.82**
Standard Level 4										
CO_2 (Mt/yr)	0.00	-0.23	-1.38	-2.30	-2.75	-2.95	-2.95	-2.95	-2.95	**-68.7**
NOx (1,000 tons/yr)	0.00	-0.18	-1.10	-1.82	-2.17	-2.33	-2.33	-2.33	-2.33	**-54.3**
SO_2 (1,000 tons/yr)	0.00	-0.03	-0.21	-0.34	-0.41	-0.44	-0.44	-0.44	-0.44	**-10.2**
Standard Level 5										
CO_2 (Mt/yr)	0.00	-0.27	-1.63	-2.71	-3.21	-3.45	-3.45	-3.45	-3.45	**-80.5**
NOx (1,000 tons/yr)	0.00	-0.22	-1.29	-2.14	-2.54	-2.73	-2.73	-2.73	-2.73	**-63.7**
SO_2 (1,000 tons/yr)	0.00	-0.04	-0.23	-0.39	-0.46	-0.49	-0.49	-0.49	-0.49	**-11.5**

*All results in metric tons (t), equivalent to 1.1 short tons

15.7 EFFECTS ON UPSTREAM FUEL-CYCLE EMISSIONS

Upstream fuel-cycle emissions refer to the emissions associated with the amount of energy used in the upstream production and downstream consumption of electricity, including energy used at the power plant. Upstream processes include the mining of coal or extraction of natural gas, physical preparatory and cleaning processes, and transportation to the power plant. The NEMS-BT does a thorough accounting of emissions at the power plant due to downstream energy consumption, but does not account for upstream emissions (*i.e.*, emissions from energy losses during coal and natural gas production). Thus, this analysis reports only power plant emissions.

However, previous DOE environmental assessment documents have developed approximate estimates of effects on upstream fuel-cycle emissions. These emissions factors provide the reader with a sense of the possible magnitude of upstream effects. These upstream emissions would be in addition to emissions from direct combustion.

Relative to the entire fuel cycle, estimates based on the work of Dr. Mark DeLuchi, and reported in earlier DOE environmental assessment documents, find that an amount approximately equal to eight percent, by mass, of emissions (including SO_2) from coal production are due to mining, preparation that includes cleaning the coal, and transportation from the mine to the power plant.[13] Transportation emissions include emissions from the fuel used by the mode of transportation that moves the coal from the mine to the power plant. In addition, based on Dr. DeLuchi's work, DOE estimated that an amount equal to approximately 14 percent of emissions from natural gas production result from upstream processes.

Emission factor estimates and corresponding percentages of contributions of upstream emissions from coal and natural gas production, relative to power plant emissions, are shown in Table 15.7.1 for CO_2 and NO_X. The percentages provide a means to estimate upstream emission savings based on changes in emissions from power plants. This approach does not address Hg emissions.

Table 15.7.1 Estimated Upstream Emissions of Air Pollutants as a Percentage of Direct Power Plant Combustion Emissions

Pollutant	Percent of Coal Combustion Emissions	Percent of Natural Gas Combustion Emissions
CO_2	2.7	11.9
NO_X	5.8	40

15.8 SUMMARY OF EMISSIONS IMPACTS

Table 15.8.1 summarizes the estimated emissions impacts for each of the TSLs for residential clothes washers. It shows cumulative changes in emissions for CO_2, NO_X, and Hg from 2015 through 2044 for each of the TSLs. Cumulative CO_2, NO_X, and Hg emissions are

reduced compared to the Reference case for all TSLs. For comparison, the cumulative power sector emissions in the *AEO2010* Reference case, over the period 2015 through 2044, are 74,909 Mt for CO_2, 61,446 thousand tons for NO_X, and 904 tons for Hg.

Table 15.8.1 Cumulative Emissions Reductions Under Clothes Washer TSLs from 2015 through 2044*,**

	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Power Sector Emissions					
CO_2 (Mt)	47.0	53.9	67.6	86.8	98.3
NO_X (kt)	38.0	43.6	54.7	70.2	79.5
Hg(t)	0.198	0.226	0.269	0.364	0.413
Household Emissions					
CO_2 (Mt)	40.7	28.1	45.3	68.7	80.5
NO_X (kt)	32.2	22.2	35.8	54.3	63.7
Total Emissions					
CO_2 (Mt)	87.6	82.0	113	156	179
NO_X (kt)	73.5	68.1	94.2	130	150
Hg (t)	0.198	0.226	0.269	0.364	0.413

*CO2 results are in metric tons, NO_X and Hg results are in short tons.
**Household NO_X emissions are in metric tons.

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CHAPTER 16. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

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CHAPTER 16. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

16.1 INTRODUCTION

As part of its assessment of energy conservation standards, DOE considered the estimated monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_X) that are expected to result from each of the TSLs considered. This chapter summarizes the basis for the estimated monetary values used for each of these emissions and presents the benefits estimates considered.

16.2 MONETIZING CARBON DIOXIDE EMISSIONS

16.2.1 Social Cost of Carbon

Under Executive Order 12866, agencies must, to the extent permitted by law, "assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs."

The social cost of carbon (SCC) is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. Estimates of the SCC are provided in dollars per metric ton of carbon dioxide.

The purpose of the SCC estimates presented here is to allow agencies to incorporate the monetized social benefits of reducing CO_2 emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

As part of the interagency process that developed these SCC estimates, technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, at discount rates

of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For emissions (or emission reductions) that occur in later years, these values grow in real terms over time, as depicted in Table 16.2.1.

Table 16.2.1 Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per metric ton)

	Discount Rate			
	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Research Council[a] points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Consistent with the directive quoted above, the purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. Most Federal regulatory actions can be expected to have marginal impacts on global emissions.

[a] National Research Council. Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use. National Academies Press: Washington, DC. 2009.

For such policies, the agency can estimate the benefits from reduced (or costs from increased) emissions in any future year by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions. DOE does not attempt to answer that question here.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, the interagency group has set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, the interagency group will continue to explore the issues raised by this analysis and consider public comments as part of the ongoing interagency process.

16.2.2 Social Cost of Carbon Values Used in Past Regulatory Analyses

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing carbon dioxide emissions. In the final model year 2011 CAFE rule, the Department of Transportation (DOT) used both a "domestic" SCC value of \$2 per ton of CO_2 and a "global" SCC value of \$33 per ton of CO2 for 2007 emission reductions (in 2007 dollars), increasing both values at 2.4 percent per year. It also included a sensitivity analysis at \$80 per ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in carbon dioxide emissions, while a global SCC value is meant to reflect the value of damages worldwide.

A 2008 regulation proposed by DOT assumed a domestic SCC value of \$7 per ton of CO_2 (in 2006 dollars) for 2011 emission reductions (with a range of \$0-\$14 for sensitivity analysis), also increasing at 2.4 percent per year. A regulation finalized by DOE in October of 2008 used a domestic SCC range of \$0 to \$20 per ton CO_2 for 2007 emission reductions (in 2007 dollars). In addition, EPA's 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as "very preliminary" SCC estimates subject to revision. EPA's global mean values were \$68 and \$40 per ton CO_2 for discount rates of approximately 2 percent and 3 percent, respectively (in 2006 dollars for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted.

The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006 dollars) of $55, $33, $19, $10, and $5 per ton of CO_2. The $33 and $5 values represented model-weighted means of the published estimates produced from the most recently available versions of three integrated assessment models—DICE (Dynamic Integrated Climate Economy), PAGE (Policy Analysis of the Greenhouse Effect), and FUND (Climate Framework for Uncertainty, Negotiation and Distribution)—at approximately 3 and 5 percent discount rates. The $55 and $10 values were derived by adjusting the published estimates for uncertainty in the discount rate (using factors developed by Richard Newell and William Pizer)[b] at 3 and 5 percent discount rates, respectively. The $19 value was chosen as a central value between the $5 and $33 per ton estimates. All of these values were assumed to increase at 3 percent annually to represent growth in incremental damages over time as the magnitude of climate change increases.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and CO_2 tailpipe emission proposed rules.

16.2.3 Current Approach and Key Assumptions

Since the release of the interim values, the interagency group reconvened on a regular basis to generate improved SCC estimates, which were considered for this proposed rule. Specifically, the group considered public comments and further explored the technical literature in relevant fields.

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Research Council report mentioned above points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. There are a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC.

The U.S. Government intends to periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance. The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them and with a sincere promise to continue work to improve them.

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[b] R. Newell and W. Pizer. "Discounting the Distant Future: How Much Do Uncertain Rates Increase Valuations?" J. Environ. Econ. Manage. 46 (2003) 52-71)

In summary, in considering the potential global benefits resulting from reduced CO_2 emissions, DOE used the most recent values identified by the interagency process, adjusted to 2010$ using the standard GDP deflator values for 2008 and 2009. For each of the four cases specified, the values used for emissions in 2010 were $4.9, $22.3, $36.5, and $67.6 per metric ton avoided (values expressed in 2010$). To monetize the CO_2 emissions reductions expected to result from amended standards for furnaces and central air conditioners and heat pumps, DOE used the values identified in Table A1 of the "Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866," which is reprinted in appendix 16-A of this TSD, appropriately escalated to 2010$. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the discount rates that had been used to obtain the SCC values in each case.

16.3 VALUATION OF OTHER EMISSIONS REDUCTIONS

As discussed in chapter 15, DOE's analysis assumed the presence of nationwide emission caps on SO_2 and caps on NO_X emissions in the 28 States covered by the CAIR. In the presence of these caps, the NEMS–BT modeling system that DOE used to forecast emissions reduction indicated that no physical reductions in power sector emissions would occur for SO_2, but that the standards could put slight downward pressure on the prices of emissions allowances in cap-and-trade markets. Estimating this effect is very difficult because such factors as credit banking can change the trajectory of prices. From its modeling to date, DOE is unable to estimate a benefit from SO_2 emissions reductions at this time.

DOE investigated the potential monetary benefit of reduced NO_X emissions from the TSLs it considered. As noted above, new or amended energy conservation standards would reduce NO_X emissions in those 22 States that are not affected by the CAIR, in addition to the reduction in site NO_X emissions nationwide. DOE estimated the monetized value of NO_X emissions reductions resulting from each of the TSLs considered for today's NOPR based on environmental damage estimates from the literature. Available estimates suggest a very wide range of monetary values, ranging from $370 per ton to $3,800 per ton of NO_X from stationary sources, measured in 2001$ (equivalent to a range of $447 to $4,591 per ton in 2010$).[c] In accordance with OMB guidance, DOE conducted two calculations of the monetary benefits derived using each of the economic values used for NO_X, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.[d]

DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg in its rulemakings.

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

[d] OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003).

16.4 RESULTS

Table 16.4.1 presents the global values of CO_2 emissions reductions at each TSL. DOE calculated domestic values as a range from 7 percent to 23 percent of the global values, and these results are presented in Table 16.4.2.

Table 16.4.1 Clothes Washers: Estimates of Global Present Value of CO_2 Emissions Reduction in 2015–2044 Under Trial Standard Levels

	Million 2010$			
TSL	**5% discount rate, average***	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	410	2145	3648	6532
2	384	2008	3415	6114
3	530	2778	4728	8458
4	729	3814	6488	11614
5	838	4386	7462	13357

***** Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.4.2 Clothes Washers: Estimates of Domestic Present Value of CO_2 Emissions Reduction in 2015–2044 Under Trial Standard Levels

	Million 2010$*			
TSL	**5% discount rate, average****	**3% discount rate, average****	**2.5% discount rate, average****	**3% discount rate, 95th percentile****
1	29 to 94	150 to 493	255 to 839	457 to 1502
2	27 to 88	141 to 462	239 to 786	428 to 1406
3	37 to 122	194 to 639	331 to 1087	592 to 1945
4	51 to 168	267 to 877	454 to 1492	813 to 2671
5	59 to 193	307 to 1009	522 to 1716	935 to 3072

* Domestic values are presented as a range between 7% and 23% of the global values.
****** Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.4.3 presents the cumulative monetary value of the economic benefits associated with NO_X emissions reductions for each TSL, calculated using seven-percent and three-percent discount rates.

Table 16.4.3 Clothes Washers: Estimates of Present Value of NO_X Emissions Reduction in 20154-2044 Under Trial Standard Levels

TSL	3% discount rate Million 2010$	7% discount rate Million 2010$
1	22 to 224	9 to 97
2	20 to 207	9 to 90
3	28 to 286	12 to 122
4	39 to 396	17 to 171
5	44 to 456	19 to 197

CHAPTER 17. REGULATORY IMPACT ANALYSIS

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CHAPTER 17. REGULATORY IMPACT ANALYSIS

17.1 INTRODUCTION

The U.S. Department of Energy (DOE) has determined that energy conservation standards for consumers of residential clothes washers constitute an "economically significant regulatory action" under Executive Order (E.O.) 12866, Regulatory Planning and Review. 58 FR 51735 (October 4, 1993). Under 10 CFR part 430, subpart C, appendix A, section III.12, DOE committed to evaluating non-regulatory alternatives to proposed standards by performing a regulatory impact analysis (RIA). 61 FR 36978 (November 15, 1996). This RIA, which DOE has prepared pursuant to E.O. 12866, evaluates potential non-regulatory alternatives, comparing the costs and benefits of each to those of the proposed standards. 58 FR 51735, 51741. As noted in E.O. 12866, this RIA is subject to review by the Office of Management and Budget's Office of Information and Regulatory Affairs. 58 FR 51735, 51740.

For this RIA, DOE used an integrated model built on the national impacts analysis (NIA) model discussed in chapter 10. DOE studied the impacts of non-regulatory policies for the two product classes that are the subject of this rulemaking: front-loading and top-loading clothes washers. DOE identified six non-regulatory policy alternatives that potentially could achieve the same energy efficiency levels as the proposed consensus standards. The non-regulatory policy alternatives are listed in Table 17.1.1. 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.

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
Early Replacement
Bulk Government Purchases

Sections 17.2 and 17.3 describe DOE's analysis of the six policies listed above. Sections 17.4 and 17.5 present the results of the analysis.

17.2 NON-REGULATORY POLICIES

This section describes the methods DOE used to analyze the energy savings and cost-effectiveness of the six non-regulatory policy alternatives (excluding the alternative of no new regulatory action) for residential clothes washers. This section also describes the assumptions underlying the analysis.

17.2.1 Methodology

DOE used its integrated NIA-RIA spreadsheet model to calculate the national energy savings (NES) and net present value (NPV) associated with each non-regulatory policy alternative. Chapter 10 of the technical support document (TSD) describes the NIA spreadsheet model. Appendix 17-A, section 17-A.3, documents DOE's use of the integrated NIA-RIA model.

DOE quantified the effect of each alternative on the purchase of products that meet target levels, which are defined as the efficiency levels in the proposed consensus standards. After establishing the assumptions underlying each alternative, DOE revised inputs to the NIA-RIA model. The primary revised inputs were market shares of products meeting target efficiency levels and product replacement rates. The shipments of products for any given year reflect a distribution of efficiency levels. DOE assumed that the proposed standards would affect 100 percent of the shipments of products that do not meet target levels in the base case,[a] whereas the non-regulatory policies would affect a smaller percentage of those shipments. DOE made certain assumptions about the percentage of shipments affected by each alternative policy. DOE used those percentages to calculate the shipment-weighted average energy consumption and costs of residential clothes washers attributable to each policy alternative.

Increasing the efficiency of a product often increases its average installed cost. Operating costs generally decrease, however, 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 scenarios, increases in total installed cost are mitigated by government rebates or tax credits. Because DOE assumed that consumers would re-pay credits and rebates in some way (such as additional taxes), DOE did not include rebates or tax credits as a consumer benefit when calculating national NPV. DOE's analysis also excluded any administrative costs for the non-regulatory policies; including such costs would decrease the NPVs slightly.

[a] The base case for the NIA is a market-weighted average of units that operate at several efficiency levels.

The following are key measures for evaluating the impact of each alternative.

- National energy savings (NES), given in quadrillion British thermal units (quads), describes the cumulative national primary energy savings for products bought from the effective date of the policy (2015) through the end of the analysis period (2044).

- Net present value (NPV) represents the value in 2010$ (discounted to 2011) of net monetary savings from products bought from the effective date of the policy (2015) through the end of the analysis period (2044).

- DOE calculated the NPV as the difference between the present value of installed product costs and operating expenditures in the base case and the present value of those costs in each policy case. DOE calculated operating expenses (including energy costs) for the life of the product.

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 consumers' responses to a program. Because the projected effects depend on assumptions regarding the rate of consumer participation, they are subject to more uncertainty than are the impacts of mandatory standards, which DOE assumes will meet 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 various 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 modeling of each policy.

Each non-regulatory policy that DOE considered would improve the average efficiency of new residential clothes washers relative to their base-case efficiency scenarios (which involve no new regulatory action). The analysis considered that each alternative policy would induce consumers to purchase units having the same (target) efficiency levels as required by the proposed standards. As opposed to the standards case, however, the policy cases may not lead to 100 percent market penetration of units that meet target levels.

Table 17.2.1 shows the efficiency levels stipulated in the proposed standards for residential clothes washers.

Table 17.2.1 Efficiency Levels in Proposed Standards for Residential Clothes Washers

TSL	Front-Loading		Top-Loading			
	IMEF*	IWF†	IMEF		IWF	
Consensus (3)	1.84	4.73	1/1/2015	1.29	1/1/2015	8.44
			1/1/2018	1.57	1/1/2018	6.47

* IMEF = integrated modified energy factor.
† IWF = integrated water factor.

DOE assumed that the effects of non-regulatory policies would last from the effective date of standards—2015—through the end of the analysis period, which is 2044.

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 early replacement implemented with consumer rebates, or early replacement implemented with bulk government purchases. However, DOE made conservative assumptions to avoid double-counting policy impacts. The resulting impacts may not be added; the combined effect of several or all policies cannot be inferred from summing their results.

Section 17.4 presents graphs that illustrate the market penetration estimated under each non-regulatory policy, along with tables that summarize the impacts of the non-regulatory policy alternatives for residential clothes washers.

17.3 ASSUMPTIONS REGARDING NON-REGULATORY POLICIES

The following subsections describe DOE's analysis of the impacts of the six non-regulatory policy alternatives. Because the alternative of No New Regulatory Action does not affect energy use or NPV, but essentially represents the NIA base case, DOE did not analyze that alternative further. DOE developed estimates of the market penetration of high-efficiency products both with and without each of the non-regulatory policy alternatives.

17.3.1 No New Regulatory Action

The case in which no new regulatory action is taken with regard to the energy efficiency of residential clothes washers constitutes the base case, as described in Chapter 10, National Impact Analysis. The base case provides the basis of comparison for all other policies. By definition, no new regulatory action yields zero energy savings and an NPV of zero dollars.

17.3.2 Consumer Rebates

DOE considered the scenario in which the Federal government would provide consumers with financial incentives, in the form of rebates, for purchasing energy-efficient appliances. This policy provides a consumer rebate for purchasing clothes washers that operate at (or above) the target efficiencies stipulated in the proposed standards.

17.3.2.1 Methodology

To inform its estimate of the market impacts of consumer rebates, DOE researched utility and agency rebate programs for residential clothes washers nationwide. DOE also reviewed the current State Energy Efficient Appliance Rebate Program (SEEARP) funded by the American Recovery and Reinvestment Act (ARRA).[1, b] SEEARP may be considered a combination of a consumer rebate and an early replacement program, with intention to induce appliance sales during the economic recession. DOE analyzed summary material from DOE on SEEARP rebates for clothes washers.[2]

DOE also incorporated previous research that disaggregated the effect of rebates 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.[3, 4] 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 policy would encompass both direct price effects and announcement effects, and that half the increase in market penetration associated with the policy would be due to the direct price effect and half to the announcement effect.

DOE based its evaluation methodology for consumer rebates on a comprehensive study of California's potential for achieving energy efficiency. This study, performed by XENERGY, Inc.,[c] summarized experiences with various utility rebate programs.[5][3] XENERGY's analytical method utilized 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,[6, 7, 8, 9, 10, 11] used different economic parameters (*e.g.*, payback period), expert surveys, or model calibration based on specific utility program data rather than multi-utility data. Some models used in evaluating programs were so client-specific that generic relationships between economic parameters and consumer response could not be established.[9] DOE decided that the most appropriate method for this RIA analysis was the XENERGY approach of penetration curves based on B/C ratio, which incorporates lifetime operating cost savings.

XENERGY's model estimates market impacts induced by financial incentives based on the premise that two types of information diffusion drive the adoption of new technologies. *Internal sources* of information encourage consumers to purchase new products 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 17-A, section 17-A.4.1, contains additional details on internal and external information diffusion.

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[b] SEEARP provides Federal funding for State-run rebate programs for purchases of new ENERGY STAR-qualified home appliances. SEEARP was implemented in late 2009 by the 50 States and six U.S. territories, each selecting its own appliances, rebate levels, efficiency levels, appliance recycling requirements, and eligible populations.

[c] XENERGY is now owned by KEMA, Inc. (www.kema.com).

XENERGY's model 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 measure. XENERGY then calibrated the curves based on participation data from utility rebate programs. The curves illustrate the increased penetration (*i.e.*, increased market share) of efficient products driven by consumer response to rebate programs that change the B/C ratio. The penetration curves depict various diffusion patterns based on perceived barriers (from no barriers to extremely high barriers) to consumer purchase of high-efficiency products.

DOE adjusted the XENERGY penetration curves based on expert advice founded on more recent utility program experience.[9, 12] DOE also devised an interpolation method to create penetration curves based on relationships between the actual base-case market penetrations and B/C ratios for each product class. Appendix 17-A, sections 17-A.4.2 and 17-A.4.3, discuss DOE's method for adjusting and interpolating the curves.DOE modeled the effects of a consumer rebate policy for residential clothes washers by determining the increases in market penetration of products meeting the target level relative to their market penetrations in the base case. It did this using the interpolated penetration curves created for each product class based on the XENERGY methodology to reflect the market barrier levels faced by that product class.

17.3.2.2 Analysis

DOE estimated the effect of increasing the B/C ratio of each product class via a rebate that would pay part or all of the increased installed cost of a unit meeting the target efficiency level compared to one meeting the baseline efficiency level.[d] DOE based the rebate amounts on a large sample of 163 rebates for residential clothes washers initiated by 119 utilities or agencies in various States. Appendix 17-A, section 17-A.5.1, identifies and provides details regarding utility rebate programs. DOE calculated the simple average of the rebate amounts for units meeting or exceeding the target levels in the various programs. DOE assumed that those average rebate amounts would apply to all units that meet or exceed the target efficiency level for each product class. DOE assumed that rebates would remain in effect at the same levels throughout the forecast period (2015–2044).

For each product class, DOE first calculated the B/C ratio without a rebate using the difference in total installed costs and lifetime operating cost savings between the unit meeting the target level and the baseline unit. It then calculated the B/C ratio given a rebate for the unit meeting the target efficiency level. Because the rebate reduced the incremental cost, the unit receiving the rebate had a larger B/C ratio. Table 17.3.1 shows the effects of consumer rebates on B/C ratios for both product classes. Each B/C value for units given rebates represents a

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[d] The baseline technology for each product class is defined in the engineering analysis, chapter 5, as the technology that represents the basic characteristics of products in that class. A baseline unit typically is one that just meets current Federal energy conservation standards and provides basic consumer utility.

weighted average[e] of the values for the efficiency levels at or above the target level to which the rebate would apply.

Table 17.3.1 Benefit/Cost Ratios Without and With Rebates for Residential Clothes Washers (2010$)

	Front-Loading	Top-Loading
B/C Ratio Without Rebate	33.8	36.6
Rebate Amount	$82	$61
B/C Ratio with Rebate	Inf.*	Inf.
Calculated Market Barrier Curve	Low–Moderate	X–high

* Inf. = infinite B/C ratio, which occurs when the rebate pays the full incremental cost.

DOE used the B/C ratios along with the penetration curves shown in Figures 17.3.1 and 17.3.2 to estimate the percentage of consumers who would purchase clothes washers that meet the target levels both with and without a rebate incentive. The curve calculated by DOE to represent the market behavior for front-loading clothes washers was between the *low* and *moderate barriers* penetration curves. For top-loading clothes washers the curve was close to the *extremely high barriers* curve.

Figure 17.3.1 Market Penetration Curve for Front-Loading Clothes Washers

[e] The weighting factor is the 2015 base-case market share of each corresponding efficiency level.

Figure 17.3.2 Market Penetration Curve for Top-Loading Clothes Washers

For each product class, DOE next estimated the percent increase represented by the change in penetration rate shown by the penetration curves. It then added that percent increase to the market share of units that meet the target level in the base case to obtain the market share of units that meet the target level in the rebate case. Table 17.3.2 summarizes the market shares for the two product classes in 2015. DOE used the resulting increases in market shares as inputs to represent the policy-case scenarios in its NIA-RIA model. Appendix 17-A, section 17-A.2, shows the annual market share increases attributable to this policy. Section 17.4 below presents the resulting efficiency trends for the policy case of consumer rebates for residential clothes washers.

Table 17.3.2 Market Penetrations in 2015 Attributable to Rebates for Residential Clothes Washers

	Front-Loading %	**Top-Loading %**
Base-Case Market Share of Units that Meet Target Levels	72	13
Market Share of Units that Meet Target Levels with Rebates	77	33
Increased Market Share of Units that Meet Target Level with Rebates	5	20

17.3.3 Consumer Tax Credits

DOE used its previous analysis of consumer participation in tax credits to estimate the effects of tax credits on consumer purchases of target-level clothes washers. In estimating the effects, DOE assumed the amount of the tax credits for each product class would be the same as the corresponding rebate amounts described above. As with rebates, DOE incorporated previous research that disaggregated the effect of 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.[3, 4] 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 consumer tax credit policy, like the rebate policy, would encompass both direct price effects and announcement effects, and that half the increase in market penetration associated with the policy would be due to the direct price effect and half to the announcement effect.

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 developing its assumptions, DOE reviewed other Federal and State tax credit programs offered for energy efficient appliances. The Energy Policy Act of 2005 (EPACT 2005) included Federal tax credits for consumers who purchased energy efficient products, including water heaters, furnaces, and furnace fans for new or existing homes.[14] Those tax credits were in effect in 2006 and 2007, expired in 2008, and were reinstated for 2009–2010 by ARRA.[1, 15] 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 from the 1980s. DOE did not find data specific enough to residential clothes washers to warrant adjusting its analysis method for the policy case of consumer tax credits. Appendix 17-A, section 17-A.6.1, contains more information on Federal consumer tax credits.

DOE supported its approach using data from Oregon State's tax credit program for energy efficient appliances. DOE reviewed its previous analysis of Oregon's tax credits for clothes washers.[16] In the 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 efficiencies. This finding supports DOE's 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 is in Appendix 17-A, section 17-A.6.3.

DOE applied the assumed 60-percent participation rate to the penetration rates estimated for the rebate policy to estimate penetration rates attributable to consumer tax credits. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the penetration curves selected for each product class. Table 17.3.3 summarizes DOE's assumptions regarding the market penetration in 2015 of residential clothes washers that meet target efficiency levels given a consumer tax credit.

Table 17.3.3 Market Penetrations in 2015 Attributable to Consumer Tax Credits for Residential Clothes Washers

	Front-Loading %	Top-Loading %
Base-Case Market Share of Units that Meet Target Levels	72	13
Market Share of Units that Meet Target Levels with Consumer Tax Credits	75	25
Increased Market Share of Units that Meet Target Level with Consumer Tax Credits	3	12

DOE assumed that this policy would transform the market permanently, so that the increases in market shares seen in the first year of the program would be maintained throughout the forecast period. 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 17-A, section 17-A.2, shows the annual increases in market shares attributable to this policy. Section 17.4 below presents the resulting efficiency trends for the policy case of consumer tax credits for residential clothes washers that meet target efficiency levels.

17.3.4 Manufacturer Tax Credits

To analyze the potential effects of a policy that offers tax credits to manufacturers that produce residential clothes washers that meet target efficiency levels, DOE assumed that such a tax credit would lower the consumer's purchase cost by an amount equivalent to that provided by the consumer rebate or tax credit described above. DOE further assumed that manufacturers would pass on some of their reduced costs to consumers, causing a direct price effect. DOE assumed that no announcement effect would occur, because the program would not be visible to consumers.[f] Because the direct price effect is approximately equivalent to the announcement effect,[3] 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. This assumed participation rate is equal to 30 percent of the number of consumers who would participate in a rebate program. DOE applied the assumption of 30-percent participation

[f] This is a conservative assumption, because manufacturers or utility/agency efficiency programs might promote those models for which manufacturers increase production because of the tax credits, which in turn might induce some announcement effect. DOE, however, found no data on such programs on which to base an estimate of the magnitude of this possible announcement effect on consumer behavior.

to the penetration rates predicted for the rebate policy to estimate the effects of a manufacturer tax credit policy. In doing so, the Department incorporated the assumptions for consumer response to financial incentives from the penetration curves selected for each product class.

DOE attempted to investigate manufacturer response to the Energy Efficient Appliance Credits for manufacturers, which were mandated by EPACT 2005.[17] Those tax credits were in effect for clothes washer models produced in 2006 and 2007 and then reinstated for 2009 and 2010. DOE was unable to locate data from the Internal Revenue Service or other sources on manufacturer response to the Federal credits. Appendix 17-A, section 17-A.6.2 presents details of Federal manufacturer tax credits.

Table 17.3.4 summarizes DOE's assumptions regarding the market penetration in 2015 of residential clothes washers meeting target efficiency levels given a manufacturer tax credit.

Table 17.3.4 Market Penetrations in 2015 Attributable to Manufacturer Tax Credits for Residential Clothes Washers

	Front-Loading %	Top-Loading %
Base-Case Market Share of Units that Meet Target Levels	72	13
Market Share of Units that Meet Target Levels with Manufacturer Tax Credits	73	19
Increased Market Share of Units that Meet Target Level with Manufacturer Tax Credits	2	6

DOE assumed that the manufacturer tax credit policy would transform the market permanently, so that the increases in market share seen in the first year of the program would be maintained throughout the forecast period. 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 17-A, section 17-A.2, shows the annual market share increases due to this policy. Section 17.4 below presents the resulting efficiency trends for the policy case of manufacturer tax credits for residential clothes washers.

17.3.5 Voluntary Energy Efficiency Targets

For this scenario, DOE assumed that voluntary energy efficiency targets would be achieved as manufacturers gradually stopped producing units that operated below target levels. DOE assumed that the impetus for phasing out production of low-efficiency units would be a program similar to the ENERGY STAR labeling program conducted by the Environmental Protection Agency and DOE. The program specifies the minimum energy efficiencies that various products, including residential clothes washers, 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.

Program efforts generally involve a combination of information dissemination and utility or agency rebates. Researchers have analyzed the ENERGY STAR program's effects on sales of several consumer products based on State-specific data on percentages of shipments of 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.[18, 19, 20]

ENERGY STAR projects market penetration of compliant appliances and estimates the percentage of sales of compliant appliances that are attributable to the program. DOE estimated the percentage of market shares attributable to the ENERGY STAR program for residential clothes washers for 1997–2025.[21] DOE then assumed that, beginning in 2015, an enhanced ENERGY STAR program for each product class would add 50 percent to the annual increases in market penetration shown by existing programs. From this forecast DOE calculated the annual percent increases in market share represented by the shipments attributed to ENERGY STAR. DOE added those percent increases to the market shares of residential clothes washers that meet target levels in the RIA base case, starting in 2015, to obtain the annual market shares of units meeting the target efficiency level in the voluntary efficiency targets case.

DOE estimated that the programs developed in support of voluntary efficiency targets would increase market shares of efficient units. Appendix 17-A, section 17-A.2, shows the annual increases in market share due to this policy used as inputs to the NIA-RIA model. Section 17.4 below presents the resulting efficiency trends for the policy case of voluntary energy efficiency targets for clothes washers that meet target efficiency levels.

17.3.6 Early Replacement

The non-regulatory policy of early replacement refers to a program to replace residential appliances before the ends of their useful lives. The purpose of such a policy is to replace old, inefficient units with higher efficiency units. The economic feasibility of early replacement depends on the vintage of the unit being replaced, the installed cost of the new unit, and the energy cost savings. DOE examined several resources to inform its analysis of the policy. One report detailed the Connecticut Appliance Retirement Program (ARP), which was conducted in 2004.[22] Another was a 2006 study of the potentials for electric energy efficiency performed for the State of Vermont.[23]

The Connecticut ARP was conducted from June through December 2004 by Nexus Market Research, Inc., and RLW Analytics, Inc., for Northeast Utilities–Connecticut Light and Power and the United Illuminating Company's State programs. The purpose of the ARP was to help Connecticut utility customers overcome barriers to recycling room air conditioners (RACs), secondary refrigerators, and freezers. The program picked up used appliances at customers' homes or at turn-in events, paid participants to retire their units, and educated customers about the costs of operating older appliances. In addition, the program provided consumers with financial incentives to replace inefficient RACs with ENERGY STAR-qualified units. DOE considers the RAC program to most closely resemble the early replacement policy scenario for residential clothes washers, because consumers replaced primary units rather than retiring second

units. Nexus/RLW used program data and surveys to estimate the number of RACs retired by ARP participants, the percentage of retired units that were replaced with an ENERGY STAR model, and the number of RACs replaced by non-participants during the program. According to the Nexus/RLW analysis, about 7 percent of all RACs retired during the program were retired through the ARP, and 63 percent of those were replaced with ENERGY STAR models. Thus the program resulted directly in about 4 percent of total eligible RAC consumers deciding on early replacement of inefficient units.

In 2006, GDS Associates, Inc., conducted a study for the State of Vermont of the potential for reducing electricity use and peak demand through energy efficiency and fuel conversion measures. The study took an aggressive, multi-program approach, one aspect of which was early replacement of appliances. GDS considered that under the program residential appliances, including RACs, would be replaced during 4 years (2006–2009). GDS estimated achievable market penetrations assuming that consumers would receive a financial incentive equal to 50 percent of the incremental cost of each program measure. GDS assumed a maximum 80-percent penetration. For early replacement of RACs, GDS estimated a maximum achievable participation of 5 percent of eligible single-family or multi-family homes in the year before the program began (2005).

DOE also reviewed a study it had conducted in the 1990s, under EPACT 1992, which analyzed the effectiveness of Federal programs that supported early retirement of appliances.[24] The study identified policy options for early replacement that included a direct national program; replacement of Federally owned appliances; and promotion through equipment manufacturers, consumer incentives, incentives to utilities, and building regulations.[g]

For this RIA analysis, DOE analyzed a program to target installed units having efficiency levels lower than target levels and encourage their early replacement with products that perform at target levels. For each product class, DOE modeled the effects of the early replacement policy by increasing by 4 percent per year the retirement rate of units that were in the stock in the first year of the analysis period (2015). DOE used the 4-percent rate from the Connecticut study, because it was based on real-world experience. DOE assumed that the early replacement program would continue until it had facilitated the replacement of all eligible residential clothes washers in the stock in the year the program began (2015). Shipments of new units in 2015 and beyond were not affected by the program, but remained at base-case efficiency levels. After the stock of inefficient units was replaced completely, the policy would produce no additional impacts.

[g] The analysis concluded that, although cost-effective opportunities for early replacement exist, a widespread Federal program was not justified economically. Because early retirement means that a unit may be replaced by an appliance less efficient than the eventual replacement would have been, energy savings would be less than anticipated. Early replacement programs also could increase long-term sales volatility by encouraging a temporary increase in production, followed by a lull in demand. Early replacement could be economical in localities subject to high energy costs or environmental constraints; when replacement appliances are much more efficient than existing stock; or when a major technology breakthrough has occurred, creating the need for a ready market.

An early replacement policy would create a fairly immediate jump in shipments of products that meet target efficiency levels, leading to an immediate gain in the market share of efficient units compared to the base case. As opposed to the policy cases discussed previously, however, an early replacement policy results in market shares of efficient units returning to base-case percentages as the eligible market is depleted. In addition, because units removed early from the stock would have been replaced later (at the ends of their useful lives) without the program, the number of shipments in later years drops below the base-case shipments forecast. Section 17.4 below presents the resulting efficiency trends for the policy case of early replacement for residential clothes washers.

17.3.7 Bulk Government Purchases

DOE assumed that a policy requiring bulk government purchases would lead to Federal, State, and local governments purchasing products that meet target efficiency levels. Combining the market demands of multiple public sectors would 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 could 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 equipment. 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.[25, 26]

DOE assumed that government agencies, such as the Department of Housing and Urban Development, would administer bulk purchasing programs for residential clothes washers. The policy also would be incorporated into the FEMP program. The FEMP program currently has procurement guidelines in place for residential clothes washers.[27] Federal construction requirements include the FEMP guidelines for installing or replacing equipment. 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.[28] Based on its 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 residential clothes washers meeting target efficiency levels.

DOE assumed that bulk government purchases would affect a subset of housing units for which government agencies purchase or influence the purchase of clothes washers. This subset consists primarily of public housing and housing on military bases. DOE defined this subset based on the American Housing Survey (AHS) for 2009, which identified 1.8 million households, or about 1.4 percent of all U.S. households, as publicly owned housing.[29] (The AHS reports 130.0 million U.S. households.[30]) The 2005 Residential Energy Consumption Survey (RECS 2005) reported that 0.2 percent of publicly owned households had front-loading clothes washers and 40.1 percent had top-loading clothes washers.[31] RECS 2005 estimated that 0.56 percent of U.S. housing units are publicly owned households that use top-loading clothes washers; this constitutes the population to which this policy would apply. DOE estimated that a miniscule percentage of U.S. housing units represent publicly owned households that use front-loading clothes washers; for them the potential energy savings are minor.

DOE estimated that, starting in 2015, each year of a bulk government purchase policy would result in an increasing percent of shipments of government-purchased units beyond the base case would meet target efficiency levels. DOE estimated that within 10 years (by 2024), bulk government purchasing programs would result in 80 percent of the top-loading clothes washer market for publicly owned housing meeting target levels. DOE modeled the bulk government purchase program assuming that the market share for each product achieved in 2024 would be maintained throughout the rest of the forecast period. Appendix 17-A, section 17-A.2, shows the annual market share increases due to this policy used as inputs to the NIA-RIA model. Section 17.4 below presents the resulting efficiency trends for the policy case of bulk government purchase of residential clothes washers.

17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

Figures 17.4.1 and 17.4.2 show the effects of all six non-regulatory policies on market penetration of the two product classes of residential clothes washers. The market share of products that meet the target level in the base case is forecasted to be constant for both product classes. Relative to the base case, every policy case increases the market share of products that meet target efficiency levels. Recall that the proposed consensus standards (not shown in the figures) would result in a 100-percent market penetration of products that meet the target efficiency level.

Figure 17.4.1 Market Penetration of Front-Loading Clothes Washers Meeting Target Efficiency Levels in Various Policy Cases

Figure 17.4.2 Market Penetration of Top-Loading Clothes Washers Meeting Target Efficiency Levels in Various Policy Cases

Tables 17.4.1 and 17.4.2 show the national energy savings and net present values (NPVs) of the non-regulatory policies analyzed for residential clothes washers. The target level for each

policy equals the efficiency level in the proposed standard. These results correspond to the market shares in Figures 17.4.1 and 17.4.2. The case in which no regulatory action is taken with regard to residential clothes washers constitutes the base case (or "No New Regulatory Action" scenario), in which energy savings and NPV are zero by definition. For comparison, the tables include the impacts of the proposed consensus standards. Energy savings are given in quads. The NPVs shown in Tables 17.4.1 and 17.4.2 are based on two discount rates, 7 percent and 3 percent.

Table 17.4.1 Impacts of Non-Regulatory Alternatives for Residential Front-Loading Clothes Washers that Meet the Proposed Consensus Standards (TSL 3)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2010$	
		7% discount rate	3% discount rate
Consumer Rebates	-0.076	-1.861	-3.641
Consumer Tax Credits	-0.045	-1.119	-2.190
Manufacturer Tax Credits	-0.023	-0.560	-1.097
Voluntary Energy Efficiency Targets	0.021	0.467	1.316
Early Replacement			
Bulk Government Purchases	-0.001	-0.013	-0.029
Proposed Standards	-0.172	-4.137	-8.276

* For products shipped in 2015–2044.

Table 17.4.2 Impacts of Non-Regulatory Alternatives for Residential Top-Loading Clothes Washers that Meet the Proposed Consensus Standards (TSL 3)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2010$	
		7% discount rate	3% discount rate
Consumer Rebates	0.641	5.825	13.487
Consumer Tax Credits	0.388	3.519	8.150
Manufacturer Tax Credits	0.195	1.768	4.096
Voluntary Energy Efficiency Targets	0.183	1.151	2.851
Early Replacement			
Bulk Government Purchases	0.006	0.040	0.101
Proposed Standards	2.361	20.200	48.072

* For products shipped in 2015–2044.

Note that the national energy savings for front-loading clothes washers are negative for the standards case and for most non-regulatory policy cases. This effect reflects the cross-price elasticity for total installed costs assumed in the NIA model, which results in market shifts between the two product classes. (See chapter 10 for more discussion on cross-price elasticity.) The total national energy savings for both product classes together is positive, however. Table 17.4.3 shows the total NES and NPV for residential clothes washers for the non-regulatory policies and standards. Consumer rebates produce the most national energy savings of the six non-regulatory policies, while bulk government purchases provide the least savings.

Table 17.4.3 Impacts of Non-Regulatory Alternatives for All Residential Clothes Washers that Meet the Proposed Consensus Standard (TSL 3)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2010$	
		7% discount rate	3% discount rate
Consumer Rebates	0.566	3.964	9.846
Consumer Tax Credits	0.342	2.400	5.959
Manufacturer Tax Credits	0.172	1.208	2.999
Voluntary Energy Efficiency Targets	0.204	1.618	4.166
Early Replacement			
Bulk Government Purchases	0.006	0.027	0.072
Proposed Standards	2.189	16.063	39.796

* For products shipped in 2015–2044.

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CHAPTER 18. IMPACT OF STANDARDS ON CONSUMER WELFARE: EVIDENCE FROM A 2007 CHANGE IN ENERGY EFFICIENCY REQUIREMENTS FOR CLOTHES WASHERS

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CHAPTER 18. IMPACT OF STANDARDS ON CONSUMER WELFARE: EVIDENCE FROM A 2007 CHANGE IN ENERGY EFFICIENCY REQUIREMENTS FOR CLOTHES WASHERS

18.1 INTRODUCTION

In this chapter, DOE sets forth the results of a panel analysis conducted on energy conservation standards for clothes washers that required compliance in 2007. DOE conducted the panel analysis to explore the potential impacts of efficiency standards for clothes washers, generally, on consumer welfare. Specifically, the New York Times published a 2011 article on energy efficiency that discussed the impact of efficiency standards on clothes washer performance. Notwithstanding the fact that Consumer Reports, whose clothes washer data was cited, subsequently rebutted the findings asserted in the New York Times article, DOE investigated potential consumer welfare impacts in this panel analysis. (The article and rebuttal statement are available at http://www.nytimes.com/2011/03/15/science/15letters1.html?pagewanted=all.) DOE was able conduct this analysis because it had specific information available for clothes washers. DOE did not consider the analysis in its adoption of the standards in the direct final rule, and DOE's inclusion of this analysis is not indicative of any change or addition to DOE's analytical methodology.

18.2 THE 2007 CHANGE IN ENERGY EFFICIENCY REQUIREMENTS

A 2007 policy change for clothes washers increased both the minimum threshold of energy efficiency and the threshold for ENERGY STAR® certification. The minimum threshold increased from a modified energy factor (MEF) of 1.04 to 1.26; ENERGY STAR certification increased the MEF from 1.42 to 1.72. The MEF measures the ratio of the capacity of a washer to the total energy used in one cycle.

The policy change could have had a wide range of effects. To consider those effects, it may help to think of the washer market as composed of a large number of submarkets for different classes of washer that vary in quality, functions, size, and efficiency, among other factors. The policy change effectively banned one portion of the market. Note, however, that the change in policy affected only the manufacture of washer units, not unit sales, so the supply of banned units was not completely eliminated due to the policy change.

The policy change had two primary effects: (1) it sharply reduced the supply of low-efficiency units, reducing quantity and increasing price (Figure 18.2.1); (2) higher prices and less availability of low-efficiency units shifted demand for higher efficiency units outward, increasing quantity and, presumably, price (Figure 18.2.2, panel A). This simple analysis assumes perfect competition and decreasing returns to scale in the production of washer units. If,

however, washer manufactures have pricing power and/or there are increasing returns to scale in washer production (cost per unit declines with volume), prices for higher efficiency units may fall (Figure 18.2.2, panel B).

The net welfare effect of the policy change would need to account for changing surplus measures across the continuum of washer unit types. Changes in the ENERGY STAR label would influence flow of information, which could further shift demands. Finally, the change in policy may cause suppliers to introduce new products into the market, which would then feed back and affect pre-existing models. The new products would be useful to monopolistically competitive firms that attempt to discriminate across buyers. Although strategic pricing effects are likely important, we generally abstract from these issues and assume perfect competition.

Because the policy change was announced well in advance, it likely would influence production, pricing, and purchasing behavior well before the policy was enacted, and decisions made prior to the policy change likely would influence production, pricing, and purchasing behavior long after the policy change. The long transition period would be especially important for durable goods such as washers. Furthermore, it is our understanding that the policy change affected the manufacture of washers and not necessarily the sale of washers, so units manufactured before 2007 but not meeting the 2007 standard might nevertheless have been sold after 2007. Similarly, washers manufactured before 2007 not meeting the ENERGY STAR criteria may have been labeled as ENERGY STAR after 2007.

Panel A

Panel B

Figure 18.2.1 The changed standard reduces the supply of low-efficiency units

Panel A shows a hypothetical market with supply and demand for low-efficiency washer units. The policy change causes the supply curve to shift inward, causing a loss in consumer surplus equal to the shaded area. In panel B, demand for low-efficiency units is flatter, and the loss in consumer surplus is greater. We cannot, however, identify the supply curve from the policy's effects on price and quantity.

Figure 18.2.2 The standard change shifts out demand for high-efficiency units.

Panel A shows a hypothetical market with supply and demand for high-efficiency units. The policy change causes prices of low-efficiency units to increase, which causes demand for high-efficiency units to shift out, which increases quantity and price as well as consumer and producer surpluses. In panel B, supply is downward-sloping because of increasing returns to scale, and price decreases rather than increasing. We cannot identify the size of surplus benefits because the slope of the demand curve cannot be identified from the policy's effects on price and quantity.

Putting aside issues related to market transition and non-competitive pricing, the event of the policy change still cannot fully identify welfare changes due to the policy. We can only identify changes in prices and quantities, and these effects only under strong assumptions about the effects of potentially confounding factors occurring at about the same time of the policy change. Taking estimated changes in prices and quantities as given, what we plausibly can estimate is the loss in consumer surplus in the low-efficiency market (Figure 18.2.1). This value is identifiable because changes in quantity and price occur along the demand curve for those washers. If price increases are large, it implies the demand curve is relatively steep and the loss in consumer surplus will be large (panel A); if the price increase is small, it implies the demand curve is relatively flat, and the loss in consumer surplus is small (panel B).

What we cannot estimate is the gain in consumer surplus due to the shift in demand for high-efficiency washers (Figure 18.2.2), because the changes in price and quantity occur along the supply curve. But the less the price increases, the greater the gain in consumer surplus, all else being held the same. And if price actually decreases due to economies of scale (panel B of Figure 18.2.2), one might be able to estimate a lower bound on the increase in consumers' surplus.[1]

Concurrently with changes in policy are technological changes driven by non-policy factors and shifts in demand from non-policy factors. These factors include changes in energy prices, the collapse of the housing market, the recession that began at the end of 2007, and the subsequent financial crisis and prolonged downturn in the aggregate economy. Although we attempt to control for these factors as well as possible by using standard panel regression techniques, they nevertheless may confound the estimated effects of the 2007 policy change.

18.3 IMPLICIT VALUE OF CHANGES IN WASHER QUALITY

Some concern has been voiced regarding the effects of the policy change on the quality and characteristics of washing machines. Although some attributes of washers (such as energy efficiency, capacity, soil sensors, spin speed, and wear on the clothes) arguably have improved with the change in standards, other features may be less desirable, such as a longer wash cycle or quality of the cleaning. Quality, after all, depends on the tastes and preferences of individual buyers, so changes that some buyers perceive as improvements likely are perceived as detriments by other buyers.

Changes in consumers' surplus should embody the economic value of those changes. For example, if changes in washer design made necessary by the 2007 policy change were particularly undesirable to some consumers, then the relative scarcity of banned units that were manufactured before 2007 but still available after 2007 should see a significant increase in price, as in panel A of Figure 18.2.1. If, however, the new units are close substitutes for the banned units, demand for the old units will be relatively elastic (flatter), as in panel B of Figure 18.2.1.

[1] This calculation is beyond the scope of the current analysis, but may be feasible.

Alternatively, one might be able to obtain direct objective, non-economic measures of changes in washer quality. Such measure would require testing specific washers by other means. Engineers, for example, could test whether washers manufactured before the ban tended to last longer without malfunction or breakage or could test the length of wash, the ability of washers to remove soils, wear on the clothes, and so on. Consumer surveys might also assess subjective statements about ease of use and whether increased capacity was preferred to shorter wash cycles. The data used in this study do not contain such measures. If we held objective measures for these characteristics, one might also attempt to attach economic values to them by relating objective washer quality characteristics to observed prices.

18.4 THE DATA AND ASSOCIATED LIMITATIONS

We have data on large but varying shares of total sales of washers purchased in the United States, with measures for units sold and average price broken down by washer brand and model. Values are reported for each month. It is not clear to what extent and at what times different retailers enter and exit the sample. The data include a limited number of attributes for each model, plus an FTC measure of energy efficiency in terms of kilowatt hours per year (kWh/y) for standard usage. This measure of energy efficiency cannot be perfectly mapped into the MEF measure, probably because it does not fully account for energy used to heat the water and dry the clothes, in addition to energy used by the washer itself.

If precise MEF data were available and matched to each washer, one approach might be to consider separately four categories of washers: (1) those that met the minimum standard before and after the 2007 change; (2) those that met the minimum standard before but not after 2007; (3) those that met the ENERGY STAR criteria before and after 2007; and (4) units that met the ENERGY STAR criteria before but not after the policy change. Because we do not have MEF data, we proxy for washers that may have been closer and farther from the 2007 minimum and ENERGY STAR specifications using the FTC measure of efficiency (kWh/y). We do not have this measure for all units, but we have it for a significant majority of models in our data. Specifically, we divide units into ENERGY STAR and non-ENERGY STAR, and we further divide each of these sub-samples by the median FTC measure of efficiency (kWh/y). We consider these four categories of washer separately for the full sample of washers, which includes entry and exit of units, plus a limited sample of washers that includes only model numbers that were sold both before and after the 2007 policy change. Summary statistics for these data, broken down by sub-sample and category, are reported in Table 18.4.1and Table 18.4.2. The limited sample facilitates “apples to apples” comparisons of washer prices before and after the 2007 policy changes, which might be obscured in analysis of the full sample, because the full sample includes a large number washers that were either discontinued or introduced around the time of the policy change

Table 18.4.1 Summary statistics of the full sample

	ENERGY STAR				Non-ENERGY STAR			
	High-Efficiency		Low-Efficiency		High-Efficiency		Low-Efficiency	
	Pre-2007	Post-2007	Pre-2007	Post-2007	Pre-2007	Post-2007	Pre-2007	Post-2007
Units sold/month	16,933	95,301	39,941	44,649	14,291	70,580	46,999	14,763
Average price (current $)	899.64	797.48	722.38	738.53	264.13	409.36	349.16	422.5
Standard deviation of price	162.41	256.03	280.75	236.5	74.74	149.63	134.33	113.78
Front-loading (%)	98.9	97.3	47.5	32.1	1.1	4.8	0.0	0.0
Top-loading (%)	1.1	2.7	52.5	67.9	98.9	95.2	100.0	100.0
Average FTC (kWh/y)	193.80	176.12	342.21	328.05	446.84	402.98	715.61	735.42
Standard deviation of FTC	25.10	25.53	121.12	74.50	65.94	56.06	131.72	112.76
Average no. cycles	7.92	9.95	13.08	13.02	7.52	10.16	10.05	13.81
Standard deviation of no. cycles	2.33	3.63	4.77	3.86	3.64	4.83	4.76	5.14
Average rpm	1,066	1,145	949	1,091	678	874	714	649
Standard deviation of rpm	128	125	197	185	131	294	204	116
Side by side (%)	22.3	14.6	55.4	68.8	89.1	90.2	89.9	95.3
Portable side by side (%)	0.0	0.0	0.0	0.0	9.8	0.6	0.7	0.2
Stackable (%)	75.9	84.7	40.7	30.7	1.1	2.3	0.0	0.0
Prestacked (%)	0.0	0.2	3.6	0.4	0.0	6.8	9.5	4.5
Portable stackable (%)	0.6	0.3	0.0	0.0	0.0	0.1	0.0	0.0
Washer/dryer combo (%)	0.7	0.0	0.3	0.1	0.0	0.0	0.0	0.0
Portable washer/dryer combo (%)	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Not specified (%)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Load sensor (%)	79.2	53.7	30.8	27.2	0.0	6.3	0.2	0.1
Soil sensor (%)	6.5	2.2	25.8	17.2	0.6	6.1	11.7	17.1
Load and soil sensor (%)	10.7	32.1	3.4	17.1	1.1	0.0	0.0	0.0
No sensor (%)	1.1	8.9	30.7	37.5	96.7	84.2	76.7	82.0
Not specified (%)	2.5	3.1	9.3	1.1	1.7	3.4	11.3	0.8
Average capacity (cu. ft.)	3.59	3.88	3.52	4.06	2.95	3.30	3.29	3.48
Standard deviation of capacity	0.27	0.37	0.29	0.36	0.25	0.32	0.39	0.32
Electronic control (%)	96.8	98.3	58.3	80.3	1.3	4.4	2.0	0.2
Mechanical control (%)	3.2	1.7	41.7	19.7	98.7	95.6	98.0	99.8

Notes: Full sample includes all data having an FTC energy efficiency rating. High- and low-efficiency values are based on the median value of the FTC rating across model numbers in sample. Data include a varying number of retailers over time; the sample of retailers may not be representative of the population. Monthly data are for 2004–2009, 36 months before 2007 and 35 months after because of missing data in December 2008. All averages and standard deviations are weighted by total units sold during that period. Characteristics such as No. of cycles, rpm, and Capacity are given as ranges; middle point of range is used to calculate the average: 1,009.5 rpm is used for the range 1,000–1,119 rpm. For ranges with one boundary, the boundary is used in calculation: 2.5 cu. ft. includes those less than 2.5 cu. ft., and 4.5 cu. ft. those 4.5+ cu. ft. "Not specified" data are treated as missing and excluded from calculation of characteristic average.

Table 18.4.2 Summary statistics of the limited sample

	ENERGY STAR				Non-ENERGY STAR			
	High-Efficiency		Low-Efficiency		High-Efficiency		Low-Efficiency	
	Pre-2007	Post-2007	Pre-2007	Post-2007	Pre-2007	Post-2007	Pre-2007	Post-2007
Units sold/month	21,657	24,376	31,064	13,630	17,748	19,339	32,801	1,829
Average price (current $)	903	744	701	782	309	359	352	407
Standard deviation of price	189	245	268	174	117	111	143	176
Front-loading (%)	97.6	90.3	40.2	23.2	0.1	0.0	0.0	0.0
Top-loading (%)	2.4	9.7	59.8	76.8	99.9	100.0	100.0	100.0
Average FTC (kWh/y)	178.82	160.51	342.80	269.26	413.54	358.43	731.75	511.47
Standard deviation of FTC	10.64	19.93	150.50	68.42	42.84	76.44	151.21	96.83
Average no. cycles	9.94	8.98	12.88	11.34	9.91	7.76	9.48	9.90
Standard deviation of no. cycles	4.04	3.40	4.80	2.53	5.86	4.25	3.97	4.22
Average rpm	1,050	1,117	949	1,040	1,124	626	641	726
Standard deviation of rpm	148	129	197	144	243	29	59	224
Side by side (%)	12.1	37.4	62.8	78.3	92.5	97.4	87.5	78.4
Portable side by side (%)	0.0	0.0	0.0	0.0	5.4	1.1	0.2	0.5
Stackable (%)	86.8	60.7	32.8	20.2	0.0	0.0	0.0	0.0
Prestacked (%)	0.4	0.1	4.0	1.1	2.1	1.5	12.3	21.1
Portable stackable (%)	0.5	1.2	0.0	0.0	0.0	0.0	0.0	0.0
Washer/dryer combo (%)	0.0	0.0	0.4	0.3	0.0	0.0	0.0	0.0
Portable washer/dryer combo (%)	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Load sensor (%)	60.4	61.8	35.9	67.3	0.7	0.1	0.0	0.0
Soil sensor (%)	15.5	4.3	25.2	7.9	20.5	17.2	2.6	4.9
Load and soil sensor (%)	10.8	19.4	1.8	22.5	0.0	0.0	0.0	0.0
No sensor (%)	11.6	13.6	28.7	1.5	76.3	82.0	90.2	91.7
Not specified (%)	1.7	0.8	8.4	0.8	2.5	0.7	7.2	3.4
Average capacity (cu. ft.)	3.61	3.71	3.51	3.50	3.02	3.27	3.37	3.32
Standard deviation of capacity	0.24	0.48	0.30	0.57	0.27	0.19	0.41	0.21
Electronic control (%)	89.2	92.0	60.0	91.3	0.9	0.3	0.2	0.5
Mechanical control (%)	10.8	8.0	40.0	8.7	99.1	99.7	99.8	99.5

Limited sample, subset of full sample, includes all washer models observed at least once before and after 2007 policy change. High- and low-efficiency values based on median value of FTC rating across model numbers in limited sample. Data include varying number of retailers over time; sample of retailers may not represent population. Monthly data are for 2004–2009, 36 months before 2007 and 35 months after because of missing data in December 2008. Averages and standard deviations weighted by total units sold during period. Characteristics such as rpm and Capacity given as ranges; middle point of range used to calculate average: 1,009.5 rpm is used for 1,000–1,119 rpm. If range has one boundary, boundary is used in calculation: 2.5 cu. ft. includes those less than 2.5 cu. ft; 4.5 cu. ft. those 4.5+ cu. ft. "Not specified" data are treated as missing and excluded from calculation of characteristic average.

18.5 PRICE AND QUALITY CHANGES OVER TIME

The data described above are plotted in Figure 18.5.1 through Figure 18.5.6. The figures show prices, units sold, and shares of units sold for each of the four categories of washer, for both the full sample and the limited sample that includes only units sold both before and after the 2007 policy change. The average price taken across all units sold in the sample (individual washers weighted by quantity sold) also is shown. The data appear to show a slight discontinuity in quantities and prices at about the time of the policy change. Prices decline for high-efficiency units and increase slightly for low-efficiency units. Note that all prices are in current dollars (not adjusted for inflation). Changes in quantities, with a strong shift toward more efficient ENERGY STAR units, appear to be trending before and well after the policy change. The longer-run trends obviously are difficult to disentangle from other factors influencing technological advance and demand. Despite the marked shift in purchasing behavior toward more efficient units, nominal average prices show little if any trend upward, even in the full sample. Because the price of more-efficient units appears to be falling faster than for less-efficient units, the concurrent trends in prices and quantities provide some evidence of scale economies.

Figure 18.5.1 Units sold, full sample

The full sample includes all data having an FTC energy efficiency rating. High- and low-efficiency values are selected according to the median value of the FTC energy rating taken across model numbers in this sample. Note that the data include a varying number of retailers over time, and the sample of retailers may not be representative of the population.

Figure 18.5.2 Units sold, limited sample.

The limited sample is a subset of the full sample that includes all washer models observed in the data at least once before and once after the 2007 policy change. High- and low- efficiency values are selected according to the median value of the FTC energy rating taken across model numbers in this limited sample. Note that the data include a varying number of retailers over time, and the sample of retailers may not be representative of the population.

Figure 18.5.3 Washer prices, full sample.

The full sample includes all data having an FTC energy efficiency rating. High- and low-efficiency values are selected according to the median value of the FTC energy rating taken across model numbers in this sample. Note that the data include a varying number of retailers over time, and the sample of retailers may not be representative of the population. The lines for each category of washer indicate the value for the median washer sold in that category, and the band around the line marks the first and third quartiles. The thick dashed line is the average price across all models, with models weighted by number of units sold.

Figure 18.5.4 Washer prices, limited sample.

The limited sample is a subset of the full sample that includes all washer models observed in the data at least once before and after the 2007 policy change. High- and low-efficiency values are selected according to the median value of the FTC energy rating taken across model numbers in this limited sample. Note that the data include a varying number of retailers over time, and the sample of retailers may not be representative of the population. The lines for each category of washer indicate the value for the median washer sold in that category, and the band around the line marks the first and third quartiles. The thick dashed line is the average price across all models, with models weighted by number of units sold.

Figure 18.5.5 Market share, full sample.

The full sample includes all data having an FTC energy-efficiency rating. High- and low-efficiency values are selected according to the median value of the FTC energy rating taken across model numbers in this sample. Note that the data include a varying number of retailers over time, and the sample of retailers may not be representative of the population.

Figure 18.5.6 Market share, limited sample.

The limited sample is a subset of the full sample that includes all washer models observed in the data at least once before and after the 2007 policy change. High- and low-efficiency values are selected according to the median value of the FTC energy rating taken across model numbers in this limited sample. Note that the data include a varying number of retailers over time, and the sample of retailers may not be representative of the population**.**

18.6 REGRESSION DISCONTINUITY

Here we use a regression-discontinuity framework to attempt to discern model-specific effects of the policy on price and quantity of units sold. This approach to regression includes fixed effects for each washer model and smooth functions of time to account for other factors that changed at about the time of the policy change. Fixed effects of the model remove all model-specific features of washers so that price effects cannot be attributed to change in quality or characteristics over time. In effect, we attempt to explain how individual model prices change over time, and whether changes were unusually sharp near the time of the 2007 policy change.

The effect of the policy itself is estimated using a dummy variable to capture effects around the specific time of the policy change under the maintained assumption that the change itself is purely exogenous. It is important to note that the design of the regression discontinuity is not especially well suited to this particular policy change because, as described in the opening section, (a) the change was anticipated in advance and likely influenced behavior long before and

long after the event of the change, and (b) many other factors likely were influencing the appliance industry around the time of the policy change.

Baseline regression models estimated are specified as follows:

$$q_{it} = \alpha_i + f(t) + \beta d2007 + \gamma(d2007 \times kWh/y_i) + \epsilon_{it} \quad (1)$$

$$p_{it} = \alpha_i + f(t) + \beta d2007_t + \gamma(d2007_t \times kWh/y_i) + \epsilon_{it} \quad (2)$$

We also estimate models that include more robust controls for time, achieved by interacting smooth functions of time with each of the four categories (*c*) of washer described in earlier analysis. These controls allow for unobserved *time-varying* effects related to energy efficiency. The models incorporating trend interactions are:

$$q_{it} = \alpha_i + f_c(t) + \beta d2007_t + \gamma(d2007_t \times kWh/y_i) + \epsilon_{it} \quad (3)$$

$$p_{it} = \alpha_i + f_c(t) + \beta d2007_t + \gamma(d2007_t \times kWh/y_i) + \epsilon_{it} \quad (4)$$

All regressions are estimated using both the full sample of washers and the limited sample for which transactions were observed both before and after the 2007 policy change. The smooth functions of time are estimated using a natural cubic spline with four knots and three degrees of freedom.

Results from these regressions are reported in Table 18.6.1. These results indicate that the policy change caused prices to fall and quantities to increase. These effects are largest for relatively efficient units (low kWh/y) and smaller for relatively inefficient units. The signs reverse for the most inefficient units.

Table 18.6.1 Summary of regressions

	Price Effect of Policy			Quantity Effect of Policy		
	β	γ	Adj. R^2	β	γ	Adj. R^2
	Estimate/(t-statistic)					
Basic—full sample	-162.40	0.21	0.86	580.26	-1.00	0.57
	(-15.56)	(11.16)		(5.64)	(-5.36)	
Robust—full sample	-65.55	0.04	0.87	694.18	-1.36	0.57
	(-5.43)	(1.43)		(5.64)	(-5.24)	
Basic—limited sample	-113.61	0.20	0.88	823.12	-1.20	0.54
	(-11.76)	(12.24)		(7.79)	(-6.73)	
Robust—limited sample	-24.82	-0.007	0.90	600.09	-0.64	0.54
	(-2.07)	(-0.315)		(4.37)	(-2.34)	

Notes: All regression models include fixed effects for each model of washing machine. *Basic* models include a natural spline of time (on a monthly scale) with four knots. *Robust* models include a separate natural spline of time for each of the fours classes of washer as classified in the data section and plotted in the above figures. The β coefficient is for the dummy variable indicating the post-2007 period. The γ coefficient is the effect on the interaction of the year-2007 dummy variable and a unit's FTC energy-efficiency rating, measured in kWh of energy use per year.

18.7 DISCUSSION

The analysis can estimate some, but not all, effects of the 2007 changes in energy standards using panel regression techniques and a regression discontinuity design that exploits changes in prices and quantity that occur at about the time of the policy change. The analysis suggests that standard changes reduced prices and increased quantities of more energy efficient units, and reduced quantities and slightly increased prices of less-efficient units, some of which likely were banned from manufacture in 2007 but still sold after 2007.

Because the policy change would have increased demand for more efficient units, the observed fall in prices would seem possible under two scenarios: (a) there are significant economies of scale in production, which caused average production costs to decline with higher sales; or (b) washer markets are imperfectly competitive, and the policy change caused not just an outward shift in demand for higher efficiency units, but a change in the elasticity of demand for higher efficiency units. In the latter case, it is easy to imagine that the new demand for higher efficiency units would be more elastic to price than earlier demand. Specifically, new buyers of high-efficiency units may have preferences that are less brand- or feature-specific than those of buyers of high-efficiency washers before the policy change. A more elastic demand could incite monopolistically competitive producers to lower prices. Of course, a combination of these two explanations is also possible.

Other factors likely changing around the time of the policy change might bias the above inferences. The most logical alternative explanation for the decline in prices is the rapid slowdown in the housing market and the aggregate economy that occurred around this time. The resulting downward shift in demand could have encouraged firms to lower prices in general. This explanation, however, cannot reconcile the strong shift in the *share* of sales toward more

efficient washers. In general, we see larger growth in sales and larger declines in prices for higher efficiency units as compared to less-efficient units. This pattern cannot easily be reconciled by a general inward shift in demand due to a slowing economy.

Another possibility is that technological advance in production of relatively more efficient machines occurred simultaneously with the policy. If this were the case, the policy may not have *caused* the decline in price, but the advance nevertheless would have made the welfare costs of the policy change much smaller.

Yet another possibility is that rising energy prices in 2007 and 2008 precipitated higher demand for high-efficiency washers. But even if energy prices were more responsible than the policy change for the shift in demand away from low-efficiency units and toward higher efficiency units, the observed decline in washer prices would seem possible only if there were significant economies of scale and/or changes in strategic pricing by monopolistically competitive firms.

In general, these results are difficult to reconcile with the idea that the policy change caused significant welfare losses, and are consistent with plausible scenarios in which the policy change actually improved welfare. Because of the basic challenges of identification described earlier, total estimates of welfare are not possible. It may be possible, however, to construct a lower bound on the overall change in consumer welfare.

APPENDIX 5-A. DRAFT ENGINEERING ANALYSIS DATA REQUEST SHEETS

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5-A.1 ENGINEERING ANALYSIS DATA REQUEST SHEETS FOR RESIDENTIAL CLOTHES WASHERS

DOE seeks average **incremental production cost** to take basic models in the categories shown from the current DOE minimum efficiency level (or proposed baseline level) to the specified efficiency level. For those product classes where more than one basic model may exist, please indicate the minimum and maximum incremental costs that would be incurred across the array of basic models.

The data sheets are divided by product and contain tables requesting shipment and manufacturer cost data.

The shipment-weighted energy use data of Table A2 should be based on the DOE clothes washer test procedure (10 CFR 430, subpart B, appendix J, J1).

Shipments

For residential clothes washers, the AHAM 2005 Fact Book offers historical shipments data, but the information is not disaggregated by product class. As shown in the "shipment request" tables below, DOE hopes to collect both shipments data and shipment-weighted average efficiency data dating back to 1993. In addition, DOE hopes to collect market share efficiency (*i.e.*, data on the distribution of product shipments by efficiency) for each product class.

Manufacturer Costs

Incremental cost data (in U.S. dollars) include the materials, labor, and overhead needed to take basic models from the current minimum DOE baseline efficiency standard to each higher efficiency level. The depreciation of the conversion capital expenditures is an important component of the overhead for DOE to understand. Therefore, DOE is requesting information about conversion capital expenditures by efficiency level.

Table 5-A.1.1 Residential Clothes Washer Shipments

Year	Shipments, Domestic + Imports (Thousands of Units)				
	Top-Loading			Front-Loading	Suds-Saving
	Compact	Standard	Semi-automatic		
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
2002					
2003					
2004					
2005					
2006					
2007					
2008					

Table 5-A.1.2 Shipment-Weighted Average Efficiency Data

Year	Shipment-Weighted Average Efficiency									
	Top-Loading						Front-Loading		Suds-Saving	
	Compact		Standard		Semiautomatic					
	(MEF or EF)	(WF)	(MEF or EF)	(WF)	(MEF or EF)	(WF)	(MEF or EF)	(WF)	(MEF or EF)	(WF)
1993										
1994										
1995										
1996										
1997										
1998										
1999										
2000										
2001										
2002										
2003										
2004										
2005										
2006										
2007										
2008										

Table 5-A.1.3 Market Share Efficiency Data: Top-Loading – Compact and Standard, and Front-Loading

Top-Loading - Compact					Top-Loading - Standard					Front-Loading				
Efficiency Bins		Market Share (Percent)*			Efficiency Bins		Market Share (Percent)*			Efficiency Bins		Market Share (Percent)*		
(MEF)	(WF)	2006	2007	2008	(MEF)	(WF)	2006	2007	2008	(MEF)	(WF)	2006	2007	2008
0.65	18.40				1.26	9.50				1.72	8.00			
0.78	13.90				1.40	9.50				1.80	7.50			
					1.72	8.00				2.00	6.00			
					1.80	7.50				2.20	4.50			
					2.00	6.00				2.40	4.20			
					2.25	4.45				2.89	3.36			

* Total market share percentages for each year should equal 100%. DOE believes that there are no top-loading semi-automatic or suds-saving residential clothes washers currently on the market in the United States.

Table 5-A.1.4 Manufacturer Cost Data: Top-Loading – Compact and Standard

Product Class ➔	Top-Loading – Compact	Top-Loading – Standard				
Efficiency Level	1	1	2	3	4	5
MEF	0.78	1.40	1.72	1.80	2.00	2.25
WF	13.90	9.50	8.00	7.50	6.00	4.45
Average Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Minimum Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Maximum Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Conversion Capital Expenditures ($, Millions)						
Building CAPX						
Tooling/ Equipment CAPX						
One-Time Product Conversion Expenses ($, Millions)						
R&D						
Marketing						

Depreciation on the conversion capital expenditure should NOT be included in the incremental overhead.
***** Incremental costs per unit should be reported relative to the baseline unit's cost. The baseline unit complies with the federal standard for residential clothes washers and is equal to an MEF of 1.26 and WF of 9.50 for Top-Loading – Standard and an MEF of 0.65 for Top-Loading - Compact. The baseline WF of 18.40 for Top-Loading – Compact was selected based on a survey of clothes washers listed in the NRCan product database.

Other Information:

1. What depreciation method would your company use to depreciate the conversion capital expenditures? _____.

Direct material – Costs of raw materials including scrap that can be traced to final or end products. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process but are not assigned to final products (*e.g.*, lubricating oil for production machinery).
Direct labor – The earnings of workers who assemble parts into a finished good for operate machines in the production process. Direct labor includes the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor does not include indirect labor which is defined as the earnings of employees who do not work directly in assembling a product, such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.
Overhead – Factory overhead excluding depreciation. Factory overhead includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A); R&D; interest; or profit (accounted for by DOE separately).
Full Production Cost = Direct Material + Direct Labor + Overhead (factory) + Depreciation
Full Cost of Product = Full Production Cost + Non-production Costs (SG&A, R&D, interest, and profit)

Table 5-A.1.5 Manufacturer Cost Data: Front-Loading

Product Class ➔	Front-Loading				
Efficiency Level	1	2	3	4	5
MEF	1.80	2.00	2.20	2.40	2.89
WF	7.50	6.00	4.50	4.20	3.36
Average Incremental Costs ($ Per Unit)*					
Material					
Labor					
Overhead#					
Minimum Incremental Costs ($ Per Unit)*					
Material					
Labor					
Overhead#					
Maximum Incremental Costs ($ Per Unit)*					
Material					
Labor					
Overhead#					
Conversion Capital Expenditures ($, Millions)					
Building CAPX					
Tooling/ Equipment CAPX					
One-Time Product Conversion Expenses ($, Millions)					
R&D					
Marketing					

Depreciation on the conversion capital expenditure should NOT be included in the incremental overhead.
***** Incremental costs per unit should be reported relative to the baseline unit's cost. The baseline unit for the front-loading product class complies with the current ENERGY STAR level for residential clothes washers and is equal to an MEF of 1.72 and WF of 8.00.

Other Information:

1. What depreciation method would your company use to depreciate the conversion capital expenditures? _____.

Direct material – Costs of raw materials including scrap that can be traced to final or end products. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process but are not assigned to final products (*e.g*., lubricating oil for production machinery).
Direct labor – The earnings of workers who assemble parts into a finished good for operate machines in the production process. Direct labor includes the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor does not include indirect labor which is defined as the earnings of employees who do not work directly in assembling a product, such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.
Overhead – Factory overhead excluding depreciation. Factory overhead includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A); research and development (R&D); interest; or profit (accounted for by DOE separately).
Full Production Cost = Direct Material + Direct Labor + Overhead (factory) + Depreciation
Full Cost of Product = Full Production Cost + Non-production Costs (SG&A, R&D, interest, and profit)

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APPENDIX 5-B. DATA SUBMISSIONS

5-B.1 INTRODUCTION

This appendix presents the shipments and incremental cost data submitted to the U.S. Department of Energy (DOE) by the Association of Home Appliance Manufacturers (AHAM) support of the engineering analysis for this rulemaking. Information was provided for residential clothes washers in response to data request sheets generated by DOE and provided to AHAM. See chapter 5 of the preliminary technical support document (preliminary TSD) for details of the engineering analysis for which these data were used.

5-B.2 AHAM DE-IDENTIFIED CLOTHES WASHER DATA

AHAM supplied shipments, market share efficiency data, and incremental cost data, representing the aggregated inputs from manufacturers that produce the significant majority of residential clothes washers.

Table 5-B.2.1. Residential Clothes Washer Shipments

Year	Domestic Shipments	Front Load Shipments	Top Load Shipments
1989	5,609,980		
1990	5,590,800		
1991	5,414,837		
1992	5,632,074		
1993	5,923,000		
1994	6,161,000		
1995	6,080,000		
1996	6,225,000		
1997	6,326,000		
1998	6,835,000		
1999	7,313,000		
2000	7,495,000		
2001	7,362,000		
2002	7,745,000		
2003	8,146,000		
2004	8,832,000		
2005	9,225,000		
2006	9,500,000	2,212,859	6,360,866
2007	8,825,000	2,883,828	5,941,197
2008	8,292,000	3,022,077	5,269,625

Front Load and Top Load shipments do not sum to total domestic shipments - data baseline differs
AHAM began segregating front load and top load shipments in 2006.

Table 5-B.2.2 Shipment-Weighted Average Efficiency Data

Size Standard

Year	Product Class Front Load		Top Load	
	Weighted MEF	Weighted WF	Weighted MEF	Weighted WF
2006	1.99	5.12	1.24	11.38
2007	2.28	4.28	1.39	11.35
2008	2.26	4.23	1.44	10.88

AHAM does not maintain detailed energy data by product for more than three years; therefore, only data for 2006, 2007 and 2008 are available.

AHAM obtained data on compact units from only one company; therefore, AHAM cannot release information on compact RCWs.

AHAM has no shipment or efficiency data on semi-automatic or suds-saving RCWs.

Table 5-B.2.3 Market Share Efficiency Data: Top-Loading (Compact and Standard) and Front-Loading

				Year		
Energy Level	**Type**	**MEF**	**WF**	**2006**	**2007**	**2008**
Current Baseline	Front Load	1.72	8.00	10.7%	3.8%	
2011 Baseline	Front Load	1.80	7.50			
Level 1	Front Load	2.00	6.00	32.9%	8.3%	4.3%
Level 2	Front Load	2.20	4.50	51.1%	19.7%	24.0%
Level 3	Front Load	2.40	4.20	5.3%	37.9%	48.9%
Level 4	Front Load	2.89	3.36		30.4%	22.8%

				Year		
Energy Level	**Type**	**MEF**	**WF**	**2006**	**2007**	**2008**
Current Baseline	Top Load	1.26	9.50	93.7%	91.4%	87.2%
2011 Baseline	Top Load	1.40	9.50	0.0%		
Level 1	Top Load	1.72	8.00	1.1%	1.2%	3.7%
Level 2	Top Load	1.80	7.50			
Level 3	Top Load	2.00	6.00	5.2%	7.3%	9.1%
Level 4	Top Load	2.25	4.45	0.0%		

Front Load

2006 - combine current baseline and 2011 baseline (assuming that current baseline will move up to 2011 baseline). Combine Level 3 and Level 4 to maintain member confidentiality.
2007 - combine current baseline and 2011 baseline (assuming that current baseline will move up to 2011 baseline).

2008 - Cannot provide information for current baseline or 2011 baseline - do not have sufficient data

Top Load

2006 - Levels 1 and 2 are combined to maintain member confidentiality.
2007 - Current Baseline and 2011 Baseline, Levels 1 and 2 and Levels 3 and 4 combined to maintain member confidentiality
2008 - Current Baseline and 2011 Baseline, Levels 1 and 2 and Levels 3 and 4 combined to maintain member confidentiality

Table 5-B.2.4 Aggregate Calculations on Incremental Cost Data for Residential Clothes Washers – Top-Loading (updated May 2010)

Top Load (Vertical Axis)						
	n	3	3	3	3	3
Effieicncy Level		1	2	3	4	5
Weighted Average Incremental Cost						
Material		$ 3.15	$ 6.90	$ 10.63	$ 20.56	$ 57.20
Labor		$ 0.09	$ 1.72	$ 3.10	$ 5.01	$ 8.20
Overhead		$ 0.23	$ 0.83	$ 0.97	$ 1.55	$ 1.84
Weighted Average Standard Deviation						
Material		$ 11.88	$ 14.58	$ 18.47	$ 35.14	$ 36.85
Labor		$ 1.01	$ 3.14	$ 3.74	$ 5.78	$ 6.22
Overhead		$ 3	$ 10	$ 11	$ 18	$ 18
	n	3	3	3	3	3
Weighted Average Minimum Incremental Cost						
Material		$ 2.60	$ 5.70	$ 8.92	$ 16.77	$ 42.31
Labor		$ 0.08	$ 1.20	$ 2.16	$ 3.49	$ 5.75
Overhead		$ 0.25	$ 0.78	$ 0.92	$ 1.56	$ 1.89
Weighted Average Minimum Standard Deviation						
Material		$ 11.30	$ 13.78	$ 17.58	$ 32.97	$ 34.02
Labor		$ 0.96	$ 2.99	$ 3.55	$ 5.48	$ 5.76
Overhead		$ 3	$ 9	$ 11	$ 17	$ 18
	n	3	3	3	3	3
Weighted Average Maximum Incremental Cost						
Material		$ 3.71	$ 8.09	$ 12.30	$ 24.35	$ 72.10
Labor		$ 0.09	$ 2.31	$ 4.21	$ 6.77	$ 10.89
Overhead		$ 0.27	$ 1.12	$ 1.28	$ 1.97	$ 2.30
Weighted Average Maximum Standard Deviation						
Material		$ 12.46	$ 24.82	$ 32.41	$ 60.25	$ 86.33
Labor		$ 2.88	$ 9.85	$ 11.15	$ 26.12	$ 43.49
Overhead		$ 5	$ 16	$ 19	$ 30	$ 31
	n	3	3	3	3	3
Weighted Average Conversion capital Expenditures (Million $)						
Building CAPX		$ 0.30	$ 2.53	$ 3.27	$ 3.64	$ 6.60
Tooling/Equipment CAPX		$ 1.42	$ 37.32	$ 39.84	$ 43.95	$ 62.77
Weighted Average Conversion Capital Expenditures Standard Deviation						
Material		$ 0.18	$ 1.48	$ 1.92	$ 2.13	$ 3.88
Labor		$ 2.56	$ 17.66	$ 18.57	$ 17.32	$ 24.06
	n	3	3	3	3	3
Weighted Average One-Time Product Conversion Expenses (Million $)						
R&D		$ 0.79	$ 1.36	$ 2.37	$ 5.78	$ 8.87
Marketing		$ 0.26	$ 0.27	$ 1.76	$ 3.28	$ 5.77
Weighted Average One-Time Product Conversion Expenses (Million $) Standard Deviation						
Material		$ 2.02	$ 3.40	$ 3.81	$ 10.26	$ 16.02
Labor		$ 0.67	$ 0.68	$ 0.65	$ 2.07	$ 2.55

Table 5-B.2.5 Aggregated Total Industry Cost – Top-Loading

Top Load (Vertical Axis)						
Total Industry Cost						
Average Material, Labor, OH Cost - all (Million $)		$ 18.3	$ 49.8	$ 77.4	$ 142.9	$ 354.3
Minimum Material, Labor, OH Cost - all(Million $)		$ 15.4	$ 40.5	$ 63.2	$ 115.0	$ 263.2
Maximum Material, Labor, OH Cost - all (Million $)		$ 21.4	$ 60.7	$ 93.8	$ 174.4	$ 449.5
CAPX - all (Million $)		$ 10.1	$ 75.6	$ 86.6	$ 110.9	$ 175.4
One-Time Product Conversion - all (Million $)		$ 9.7	$ 20.1	$ 27.8	$ 62.9	$ 87.3
Total Industry Cost		$ 38.0	$ 145.4	$ 191.8	$ 316.7	$ 617.1

Table 5-B.2.6 Aggregate Calculations on Incremental Cost Data for Residential Clothes Washers (All Data) – Front-Loading (updated May 2010)

Front Load (Horizontal Axis)						
	n	6	6	6	6	6
Effieicncy Level		1	2	3	4	5
Weighted Average Incremental Cost						
Material		$ 2.07	$ 6.21	$ 12.84	$ 33.64	$ 67.00
Labor		$ 0.18	$ 0.41	$ 4.25	$ 9.29	$ 12.81
Overhead		$ 0.16	$ 0.28	$ 0.73	$ 1.21	$ 2.07
Weighted Average Standard Deviation						
Material		$ 7.20	$ 20.90	$ 39.70	$ 43.17	$ 82.78
Labor		$ 0.74	$ 1.43	$ 2.45	$ 3.03	$ 2.92
Overhead		$ 2	$ 3	$ 5	$ 7	$ 11
	n	4	4	4	4	4
Weighted Average Minimum Incremental Cost						
Material		$ 0.03	$ 0.48	$ 1.47	$ 16.79	$ 34.38
Labor		$ 0.05	$ 0.07	$ 2.61	$ 5.95	$ 7.68
Overhead		$ 0.14	$ 0.20	$ 0.57	$ 0.93	$ 1.37
Weighted Average Minimum Standard Deviation						
Material		$ 0.32	$ 5.69	$ 9.58	$ 11.36	$ 30.58
Labor		$ 0.56	$ 0.80	$ 1.91	$ 2.93	$ 2.83
Overhead		$ 2	$ 2	$ 5	$ 7	$ 10
	n	4	4	4	4	4
Weighted Average Maximum Incremental Cost						
Material		$ 0.03	$ 0.54	$ 2.26	$ 23.42	$ 47.99
Labor		$ 0.05	$ 0.08	$ 0.33	$ 6.65	$ 10.10
Overhead		$ 0.16	$ 0.23	$ 0.70	$ 1.37	$ 2.21
Weighted Average Maximum Standard Deviation						
Material		$ 0.35	$ 10.14	$ 16.77	$ 28.32	$ 52.36
Labor		$ 3.25	$ 1.43	$ 3.62	$ 8.36	$ 77.52
Overhead		$ 3	$ 4	$ 8	$ 12	$ 19
	n	5	5	5	5	5
Weighted Average Conversion capital Expenditures (Million $)						
Building CAPX		$ 0.07	$ 0.07	$ 2.68	$ 2.79	$ 3.65
Tooling/Equipment CAPX		$ 0.89	$ 0.90	$ 12.50	$ 19.38	$ 25.72
Weighted Average Conversion Capital Expenditures Standard Deviation						
Material		$ 0.26	$ 0.26	$ 8.70	$ 8.83	$ 8.79
Labor		$ 3.14	$ 3.14	$ 24.80	$ 23.32	$ 24.79
	n	5	5	5	5	5
Weighted Average One-Time Product Conversion Expenses (Million $)						
R&D		$ 0.23	$ 0.23	$ 0.95	$ 3.10	$ 6.94
Marketing		$ 0.37	$ 0.38	$ 2.58	$ 3.63	$ 6.15
Weighted Average One-Time Product Conversion Expenses (Million $) Standard Deviation						
Material		$ 0.79	$ 0.79	$ 2.16	$ 6.19	$ 11.07
Labor		$ 1.31	$ 1.31	$ 2.71	$ 2.43	$ 2.61

Note 1: Min and Max values are not consistent with the average values as we received 6 responses for average costs, and 4 responses for minimum and maximum costs. A separate summary table is provided for average, min and max all determined from four responses.

Note 2: Red values for labor costs under efficiency level 5 indicate one less response. For this series of data, the labor costs are an aggregate of 5 responses.

Table 5-B.2.7 Aggregated Total Industry Cost – Front-Loading

Front Load (Horizontal Axis)						
Total Industry Cost						
Average Material, Labor, OH Cost - all (Million $)		$ 7.3	$ 20.8	$ 53.9	$ 133.4	$ 247.5
Minimum Material, Labor, OH Cost - all(Million $)		$ 0.7	$ 2.3	$ 14.1	$ 71.5	$ 131.2
Maximum Material, Labor, OH Cost - all (Million $)		$ 0.7	$ 2.5	$ 9.9	$ 95.0	$ 182.2
CAPX - all (Million $)		$ 13.7	$ 14.1	$ 173.3	$ 218.0	$ 276.1
One-Time Product Conversion - all (Million $)		$ 8.8	$ 10.3	$ 36.2	$ 61.2	$ 103.6
Total Industry Cost		$ 29.8	$ 45.2	$ 263.4	$ 412.5	$ 627.1

Table 5-B.2.8 Aggregate Calculations on Incremental Cost Data for Residential Clothes Washers (Subset) – Front-Loading (updated May 2010)

Front Load (Horizontal Axis)						
	n	4	4	4	4	4
Effieicncy Level		1	2	3	4	5
Weighted Average Incremental Cost						
Material		$ 0.03	$ 0.51	$ 1.84	$ 20.19	$ 40.92
Labor		$ 0.05	$ 0.07	$ 3.61	$ 8.50	$ 11.09
Overhead		$ 0.13	$ 0.19	$ 0.56	$ 1.00	$ 1.57
Weighted Average Standard Deviation						
Material		$ 0.34	$ 5.99	$ 10.20	$ 12.15	$ 35.62
Labor		$ 0.59	$ 0.84	$ 2.33	$ 3.84	$ 4.21
Overhead		$ 2	$ 3	$ 5	$ 7	$ 11
	n	4	4	4	4	4
Weighted Average Minimum Incremental Cost						
Material		$ 0.03	$ 0.48	$ 1.47	$ 16.79	$ 34.38
Labor		$ 0.05	$ 0.07	$ 2.61	$ 5.95	$ 7.68
Overhead		$ 0.14	$ 0.20	$ 0.57	$ 0.93	$ 1.37
Weighted Average Minimum Standard Deviation						
Material		$ 0.32	$ 5.69	$ 9.58	$ 11.36	$ 30.58
Labor		$ 0.56	$ 0.80	$ 1.91	$ 2.93	$ 2.83
Overhead		$ 2	$ 2	$ 5	$ 7	$ 10
	n	4	4	4	4	4
Weighted Average Maximum Incremental Cost						
Material		$ 0.03	$ 0.54	$ 2.26	$ 23.42	$ 47.99
Labor		$ 0.05	$ 0.08	$ 0.33	$ 6.65	$ 10.10
Overhead		$ 0.16	$ 0.23	$ 0.70	$ 1.37	$ 2.21
Weighted Average Maximum Standard Deviation						
Material		$ 0.35	$ 10.14	$ 16.77	$ 28.32	$ 52.36
Labor		$ 0.08	$ 1.43	$ 3.62	$ 8.36	$ 77.52
Overhead		$ 3	$ 4	$ 8	$ 12	$ 19
	n	4	4	4	4	4
Weighted Average Conversion capital Expenditures (Million $)						
Building CAPX		$ -	$ -	$ 0.24	$ 0.35	$ 1.21
Tooling/Equipment CAPX		$ 0.01	$ 0.01	$ 5.10	$ 11.97	$ 18.31
Weighted Average Conversion Capital Expenditures Standard Deviation						
Material		$ -	$ -	$ 1.50	$ 2.24	$ 2.91
Labor		$ 0.06	$ 0.09	$ 2.22	$ 5.95	$ 14.15
	n	4	4	4	4	4
Weighted Average One-Time Product Conversion Expenses (Million $)						
R&D		$ 0.00	$ 0.01	$ 0.35	$ 2.50	$ 6.35
Marketing		$ 0.00	$ 0.01	$ 1.69	$ 2.74	$ 5.26
Weighted Average One-Time Product Conversion Expenses (Million $) Standard Deviation						
Material		$ 0.04	$ 0.11	$ 0.83	$ 6.07	$ 11.21
Labor		$ 0.03	$ 0.08	$ 0.67	$ 0.96	$ 2.51

Front Load (Horizontal Axis)						
Total Industry Cost						
Average Material, Labor, OH Cost - subset (Million $)		$ 0.64	$ 2.3	$ 18	$ 90	$ 162
Minimum Material, Labor, OH Cost - subset (Million $)		$ 0.66	$ 2.3	$ 14	$ 72	$ 131
Maximum Material, Labor, OH Cost - subset (Million $)		$ 0.73	$ 2.5	$ 10	$ 95	$ 182
CAPX - subset (Million $)		$ 0.73	$ 1.1	$ 40.3	$ 85.0	$ 143.1
One-Time Product Conversion - subset (Million $)		$ 0.82	$ 2.3	$ 16.2	$ 41.2	$ 83.6
Total Industry Cost		$ 2.2	$ 5.7	$ 74.7	$ 215.8	$ 388.6

APPENDIX 5-C. ENGINEERING QUESTIONNAIRES

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APPENDIX 5-C. ENGINEERING QUESTIONNAIRES

5-C.1 DESIGN FOR ENERGY IMPROVEMENT INFORMATION REQUEST FOR RESIDENTIAL CLOTHES WASHERS

The United States Department of Energy (DOE) is currently reviewing energy conservation standards for residential clothes washers. DOE would like to confirm information on the incremental costs of increasing product efficiency by understanding the design options involved in the efficiency improvement.

1. Market Share of Products You Sell

To help DOE discover manufacturer sub-groups and the relative importance of various product classes to specific manufacturers, please disaggregate your annual unit shipments for each product category as shown below. Please also indicate whether you purchase these products from other manufacturers (*i.e.* private label), and whether the factory that supplies the product is located in the United States.

Product Class	% Private Label	% Made in US	2008 Unit Shipments
Top-Loading, Compact			
Top-Loading, Standard			
Top-Loading, Semi-automatic			
Front-Loading			
Suds-Saving			

- Are you aware of any top-loading semi-automatic or suds-saving units on the market?

2. Product Design Features

The following series of exhibits and questions address technical characteristics of key residential clothes washer components for both baseline and improved-efficiency products.

Baseline Clothes Washers

Which design features impacting energy use are generally incorporated into a "baseline" clothes washer (*i.e.* one that just meets existing modified energy factor (MEF) and water factor (WF) standards, if any) in the following product classes?

- Top-loading, Compact-size
- Top-loading, Standard-size

- Top-loading, Semi-automatic
- Front-loading
- Subs-Saving

Incremental Efficiency Levels

DOE proposed in the framework document to use efficiency levels based on the MEF and WF specifications prescribed by ENERGY STAR and the Consortium for Energy Efficiency (CEE)'s Super-Efficient Home Appliances Initiative, along with the maximum levels that are currently available in the market. For top-loading clothes washers, DOE did not include CEE Tier 3 as an efficiency level because the difference between the Tier 3 criteria (2.20 MEF/4.50 WF) and the maximum available level (2.26 MEF/4.48 WF) was so small. For top-loading standard-size clothes washers, DOE proposed to add a level to fill the gap between the baseline and the ENERGY STAR criteria. For front-loading clothes washers, DOE proposes to add a level to fill the gap between the CEE Tier 3 criteria and the maximum available level. It will set these gap-fill levels at combinations of MEF and WF that are strongly represented in the California Energy Commission (CEC) appliance product directory.

For both top- and front-loading clothes washers, DOE recognizes that MEF and WF pairings may not simultaneously achieve max-tech levels. That is, a clothes washer with the highest possible MEF may not achieve the lowest possible WF. Similarly, a clothes washer with the lowest WF may not achieve the highest MEF. DOE considered several models in each product class to determine max-tech values that best represent optimal performance for products on the market. DOE did not suggest max-tech levels that represent a "hybrid" of the highest possible MEF and the lowest possible WF for each product class.

For top-loading compact-size clothes washers, DOE did not establish efficiency levels for analysis in previous rulemakings. Based on a review of the top-loading compact-size clothes washers in the CEC directory, which revealed little difference between the maximum available efficiency and the baseline DOE standard, DOE proposed to analyze one efficiency level above the baseline represented by the currently available maximum technology.

Table 1 through Table 3 shows the proposed efficiency levels for each product class.

- Are the proposed efficiency levels appropriate?
- Can you suggest an appropriate "max-tech" efficiency level?
- Do you believe that the gap-fill efficiency levels defined by DOE for top-loading standard-sized and front-loading clothes washers are representative? If not, can you suggest appropriate gap-fill values?
- If you believe the top-loading semiautomatic and suds-saving clothes washer product classes should be analyzed, can you suggest baseline, gap-fill, and max-tech efficiency levels for those product classes?

Table 1: Efficiency Levels for Top-Loading Standard-Size Residential Clothes Washers

Level	Efficiency Level Source	Efficiency Level	
		MEF	WF
Baseline	DOE Standard	1.26	9.50
1	Gap Fill	1.40	9.50
2	ENERGY STAR	1.72	8.00
3	CEE Tier 1	1.80	7.50
4	CEE Tier 2	2.00	6.00
5	Max Available	2.26	4.48

Table 2: Efficiency Levels for Top-Loading Compact-Size Residential Clothes Washers

Level	Efficiency Level Source	Efficiency Level	
		MEF	WF
Baseline	DOE Standard	0.65	18.40
1	Max Available	0.78	13.90

Table 3: Efficiency Levels for Front-Loading Residential Clothes Washers

Level	Efficiency Level Source	Efficiency Level	
		MEF	WF
Baseline	ENERGY STAR	1.72	8.00
1	CEE Tier 1	1.80	7.50
2	CEE Tier 2	2.00	6.00
3	CEE Tier 3	2.20	4.50
4	Gap Fill	2.40	4.20
5	Max Available	2.89	3.36

- What design changes are generally required to convert a typical baseline top-loading standard-sized clothes washer (1.26 MEF, 9.50 WF) to each incremental efficiency level up to the max available level (2.26 MEF, 4.48 WF)?
    - What are the costs of the individual design options selected?
- What design changes are associated with converting a baseline top-loading compact-sized clothes washer (0.65 MEF, 18.40 WF) to the maximum available level (0.78 MEF, 13.90 WF)?
    - Are these design changes comparable for top-loading standard-sized clothes washers?
    - What are the costs of the individual design options selected?

- What design changes are associated with converting a baseline front-loading clothes washer (1.72 MEF, 8.00 WF) to each incremental efficiency level up to the maximum available level (2.89 MEF, 3.36 WF)?
    - Are these design changes comparable for other product classes?
    - What are the costs of the individual design options selected?
- Are the aggregated industry costs for each product class (highlighted in red in the Tables below) representative of your firm's costs? Please indicate your firm's costs for achieving the proposed efficiency levels in the Tables below.
- Are there fundamental differences between required design changes that make the cost increment much higher for some product classes than others?
- Would you help DOE understand and estimate the conversion capital investments that would be necessary at each candidate standard level? What is the nature of the capital investments?
- What depreciation method would your company use to depreciate the conversion capital expenditures?
- Are installation costs a function of efficiency? Maintenance costs? Repair costs? If yes, would you please characterize this relationship by providing incremental installation, maintenance, and/or repair cost data?
- Is there a relationship between MEF and WF? If yes, please characterize this relationship.

Table 4: Manufacturer Cost Data: Top-Loading – Compact and Standard

Product Class ➔	Top-Loading – Compact	Top-Loading – Standard				
Efficiency Level	1	1	2	3	4	5
MEF	0.78	1.40	1.72	1.80	2.00	2.25
WF	13.90	9.50	8.00	7.50	6.00	4.45
Average Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Minimum Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Maximum Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Conversion Capital Expenditures ($, Millions)						
Building CAPX						
Tooling/ Equipment CAPX						
One-Time Product Conversion Expenses ($, Millions)						
R&D						
Marketing						

Depreciation on the conversion capital expenditure should NOT be included in the incremental overhead.
***** Incremental costs per unit should be reported relative to the baseline unit's cost. The baseline unit complies with the federal standard for residential clothes washers and is equal to an MEF of 1.26 and WF of 9.50 for Top-Loading – Standard and an MEF of 0.65 for Top-Loading - Compact. The baseline WF of 18.40 for Top-Loading – Compact was selected based on a survey of clothes washers listed in the NRCan product database.

Direct material – Costs of raw materials including scrap that can be traced to final or end products. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process but are not assigned to final products (*e.g.*, lubricating oil for production machinery).
Direct labor – The earnings of workers who assemble parts into a finished good for operate machines in the production process. Direct labor includes the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor does not include indirect labor which is defined as the earnings of employees who do not work directly in assembling a product, such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.
Overhead – Factory overhead excluding depreciation. Factory overhead includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A); R&D; interest; or profit (accounted for by DOE separately).
Full Production Cost = Direct Material + Direct Labor + Overhead (factory) + Depreciation
Full Cost of Product = Full Production Cost + Non-production Costs (SG&A, R&D, interest, and profit)

Table 5: Manufacturer Cost Data: Front-Loading

Product Class ➔	Front-Loading				
Efficiency Level	1	2	3	4	5
MEF	1.80	2.00	2.20	2.40	2.89
WF	7.50	6.00	4.50	4.20	3.36
Average Incremental Costs ($ Per Unit)*					
Material					
Labor					
Overhead#					
Minimum Incremental Costs ($ Per Unit)*					
Material					
Labor					
Overhead#					
Maximum Incremental Costs ($ Per Unit)*					
Material					
Labor					
Overhead#					
Conversion Capital Expenditures ($, Millions)					
Building CAPX					
Tooling/ Equipment CAPX					
One-Time Product Conversion Expenses ($, Millions)					
R&D					
Marketing					

Depreciation on the conversion capital expenditure should NOT be included in the incremental overhead.
***** Incremental costs per unit should be reported relative to the baseline unit's cost. The baseline unit for the front-loading product class complies with the current ENERGY STAR level for residential clothes washers and is equal to an MEF of 1.72 and WF of 8.00.

Direct material – Costs of raw materials including scrap that can be traced to final or end products. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process but are not assigned to final products (*e.g.*, lubricating oil for production machinery).
Direct labor – The earnings of workers who assemble parts into a finished good for operate machines in the production process. Direct labor includes the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor does not include indirect labor which is defined as the earnings of employees who do not work directly in assembling a product, such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.
Overhead – Factory overhead excluding depreciation. Factory overhead includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A); research and development (R&D); interest; or profit (accounted for by DOE separately).
Full Production Cost = Direct Material + Direct Labor + Overhead (factory) + Depreciation
Full Cost of Product = Full Production Cost + Non-production Costs (SG&A, R&D, interest, and profit)

DOE is requesting data on efficiency improvements and manufacturing costs associated with specific technology options. When providing data on efficiency improvements please indicate the improvements with respect to MEF and WF.

Control Systems

Adaptive Control Systems

- Is there any room for further, significant energy efficiency improvement via adaptive control systems that adjust washer operation or conditions (*i.e.*, wash temperature, cycle time, number of rinse cycles, spin speed, and other parameters) based on characteristics of the clothes load? If so, how much improvement can be achieved? What is the incremental manufacturing cost associated with adaptive control systems? What adaptive control sensor technologies do you use in your washers (*e.g.*, sensors to measure the soil load, turbidity sensors to detect water quality, etc)?
- Do any of your clothes washers use a fuzzy logic to weigh laundry loads and regulate the length of the wash cycle, water level, number of rinses, and drying time? If so, how much efficiency improvement can be achieved? What would be the incremental manufacturing cost?

Automatic Fill Controls

- What types of automatic fill control technologies do you incorporate in your front-load clothes washers? Top-load clothes washers? What are the incremental costs associated with these automatic fill control technologies? How much energy can be saved using this technology option?
- Are there fundamental differences in the implementation of this technology option that make the cost increment much higher for some product classes than others? If so, please elaborate on these differences.

Improved Fill Control

- Is there any room for further significant energy efficiency improvement via improved fill control? For example, improving tolerances on existing wash-water fill sensing (pressure sensors or improving switch design) to avoid overfilling the wash tub? What would be the incremental manufacturing cost?

Other Control Issues

- Are you aware of any intellectual property or patent infringement issues that might affect your choice of adaptive control, automatic fill, or improved fill control technology?
- What is the incremental manufacturing cost of switching from electromechanical controls to electronic controls? Which technology options require electronic controls?
- Have you considered requiring a cold rinse and offering more warm or cold wash programs while reducing the number of hot wash cycle options in order to increase the MEF without affecting the WF per the DOE test procedure?

Advanced Agitation Concepts for Vertical-Axis Machines

- What types of advanced agitation technologies do you incorporate in your top-loading clothes washers (*e.g.*, nutating plates, rotating disks, side-mount agitators)? How much efficiency improvement can be achieved with each type of advanced agitation technology? What is the incremental manufacturing cost compared to the standard agitator found in traditional top-loading machines?

Drum/Tub Upgrades

Added Insulation

- Have you considered increased insulation as a design option? If so, what thicknesses and insulation materials have you considered? How much efficiency improvement can be achieved? What would be the incremental manufacturing cost?

Horizontal-Axis Design

- DOE's review of research and literature shows that horizontal-axis machines use on average 40 percent less energy and 25 percent less water than traditional vertical-axis washers. Would you consider this accurate? If not, please suggest a more appropriate value.
- Are performance or consumer utilities limited by horizontal-axis designs?

Horizontal-Axis Design with Recirculation

- Have you considered horizontal-axis design with recirculation as a design option (*i.e.*, using a pump to recirculate water and spray it into the drum)? How much efficiency improvement can be achieved with this design option? What would be the associated incremental manufacturing cost?
- Would this design option limit consumer utilities or performance?

Horizontal-Axis Design with Top-Loading Configuration

- Have you considered a horizontal-axis drum design that can be loaded from the top? Would you consider this to be a viable design option? Would a top-loading horizontal-axis washer have any inherent differences in performance compared to a traditional front-loading horizontal-axis washer? What would be the associated incremental manufacturing cost for this feature?

Improved Horizontal-Axis Drum Design

- Is there any room for further significant energy efficiency improvements via horizontal-axis drum design (*i.e.*, to improve wash performance, reduce mass, and increase spin speeds)? Have you considered drums featuring special paddles, drum-wall textures, or similar enhancements? If so, how much efficiency improvement can be achieved? What would be the incremental manufacturing cost?

Reduced Thermal Mass

- Have you considered using a plastic wash tub specially designed to minimize the thermal mass that is heated by the water? If so, what specific materials have you considered? How much efficiency improvement can be achieved? Are there any advanced materials (plastics, composites, or others) that could be used to lower the thermal mass of the tub beyond the current practice? What would be the incremental manufacturing cost?

Tighter Tub Tolerance

- Have you considered tighter tub tolerances (*i.e.*, reducing the annular volume between the inner wash basket and outer tub) as a means for improving efficiency? If so, how much efficiency improvement can be achieved? What is the incremental manufacturing cost?
- Are there other design considerations that are important in determining an appropriate clearance between basket and tub? If so, please elaborate.

Improved Water Extraction to Lower Remaining Moisture Content (RMC)

- Have you considered increasing the spin speed of the wash basket for the final spin cycle? What design changes would be required for this and what would be the incremental manufacturing cost? What would be the associated improvement in efficiency?
- Have you considered changing the direction of rotation to more evenly distribute clothes? If so, how much efficiency improvement can be achieved? What would be the incremental manufacturing cost?
- Have you considered longer spin cycles to lower the RMC? How much efficiency improvement can be achieved?
- How much efficiency improvement can be achieved through increasing the size or number of drainage holes in the washer drum? What would be the associated manufacturing cost?
- Based on DOE's review of the CEC product database, front-loading washer RMC values range from 30 to 53 percent and top-loading washers RMC values range from 35 to 61 percent. What RMC levels can be achieved with the above mentioned improved water extraction design changes? What RMC levels are achieved by your currently offered top-load clothes washers? Front-load clothes washers?
- Does the size of the test load affect the RMC that can be achieved? If so, are you aware of any data showing this relationship?

Drum Motor Upgrades and Improvements

- What types of drum motors do you currently employ in your clothes washers?

Increased Motor Efficiency

- Have you considered improved motor efficiency as a design option? If so, how much improvement can be achieved? What is the incremental manufacturing cost associated with improved motor efficiency?
- DOE's review of literature and research indicates that replacing a split-phase motor with a capacitor-start motor may increase the efficiency of the motor by 10 percent. Would you consider this accurate?
- How much efficiency improvement can be achieved with permanent magnet motors?
- What percentage of the overall energy consumption in a wash cycle is associated with the drum motor?

Direct-Drive Motors

- Do any of your top-loading or front-loading washers use a direct-drive motor? How much efficiency improvement can be achieved with this design option as compared to the conventional motor/transmission system? Are the efficiency improvements different for each product class?
- What type of motor would be used for this technology option (*e.g.*, brushless direct-current (BLDC) motor)?
- How would a direct-drive system affect cleaning performance, cycle times, or spin speeds?
- Are there larger standby power requirements for a direct-drive motor system? If so, how much?
- What is the incremental manufacturing cost associated with a direct-drive motor?

Spray Rinse or Similar Water-Reducing Rinse Technology

- Do your clothes washers currently incorporate spray rinse? How much efficiency improvement can be achieved through this design option? What is the incremental manufacturing cost?
- Do any of your clothes washers incorporate steam washing? How much efficiency improvement can be achieved through this design option? What is the incremental manufacturing cost?
- Do spray rinse and steam washing raise performance issues (*e.g.*, reducing soil removal)?

Thermostatically Controlled Mixing Valves

- Have you considered thermostatically controlled water valves (TCWVs) as a design option to achieve energy savings by more accurately controlling inlet water temperature? How much efficiency improvement can be achieved? What is the incremental manufacturing cost?
- Do adjustments to the water inlet temperatures raise performance issues (*i.e.*, reducing soil removal with lower wash temperatures)?

- DOE believes that TCWV technology option has the potential to overstate the real-world energy savings, depending on the proximity of the water heater to the installed clothes washer and unheated water temperatures in different geographic locations and time of year. Are the benefits of TCWVs accurately captured by the test procedure?
- Can efficiency improvements be achieved with non-thermostatically controlled water inlet systems, *i.e.*, reducing the hot water energy use by reducing the warm water temperature using different hot and cold water ratios (40 percent hot and 60 percent cold as opposed to 50-50)? How much efficiency improvement can be achieved? Are there concerns with performance and consumer utility when adjusting the hot and cold water ratios?

Hot Water Circulation Loop

- Have you considered hot water circulation loop as a design option (*i.e.*, using the hot water line running through a heat exchanger to heat cold water for use in a clothes washer)? How much efficiency improvement can be achieved? What is the incremental manufacturing cost associated with this design option?

Alternative Cleaning Processes

Plastic Particle Cleaning

- Have you considered plastic particle cleaning (*i.e.*, tumble clothes with polymer granules which absorb dirt) as a design option? Has there been any attempt to commercialize this technology? DOE's review of research and literature indicates that this technology would require 2 percent of the water used by a conventional clothes washer. Would you consider this accurate?

Bubble Action

- Have you considered an air-bubble feature as a design option (*i.e.* using air bubbles to more effectively deliver detergent to the surface of the clothing, while requiring less water than a typical wash cycle)? If so, what technology are you using to generate the bubbles? How much efficiency improvement can be achieved? What is the incremental manufacturing cost?

Electrolytic Disassociation of Water

- Have you considered electrolytic disassociation of water as a design option (*i.e.*, reducing hot water usage by substituting the electrolytic production of bleaching agents for the activation of bleaching chemical reactions in detergents by hot water)? How much efficiency improvement can be achieved? What is the incremental manufacturing cost?

Ozonated Laundering

- Would you consider ozonated laundering a viable design option? How much efficiency improvement can be achieved? What is the incremental manufacturing cost?

Smart Grid Technologies

- Have you considered smart grid technologies as a design option? If so, what specific capabilities would be enabled by the smart grid technology? Other than shifting energy usage away from peak power periods, could smart grid technology affect the overall energy efficiency of the clothes washer? How much efficiency improvement can be achieved? What is the incremental manufacturing cost?

Standby Power

- What are the consumer utilities associated with each type of display used in clothes washer? (For example, cycle/temperature selection, delay start time, cycle time, etc.)
- What types of display technologies do you use in your clothes washer product line? What are the standby power requirements for each display type assuming a comparable display (size and capability)?
- Are you aware of consumers demanding specific display types or is it other clothes washer features that attract them?
- What are the manufacturing costs associated with various display technologies?
- What drives the costs for each display technology?
- What would be the manufacturing costs associated with adding a feature to dim or turn off the displays? How much could this potentially decrease power consumption?
- What clothes washer features other than displays contribute to standby power, and what is the standby power requirement associated with each of them?
- Do any of your clothes washers incorporate switching power supplies? Is this a viable technology for reducing standby power in clothes washers? What is the incremental manufacturing cost of a switching power supply compared to a conventional linear power supply?
- Would you consider the following a viable design option for reducing standby power, and if so what would be the incremental manufacturing cost: a transformer-less power supply design, incorporated with a “soft” power pushbutton and triac to control power through the transformer, providing just enough power through the transformer-less power supply to maintain the microcontroller chip while the clothes washer is not powered on. When the power button is pressed, current would then be allowed to pass through the transformer of the conventional power supply to power the remainder of the control board.
- What other design options are available for reducing standby power consumption? What is the associated incremental manufacturing cost?

3. Test Procedure Issues

- How do you currently measure the capacity of your clothes washers? More specifically, at what level do you fill the washer with water for the DOE capacity measurement for top-loaders? What level do you fill the washer with water for front-loaders? Is the capacity measurement for the DOE energy test the same capacity used for marketing purposes? Would you suggest any changes to the current language for measuring capacity in the DOE energy test procedure?
- Do you have any data showing the effects on RMC results using test cloth from different lots for a given clothes washer unit? Have you observed significant test-to-test variation in MEF and WF measurements and RMC results as the test cloth ages (from 0 to 60 runs) for a given clothes washer unit? If so, how much is this variation? Do you have any test data showing this variation? Are there other test cloth issues that affect the measured test results that you are aware of? Would you recommend any changes to the test cloth specifications currently included in the DOE test procedure?
- Since the AHAM-2A detergent is no longer available, what detergent do you currently use to precondition the test cloths according to the DOE test procedure?
- The current DOE test procedure does not require the use of detergent during the energy test wash cycles. Do you believe the test procedure should be amended to require the use of detergent during the energy test wash cycles? If so, would you suggest using a powder or liquid detergent? Should DOE specify a specific brand of detergent to use to help ensure repeatability of test results? Would there be any concerns with the repeatability of test results using a liquid detergent?
- Do you have any consumer usage data showing the percentage of consumers that use powder detergent versus liquid detergent?
- The current DOE test procedure does not provide specifications for the test load size for clothes washer capacities greater than 3.8 ft^3. Would a linear extrapolation of test load sizes for capacities greater than 3.8 ft^3 be appropriate? If not, can you suggest appropriate test load sizes (minimum, average, and maximum) for capacities greater than 3.8 ft^3?
- Are you aware of any test procedures which account for adaptive controls (other than adaptive water fill control)?
- Are the temperature use factors specified by the current test procedure, which provide a weighted-average measurement of energy and water performance under the range of typical wash and rinse cycle temperature selections, representative of current consumer patterns and available wash cycles?
- Are there any clothes washer features currently available in the market that you believe should be incorporated into the test procedure? For example, should the test procedure incorporate steam cycles? Should the test procedure incorporate self-cleaning, deodorizing, or sanitizing cycles? Are there any other features that may impact the energy usage compared to a traditional wash and rinse cycle?
- Do you have any consumer usage data showing the percentage of consumers that use each type of wash cycle or advanced feature currently available in the market?

5-C.2 QUESTIONNAIRE TO EVALUATE THE PRODUCT CLASSES AND STANDARDS PROPOSED IN THE CONSENSUS AGREEMENT

The Association of Home Appliance Manufacturers (AHAM) and the American Council for an Energy Efficient Economy (ACEEE) recently released a multi-product standards agreement (Consensus Agreement) that addressed negotiated standards for refrigerators/freezers, clothes washers, clothes dryers, room air conditioners, and dishwashers. For clothes washers, the Consensus Agreement proposes updated standards for top-loading standard and top-loading product classes, as well as splitting the existing front-loading product class into front-loading standard and front-loading compact clothes washers. DOE's rulemaking process allows for a direct publication of a final rule if DOE concludes that standards proposed in the Consensus Agreement meet certain statutory criteria. In order to evaluate the product classes and standards proposed in the Consensus Agreement for residential clothes washers, DOE is requesting information on the topics in this questionnaire.

DOE is requesting information on the product classes in the table below.

Baseline Efficiencies for Considered Product Classes

Product Class	**Product Class Description**	**Baseline MEF** *(ft^3/kWh/cycle)*	**Baseline Standby Power** *(W)*
Top-Loading, Standard	Top-loading with capacity greater than 1.6 ft^3	1.26	0
Top-Loading, Compact	Top-loading with capacity less than 1.6 ft^3	0.65	0
Front-Loading, Standard	Front-loading with capacity greater than 1.6 ft^3	1.72	2.3
Front-Loading, Compact*	Front-loading with capacity less than 1.6 ft^3	N/A	N/A

*DOE is not aware of any compact front-loading clothes washers available on the market, and is especially interested in information on this product class to evaluate the proposed standard in the Consensus Agreement.

Any amended standards for clothes washers would be expressed in terms of the integrated modified energy factor (IMEF), as proposed in the test procedure NOPR published on September 21, 2010. 75 FR 57556. Based on the current definition, DOE expects IMEF to vary significantly from the current MEF metric. IMEF will account for standby and off mode energy consumption, as well as energy use from steam and self-cleaning cycles. The proposed test procedure also includes changes to the capacity measurement for top-loading washers, which will affect IMEF. The discussion below references efficiency levels in terms of MEF to avoid metrics unfamiliar to manufacturers.

1 KEY ISSUES

1.1 You previously indicated the following key issues in this rulemaking: [LIST KEY ISSUES] Do these remain key issues for your company in this rulemaking, and are there any additional key issues you believe DOE should consider in this

rulemaking?

2 ENGINEERING AND LIFE-CYCLE COST

2.1 Are the AHAM-supplied average incremental manufacturing costs at each efficiency level representative of costs your company incurs at each of these efficiency levels? Also, please indicate if the design options you previously stated for the given efficiency levels are still valid.

AHAM-Supplied Standard Top-Loading Incremental Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Incremental Cost** *(materials, labor, OH)*	**Actual Incremental Cost** *(if different)*	**Description of Design Options**
1.40	$3.08		
1.72	$8.39		Electronics, load sensors, spray rinse, temperature sensors, modified agitators/baskets
1.80	$13.02		Same as above
2.00	$23.99		Impeller, stainless baskets (higher spin speeds), better electronic controls/sensors, hung suspension, lower water temperatures, longer cycles, variable motor drives
2.26	$59.25		Higher spin speeds, better load detection/flow meters, sophisticated drives, accelerometers, better suspension, longer cycles

AHAM-Supplied Standard Front-Loading Incremental Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Incremental Cost** *(materials, labor, OH)*	**Actual Incremental Cost** *(if different)*	**Description of Design Options**
1.80	$2.13		
2.00	$6.09		Electronic UI
2.20	$15.73		Better damping/sensing systems, water level sensors paired with flow meters
2.40	$38.89		
2.89	$72.13		

2.2 At the time the Framework Document was published, the max-tech units had MEF ratings of 2.26 and 2.89 for top-loading and front-loading clothes washers respectively. DOE is now aware of top-loading clothes washers with a MEF of 2.57, and front-loading clothes washers with a MEF of 3.35. What design features and associated costs would be necessary to reach these efficiencies?

2.3 Do the design options and associated costs in the tables above also apply to the compact front- and top-loading product classes?

2.4 Please comment on any issues related to the following proposed changes to the DOE clothes washer test procedure and how they may impact the design options used to reach higher efficiencies for each product class, as appropriate:

2.4.1 Standby and Off Mode Power

How would accounting for standby and off mode power impact the measured efficiencies of clothes washers? Would the inclusion of standby and off mode power affect the design options currently used to reach higher efficiencies?

2.4.2 Steam Wash Cycles

How would accounting for steam wash cycles affect the measured efficiency of clothes washers with this feature compared to the efficiency as measured using the existing test procedure? Is it appropriate to account for steam wash cycles in the measured efficiency of clothes washers? What percentage of your total shipments do clothes washers offering a steam wash cycle account for?

2.4.3 Self-Clean Cycles

How would including self-clean cycles affect the measured efficiency as compared to the current test procedure? What fraction of your total clothes washer shipments includes a pre-set self-clean cycle, and how frequently do you recommend consumers use such a cycle?

2.4.4 Use Factors

Will the proposed amendments to the use factors in the DOE test procedure significantly affect the measured efficiencies of any clothes washers? Are the proposed values consistent with actual consumer use? Can you provide any non-proprietary data related to consumer use of different cycles?

2.4.5 Capacity Measurement Method

Will the proposed capacity measurement method affect the design options you use to reach higher efficiencies?

2.4.6 Energy Test Cycle Definition

How will the changes to the energy test cycle definition change how your clothes washers are tested? Will this revised definition limit the design options available for reaching higher efficiencies?

3 CONVERSION COSTS

The MIA considers two types of conversion costs:

- *Capital conversion costs* are one-time investments in plant, property, and equipment (PPE) necessitated by an amended energy conservation standard. These may be incremental changes to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.

- *Product conversion costs* are costs related research, product development, testing, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.

3.1 The tables below show the AHAM-submitted average capital conversion costs for a number of efficiency levels. Please indicate if your expected capital conversion costs vary from the AHAM-submitted estimate. In the description column, DOE is interested in understanding the kinds of changes that would need to be implemented to production lines and production facilities at each efficiency level. Where applicable, please quantify the number and cost of new production equipment, molds, etc. that would be required to implement the specified design changes.

AHAM-Supplied Standard Top-Loading Capital Conversion Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Capital Conversion Costs ($mm)**	**Actual Capital Conversion Cost** *(if different)*	**Description**
1.40	$1.51		
1.72	$34.98		
1.80	$37.84		
2.00	$41.76		
2.26	$60.88		

AHAM-Supplied Standard Front-Loading Capital Conversion Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Capital Conversion Costs ($mm)**	**Actual Capital Conversion Cost** *(if different)*	**Description**
1.80	$0.85		
2.00	$0.86		
2.20	$13.32		
2.40	$19.46		
2.89	$25.78		

3.2 The tables below show the AHAM-submitted average product conversion costs for a number of efficiency levels. Please indicate if your expected product conversion costs vary from the AHAM-submitted estimate. In the description column, DOE is interested in understanding such expenses as product development, prototyping, testing, certification, and marketing. In the description column, please describe the assumptions behind the estimates provided.

AHAM-Supplied Standard Top-Loading Product Conversion Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Product Conversion Costs**	**Actual Product Conversion Cost** ***(if different)***	**Description**
1.40	$0.93		
1.72	$1.43		
1.80	$3.62		
2.00	$7.95		
2.26	$12.84		

AHAM-Supplied Standard Front-Loading Product Conversion Costs

MEF (ft^3/kWh/cycle)	AHAM Average Product Conversion Costs	Actual Product Conversion Cost *(if different)*	Description
1.80	$0.53		
2.00	$0.53		
2.20	$3.10		
2.40	$5.91		
2.89	$11.48		

3.3 Are the capital and product conversion costs described above applicable to the compact product classes as well? Would the magnitude and nature of the conversion costs differ for the compact product classes?

3.4 Please provide additional qualitative information to help DOE understand the types and nature of your investments, including the plant and tooling changes and the product development effort required at different efficiency levels.

4 MARKUPS AND PROFITABILITY

DOE estimated the manufacturer production costs for the two standard product classes of residential clothes washers. DOE assumed the other two compact product classes would have similar baseline markup values. DOE defines manufacturer production cost as all direct costs associated with manufacturing a product: direct labor, direct materials, and overhead (which includes depreciation). The manufacturer markup is a multiplier applied to manufacturer production cost to cover non-production costs, such as SG&A and R&D, as well as profit. *It does not reflect a "profit margin."*

The manufacturer production cost multiplied by the manufacturer markup equals the manufacturer selling price. Manufacturer selling price is the price manufacturers charge their first customers, but *does not* include additional costs along the distribution channels.

4.1 Please comment on the baseline markups DOE calculated as compared to your company's baseline markups for the clothes washer product classes.

Residential Clothes Washer Baseline Manufacturer Markups by Product Class

Product Class	Product Class Description	Estimated Baseline Markup	Manufacturer Comments or Revised Estimates
Top-Loading, Compact	Top-loading with capacity less than 1.6 ft^3	1.22	
Top-Loading, Standard	Top-loading with capacity greater than 1.6 ft^3	1.22	
Front-Loading, Compact	Front-loading with capacity less than 1.6 ft^3	1.30	
Front-Loading, Standard	Front-loading with capacity greater than 1.6 ft^3	1.30	

4.2 One of the possible scenarios DOE uses to model impacts on industry profitability is the impact of commoditization of premium products. Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding if efficiency is a feature that earns a premium. Within each product class, do markups vary by efficiency level? If yes, please provide information about the markups at efficiencies above the baseline in the tables below. Would these markups also vary for compact product classes?

Estimated Standard Top-Loading Markups by Efficiency Level

MEF *(ft^3/kWh/cycle)*	**Estimated Markup**	**Manufacturer Comments**
1.40		
1.72		
1.80		
2.00		
2.26		

Estimated Standard Front-Loading Markups by Efficiency Level

MEF *(ft^3/kWh/cycle)*	**Estimated Markup**	**Manufacturer Comments**
1.80		
2.00		
2.20		
2.40		
2.89		

4.3 Would you expect changes in your estimated profitability following an amended energy conservation standard? If so, please explain why. Can you suggest any scenarios that would model these expected changes?

5 FINANCIAL PARAMETERS

5.1 In order to accurately collect information about clothes washer manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Financial Parameters for Residential Clothes Washer Manufacturing

GRIM Input	Definition	Industry Estimated Value *(%)*	Your Actual (If Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	34.3	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	8.0	
Working Capital	Current assets less current liabilities (percentage of revenues)	6.5	
Net PPE	Net plant property and equipment (percentage of revenues)	17.7	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	11.3	
R&D	Research and development expenses (percentage of revenues)	2.2	
Depreciation	Amortization of fixed assets (percentage of revenues)	4.7	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	2.7	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	83.0	

6 ADDITIONAL IMPACTS

6.1 You previously indicated the following regulatory burdens: changes in refrigerants, outcome of Copenhagen, building codes (green building programs and LEED), management over product life (take-back legislation), and RoHS regulations in California, Minnesota, and Canada. You additionally listed the DOE's regulation of commercial clothes washers, clothes dryers, refrigerators and room air conditioners. Do these still represent regulatory burdens, and are there any additional regulatory burdens at this time? What costs do you anticipate incurring to meet these regulations?

6.2 The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. Where are your residential clothes washer facilities that produce products for the United States located? Please also provide employment levels and total washer shipments at each of these facilities.

6.3 At what efficiency levels would you consider relocating current domestic production abroad?

6.4 Are you aware of any small businesses, niche manufacturers, or component manufacturers for which amended energy conservation standards would have a severe impact? If so, why?

6.5 Have any of your US facilities qualified for grants available through the American Recovery and Reinvestment Act? Has your company reached the $75 million limit for efficient appliances under the Energy Improvement and Extension Act of 2008? How

many shipments of washers qualifying for a $250 production tax credit under the Energy Improvement and Extension Act do you anticipate manufacturing in 2010?

5-C.3 INFORMATION REQUEST FOR COMPACT-SIZE PRODUCT CLASSES FOR RESIDENTIAL CLOTHES WASHERS

The United States Department of Energy (DOE) is currently reviewing energy conservation standards for residential clothes washers, including the standards proposed in the AHAM-ACEEE Multi-Product Standards Agreement ("Consensus Agreement"). In particular, DOE would like to understand the rationale for the proposed efficiency standards for the top-loading compact and front-loading compact product classes.

1. Consensus Agreement Standard Levels

Table 1 shows the proposed standards in the Consensus Agreement.

Table 6. AHAM-ACEEE Multi-Product Standards Agreement for Residential Clothes Washers

Product Description	New Standard Jan. 1, 2015 (MEF/WF)	New Standard Jan. 1, 2018 (MEF/WF)
Top-Loading, Compact (less than 1.6 cubic feet capacity)	1.26 / 14.0	1.81 / 11.6
Top-Loading, Standard	1.72 / 8.0	2.0 / 6.0
Front-Loading, Compact (less than 1.6 cubic feet capacity)	1.72 / 8.0	
Front-Loading, Standard	2.2 / 4.5	

Table 2 compares the Consensus Agreement standards for the compact product classes to the current DOE standard, as well as the efficiency levels of compact top-loaders currently on the market.

Table 7. Efficiency Levels for Compact-Size Residential Clothes Washers

Efficiency Level Source	Efficiency Level	
	MEF	WF
Top-Loading, Compact		
DOE Standard	0.65	none
Level 1 (currently on the market)	0.78	13.9
Level 2 (currently on the market)	1.00	12.7
Consensus Agreement, 2015	1.26	14.0
Consensus Agreement, 2018	1.81	11.6
Front-Loading, Compact		
DOE Standard	1.26	none
Consensus Agreement, 2015	1.72	8.0

Questions:

- Top-loading compact
  - How were the standards for the top-loading compact product class established?
  - What was the rationale for the tiered standards?
  - Are you aware of any products on the market that meet the 2015 standards? 2018 standards?
  - Within the top-loading compact product class, what percentage market share do your company's shipments represent?
  - Do you foresee any potential changes in the competitive landscape for compact clothes washers due to the proposed standards?
- Front-loading compact
  - How were the proposed standards for the front-loading compact product class established?
  - Are you aware of any compact front-loaders on the market that meet the proposed standards? If not, do you foresee any entrants into this market in the future?

2. Design Options and Costs for Achieving Proposed Standard Levels

The inclusion of more stringent standards for top-loading compact and front-loading compact product classes in the Consensus Agreement implies that these standards are technologically achievable and economically justifiable. Because the proposed standards for the top-loading product class represent a significant improvement over current standards, DOE would like to better understand how these higher standard levels can be achieved. Table 3 shows the design options considered for standard-size top-loading clothes washers.

Table 8. Design Options for Standard-Size Top-Loading Clothes Washers

Design Options	Applicable to Compact Product Class?
More Advanced Controls	
Adaptive fill control (more accurate pressure switches)	
Temperature control (more accurate sensors)	
Water inlet valves (more accurate flow control)	
Electronic controls	
Accelerometers	
Motor Improvements	
More efficient motor	
Variable speed drive	
Higher spin speeds	
Basket/Drum Modifications	
Basket shape modification	
Stainless steel basket	
Larger capacity	
Stronger basket	
Agitator modification	
Reduced Water Consumption	
Spray rinse	
Recirculation pumps	
Gray-water rinse	
Structural Improvements	
Better suspension system	
Out-of-balance detection	
Operational Design Options	
Longer cycle times	
Lower water temperatures	

Questions:

- What design options are available for the compact product classes to meet the higher standard levels?
- What design options are most likely to be used to reach the proposed 2015 standards? The 2018 standards?
- What are the average costs associated with meeting each incremental standard level? (See Table 4)

Table 9. Cost Associated with Meeting Each Incremental Efficiency Level

Efficiency Level Source	Efficiency Level		Incremental Cost ($/Unit)
	MEF	WF	
Top-Loading, Compact			
DOE Standard	0.65	none	
Level 1 (currently on the market)	0.78	13.9	
Level 2 (currently on the market)	1.00	12.7	
Consensus Agreement, 2015	1.26	14.0	
Consensus Agreement, 2018	1.81	11.6	
Front-Loading, Compact			
DOE Standard	1.26	none	
Consensus Agreement, 2015	1.72	8.0	

- Are there any significant differences between product types or platforms (*e.g.* stacked washer/dryer vs. portable top-loading washer) that could affect the ability for a particular product type to achieve the proposed standard levels?
- Can the front-loading compact efficiency standards be achieved assuming similar design options as "nearly compact" front-loaders ranging from 1.6-2.4 cubic feet?

3. Consumer Utility

DOE would like to better understand the unique consumer utility offered by compact-size clothes washers.

Questions:

- Does the market continue to demand clothes washers with capacity less than 1.6 cubic feet?
- Are the disparate compact top-loading products considered substitutes for each other? Or does each distinct product type satisfy a unique niche within the market? (*e.g.* stacked washer/dryer vs. portable top-loading washer)
- Would the proposed standards have any negative impacts on consumer utility of compact-size clothes washers?

APPENDIX 8-A. USER INSTRUCTIONS FOR LIFE-CYCLE COST AND PAYBACK PERIOD SPREADSHEETS

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APPENDIX 8-A. USER INSTRUCTIONS FOR LIFE-CYCLE COST AND PAYBACK PERIOD SPREADSHEETS

8-A.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 residential clothes washers by using Microsoft Excel spreadsheets available on DOE's website at http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers.html. 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 2007. The LCC and PBP workbook for residential clothes washers comprises the following worksheets.

Statistics — Presents a statistical summary of the simulation runs performed: the range in LCC savings and PBPs; retail purchase price; total installed cost; total operating costs over the product lifetime (discounted); annual electricity, gas, and oil use; annual water use; and household characteristics. The worksheet provides minimum, maximum, and average values, along with 5th, 25th, 50th, 75th, and 95th percentile values.

Summary — Presents the results of an analysis in terms of average LCC, LCC savings, and median, average, and undefined PBP for both front- and top-loading washers. A table includes, for each efficiency level considered, installed price; lifetime operating cost; LCC; average savings; and the percentage of households that would incur a net cost, no impact, or net savings 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 year, from 2014–2018, at which to begin the calculation of LCC and PBP (2015 is default); and the number of simulation runs to be performed within a range of 100–50,000 (10,000 is default).

LCC & Payback — Lists the input values used to calculate LCC and PBP. Many values were derived from data from sampled RECS households. Parameters include fuel type for water heating and clothes drying; annual numbers of washer and dryer loads; product lifetime; the discount rate applied to costs and savings; energy and water prices; the base-case efficiency distribution; product price and total installed cost; and energy and water use. The result is annual and

	cumulative cash flow for both front- and top-loading clothes washers operating at each efficiency level.
RECS Samples	Presents the data from the 299 RECS households DOE sampled for front-loading machines and the 3,311 sampled for top-loading models. Identifies the parameters exported to (1) the LCC and PBP analysis (water heating and dryer fuel and price, numbers of washer and dryer loads per year); (2) product prices; (3) energy and water prices; and (4) discount rate (whether new or replacement unit).
Energy & Water Use	Contains per-cycle energy and water use data at each efficiency level broken down into washer machine energy use, dryer energy use (gas or electric); water heating energy use (electric, gas, or oil); and both total and hot water use. Identifies the parameters exported to the LCC and PBP analysis.
Base-Case Efficiency Distribution	Gives the market shares for efficiency levels in the base case.
Equipment Prices	Develops total installed cost for clothes washers in 2010$. Gives baseline and incremental manufacturer costs, retail price, sales tax, and installation cost for both product classes and each efficiency level. Includes the assumptions used about mark-ups and sales tax.
Energy & Water Prices	Contains the regional prices in 2010$ for electricity, gas, oil, and water used in the LCC and PBP analysis.
Energy Price Trends	Displays the trends in energy prices for electricity, gas, and distillate for 2008–2045 under the reference, high, and low economic growth scenarios from AEO 2010.
Water Price Trend	Contains the trend for water prices for 2011–2045 based on the consumer price index (CPI) 1981–2010
Discount Rate	Presents data used to develop average real discount rates and a distribution of discount rates for various types of household debt and equity used to purchase products installed in new homes and replacement products. Appendix 8D describes development of discount rates in detail.
Forecast Cells	Gives details regarding base-case efficiency distributions for both classes of clothes washers. Median, minimum, maximum, and average values are given, along with 5th, 25th, 50th, 75th, and 95th percentile values. Included are product prices and details of the

	LCC and PBP (LCC savings in terms of money, energy, and water and the percentages of households that would experience a net cost, no impact, or net savings from each efficiency level).
Lifetime	Presents the average lifetime, in years, for front- and top-loading clothes washers (14.2), the Weibull parameters used for the survival function, and a graph of the Weibull retirement function for residential clothes washers.

8-A.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 8-B. UNCERTAINTY AND VARIABILITY

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APPENDIX 8-B. UNCERTAINTY AND VARIABILITY

8-B.1 INTRODUCTION

Analysis of a potential energy efficiency standard involves calculating effects, for example, the effect of a standard on consumer life-cycle cost (LCC). 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 or model; and (3) provide numerical values for each quantity. In the simplest case, the equation is unambiguous (it contains all relevant quantities and no others), each quantity has a single numerical value, and the calculation produces a single value. Unambiguousness and precision are rarely the case, however. In most 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. Although the simplest analysis involves a single numerical value for each quantity in the calculation, arguments can arise about the appropriate value for each quantity. Explicit analysis of uncertainty and variability provides more complete information to the decision-making process.

8-B.2 UNCERTAINTY

When making observations of past events or speculating about the future, imperfect knowledge is the rule rather than the exception. For example, the energy consumed by a particular type of appliance (such as the average residential clothes washer) is not recorded directly, but rather estimated based on available information. Even direct laboratory measurements have a margin of error. When estimating numerical values expected for quantities at some future date, the exact outcome rarely is known.

8-B.3 VARIABILITY

Variability in the calculation of a quantity means that different applications or situations produce different numerical values. Specifying an exact value for a quantity may be difficult because the value depends on something else. For example, the number of hours a household operates a clothes washer depends on the specific circumstances and behaviors of the occupants (*e.g.*, number of persons, personal habits). Variability makes specifying an appropriate population value more difficult, because no one value is likely to 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.*, number of persons per household).

8-B.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. Numerous calculations are performed, which provide some indication of the extent to which the result depends on the assumptions. For example, the LCC of an appliance could be calculated based on electricity costs of 2, 8, and 14 cents per kilowatt-hour.

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 LCC is reduced, holding all other inputs constant; that is, the energy rate at which the consumer achieves savings in operating costs that more than compensate for the increased purchase price.) 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 characterized by 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 subject to electricity rates at particular levels) to estimate the probability of each value. For quantities characterized by uncertainty, statistical or subjective measures can be used to provide probabilities (*e.g.*, manufacturing cost to improve energy efficiency to a given 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 more 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 a policy given the identified uncertainties and variability. A policy is robust when the impacts are acceptable over a wide range of possible conditions.

8-B.5 PROBABILITY ANALYSIS AND THE USE OF CRYSTAL BALL

To quantify the uncertainty and variability that exist in inputs to the engineering, LCC, and payback period analyses, DOE used Microsoft Excel spreadsheets combined with Crystal Ball, a commercially available add-in software, to conduct probability analyses. The probability analyses used Monte Carlo simulation and probability distributions.

Simulation refers to any analytical method meant to duplicate a real-life system, especially when other analyses are too mathematically complex or difficult to reproduce. Without the aid of simulation, a spreadsheet model will reveal only a single outcome, generally the most likely or average outcome. 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 numerous times. Monte Carlo simulation was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance. Games of chance such as roulette wheels, dice, and slot machines, exhibit random behavior. The random behavior in games of chance is similar to how Monte Carlo simulation selects variable values at random to simulate a model. When you roll a die, you know that a 1, 2, 3, 4, 5, or 6 will come up, but you do not know which number for any particular roll. So too with variables that have a known range of values but an uncertain value for any particular time or event (*e.g.*, product lifetime, discount rate, and installation cost).

For each uncertain variable (a variable that has a range of possible values), a probability distribution is used to define possible values. The type of distribution selected is based on the conditions surrounding that variable. Types of probability distributions include the following.

Figure 8-B.5.1 Normal Probability Distribution

Figure 8-B.5.2 Triangular Probability Distribution

Figure 8-B.5.3 Uniform Probability Distribution

During a simulation, multiple scenarios are calculated by sampling values repeatedly from the probability distributions for the uncertain variables. 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 8-C. LIFETIME DISTRIBUTIONS

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APPENDIX 8-C. LIFETIME DISTRIBUTIONS

8-C.1 INTRODUCTION

The U.S. Department of Energy (DOE) characterized the lifetime of both product classes of clothes washers being considered for new energy efficiency standards (front-loading and top-loading). DOE characterized clothes washer 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]

8-C.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.

8-C.3 LIFETIME DISTRIBUTIONS FOR CLOTHES WASHERS

Table 8-C.3.1 shows the average, minimum, and maximum lifetimes plus maximum percentile values used to determine the Weibull distribution parameters α and β for residential clothes washers. DOE estimated that the maximum lifetime percentile for both front- and top-loading units was 99 percent.

Table 8-C.3.1 Distribution Parameters for Clothes Washers

Values				Weibull Parameters	
Minimum years	**Average years**	**Maximum years**	**Maximum Percentile %**	**Alpha (scale)**	**Beta (shape)**
2	14.2	50	99	10.126	2.655

Figure 8-C.3.1 show the Weibull distribution for the lifetime of both front- and top-loading clothes washers.

Figure 8-C.3.1 Likelihood that Clothes Washer Will Fail

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APPENDIX 8-D. DISTRIBUTIONS USED FOR DISCOUNT RATES

8-D.1 INTRODUCTION

DOE derived discount rates for the LCC analysis using data on interest or return rates for various types of debt and equity. To account for variation among households in rates for each of the types, DOE sampled a rate for each household from a distribution of rates for each debt and equity type. This appendix describes the distributions used.

8-D.2 DISTRIBUTION OF MORTGAGE INTEREST RATES

Figure 8-D.2.1 shows the distribution of real interest rates for new home mortgages. The data source DOE used for mortgage interest rates is the Federal Reserve Board's *Survey of Consumer Finances (SCF)* in 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[1] Using the appropriate *SCF* data for each year, DOE adjusted the nominal mortgage 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 8-D.2.1 Distribution of New Home Mortgage Interest Rates

8-D.3 DISTRIBUTION OF RATES FOR DEBT CLASSES CONSIDERED FOR REPLACEMENT PRODUCTS

Figure 8-D.3.1 through Figure 8-D.3.5 show the distribution of real interest rates for different types of debt used to finance replacement clothes washers. The data source for the

interest rates for home equity loans, credit cards, installment loans, other residence loans, and other lines of credit is the Federal Reserve Board's *SCF* in 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[1] DOE adjusted the nominal rates to real rates using the annual inflation rate in each year. For home equity loans, DOE calculated effective interest rates in a similar manner as for mortgage rates, since interest on such loans is tax deductible.

Figure 8-D.3.1 Distribution of Home Equity Loan Interest Rates

Figure 8-D.3.2 Distribution of Credit Card Interest Rates

Figure 8-D.3.3 Distribution of Installment Loan Interest Rates

Figure 8-D.3.4 Distribution of Other Residence Loan Interest Rates

Figure 8-D.3.5 Distribution of Other Lines of Credit Loan Interest Rates

8-D.4 DISTRIBUTION OF RATES FOR EQUITY CLASSES CONSIDERED FOR REPLACEMENT PRODUCTS

Figure 8-D.4.1 through Figure 8-D.4.6 show the distribution of real interest rates for different types of equity used to finance replacement clothes washers. 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. The interest rates associated with certificates of deposit (CDs),[2] savings bonds,[3] and AAA corporate bonds[4] are from Federal Reserve Board time-series data covering 1977 to 2009. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts are from Cost of Savings Index data covering 1984 to 2009.[5] The rates for stocks are the annual returns on the Standard and Poor's (S&P) 500 from 1977 to 2009.[6] The mutual fund rates are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year from 1977 to 2009. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year.

Figure 8-D.4.1 Distribution of Annual Rate of Return on CDs

Figure 8-D.4.2 Distribution of Annual Rate of Return on Savings Bonds

Figure 8-D.4.3 Distribution of Annual Rate of Return on Corporate AAA Bonds

Figure 8-D.4.4 Distribution of Annual Rate of Savings Accounts

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Figure 8-D.4.6 Distribution of Annual Rate of Return on Mutual Funds

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APPENDIX 8-E. ESTIMATION OF EQUIPMENT PRICE TRENDS FOR RESIDENTIAL CLOTHES WASHERS

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APPENDIX 8-E. FORECAST OF PRODUCT PRICES FOR RESIDENTIAL CLOTHES WASHERS

8-E.1 PRICE TREND ESTIMATION

To derive a price trend for residential clothes washers, DOE obtained historical Producer Price Index (PPI) data for household laundry equipment spanning the time period 1980-2010 from the Bureau of Labor Statistics' (BLS). DOE used PPI data for household laundry equipment as representative of residential clothes washers because PPI data specific to residential clothes washers are not available. The PPI data reflect nominal prices, adjusted for product quality changes. An inflation-adjusted price index for household laundry equipment was calculated by dividing the PPI series by the Gross Domestic Product Chained Price Index (see Figure 8-E.1.1).

Figure 8-E.1.1 Historical Nominal and Real Producer Price Indexes for Household Laundry Equipment

To project the price trend for clothes washers, DOE used the inflation-adjusted household laundry equipment PPI in the past 20 years (1991 to 2010) to fit an exponential model with *year* as the explanatory variable. In this case, the exponential function takes the form of:

$$Y = a \cdot e^{bX}$$

where Y is the clothes washer price index, X is the time variable, *a* is the constant and *b* is the slope parameter of the time variable.

The regression performed as an exponential trend line fit results in an R-square of 0.99, which indicates a good fit to the data. The final estimated exponential funtcion is:

$$Y = 1.06 \times 10^{22} \cdot e^{(-0.025)X}$$

Figure 8-E.1.2 shows the price factor index to 2045 derived from this exponential model. The value for 2015 used in the LCC and PBP analysis is 0.882. Thus, prices forecast for the LCC and PBP analysis are equal to 0.882 times the 2010 values for each efficiency level in each product class.

Figure 8-E.1.2 Household Laundry Equipment Price Factor Index for the Default Case

8-E.2 DISCUSSION OF ANALYTICAL ISSUES

To estimate equipment prices in both the standards and the base (no-standards) case, DOE develops engineering cost estimates that DOE then uses to estimate the manufacturer selling price. The manufacturer selling price includes direct manufacturing production costs (labor, material, and overhead estimated in DOE's manufacturer production costs) and all non-production costs (SG&A, R&D, and interest), along with profit. The process of the cost-based method for developing the manufacturer selling prices is described in the engineering analysis described in chapter 5 of this TSD. To convert the manufacturer selling price to an equipment price for the consumer, DOE performs an analysis of distribution chain markups and estimates markups on both the baseline and incremental manufacture selling prices to determine equipment prices after distribution to the consumer.

In analyzing experience curves to estimate price trends, DOE uses producer price indices as a key data input and analyzes this data to estimate the experience curve exponent. This approach has only one model parameter to describe the price trend and assumes a simple relationship between producer price and retail equipment price. Specifically, the approach assumes that producer prices, distribution chain markups and equipment prices all scale proportionally over time for the same product.

DOE could have developed a more complex price trend forecasting model with more parameters that could explain different trends in different equipment price and cost components over time. But the relatively few available data points present a risk that a fit with multiple parameters would "overfit" the data. Overfitting occurs when there are too many degrees of freedom in a statistical model compared to the data and the fits are sensitive to random noise unrelated to long term trends. Due to the risk of overfitting the available data, DOE has decided to not develop a more complex multi-parameter price trend estimation model at this time.

Due to the simple nature of the price trend estimation model, there are several well known economic and market phenomenon that will not be captured in detail by the price trend forecast. Some effects might lead to an overestimate of the long term price trend and other effects may lead to an underestimate. For example, if there has been increasing market concentration historically on the part of manufacturers, this may have resulted in increasing manufacturer and wholesale markups over time. This would result in an observed historical producer price trend that did not decrease as fast as the underlying industrial learning rate. Depending on whether market concentration accelerated or decelerated into the future this could lead to an over- or under-estimation of future price trends.

Similarly, if there are cost components that have relatively slow long term price trends that have an increasing impact on price over time, the decreasing share of costs that are declining rapidly can result in a change in the empirically estimated experience curve exponent over time.

APPENDIX 9-A RELATIVE PRICE ELASTICITY OF DEMAND FOR CLOTHES WASHERS

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Appendix 9-A. **RELATIVE PRICE ELASTICITY OF DEMAND FOR CLOTHES WASHERS**

9-A.1 INTRODUCTION

This appendix summarizes DOE's study of the price elasticity of demand for residential clothes washers. Section 9-A.2 reviews the literature regarding the impact of economic variables on the sale of durable goods. Section 9-A.3 describes the market for home appliances and the changes that have occurred during the past 20 years. In section 9-A.4, DOE summarizes the results of its regression analysis and presents estimates of the relative price elasticity of demand for clothes washers. In section 9A.5, DOE presents development of an "effective" purchase price elasticity. Cross-price elasticity of demand for front- and top-loading washers is discussed in section 9-A.6. DOE presents its interpretation of results in section 9-A.7. Finally, section 9-A.8 describes the data DOE used in its analysis.

9-A.2 LITERATURE REVIEW

Relatively few studies measure the effect of price, income, and efficiency on the sale of household appliances. This section briefly reviews the literature that describes the likely importance of those variables to the purchase of residential clothes washers.

9-A.2.1 Price

DOE reviewed many studies that sought to measure the impact of price on sales in a dynamic market. One study of the automobile market prior to 1970 found that the price elasticity of demand declined over time. The author attributed this effect to buyers delaying a purchase after a price increase but eventually making the purchase (Table 9-A.2.1).[1] A contrasting study of household white goods, also prior to 1970, found the elasticity of demand to increase over time as more price-conscious buyers enter the market.[2] Estimates of the price elasticity of demand for different brands of the same product tend to vary. A review of 41 studies of the effect of price on market share found an average price elasticity of -1.75.[3] The average estimate of price elasticity of demand reported in those studies was -0.34 in the appliance market and -0.47 in the combined automobile and appliance markets.

Table 9-A.2.1 Effect of Price, Income, and Efficiency on Automobile and Appliance Sales

Durable Good	Price Elasticity	Income Elasticity	Brand Price Elasticity	Implicit Discount Rate %	Model	Data Years	Duration
Automobiles[1]	-1.07	3.08	-	-	Linear regression, stock adjustment	-	Short term
Automobiles[1]	-0.36	1.02	-	-	Linear regression, stock adjustment	-	Long term
Clothes Dryers[2]	-0.14	0.26	-	-	Cobb-Douglas, diffusion	1947–1961	Mixed
Room Air Conditioners[2]	-0.37*	0.45	-	-	Cobb-Douglas, diffusion	1946–1962	Mixed
Dishwashers[2]	-0.42	0.79	-	-	Cobb-Douglas, diffusion	1947–1968	Mixed
Refrigerators[3]	-0.37	-	-	39	Logit probability, survey data*	1997	Short term
Various[4]	-	-	-1.76†	-	Multiplicative regression	-	Mixed
Room Air Conditioners[5]	-	-	-1.72	-	Non-linear diffusion	1949–1961	Short term
Clothes Dryers[5]	-	-	-1.32	-	Non-linear diffusion	1963–1970	Short term
Room Air Conditioners[6]	-	-	-	20	Qualitative choice, survey data	-	-
Household Appliances[7]	-	-	-	37‡	Assorted	-	-

Sources: [1]S. Hymens, 1971; [2]P. Golder and G. Tellis, 1998; [3]D. Revelt and K. Train, 1997; [4]G. Tellis, 1988; [5]D. Jain and R. Rao; [6]J. Hausman; [7]K. Train, 1985.

Notes: * Logit probability results are not directly comparable to other elasticity estimates in this table.
† Average brand price elasticity across 41 studies.
‡ Averaged across several studies referenced herein regarding household appliances.

9-A.2.2 Income

Higher-income households are more likely to own appliances.[4] The effect of income on appliance shipments is explored in two econometric studies of the automobile and appliance markets.[1,2] The average income elasticity of demand is 0.50 in the appliance study cited in the literature review, much larger in the automobile study (Table 9.A.2.1).

9-A.2.3 Appliance Efficiency and Discount Rate

Many studies estimate the effect of appliance efficiency on consumers' choice of appliance. This effect typically is summarized by the implicit discount rate; that is, the rate consumers use to compare future savings in operating costs against a higher initial purchase price. One early and much-cited study concluded that consumers use a 20-percent implicit discount rate when purchasing room air conditioners (Table 9-A.2.1).[5] A survey of several studies of various appliances suggested that the consumer implicit discount rate has a broad range, averaging about 37 percent.[6]

9-A.3 VARIABLES THAT DESCRIBE THE MARKET FOR CLOTHES WASHERS

In this section DOE discusses variables that appear to affect shipments of clothes washers, including those pertaining to the consumer household, the appliance itself, and economic factors.

9-A.3.1 Household/Appliance Variables

Several variables influence the sale of clothes washers. The most important for explaining trends in appliance sales are the annual number of new housing units constructed (housing starts) and the number of appliances that reach the end of their operating life (replacement units). Housing starts affect appliance sales, because new homes often are provided with, or soon receive, new appliances, including clothes washers. Replacements are correlated with sales, because new appliances typically are purchased when old ones wear out. In principle, if households maintain a fixed number of appliances, shipments should equal housing starts plus appliance replacements.

9-A.3.2 Economic Variables

Appliance price, appliance operating cost, and household income are economic variables that affect shipments. Low prices and costs encourage consumers to purchase household appliances, and an increase in income improves a consumer's ability to purchase appliances. In principle, changes in economic variables should explain changes in the number of appliances per household.

During a 1980–2002 study period, annual shipments of clothes washers grew 69 percent.[8, 9] This rising trend in shipments is explained in part by housing starts, which increased 6 percent[11] and by replacements, which rose 50 percent during the period. Replacements are determined based on the expected operating life of 14.2 years for clothes washers and on past shipments (average of annual lagged shipments, with lag equal to expected appliance operating life ± 5 years). For a mature market such as the one for clothes washers, replacements exceed sales to new housing construction.

Shipments increased somewhat more rapidly than housing starts plus replacements (69 percent versus 56 percent). This situation is shown by comparing the beginning and end points of lines that represent starts plus replacements (uppermost solid line in Figure 9-A.3.1) and shipments (diamond-linked line in Figure 9-A.3.1). In 1980 the shipments line lies below the line for starts plus replacements. In 2002, the shipments line lies above the line for starts plus replacements. The more rapid increase in shipments, compared to housing starts plus replacements, suggests that the ratio of appliances per household increased during the study period.

Figure 9-A.3.1 Trends in Clothes Washer Shipments, Housing Starts, and Replacements

Economic variables, including price, cost, and income, may explain the increase in clothes washers per household. During the study period, clothes washer prices decreased 50 percent,[8, 9] operating costs fell 33 percent,[8] and median household income rose 16 percent.[13]

9-A.4 REGRESSION ANALYSIS OF VARIABLES AFFECTING APPLIANCE SHIPMENTS

Few data are available for estimating the effect of economic variables on the demand for appliances. Industry data regarding operating costs are incomplete—appliance energy use data are available for only 12 of the 1980–2002 study years. Industry price data also are incomplete—available for only 8 years of the study period for each type of appliance.

The lack of data suggests that regression analysis can at best evaluate broad trends, utilizing relatively few explanatory variables. This section begins by describing broad trends apparent in the economic and household data sets and then specifies a simple regression model to measure those trends, making assumptions to minimize the number of explanatory variables. Finally, results of the regression analysis are presented, along with an estimate of the price elasticity of demand for appliances. In section 9-A.4.5, DOE presents the results of regression analyses performed using more complex models, which are used to test the assumptions underlying the simple model. The results support the specification of the simple model and the price elasticity of appliance demand estimated with that model.

9-A.4.1 Broad Trends

In this section DOE reviews trends in the physical household and economic data sets and posits a simple approach for estimating the price elasticity of appliance demand. As noted above, household variables (housing starts and appliance replacements) explain most of the variability

in appliance shipments during the study period (1980–2002). A log regression of the form: shipments = a + b × housing starts + c × retirements indicates that the two variables explain 89 percent of the variation in refrigerator shipments, 97 percent of the variation in clothes washer shipments, and 97 percent of the variation in dishwasher shipments. DOE assumes the rest of the variability in shipments (referred to as "residual shipments") can be explained by economic variables. Below DOE presents a tabular method for measuring price elasticities.

To illustrate the tabular approach, DOE defined two new variables—residual shipments and total price. Residual shipments are defined as the difference between shipments and physical household demand (housing starts plus replacements). Total price, represented by the following equation, is defined as appliance price plus the present value of lifetime operating costs.[a]

$$\boldsymbol{TP} = \boldsymbol{PP} + \boldsymbol{PVOC}$$

Where:

TP =	total price,
PP =	appliance purchase price, and
PVOC =	present value of operating costs.

During the study period, residual shipments in proportion to total shipments increased 30 percent for refrigerators, 19 percent for clothes washers, and 23 percent for dishwashers. At the same time, total prices declined 47 percent, 45 percent and 48 percent for refrigerators, clothes washers, and dishwashers, respectively. Assuming that total price explains the entire change in per-household appliance usage, a rough estimate is calculated of the total price elasticity of demand equal to -0.48 for refrigerators, -0.32 for clothes washers and -0.37 for dishwashers (Table 9-A.4.1).

[a] Present value operating cost is calculated assuming a 19-year operating life for refrigerators, 14-year operating life for clothes washers, and a 12-year operating life for dishwashers. A 37-percent discount rate is used to sum annual operating costs into a present value operating cost.

Table 9-A.4.2 Tabular Estimate of Total Price Elasticity of Demand

	Residual Shipments million				Total Price 2002$			
Appliance	**1980**	**2002**	**Difference**	**Change %**	**1980**	**2002**	**Change %**	**Elasticity**
Refrigerator	-0.5	1.6	2.1	30	1,541	820	-61	-0.48
Clothes Washer	-1.0	0.2	1.1	19	1,042	567	-59	-0.32
Dishwasher	-1.0	-0.01	1.0	23	896	464	-64	-0.37

The negative correlation between total price and residual shipments suggested by the negative price elasticities is illustrated in a graph of residual shipments on the y-axis and total price on the x-axis (Figure 9-A.4.1).

Yellow points are observed price data; red points are interpolated price data.

Figure 9-A.4.2 Residual Shipments and Appliance Price

Household income rose during the study period, making it easier for households to purchase appliances. Assuming that a rise in income has a similar effect on shipments as a decline in price, the effect of income is incorporated by defining a third variable, termed *relative* price, which is calculated as total price divided by household income. The variable is represented by the following equation.[b]

$$RP = \frac{TP}{Income}$$

Where:

RP = relative price,
TP = total price, and
Income = household income.

[b] Recall that the income elasticity of demand cited in the literature review was 0.50, and the price elasticity of demand cited in the review averaged -0.35. Those results suggest that combining the effects of income and price will yield an elasticity less negative than price elasticity alone.

The percent decline in *relative* price for the three appliances divided by the percent decline in residual shipments suggests a rough estimate of *relative* price elasticity equal to -0.40 for refrigerators, -0.26 for clothes washers and -0.30 for dishwashers (Table 9-A.4.2)

Table 9-A.4.3 Estimate of Relative Price Elasticity of Appliance Demand

	Residual Shipments millions			*Relative* Price 1999$			
Appliance	**1980**	**2002**	**Change %**	**1980**	**2002**	**Change %**	**Elasticity**
Refrigerator	-0.532	1.597	30	0.041	0.019	-74	-0.40
Clothes Washer	-0.953	0.174	19	0.028	0.013	-72	-0.26
Dishwasher	-0.974	-0.005	23	0.024	0.011	-76	-0.30

9-A.4.2 Model Specification

The limited price data suggest it is appropriate to use a simple regression model to estimate the effect of economic variables on shipments, using few explanatory variables. The following equation, which DOE chose for this analysis, includes one physical household variable (housing starts plus replacements) and one *relative* price variable (the sum of purchase price plus operating costs, divided by income).

$$\boldsymbol{Ship} = \boldsymbol{a} + \boldsymbol{b} \times \boldsymbol{RP} + \boldsymbol{c} \times \lfloor \boldsymbol{Starts} + \boldsymbol{Rplc} \rfloor$$

Where:

Ship = quantity of appliance sold,
RP = relative price,
Starts = number of new homes, and
Rplc = number of appliances at the end of their operating life.

The natural logs are taken of all variables so that the estimated coefficient for each variable in the model may be interpreted as the percent change in shipments associated with the percent change in the variable. Thus, the coefficient *b* in the model is interpreted as the *relative* price elasticity of demand for the three appliances.

DOE used the following combined regression equation to estimate an average price elasticity of demand across the three appliances, using pooled data in a single regression. A combined regression specification is justified, given the limited data available and the similarity in price and shipment behavior across appliances (see Figure 9-A.4.1). Thus, the model represented by the combined regression equation is considered the basic model in DOE's analysis of appliance shipments.

$$\boldsymbol{Ship} = \boldsymbol{a} + \boldsymbol{b} \times \boldsymbol{RP} + \boldsymbol{c} \times \lfloor \boldsymbol{Starts} + \boldsymbol{Rplc} \rfloor + \boldsymbol{d} \times \boldsymbol{CW} + \boldsymbol{e} \times \boldsymbol{DW}$$

Where:

CW = quantity of clothes washers sold, and

DW = quantify of dishwashers sold.

9-A.4.3 Discussion of Model

The most important assumption used to specify the model is that changes in economic variables—income, price, and operating costs—are responsible for the total observed increase in residual appliance shipments during the study period. In other words, DOE assumed no impact from other possible factors, such as changing consumer preferences or increases in the quality of appliances. The assumption seems unlikely, but without additional data, the effect of other variables on the price elasticity of demand cannot be measured. DOE effectively assumed that changes in consumer preferences and appliance characteristics, while affecting which models are purchased, had relatively little effect on the total number of appliances purchased in a year.

Three additional assumptions used to specify the model deserve comment. The *relative* price variable is specified, assuming that (1) the correct implicit discount rate was used to combine appliance price and operating costs and that (2) rising income has the same effect on shipments as does falling total price. In addition, the "starts + replacements" variable is specified assuming (3) that starts and replacements have similar effects on shipments.

To investigate the first assumption about discount rates, DOE calculated "present-value operating cost" using a 20-percent implicit discount rate and performed a second regression analysis based on the models described in the previous equations. The results of this analysis, presented in section 9-A.4.4, indicate that the elasticity of *relative* price is fairly insensitive to changes in discount rate.

To investigate the second and third assumptions, DOE specified a regression model that separates income from total price and replacements from starts, thereby adding two explanatory variables to the basic model. The following equation shows the separations.

$$\boldsymbol{Ship = a + b \times TP + c \times Incone + d \times Start + e \times Rplc + f \times CW + g \times DW}$$

The results of the regression analysis using this model are presented in section 9-A.4.5. The results suggest that the elasticity of total price (coefficient *b*) is relatively insensitive to changes in the treatment of income and "starts + replacements" in the model.

9-A.4.4 Analysis Results

The following sections describe results of analyses using both the individual and combined models for appliances. Also described are the effects of a lower consumer discount rate and disaggregated variables.

9A.4.4.1 Individual Appliance Model

The individual appliance regression equations are specified as shown by the following equation.

$$Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor$$

In regression analysis of this model, the elasticity of *relative* price (*b*) is estimated to be -0.40 for refrigerators, -0.31 for clothes washers and -0.32 for dishwashers (Table 9-A.4.3), averaging -0.35. Those elasticities are similar to the ones reported in the literature survey for appliances (Table 9-A.2.1). They are remarkably similar to the price elasticities calculated using a tabular approach (Table 9-A.4.2).

The estimated coefficient associated with the "starts + replacements" variable is close to one. A coefficient equal to one for this variable would imply that, holding economic variables constant, shipments increase in direct proportion to an increase in "starts + replacements." The high values for R-squared (greater than 0.95) and t-statistics (t-stat in the table; greater than 5) in the results provide a measure of confidence in the analysis, despite the small data set.

Table 9-A.4.4 Results of Individual Appliance Models

	Refrigerator		Clothes Washer		Dishwasher	
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Intercept	-1.51	-7.26	-1.47	-8.23	-2.08	-16.78
Relative Price	-0.40	-6.60	-0.31	-5.69	-0.32	-7.03
Starts + Replacements	1.05	5.90	1.08	6.41	1.35	11.46
R^2	0.954		0.954		0.975	
Observations	23		23		23	

9A.4.4.2 Combined Appliance Model

The combined appliance regression equation is specified as shown in the next equation.

$$Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor + d \times CW + e \times DW$$

This regression analysis indicates that the model fits the shipments data well (high R-squared), and that the variables included in the model are statistically significant (Table 9-A.4.4). Based on this model the elasticity of *relative* price estimated is -0.34, close to the average value estimated by the individual appliance models (-0.35). The elasticity also is close to estimates reported in the literature survey and calculated using the tabular approach described in section 9-A.4.1.

Table 9-A.4.5 Results of Combined Appliance Model

Variable	**Coefficient**	**t-stat**
Intercept	-1.60	-15.54
Relative Price	-0.34	-10.74
Starts + Replacements	1.21	13.95
CW	-0.20	-9.04
DW	-0.32	-6.58
R^2	0.983	
Observations	69	

9-A.4.5 Additional Regression Specifications and Results

As described in section 9-A.4.3, DOE used three assumptions to specify its appliance models. The first, made to aggregate appliance price and operating cost, is that the price variable in the basic regression model is a 37-percent implicit discount rate. The second states that the implicit price variable is defined assuming that rising income has the same effect on shipments as does falling total price. The third states that the "starts + replacements" variable is defined assuming that housing starts have a similar effect on shipments as do appliance replacements.

9A.4.5.1 Lower Consumer Discount Rate

To investigate the first assumption about discount rates, DOE calculated present-value operating costs using a 20-percent implicit discount rate and performed a second regression analysis based on the models described in earlier equations. The estimated coefficient associated with the *relative* price variable in these regressions is almost identical to the coefficients estimated for the same variable based on a 37-percent implicit discount rate. The elasticity of *relative* price calculated using a 20-percent discount rate is -0.33 in the combined regression and averages -0.35 for the three appliances (Table 9-A.4.5 and Table 9-A.4.6). The elasticity of price calculated using a 37-percent discount rate is -0.34 in the combined regression and averages -0.35 for the three appliances. DOE concludes from this analysis that the elasticity of *relative* price is fairly insensitive to changes in the discount rate.

Table 9-A.4.6 Combined Results, 20-Percent Discount Rate

Variable	Coefficient	t-stat
Intercept	-1.53	-14.61
Total price/income	-0.33	-10.69
Starts + Replacements	1.20	13.65
Clothes Washers	-0.18	-8.69
Dishwashers	-0.32	-6.57
R^2	0.982	
Observations	69	

Table 9-A.4.7 Individual Results, 20-Percent Discount Rate

	Refrigerators		Clothes Washers		Dishwashers	
Variable	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Intercept	-1.36	-6.26	-1.41	-7.49	-2.04	-17.23
Total Price/Income	-0.38	-6.50	-0.32	-5.29	-0.33	-7.30
Starts + Replacements	1.04	5.73	1.06	5.83	1.34	11.64
R^2	0.953		0.950		0.977	
Observations	23		23		23	

9A.4.5.2 Disaggregated Variables

To investigate its second and third assumptions (identified in section 9-A.4.3), DOE constructed a regression model that separates income from total price and replacements from starts, thus adding two additional explanatory variables to the basic model (identified in section 9-A.4.2).

$$\boldsymbol{Ship} = \boldsymbol{a} + \boldsymbol{b} \times \boldsymbol{TP} + \boldsymbol{c} \times \boldsymbol{Income} + \boldsymbol{d} \times \boldsymbol{Start} + \boldsymbol{e} \times \boldsymbol{Rplc} + \boldsymbol{f} \times \boldsymbol{CW} + \boldsymbol{g} \times \boldsymbol{DW}$$

The estimated coefficient associated with the total price variable in these regressions is almost identical to the coefficients estimated for the *relative* price variable reported above. The elasticity of total price in the above equation is -0.36 in the combined appliance regression and averages -0.35 for the three appliances (Table 9-A.4.7 and Table 9-A.4.8). The elasticity of *relative* price based on the model described in section 9-A.4.2 is -0.34 in the combined regression (Table 9-A.4.4) and averages -0.35 across the individual appliances (Table 9-A.4.3). DOE concludes that the price elasticity calculated in this analysis is relatively insensitive to the specification of the variables for household income and "starts + replacements" in the model.

Table 9-A.4.8 Disaggregated Results: Combined Appliances, 37-Percent Discount Rate

Variable	Coefficient	t-stat
Intercept	-2.92	-1.26
Income	0.58	2.92
Total Price	-0.36	-7.06
Housing Starts	0.44	10.02
Replacements	0.62	8.12
Clothes Washers	-0.24	-9.25
Dishwashers	-0.46	-7.68
R^2	0.985	
Observations	69	

Table 9-A.4.9 Disaggregated Results: Individual Appliances, 37-Percent Discount Rate

	Refrigerators		Clothes Washers		Dishwashers	
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Intercept	-6.19	-2.24	-6.64	-1.63	1.00	0.23
Income	0.89	3.80	0.87	2.31	0.20	0.52
Total Price	-0.35	-5.48	-0.27	-2.51	-0.43	-5.18
Housing Starts	0.41	7.38	0.25	3.29	0.62	8.24
Replacements	0.56	6.06	0.56	2.09	0.65	5.86
R^2	0.984		0.985		0.979	
Observations	23		23		23	

9-A.5 LONG-RUN IMPACTS

As noted in Table 9-A.2.1, the literature review provides price elasticities during both short and long periods, also referred to as short-run and long-run price elasticities. As noted in the first two rows of Table 9-A.2.1, one source (Hymans) indicates that for automobiles the price elasticity of demand differs significantly over the short run and long run.[1] Because DOE's forecasts of shipments and national impacts due to standards comprises a 30-year period, consideration must be given to how the *relative* price elasticity is affected once a new standard takes effect.

DOE considers the *relative* price elasticities determined in section 9-A.4 to be short-run elasticities. DOE was unable to identify sources specific to household durable goods, such as appliances, to indicate how short-run and long-run price elasticities differ. To estimate how the *relative* price elasticity changes over time, therefore, DOE relied on the Hymans study pertaining to automobiles. Table 9-A.5.1 shows how, based on the Hymans study, the price elasticity of demand for automobiles changes in the years following a change in purchase price. With increasing years after the price change, the price elasticity becomes more inelastic until it reaches a terminal value about the 10th year following the price change.

Table 9-A.5.10 Change in Price Elasticity of Demand for Automobiles Following a Change in Purchase Price

	Years Following Price Change					
	1	**2**	**3**	**5**	**10**	**20**
Price Elasticity of Demand	-1.20	-0.93	-0.75	-0.55	-0.42	-0.40
Relative Change in Elasticity to 1st year	1.00	0.78	0.63	0.46	0.35	0.33

Source: Hymans, 1971.

Based on the relative change in the automobile price elasticity of demand shown in Table 9-A.5.1, DOE developed a time-series of *relative* price elasticities for home appliances. Table 9-A.5.2 presents the time-series.

Table 9-A.5.11 Change in *Relative* Price Elasticity for Home Appliances Following a Change in Purchase Price

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

9-A.6 PRICE IMPACTS ON THE MARKET SHARE OF FRONT AND TOP LOADER CLOTHES WASHERS

This section provides preliminary estimates of cross-price impacts on the market share of top-loading and front-loading clothes washers. Cross-price impacts measure the change in the market share of one washer configuration (*e.g.*, top loaders) caused by a change in the price of the other washer configuration (*e.g.*, front loaders).

9-A.6.1 Data and Method Used to Perform Analysis

The data DOE used to conduct this analysis derive from washer sales data collected by the NPD Group between 2004 and 2009.[c] The NPD data includes comprehensive product information, including number of programmed wash cycles available, loading type, type of sensor, capacity, ENERGY STAR certification, unit price, unit sales, and so on. For this analysis, cross-price impacts are estimated using a subset of the NPD data including loading type, washer capacity, number of programmed cycles, control type, monthly market share, and monthly average price. Figure 9-A.6.1, Figure 9-A.6.2 and Figure 9-A.6.3 summarize the data used in this analysis.

[c] The subset of data points DOE used in this analysis accounts for around 84% of the total NPD data from 2004 through2009. The other 16% of the data points were deleted due to missing values of some washer attributes.

Figure 9-A.6.1 Front- and Top-Loading Clothes Washer Price Trends (monthly average prices)

Weighted average price for each class of clothes washer was calculated by dividing the total dollar value of all sales in a given month by the number of units sold in that month. These data show two trends: First that the absolute price of front-loading clothes washers is decreasing, and second, that the absolute price of top-loading clothes washers is increasing. The decreasing price trend of front-loading clothes washers may be explained by their increasing market share and increasing number of absolute unit sales, which allow manufacturers to take advantage of economies of scale to lower prices.

The relationship between historical trends of front- and top-loading clothes washers may be better viewed as ratios, as in the following two figures. In each figure, individual trends are ratios of front-loading (numerator) to top-loading (denominator) clothes washers. The points above 1.00 represent a higher proportion going to front-loaders, and the points below 1.00 represents a higher proportion going to top-loaders.

Figure 9-A.6.2 Trends in Relative Sales and Prices of Front- and Top-Loading Clothes Washers

The price trend shown in Figure 9-A.6.2, based on sales-weighted price data, shows that in 2004, the average price of front-loaders was on average 2.5 times more than the average price of top-loaders. However, the trend decreases continuously over the six-year period, showing that in late 2009 this ratio has dropped to about 1.5; at this point front-loaders cost about 1.5 times as much as top-loaders. This trend results both from the decreasing average price of front-loaders and the increasing average price of top-loaders, as illustrated in Figure 9-A.6.1 above.

The unit sales ratio complements the price ratio and demonstrates the decreasing market dominance of top-loaders. In January 2004 (the left-most point on the chart), a ratio of 0.15 indicates that total front-loading washing machine sales were only 15% of total top-loading washing machine sales. However, this ratio has moved steadily toward unity, even crossing the 1.00 line at one point in late 2009. The unit sales trend indicates that total sales of front-loaders will equal or surpass sales of top-loaders in the near future.

Together, these two trends illustrate an important point: that the prices of top-loaders and front-loaders are growing closer, and that the market share breakdown is becoming increasingly balanced.

Figure 9-A.6.3 Trends in Relative Volume, Number of Cycles and Electric Controls of Front- and Top-Loading Clothes Washers

Figure 9-A.6.3 illustrates three trends: 1) The relative size of washer tub volume, 2) the relative number of available wash cycles, and 3) the relative number of washer models with electronic controls. We explain each of these in turn.

Washer tub volume has been increasing in absolute terms for both front-loaders and top-loaders. To calculate a ratio trend, we take the weighted average of front-loader washer tub sizes for a given month and divide by the weighted average of top-loader washer tub volume for the same month. While both of these averages have increased steadily, they do so in parallel, producing a nearly flat trend line. We note only that the trend hovers at slightly above one, showing that front-loaders tend to have a slightly larger capacity on average.

Available wash cycles refers to the number of pre-programmed wash cycles in a given model. For example, a simple clothes washer might have a cold water permanent press cycle, a hot water permanent press cycle, and warm water delicate cycle, for a total of three available wash cycles. Here, we calculate the ratio between the average number of wash cycles available on front-loaders in a given month (weighted by sales) and the average number of wash cycles available on top-loaders in the same month (also weighted by sales). Data shows that the average number of cycles for both classes of clothes washer has remained at about 10 between 2004 and 2008. Then in 2009 we see an increase to about 13 cycles for top-loaders, which pulls the ratio down to about 0.7 for that year, as seen in the chart above.

Electronic controls differentiate a particular model of clothes washer from one with mechanical controls. Today, consumers can find both top- and front-loaders with either mechanical or electronic controls. Here we calculate the ratio of the total number of front-loading models available with electronic controls to the total number of top-loading models available with electronic controls. These numbers are not sales-weighted, but simply reflect the total number of models that consumers purchased. In January 2004, manufacturers offered 22 front-loading models with electronic controls and 33 top-loading models with electronic controls.

By January 2009 this number had increased to 207 and 50, respectively. The trend line above illustrates this relatively sharp increase in the number of available front-loaders with electronic controls.

In order to estimate the impact of price changes on market share, DOE applied a logistic regression method to regress market share on price variables and other attributes. The basic form of a logistic regression is:

$$p_i = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_{1,i} + \cdots + \beta_k x_{k,i})}}$$

With some simple operations, the model can be transformed to an equivalent log-linear form:

$$\ln\left(\frac{p_i}{1 - p_i}\right) = \beta_0 + \beta_1 x_{1,i} + \cdots + \beta_k x_{k,i}$$

In this case, p_i is the market share of either top- or front-loading clothes washers, and $\frac{p_i}{1-p_i}$ is the ratio of clothes washer market shares, *i.e.*, the relative probability of the market share of top and front-loading clothes washers. The explanatory variables include price-related variables, washer size and other washer attributes.

9-A.6.2 Regression Results

The logistic regression model equation estimated in our clothes washer analysis is shown below.

$$\ln\left(\frac{Market\ Share_{Front}}{1 - Market\ Share_{Front}}\right) = -2.985386 + 0.0035452 \times Price_{Top} - 0.0049114 \times Price_{Front} + 4.24347 \times \frac{Size_{Front}}{Size_{Top}}$$

Where:

$\frac{Market\ Share_{Front}}{1 - Market\ Share_{Front}}$ = the relative probability of the market share of front and top-loading clothes washers

$Price_{Top}$ = weighted monthly average price of top-loaders (as described in Figure 9-A.6.1)

$Price_{Front}$ = weighted monthly average price of front-loaders (as described in Figure 9-A.6.1)

$\frac{Size_{Fonrt}}{Size_{Top}}$ = ratio between the monthly weighted average of front-loaders tub volume and the monthly weighted average of top-loaders tub volume

The equation indicates that front loader market share is positively correlated with top loader price and size and negatively correlated with front loader price.[d] The price coefficients suggest that top- and front-loading washers are substitutes for each other. The positive coefficient associated with the size variable indicates that capacity is a desirable clothes washer feature for most consumers.

These regression results were used to derive the cross price impact of a change in the front loading washer price on the top loading market share (and vice versa). For example, these results suggest that a 10% increase in the price of front loader washers would lead to a 10.7 % decrease in top-loader market share, holding other variables constant and measured as changes from the reference case using average values for each variable. In this case, the front-loading cross-price impact (percent change in top-loading market share over percent change in front-loading price) is 1.07.[e] Similarly, these results indicate that a 20% price increase for top-loading washers would yield a 21.49 % increase in front-loading market share, measured as changes from the variable means. Thus, in this example the top-loader cross-price impact is also 1.07.

9-A.7 SUMMARY

This appendix describes the results of a literature search, tabular analysis, and regression analyses of the impact of price and other variables on appliance shipments. In the literature, DOE finds only a few studies that are relevant to the analysis and no studies after 1980 that use time-series price and shipments data. The information that can be summarized from the literature suggests that the demand for appliances is price-inelastic. Other information in the literature suggests that appliances are a normal good, so that rising incomes increase the demand for appliances. Finally, the literature suggests that consumers use relatively high implicit discount rates when comparing appliance prices and operating costs.

There are too few data available on prices and operating costs to perform a complex analysis of dynamic changes in the appliance market. Instead, DOE used available data to evaluate broad market trends and to perform simple regression analyses. The data indicate an increase in appliance shipments and a decline in appliance prices and operating costs for1980–2002. Household income also rose during that period. To simplify the analysis, DOE combined

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[d] All variables in this regression were statistically significant; the R^2 in the regression was 0.88.

[e] Price elasticity varies according to the reference price and market share – typically measured as changes from mean values for these variables in the data set. In our data, the reference top-loading washer price is $403.78, the reference front-loading washer price is $823.83, the corresponding reference top-loading washer market share is 71% and the corresponding reference front washer market share is 29%.

the available economic information into one variable, termed *relative* price, and used that variable in a tabular analysis of market trends and in a regression analysis.

DOE's tabular analysis of trends in the number of appliances per household indicates a price inelasticity of demand for residential clothes washers. DOE's regression analysis of the same variables suggests that the *relative* price elasticity of demand is -0.34, a figure consistent with estimates in the literature. Nevertheless, DOE stresses that the measure is based on a small data set and employs simple statistical analysis. More importantly, the measure is based on an assumption that economic variables, including price, income, and operating costs, explain most of the trend in appliances per household in the United States since 1980. Changes in appliance quality and consumer preferences may have occurred during that period, but they are not accounted for in this analysis.

The estimates of cross-price impacts on the market share provided in section 9-A.6 are intuitive, but preliminary. The positive cross-price impacts on the market share for both front- and top-loading clothes washers supports the assumption that the two types of washers are substitute goods. Although more information could be captured by incorporating more washer attributes in the regression for estimating cross-price impacts, those attributes may be highly correlated with each other and with the price variables. Further analysis needs to be done to determine the value of adding more variables in estimating cross elasticity or the value of using an alternative methodology to evaluate this problem. In general, we should expect to see a reduced price impact on the market share when more variables are included in the analysis. That is because many of the variables missing from this analysis, including changes in rebate programs and energy efficiency awareness, have impacted clothes market share.

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APPENDIX 10-A. USER INSTRUCTIONS FOR SHIPMENTS AND NATIONAL IMPACT ANALYSIS SPREADSHEETS

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APPENDIX 10-A. USER INSTRUCTIONS FOR SHIPMENTS AND NATIONAL IMPACT ANALYSIS SPREADSHEETS

10-A.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 residential clothes washers using Microsoft Excel spreadsheets that are available on DOE's website. <www.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers.html>

The latest version of the Microsoft Excel shipments and NIA workbook, which is posted on the DOE website, was tested using Microsoft Excel 2007. To execute the spreadsheet requires Microsoft Excel 2003 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 both front- and top-loading residential clothes washers comprises the following worksheets.

Charts	Contains tables and graphs showing summary results of the NIA: product purchase prices, market shares of front- and top-loading washers, and historical and forecasted shipments under each trial standard level (TSL). Tables present total savings in energy and water, discounted incremental product prices, and discounted operating cost savings.
Efficiency Distributions	Provides efficiency distributions through year 2044, in terms of shipment-weighted energy factor, under the base case and each standard level being considered for both front- and top-loading clothes washers.
Input and Summary	Contains user input selections under "User Inputs" and summary tables for the NIA under the chosen CSL. A summary table gives energy and water savings and those values discounted 7 percent and 3 percent (cumulative to 2044). The worksheet provides discounted incremental product prices and operating cost savings and their NPV, along with market shares of front- and top-loading washers. Data is also provided regarding weighted average energy and water use and price for base and standards cases, along with values for machine, standby, water heating, and dryer energy use.

	The worksheet enables the user to stipulate two parameters for the calculations: a relative price elasticity effect of -0.34, which is the default setting, or no impact; and whether the DOE Energy Information Administration's Annual Energy Outlook (AEO) 2010 energy price trend reflects an economic case that is reference (default), low-growth, or high-growth.
Historical Shipments	Contains historical shipments of front- and top-loading clothes washers, 1972–2008.
RCW Shipments Base Case	Provides data and two graphs related to annual historical and projected shipments of clothes washers through 2044 under the base case (the case with no new efficiency standards). The top chart shows data from 1990 – 2044 and the bottom chart shows data from 1986 – 2044. Also provides market shares of replacements and units for new housing, plus the saturation of clothes washers in households nationwide.
RCW-Shipments Standards Case	Provides data and a graph related to the annual historical and projected shipments of clothes washers through 2044 under the chosen CSL. Provides market shares of replacements and units for new housing. plus the saturation of clothes washers nationwide.
Base Calc PC	Contains shipments (replacement, new, and total), product costs, unit and total energy and water consumption, and operating costs for the base case. The sheet starts with a stock accounting of the chosen product and uses the survival function DOE developed to calculate the surviving stock each year.
Standards Calc PC	Contains shipments (replacement, new, and total), product costs, unit and total energy and water consumption, and operating costs for the chosen CSL. Also gives discounted values for costs and savings.
Housing Projections	Contains the projected housing stock, construction starts, and demolitions for the three AEO economic scenarios (reference, low growth, and high growth).
Fuel & Water Prices	Contains projected average energy (electricity, gas, and oil) and water prices to 2072 under each of the three AEO economic scenarios.
Heat Rates	Contains the marginal site-to-source conversion factors for both electricity and gas DOE used in the calculation of source energy savings.

Lifetime Contains data and the survival function DOE used to calculate clothes washer lifetimes. Presents a graph showing clothes washer lifetimes and gives the current average lifetime (14.2 years).

10-A.2 BASIC INSTRUCTIONS

Basic instructions for operating the NIA spreadsheets are given below.

1. After downloading the NIA 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 *Input and Summary*. Ensure that calculation options are set to "Automatic."

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. The user can change two of the model parameters listed in the white box labeled "User Inputs." The parameters are:
    a. Relative Price Elasticity: Use the drop-down arrow if you wish to change the default value of -0.34 to "No impact."
    b. Economic Growth: To the change from the default AEO reference case, use the drop-down arrow and select the desired growth level (low or high).

4. After selecting the parameters, use the cell labeled "TSL Level" to select the trial standard level to analyze. The associated efficiency distributions and growth trends are fixed as specified in Chapter 10 of this preliminary technical support document. After selecting the CSL level, click the "Enter" button to make your selected CSL effective.

5. The results are automatically updated for both product classes and are reported in the summary table to the right of the "User Inputs" box.

APPENDIX 10-B. NATIONAL PRODUCT AND OPERATING COSTS

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APPENDIX 10-B. NATIONAL PRODUCT AND OPERATING COSTS

10-B.1 INTRODUCTION

In this appendix, the U.S. Department of Energy (DOE) presents the components of the calculation of the net present value (NPV) associated with base-case and standards-case efficiencies for residential clothes washers. Components include the present value of the product costs (or total installed cost) and the present value of the operating costs for each of the two product types of residential clothes washers (front-loading and top-loading). The present value of product costs is also termed the cumulative national product costs; the present value of operating costs is also termed the cumulative national operating costs.

As presented in Chapter 10, National Impact Analysis, the NPV is described by the equation:

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

Where:

PVS = present value of savings in operating cost [including energy (electricity, gas, or oil) and water], and
PVC = present value of increased total installed costs (including product purchase price and installation cost).

DOE uses the following expressions to determine the PVS and PVC.

$$\boldsymbol{PVS = \sum OCS_y \times DF_y}$$

$$\boldsymbol{PVC = \sum TIC_y \times DF_y}$$

Where:

OCS = total annual operating cost savings each year summed over vintages of the product stock,
TIC = total annual installed cost increases each year summed over vintages of the product stock,
DF = discount factor in each year, and
y = year in the forecast (2015–2044).

PVS and PVC are determined for each year from the effective date of the standard to the year that units purchased in 2044 retire.

The present value of product costs (or total installed costs) and the present value of operating costs comprise the PVC and PVS, respectively. The PVC is determined by taking the difference between the present value of product costs for the base case and the present value of product costs for a standards case. The PVS is determined by taking the difference between the present value of operating costs for the base case and the present value of operating costs for a standards case.

10-B.2 RESULTS

The following tables show the present value of product costs (also known as cumulative national product costs) and the present value of operating costs (also known as cumulative national operating costs) for the two product classes of residential clothes washers. For each product type, two sets of results are presented: one based on a 3-percent discount rate, and another based on a 7-percent discount rate.

The tables provide the national product and operating costs for each trial standard level analyzed. Differences in national product and operating costs between the base case and each standard case also are presented. The difference between the total national product and operating costs for the base case and each standards case represents the NPV for that standard.

Tables 10-B.2.1 and 10-B.2.2 present the national PVC, PVS, and NPV for clothes washers at a real discount rate of 3 percent. Tables 10-B.2.3 and 10-B.2.4 present the national PVC, PVS, and NPV for clothes washers at a real discount rate of 7 percent.

Table 10-B.2.1 Front-Loading Clothes Washers: Cumulative National Product and Operating Costs with Net Present Value from 2015–2044, 3-Percent Discount Rate

Trial Standard Level	Incremental Equipment Cost *billion 2010$*	Operating Cost Savings *billion 2010$*	Total *billion 2010$*
1	1.35	-1.56	-2.92
2	2.52	-1.28	-3.79
3	4.56	-0.39	-4.96
4	13.84	-1.86	-15.71
5	16.56	6.49	-10.07

Table 10-B.2.2 Top-Loading Clothes Washers: Cumulative National Product and Operating Costs with Net Present Value from 2015–2044, 3-Percent Discount Rate

Trial Standard Level	Incremental Equipment Cost *billion 2010$*	Operating Cost Savings *billion 2010$*	Total *billion 2010$*
1	-0.18	22.92	23.10
2	-0.30	21.96	22.26
3	-0.41	35.84	36.25
4	-0.88	56.43	57.31
5	-0.60	59.94	60.54

Table 10-B.2.3 Front-Loading Clothes Washers: Cumulative National Product and Operating Costs with Net Present Value from 2015–2044, 7-Percent Discount Rate

Trial Standard Level	Incremental Equipment Cost *billion 2010$*	Operating Cost Savings *billion 2010$*	Total *billion 2010$*
1	0.80	-0.68	-1.48
2	1.48	-0.59	-2.07
3	2.52	-0.04	-2.56
4	8.11	-0.79	-8.89
5	9.69	2.94	-6.76

Table 10-B.2.4 Top-Loading Clothes Washers: Cumulative National Product and Operating Costs with Net Present Value from 2015–2044, 7-Percent Discount Rate

Trial Standard Level	Incremental Equipment Cost *billion 2010$*	Operating Cost Savings *billion 2010$*	Total *billion 2010$*
1	-0.10	10.10	10.20
2	-0.18	9.67	9.84
3	-0.22	15.35	15.57
4	-0.50	24.81	25.31
5	-0.32	26.35	26.67

APPENDIX 10-C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS USING ALTERNATIVE PRODUCT PRICE FORECASTS

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APPENDIX 10-C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS USING ALTERNATIVE PRODUCT PRICE FORECASTS

10-C.1 INTRODUCTION

The NPV results presented in chapter 10 reflect a price trend based on historical PPI data (1991-2010) for household laundry equipment. DOE also investigated the impact of different product price forecasts on the consumer net present value (NPV) for the considered TSLs for residential clothes washers. DOE considered three product price forecast sensitivity cases: (1) a trend based on the experience curve approach; (2) a trend based on the "chained price index--other consumer durable goods except ophthalmic" that was forecasted for *AEO2010*; (3) constant prices at 2010 levels.

10-C.2 EXPERIENCE RATE ESTIMATION

For one sensitivity case, DOE using the experience curve method to forecast future prices of clothes washers.[a] In the experience curve method, the real product price (or proxy thereof) is related to the cumulative production or "experience" with a product. A common functional relationship used to model the evolution of production costs is:

$$Y = aX^{-b}$$

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 or experience rate (*ER*), and is given by:

$$ER = 1 - 2^{-b}$$

In typical experience curve formulations, the experience rate parameter is derived using two historical data series: price (or cost) and cumulative production, which is a function of shipments during a long time span.

[a] A draft paper, "Using the Experience Curve Approach for Appliance Price Forecasting," posted on the DOE web site at http://www.eere.energy.gov/buildings/appliance_standards, summarizes the data and literature currently available to DOE that is relevant to price forecasts for selected appliances and equipment.

To derive an experience rate parameter for residential clothes washers, DOE obtained historical Producer Price Index (PPI) data for household laundry equipment spanning the time period 1980-2010 from the Bureau of Labor Statistics' (BLS). DOE used PPI data for household laundry equipment as representative of residential clothes washers because PPI data specific to residential clothes washers are not available. An inflation-adjusted price index for household laundry equipment was calculated by dividing the PPI series by the Consumer Price Index (CPI) "all items" index for the same years. This inflation-adjusted price index (shown in Figure 10-D.2.1) was used in subsequent analysis steps.

Figure 10-C.2.1 Historical Real Price Index for Household Laundry Equipment

DOE assembled a time-series of annual shipments for 1972-2008 for clothes washers and for 1946-2008 for clothes dryers. Decadal shipments for the 1940s, 1950s, 1960s and 1970s for clothes washers were obtained from the 2005 AHAM Fact Book. The annual and decadal shipments data were used to estimate cumulative shipments (production). Projected shipments after 2008 were obtained from the base case projections made for the NIA (see chapter 9 of this TSD). Figure 10-D.2.2 shows the shipments time series used in the analysis.

Figure 10-C.2.2 Historical Total Shipments of Household Laundry Equipment

To estimate an experience rate parameter, a least-squares power-law fit was performed on the unified price index versus cumulative shipments. See Figure 10-D.2.3. 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 10-C.2.3 Relative Price versus Cumulative Shipments of Household Laundry Equipment, with Power Law Fit

The parameter values obtained are:

$P_o = 127.95^{+27.4}_{-22.5}$ (95% confidence) for household laundry equipment, and
b = 0.775±0.034 (95% confidence) for household laundry equipment.

The estimated experience rate (defined as the fractional reduction in price expected from each doubling of cumulative production) is $41.6^{+1.3}_{-1.4}$% (95% confidence).

10-C.3 PRODUCT PRICE TRENDS FORECASTS

DOE derived a price factor index, with 2010 equal to 1, to forecast prices in each future year in the analysis period. DOE applied the same value to forecast prices for each residential clothes washer product class at each considered efficiency level.

For the experience rate sensitivity case, the index value in a given year is a function of the experience rate and the cumulative production forecast through that year, which is based on the shipments forecast described in chapter 9.

In addition to using the above case, DOE examined a constant real price sensitivity case. DOE also used a forecast based on the "chained price index--other consumer durable goods except ophthalmic" that was forecasted for *AEO2010*. This index is the most disaggregated

category that includes appliances. To develop an inflation-adjusted index, DOE normalized the above index with the chained price index--gross domestic product forecasted for *AEO2010*.[b]

Figure 10-D.3.1 shows the default price factor index and the indexes corresponding to each of the sensitivities. All indexes are adjusted for inflation.

Figure 10-C.3.1 Household Laundry Equipment Price Factor Indexes for the Default Case and Sensitivity Cases

[b] To extend the adjusted index past 2035, DOE used the average annual growth rate in 2026-2035.

10-C.4 RESIDENTIAL CLOTHES WASHER NPV RESULTS USING ALTERNATIVE LEARNING RATES

Table 10-C.4.1 Residential Clothes Washers: Net Present Value of Consumer Impacts Under Alternative Product Price Forecasts (3 Percent Discount Rate)

		Product Price Trend Case			
Trial Standard Level		**Default Experience Rate**	**Experience rate**	**AEO Price Index**	**Constant real prices**
		Billion 2010$			
1	Incr. Installed Cost	1.179	1.273	1.290	1.809
	Operating Cost Savings	21.361	21.361	21.361	21.360
	Net Present Value	20.182	20.088	20.071	19.552
2	Incr. Installed Cost	2.214	2.392	2.422	3.401
	Operating Cost Savings	20.686	20.686	20.686	20.685
	Net Present Value	18.472	18.294	18.263	17.284
3	Incr. Installed Cost	4.153	4.524	4.561	6.598
	Operating Cost Savings	35.444	35.443	35.443	35.442
	Net Present Value	31.291	30.920	30.883	28.843
4	Incr. Installed Cost	12.959	14.003	14.181	19.930
	Operating Cost Savings	54.561	54.559	54.559	54.554
	Net Present Value	41.602	40.556	40.378	34.624
5	Incr. Installed Cost	15.963	17.249	17.468	24.545
	Operating Cost Savings	66.438	66.436	66.435	66.428
	Net Present Value	50.475	49.187	48.968	41.883

Parentheses indicate negative (-) values.

Table 10-C.4.2 Residential Clothes Washers: Net Present Value of Consumer Impacts Under Alternative Product Price Forecasts (7 Percent Discount Rate)

		Product Price Trend Case			
Trial Standard Level		**Default Experience Rate**	**Experience rate**	**AEO Price Index**	**Constant real prices**
		Billion 2010$			
1	Incr. Installed Cost	0.695	0.738	0.757	1.000
	Operating Cost Savings	9.424	9.424	9.424	9.424
	Net Present Value	8.729	8.686	8.667	8.423
2	Incr. Installed Cost	1.301	1.383	1.419	1.877
	Operating Cost Savings	9.072	9.072	9.072	9.072
	Net Present Value	7.771	7.689	7.653	7.194
3	Incr. Installed Cost	2.302	2.469	2.521	3.455
	Operating Cost Savings	15.313	15.313	15.313	15.312
	Net Present Value	13.012	12.844	12.792	11.858
4	Incr. Installed Cost	7.605	8.085	8.291	10.981
	Operating Cost Savings	24.024	24.024	24.024	24.022
	Net Present Value	16.420	15.939	15.733	13.041
5	Incr. Installed Cost	9.370	9.961	10.215	13.528
	Operating Cost Savings	29.288	29.288	29.287	29.285
	Net Present Value	19.918	19.326	19.072	15.757

Parentheses indicate negative (-) values.

APPENDIX 10-D. NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS

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APPENDIX 10-D. NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS

10-D.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 2010* (AEO 2010).[i]

Figures 10-D.1.1 and 10-D.1.2 show the forecasts for housing starts and residential electricity prices under the different economic growth scenarios. *AEO2010* provides a forecast to 2035. To estimate the trend after 2035, DOE followed guidelines that the EIA had provided to the Federal Energy Management Program, which called for using the average rate of change for electricity during 2020–2035.

Figure 10-D.1.1 Housing Starts Forecast Under Alternative AEO2010 Economic Growth Scenarios

Figure 10-D.1.2 Average Residential Electricity Price Forecasts under Alternative AEO2010 Economic Growth Scenarios

10-D.2 NIA RESULTS FOR HIGH ECONOMIC GROWTH SCENARIO

Table 10-D.2.1 Cumulative National Energy Savings in Quads, High Economic Growth Scenario

Trial Standard Level	Efficiency Level Combination		NES	NWS
	Front	Top	*quads*	*trillion gal*
1	2	2	1.86	1.38
2	4	5	1.72	1.26
3	5	2, 6	2.37	3.51
4	7	7	3.29	6.10
5	8	8	3.79	7.80

Table 10-D.2.2 Cumulative Net Present Value of Consumer Benefits, High Economic Growth Scenario

Trial Standard Level	Efficiency Level Combination		3%	7%
	Front	Top	*billion 2010$*	*billion 2010$*
1	2	2	29.40	12.38
2	4	5	26.41	10.86
3	5	2, 6	47.77	19.32
4	7	7	66.32	25.86
5	8	8	80.86	31.52

10-D.3 NIA RESULTS FOR LOW ECONOMIC GROWTH SCENARIO

Table 10-D.3.1 Cumulative National Energy Savings in Quads, Low Economic Growth Scenario

Trial Standard Level	Efficiency Level Combination		NES	NWS
	Front	Top	*quads*	*trillion gal*
1	2	2	1.59	1.19
2	4	5	1.47	1.07
3	5	2, 6	2.02	3.00
4	7	7	2.82	5.22
5	8	8	3.24	6.68

Table 10-D.3.2 Cumulative Net Present Value of Consumer Benefits, Low Economic Growth Scenario

Trial Standard Level	Efficiency Level Combination		3%	7%
	Front	Top	*billion 2010$*	*billion 2010$*
1	2	2	22.62	9.79
2	4	5	20.15	8.49
3	5	2, 6	37.34	15.43
4	7	7	51.93	20.61
5	8	8	63.61	25.25

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[i] U.S. Department of Energy–Energy Information Administration. *Annual Energy Outlook 2010 with Projections to 2035*. May 2010. U.S. DOE–EIA: Washington, D.C. DOE/EIA-0383(2010).

APPENDIX 12-A MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE, GOVERNMENT REGULATORY IMPACT MODEL, AND COMPLETE MIA RESULTS

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12-A.1. MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDES

Residential Clothes Washer Rulemaking
Manufacturer Impact Analysis Interview Guide

The Association of Home Appliance Manufacturers (AHAM) and the American Council for an Energy Efficient Economy (ACEEE) recently released a multi-product standards agreement (Consensus Agreement) that addressed negotiated standards for refrigerators/freezers, clothes washers, clothes dryers, room air conditioners, and dishwashers. For clothes washers, the Consensus Agreement proposes updated standards for top-loading standard and top-loading product classes, as well as splitting the existing front-loading product class into front-loading standard and front-loading compact clothes washers. DOE's rulemaking process allows for a direct publication of a final rule if DOE concludes that standards proposed in the Consensus Agreement meet certain statutory criteria. In order to evaluate the product classes and standards proposed in the Consensus Agreement for residential clothes washers, DOE is requesting information on the topics in this questionnaire.

DOE is requesting information on the product classes in the table below.

Baseline Efficiencies for Considered Product Classes

Product Class	**Product Class Description**	**Baseline MEF** *(ft^3/kWh/cycle)*	**Baseline Standby Power** *(W)*
Top-Loading, Standard	Top-loading with capacity greater than 1.6 ft^3	1.26	0
Top-Loading, Compact	Top-loading with capacity less than 1.6 ft^3	0.65	0
Front-Loading, Standard	Front-loading with capacity greater than 1.6 ft^3	1.72	2.3
Front-Loading, Compact*	Front-loading with capacity less than 1.6 ft^3	N/A	N/A

*DOE is not aware of any compact front-loading clothes washers available on the market, and is especially interested in information on this product class to evaluate the proposed standard in the Consensus Agreement.

Any amended standards for clothes washers would be expressed in terms of the integrated modified energy factor (IMEF), as proposed in the test procedure NOPR published on September 21, 2010. 75 FR 57556. Based on the current definition, DOE expects IMEF to vary significantly from the current MEF metric. IMEF will account for standby and off mode energy consumption, as well as energy use from steam and self-cleaning cycles. The proposed test procedure also includes changes to the capacity measurement for top-loading washers, which will affect IMEF. The discussion below references efficiency levels in terms of MEF to avoid metrics unfamiliar to manufacturers.

1. KEY ISSUES

1.1 You previously indicated the following key issues in this rulemaking: [Fill in as appropriate]. Do these remain key issues for your company in this rulemaking, and are there any additional key issues you believe DOE should consider in this rulemaking?

2. ENGINEERING AND LIFE-CYCLE COST

Are the AHAM-supplied average incremental manufacturing costs at each efficiency level representative of costs your company incurs at each of these efficiency levels? Also, please indicate if the design options you previously stated for the given efficiency levels are still valid.

AHAM-Supplied Standard Top-Loading Incremental Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Incremental Cost** *(materials, labor, OH)*	**Actual Incremental Cost** *(if different)*	**Description of Design Options**
1.40	$3.08		
1.72	$8.39		
1.80	$13.02		
2.00	$23.99		
2.26	$59.25		

AHAM-Supplied Standard Front-Loading Incremental Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Incremental Cost** *(materials, labor, OH)*	**Actual Incremental Cost** *(if different)*	**Description of Design Options**
1.80	$2.13		
2.00	$6.09		
2.20	$15.73		
2.40	$38.89		
2.89	$72.13		

Front-loading design options (not specific to a certain efficiency level): larger drum and tub, less external hot water use and more internal heating, more efficient motors, higher spin speeds, more sophisticated drum designs, and less overall water usage.

At the time the Framework Document was published, the max-tech units had MEF ratings of 2.26 and 2.89 for top-loading and front-loading clothes washers respectively. DOE is now aware of top-loading clothes washers with a MEF of 2.57, and front-loading clothes washers with a MEF of 3.35. What design features and associated costs would be necessary to reach these efficiencies?

Do the design options and associated costs in the tables above also apply to the compact front- and top-loading product classes?

Please comment on any issues related to the following proposed changes to the DOE clothes washer test procedure and how they may impact the design options used to reach higher efficiencies for each product class, as appropriate:

2.1 Standby and Off Mode Power
How would accounting for standby and off mode power impact the measured efficiencies of clothes washers? Would the inclusion of standby and off mode power affect the design options currently used to reach higher efficiencies?

2.2 Steam Wash Cycles
How would accounting for steam wash cycles affect the measured efficiency of clothes washers with this feature compared to the efficiency as measured using the existing test procedure? Is it appropriate to account for steam wash cycles in the measured efficiency of clothes washers?

What percentage of your total shipments do clothes washers offering a steam wash cycle account for?

2.3 Self-Clean Cycles
How would including self-clean cycles affect the measured efficiency as compared to the current test procedure? What fraction of your total clothes washer shipments includes a pre-set self-clean cycle, and how frequently do you recommend consumers use such a cycle?

2.4 Use Factors
Will the proposed amendments to the use factors in the DOE test procedure significantly affect the measured efficiencies of any clothes washers? Are the proposed values consistent with actual consumer use? Can you provide any non-proprietary data related to consumer use of different cycles?

2.5 Capacity Measurement Method
Will the proposed capacity measurement method affect the design options you use to reach higher efficiencies?

2.6 Energy Test Cycle Definition
How will the changes to the energy test cycle definition change how your clothes washers are tested? Will this revised definition limit the design options available for reaching higher efficiencies?

3. CONVERSION COSTS

The MIA considers two types of conversion costs:

Capital conversion costs are one-time investments in plant, property, and equipment (PPE) necessitated by an amended energy conservation standard. These may be incremental changes to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.

Product conversion costs are costs related research, product development, testing, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.

The tables below show the AHAM-submitted average capital conversion costs for a number of efficiency levels. Please indicate if your expected capital conversion costs vary from the AHAM-submitted estimate. In the description column, DOE is interested in understanding the kinds of changes that would need to be implemented to production lines and production facilities at each efficiency level. Where applicable, please quantify the number and cost of new production equipment, molds, etc. that would be required to implement the specified design changes.

AHAM-Supplied Standard Top-Loading Capital Conversion Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Capital Conversion Costs ($mm)**	**Actual Capital Conversion Cost** *(if different)*	**Description**
1.40	$1.51		
1.72	$34.98		
1.80	$37.84		
2.00	$41.76		
2.26	$60.88		

AHAM-Supplied Standard Front-Loading Capital Conversion Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Capital Conversion Costs ($mm)**	**Actual Capital Conversion Cost** *(if different)*	**Description**
1.80	$0.85		
2.00	$0.86		
2.20	$13.32		
2.40	$19.46		
2.89	$25.78		

The tables below show the AHAM-submitted average product conversion costs for a number of efficiency levels. Please indicate if your expected product conversion costs vary from the AHAM-submitted estimate. In the description column, DOE is interested in understanding such expenses as product development, prototyping, testing, certification, and marketing. In the description column, please describe the assumptions behind the estimates provided.

AHAM-Supplied Standard Top-Loading Product Conversion Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Product Conversion Costs**	**Actual Product Conversion Cost** ***(if different)***	**Description**
1.40	$0.93		
1.72	$1.43		
1.80	$3.62		
2.00	$7.95		
2.26	$12.84		

AHAM-Supplied Standard Front-Loading Product Conversion Costs

MEF *(ft^3/kWh/cycle)*	**AHAM Average Product Conversion Costs**	**Actual Product Conversion Cost** ***(if different)***	**Description**
1.80	$0.53		
2.00	$0.53		
2.20	$3.10		
2.40	$5.91		
2.89	$11.48		

Are the capital and product conversion costs described above applicable to the compact product classes as well? Would the magnitude and nature of the conversion costs differ for the compact product classes?

Please provide additional qualitative information to help DOE understand the types and nature of your investments, including the plant and tooling changes and the product development effort required at different efficiency levels.

4. MARKUPS AND PROFITABILITY

DOE estimated the manufacturer production costs for the two standard product classes of residential clothes washers. DOE assumed the other two compact product classes would have similar baseline markup values. DOE defines manufacturer production cost as all direct costs associated with manufacturing a product: direct labor, direct materials, and overhead (which includes depreciation). The manufacturer markup is a multiplier applied to manufacturer production cost to cover non-production costs, such as SG&A and R&D, as well as profit. *It does not reflect a "profit margin."*

The manufacturer production cost multiplied by the manufacturer markup equals the manufacturer selling price. Manufacturer selling price is the price manufacturers charge their first customers, but *does not* include additional costs along the distribution channels.

Please comment on the baseline markups DOE calculated as compared to your company's baseline markups for the clothes washer product classes.

Residential Clothes Washer Baseline Manufacturer Markups by Product Class

Product Class	Product Class Description	Estimated Baseline Markup	Manufacturer Comments or Revised Estimates
Top-Loading, Compact	Top-loading with capacity less than 1.6 ft^3	1.22	
Top-Loading, Standard	Top-loading with capacity greater than 1.6 ft^3	1.22	
Front-Loading, Compact	Front-loading with capacity less than 1.6 ft^3	1.30	
Front-Loading, Standard	Front-loading with capacity greater than 1.6 ft^3	1.30	

One of the possible scenarios DOE uses to model impacts on industry profitability is the impact of commoditization of premium products. Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding if efficiency is a feature that earns a premium. Within each product class, do markups vary by efficiency level? If yes, please provide information about the markups at efficiencies above the baseline in the tables below. Would these markups also vary for compact product classes?

Estimated Standard Top-Loading Markups by Efficiency Level

MEF *(ft^3/kWh/cycle)*	**Estimated Markup**	**Manufacturer Comments**
1.40		
1.72		
1.80		
2.00		
2.26		

Estimated Standard Front-Loading Markups by Efficiency Level

MEF *(ft^3/kWh/cycle)*	**Estimated Markup**	**Manufacturer Comments**
1.80		
2.00		
2.20		
2.40		
2.89		

Would you expect changes in your estimated profitability following an amended energy conservation standard? If so, please explain why. Can you suggest any scenarios that would model these expected changes?

5. FINANCIAL PARAMETERS

In order to accurately collect information about clothes washer manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Financial Parameters for Residential Clothes Washer Manufacturing

GRIM Input	Definition	Industry Estimated Value *(%)*	Your Actual (If Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	34.3	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	8.0	
Working Capital	Current assets less current liabilities (percentage of revenues)	6.5	
Net PPE	Net plant property and equipment (percentage of revenues)	17.7	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	11.3	
R&D	Research and development expenses (percentage of revenues)	2.2	
Depreciation	Amortization of fixed assets (percentage of revenues)	4.7	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	2.7	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	83.0	

6. ADDITIONAL IMPACTS

You previously indicated the following regulatory burdens: [Fill in as appropriate]. Do these still represent regulatory burdens, and are there any additional regulatory burdens at this time? What costs do you anticipate incurring to meet these regulations?

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. Where are your residential clothes washer facilities that produce products for the United States located? Please also provide employment levels and total washer shipments at each of these facilities.

At what efficiency levels would you consider relocating current domestic production abroad?

Are you aware of any small businesses, niche manufacturers, or component manufacturers for which amended energy conservation standards would have a severe impact? If so, why?

Have any of your US facilities qualified for grants available through the American Recovery and Reinvestment Act? Has your company reached the $75 million limit for efficient appliances under the Energy Improvement and Extension Act of 2008? How many shipments of washers qualifying for a $250 production tax credit under the Energy Improvement and Extension Act do you anticipate manufacturing in 2010?

Information Request for Compact-Size Product Classes for Residential Clothes Washers

The United States Department of Energy (DOE) is currently reviewing energy conservation standards for residential clothes washers, including the standards proposed in the AHAM-ACEEE Multi-Product Standards Agreement ("Consensus Agreement"). In particular, DOE would like to understand the rationale for the proposed efficiency standards for the top-loading compact and front-loading compact product classes.

1. Consensus Agreement Standard Levels

Table 1 shows the proposed standards in the Consensus Agreement.

Table 1. AHAM-ACEEE Multi-Product Standards Agreement for Residential Clothes Washers

Product Description	New Standard Jan. 1, 2015 (MEF/WF)	New Standard Jan. 1, 2018 (MEF/WF)
Top-Loading, Compact (less than 1.6 cubic feet capacity)	1.26 / 14.0	1.81 / 11.6
Top-Loading, Standard	1.72 / 8.0	2.0 / 6.0
Front-Loading, Compact (less than 1.6 cubic feet capacity)	1.72 / 8.0	
Front-Loading, Standard	2.2 / 4.5	

Table 2 compares the Consensus Agreement standards for the compact product classes to the current DOE standard, as well as the efficiency levels of compact top-loaders currently on the market.

Table 2. Efficiency Levels for Compact-Size Residential Clothes Washers

Efficiency Level Source	Efficiency Level	
	MEF	WF
Top-Loading, Compact		
DOE Standard	0.65	none
Level 1 (currently on the market)	0.78	13.9
Level 2 (currently on the market)	1.00	12.7
Consensus Agreement, 2015	1.26	14.0
Consensus Agreement, 2018	1.81	11.6
Front-Loading, Compact		
DOE Standard	1.26	none
Consensus Agreement, 2015	1.72	8.0

Questions:

- Top-loading compact
  - How were the standards for the top-loading compact product class established?
  - What was the rationale for the tiered standards?
  - Are you aware of any products on the market that meet the 2015 standards? 2018 standards?
  - Within the top-loading compact product class, what percentage market share do your company's shipments represent?
  - Do you foresee any potential changes in the competitive landscape for compact clothes washers due to the proposed standards?
- Front-loading compact
  - How were the proposed standards for the front-loading compact product class established?
  - Are you aware of any compact front-loaders on the market that meet the proposed standards? If not, do you foresee any entrants into this market in the future?

2. Design Options and Costs for Achieving Proposed Standard Levels

The inclusion of more stringent standards for top-loading compact and front-loading compact product classes in the Consensus Agreement implies that these standards are technologically achievable and economically justifiable. Because the proposed standards for the top-loading product class represent a significant improvement over current standards, DOE would like to better understand how these higher standard levels can be achieved. Table 3 shows the design options considered for standard-size top-loading clothes washers.

Table 3. Design Options for Standard-Size Top-Loading Clothes Washers

Design Options	Applicable to Compact Product Class?
More Advanced Controls	
Adaptive fill control (more accurate pressure switches)	
Temperature control (more accurate sensors)	
Water inlet valves (more accurate flow control)	
Electronic controls	
Accelerometers	
Motor Improvements	
More efficient motor	
Variable speed drive	
Higher spin speeds	
Basket/Drum Modifications	
Basket shape modification	
Stainless steel basket	
Larger capacity	
Stronger basket	
Agitator modification	
Reduced Water Consumption	
Spray rinse	
Recirculation pumps	
Gray-water rinse	
Structural Improvements	
Better suspension system	
Out-of-balance detection	
Operational Design Options	
Longer cycle times	
Lower water temperatures	

Questions:

- What design options are available for the compact product classes to meet the higher standard levels?
- What design options are most likely to be used to reach the proposed 2015 standards? The 2018 standards?
- What are the average costs associated with meeting each incremental standard level? (See Table 4)

Table 4. Cost Associated with Meeting Each Incremental Efficiency Level

Efficiency Level Source	Efficiency Level		Incremental Cost ($/Unit)
	MEF	WF	
Top-Loading, Compact			
DOE Standard	0.65	none	
Level 1 (currently on the market)	0.78	13.9	
Level 2 (currently on the market)	1.00	12.7	
Consensus Agreement, 2015	1.26	14.0	
Consensus Agreement, 2018	1.81	11.6	
Front-Loading, Compact			
DOE Standard	1.26	none	
Consensus Agreement, 2015	1.72	8.0	

- Are there any significant differences between product types or platforms (*e.g.* stacked washer/dryer vs. portable top-loading washer) that could affect the ability for a particular product type to achieve the proposed standard levels?
- Can the front-loading compact efficiency standards be achieved assuming similar design options as “nearly compact” front-loaders ranging from 1.6-2.4 cubic feet?

3. Consumer Utility

DOE would like to better understand the unique consumer utility offered by compact-size clothes washers.

Questions:

- Does the market continue to demand clothes washers with capacity less than 1.6 cubic feet?
- Are the disparate compact top-loading products considered substitutes for each other? Or does each distinct product type satisfy a unique niche within the market? (*e.g.* stacked washer/dryer vs. portable top-loading washer)
- Would the proposed standards have any negative impacts on consumer utility of compact-size clothes washers?

12-A.2. GOVERNMENT REGULATORY IMPACT MODEL

12-A.2.1 Introduction and Purpose

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards and other regulations on manufacturers. The basic mode of analysis is to estimate the change in value of the industry or manufacturers(s) following a regulation or a series of regulations. The model structure also allows an analysis of multiple products with regulations taking effect over a period of time, and of multiple regulations on the same products.

Industry net present value is defined, for the purpose of this analysis, as the discounted sum of industry free cash flows plus a discounted terminal value. The model calculates the actual cash flows by year and then determines the present value of those cash flows both without an energy conservation standard (*i.e.*, the base case) and under different trial standard levels (TSLs).

Output from the model consists of summary financial metrics, graphs of major variables, and, when appropriate, access to the complete cash flow calculation.

12-A.2.2 Model Description

The basic structure of the GRIM is a standard annual cash flow analysis that uses manufacturer selling prices, manufacturing costs, a shipments forecast, and financial parameters as inputs and accepts a set of regulatory conditions as changes in costs and investments. The cash flow analysis is separated into two major blocks: income and cash flow. The income calculation determines net operating profit after taxes. The cash flow calculation converts net operating profit after taxes into an annual cash flow by including investment and non-cash items. Below are definitions of listed items on the printout of the output sheet (see Section J.2.3).

Unit Sales: Total annual shipments for the industry were obtained from the National Impact Analysis Spreadsheet;

Revenues: Annual revenues - computed by multiplying equipment unit price at each efficiency level by the appropriate manufacturer markup;

Labor: The portion of cost of goods sold (COGS) that includes direct labor, commissions, dismissal pay, bonuses, vacation, sick leave, social security contributions, fringe, and assembly labor up-time;

Material: The portion of COGS that includes materials;

Overhead: The portion of COGS that includes indirect labor, indirect material, energy use, maintenance, depreciation, property taxes, and insurance related to assets. While included in overhead, the depreciation is shown as a separate line item;

Depreciation: Annual depreciation computed as a percentage of COGS. While included in overhead, the depreciation is shown as a separate line item;

Stranded Assets: In the year the standard becomes effective, a one time write-off of stranded assets is accounted for;

Standard SG&A: Selling, general, and administrative costs are computed as a percentage of *Revenues (2)*;

R&D: GRIM separately accounts for ordinary research and development (R&D) as a percentage of *Revenues (2)*;

Product Conversion Costs: Product conversion costs are one-time investments in research, development, testing, and marketing focused on making product designs comply with the amended energy conservation standard. GRIM allocates these costs over the period between the standard's announcement and effective dates;

Earnings Before Interest and Taxes (EBIT): Includes profits before deductions for interest paid and taxes;

EBIT as a Percentage of Sales: GRIM calculates EBIT as a percentage of sales to compare with the industry's average reported in financial statements;

Taxes: Taxes on *EBIT (11)* are calculated by multiplying the tax rate contained in Major Assumptions by *EBIT (11)*.

Net Operating Profits After Taxes (NOPAT): Computed by subtracting Cost of Goods Sold ((3) to (6)), SG&A (8), R&D (9), Product Conversion Cost (10), and Taxes (13) from Revenues (2).

NOPAT repeated: NOPAT is repeated in the Statement of Cash Flows;

Depreciation repeated: Depreciation is added back in the Statement of Cash Flows including stranded assets because both are non-cash expenses;

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.

Cash Flow From Operations: Calculated by taking *NOPAT (15)*, adding back non-cash items such as a *Depreciation (16)*, and subtracting out *Change in Working Capital (17)*;

Ordinary Capital Expenditures: Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of *Revenues (2)*;

Capital Conversion Costs: Capital conversion costs costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new product designs can be fabricated and assembled under the new regulation;

Capital Investments: Total investments in property, plant, and equipment are computed by adding Ordinary Capital Expenditures (19) and Conversion Capital Expenditures (20);

Free Cash Flow: Annual cash flow from operations and investments; computed by subtracting *Capital Investment (21)* from *Cash Flow from Operations (18)*;

Terminal Value: Estimate of the continuing value of the industry after 2044. Computed by growing the Free Cash Flow in year 2044 at a constant rate in perpetuity;

Present Value Factor: Factor used to calculate an estimate of the present value of an amount to be received in the future;

Discounted Cash Flow: Free Cash Flows (22) multiplied by the *Present Value Factor (24)*. For 2042 the discounted cash flow includes the discounted *Terminal Value (23)*; and

Industry Value thru 2044: The sum of Discounted Cash Flows (25).

STANDARD CASE SCENARIO			2008	2009	2010	Base Year 2011	2012	2013	2014
Industry Income Statement									
Unit Sales			8.3	8.1	8.6	9.2	9.3	9.3	9.4
Revenues			3,816.6	3,855.7	4,211.9	4,492.9	4,482.8	4,435.6	4,409.6
Cost of Sales									
	Labor		436.0	428.7	461.2	486.2	480.7	472.5	467.4
	Material		2,123.0	2,158.9	2,367.0	2,531.9	2,531.4	2,508.7	2,496.8
	Overhead		300.8	294.8	316.4	333.0	328.9	323.0	319.2
	Depreciation		166.1	167.4	182.7	194.7	194.1	191.9	190.7
	Stranded Assets		$ -	$ -	$ -	$ -	$ -	$ -	$ -
Selling, General and Administrative									
	Standard SG&A		$ 431.3	$ 435.7	$ 475.9	$ 507.7	$ 506.6	$ 501.2	$ 498.3
	R&D		$ 84.0	$ 84.8	$ 92.7	$ 98.8	$ 98.6	$ 97.6	$ 97.0
	Product Conversion Costs		$ -	$ -	$ -	$ -	$ -	$ -	$ 2.1
Earnings Before Interest and Taxes (EBIT)			$ 275.4	$ 285.3	$ 316.0	$ 340.6	$ 342.5	$ 340.8	$ 338.1
EBIT/Revenues			7.2%	7.4%	7.5%	7.6%	7.6%	7.7%	7.7%
Taxes			$ 94.5	$ 97.9	$ 108.4	$ 116.8	$ 117.5	$ 116.9	$ 116.0
Net Operating Profit after Taxes (NOPAT)			$ 181.0	$ 187.4	$ 207.6	$ 223.8	$ 225.0	$ 223.9	$ 222.1
Cash Flow Statement									
	NOPAT		$ 181.0	$ 187.4	$ 207.6	$ 223.8	$ 225.0	$ 223.9	$ 222.1
	Depreciation		$ 166.1	$ 167.4	$ 182.7	$ 194.7	$ 194.1	$ 191.9	$ 190.7
	Change in Working Capital		$ (248.1)	$ (2.5)	$ (23.1)	$ (18.3)	$ 0.7	$ 3.1	$ 1.7
Cash Flows from Operations			$ 99.0	$ 352.3	$ 367.1	$ 400.2	$ 419.7	$ 418.9	$ 414.5
	Ordinary Capital Expenditures		$ (175.6)	$ (177.4)	$ (193.7)	$ (206.7)	$ (206.2)	$ (204.0)	$ (202.8)
	Capital Conversion Costs		$ -	$ -	$ -	$ -	$ -	$ -	$ (6.2)
Capital Investments			$ (175.6)	$ (177.4)	$ (193.7)	$ (206.7)	$ (206.2)	$ (204.0)	$ (209.1)
Free Cash Flow			$ (76.6)	$ 175.0	$ 173.4	$ 193.5	$ 213.5	$ 214.8	$ 205.49
Terminal Value			$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor			0.000	0.000	0.000	1.000	0.922	0.849	0.783
Discounted Cash Flow			$ -	$ -	$ -	$ 193.50	$ 196.79	$ 182.50	$ 160.88
Industry Value thru	2044	$ 1,762.80							

APPENDIX 15-A. EMISSIONS FACTORS FOR FUEL COMBUSTION FROM NATURAL GAS, LPG, AND OIL-FIRED RESIDENTIAL APPLIANCES

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APPENDIX 15-A. EMISSIONS FACTORS FOR FUEL COMBUSTION FROM NATURAL GAS, LPG, AND OIL-FIRED RESIDENTIAL APPLIANCES

15-A.1 OVERVIEW

The modified version of the National Energy Modeling System (NEMS) used for the appliance energy-efficiency standards analysis, called NEMS-BT, comprehensively considers a wide range of aspects of energy use. However, this model does not consider household emissions from the combustion of natural gas, residential heating fuel oil #2 (*i.e.*, high-sulfur distillate fuel oil), and LPG. Because an efficiency standard could result in changes to household emissions, the Department has performed some elementary research to determine appropriate emissions factors for CO_2, NO_x, and SO_2 for each of the fuel types consumed by household appliances. This work focuses on emissions rates from the use of furnace and boilers and is used to calculate emissions savings for proposed appliance efficiency standards. Emissions factors for furnaces are presented over small-scale boilers whenever both are available.

This analysis attempts to verify that the emissions factors from the U.S. Environmental Protection Agency (EPA) for CO_2, NO_x, and SO_2 from natural gas, fuel oil #2, and LPG combustion are representative of the U.S.[1] The EPA cautions against the use of these emissions factors as representative of actual emissions. Rather, they are to be used, and are used here, as general approximations of national average emissions factors in order to calculate emissions savings that result from proposed appliance standards. This analysis compares the EPA's emissions factors with those from other sources and with regional regulations.

Table 15-A.1.1 summarizes the emissions factor estimates for the three fuels of interest. The values presented here are based on the EPA's assessment of combustion emissions (with the exception of SO_2 from LPG, see discussion below). These emissions estimates represent an approximate emissions factor for the U.S. as a whole. They are used, together with estimated energy savings, to calculate end-use site emissions savings. The emissions factors discussed in this analysis are represented as mass (g or kg) of the specific emission of interest per gigajoule (GJ) of energy input to the furnace and boiler.[*]

Table 15-A.1.1 Estimated National Average Emissions Factors for Household Fuel Combustion of Natural Gas, Fuel Oil #2, and LPG

	CO_2 (kg/GJ)	NO_x (g/GJ)	SO_2 (g/GJ)
Natural Gas	50.6	40	0
Fuel Oil #2	68.6	55	218
LPG	58.7	66	7

[*] 0.454 kg = 1 lb; 1.055 GJ = 1 MBtu

There are significant differences in state regulations, making it difficult to generalize about localized emissions. For residential fuel oil combustion, stricter state standards exist in the northeastern United States and southern California than elsewhere. State and local agencies like southern California's South Coast Air Quality Management District (SCAQMD)[2], the New Jersey Department of Environmental Protection, and the New York Department of Environmental Conservation have established regulations for residential fuel combustion emissions. These regulations, however, are local to individual counties and do not apply to all regions in the Northeast or even all of California.

15-A.2 EMISSIONS FACTORS BY FUEL TYPE

15-A.2.1 All Fuels: Carbon Dioxide

NEMS-BT tracks CO_2 well, but factors are included here for completeness. The CO_2 estimates in Table 15-A.1.1 are based on EPA's assessment of CO_2 combustion from natural gas, fuel oil #2, and LPG use. Other sources of information include the U.S. DOE's Energy Information Administration (EIA), Oregon State EPA, and the Gas Research Institute (GRI). All agree to within ± 2.0 percent of EPA's assessed estimate of CO_2 emissions. EPA's CO_2 emissions factors for natural gas, fuel oil #2, and LPG combustion are therefore a reasonable evaluation of nationally averaged CO_2 emissions rates.

Carbon monoxide (CO) can be formed by incomplete carbon oxidization, causing a severe health hazard. Carbon monoxide emissions only result from poorly functioning appliances, and since NEMS-BT assumes that all appliances are functioning properly, it is consistent to assume that these emissions will not change.

15-A.3 NATURAL GAS

15-A.3.1 Oxides of Nitrogen

Emissions of NO_x that result from the combustion of natural gas from appliances are also covered by regulations in some jurisdictions. The EPA's estimated NO_x emissions factor of 40 g/GJ from gas-fired furnaces is roughly equivalent to the regulation set by the state of New York. The SCAQMD limits NO_x emissions to 40 g/GW from gas-fired residential furnaces, equivalent to EPA's AP-42 estimate. The San Luis Obispo Air Pollution Control District also mandates the same NO_x limit from furnaces. The SCAQMD also provided performance test results from numerous commercially available residential gas furnaces. In general, the emissions rates ranged from 35-40 g/GJ NO_x with some higher efficiency units emitting between 26-35 g/GJ NO_x. New Jersey's state regulation mandates no more than 43 g/GJ NO_x emissions from natural gas combustion in small boilers and furnaces. The absence of regulations in other states suggests that most have emissions rates comparable to the EPA's estimated value.

15-A.3.2 Sulfur Dioxide

SO_2 emissions from natural gas combustion are assumed to be zero.

15-A.4 FUEL OIL #2

15-A.4.1 Oxides of Nitrogen

NO_x formation in combustion processes is significantly more complex than the formation of SO_2 or CO_2. NO_x can result from oxidization of N_2 in the fuel, but the larger source is N_2 in the combustion intake. This process is sensitive to combustion chemistry, and therefore, quite variable. It also implies that appliance design can lower NO_x emissions. An added difficulty is that the potential hazard of residential NO_x emissions is hard to quantify. NO_x is both an acid precipitation and ozone (O_3) precursor, but because residential appliances are a relatively small and dispersed (*i.e.*, hard to monitor) source, these emissions tend to play a small role in NO_x control strategies. The O_3 hazards of NO_x emissions are highly variable both spatially and over time, as weather conditions favor or disfavor O_3 formation. One would, therefore, expect NO_x emissions rules to vary significantly across jurisdictions.

The value estimated by EPA of 55 g of NO_x/GJ is for residential oil-fired furnaces. Additional research into specific state regulations reveals good matches with EPA's emissions factor: New Hampshire limits NO_x emissions to 60 g/GJ for non-utility boilers and New York and New Jersey regulations cap emissions at 52 g of NO_x/GJ. These state limits confirm that EPA's estimate can serve as a reasonable national average.

15-A.4.2 Sulfur Dioxide

Emissions of SO_2 are a direct function of the sulfur content of the fuel. Assuming complete combustion of sulfur to SO_2 makes it easy to assess and compare emissions across data sources. Individual state and county regulations limiting the amount of sulfur in residential fuel oil, however, reveal substantial variability in SO_2 emissions factors from EPA's estimate of 218g of SO_2/GJ of fuel energy content for both residential furnaces and boilers. This is roughly equivalent to 0.5 percent sulfur content by weight using an emissions factor for fuel oil #2 of 43,950 g/GJ weight per unit energy content. A straight multiplication of the fuel energy content and the percentage of sulfur content in the fuel provide the emissions factor.

In the state of New York, SO_2 emissions limits range from 88-659 g/GJ depending on the county. In New Hampshire, the emissions rate of SO_2 from high-sulfur distillate fuel oil combustion cannot exceed 176 g/GJ. In Maine and Michigan, the regulations are higher than EPA's assessment, limiting SO_2 emissions from fuel oil to 500 g of SO_2/GJ of heat input. Such broad ranges and varying limits in certain regions are a strong argument for using EPA's averaged national value over a regionally weighted average incorporating the various state and county regulations.

Comparing the sulfur content of fuel oil from different refineries also demonstrates regional variability. Most sources were obtained through online websites detailing product specifications. Mobil Corporation's residential heating fuel oil (#2 high-sulfur) for most states contains a maximum 0.5% sulfur by mass (219 g of SO_2/GJ of heat input), which is very close to EPA's emissions factor. Mobil also markets fuel with lower sulfur content to some regions in the Northeast. For example, Mobil's lowest sulfur content residential heating fuel oil contains 0.2 percent sulfur by weight (88 g/GJ), as required in New York City, Philadelphia, parts of Delaware, and most of New Jersey. Other regional regulations adhered to by Mobil are 132 g/GJ for most of Pennsylvania and parts of New Jersey, a limit of 127 g of SO_2/GJ of heat input for the state of Illinois, and an SO_2 emissions factor of 145 g/GJ in Massachusetts. The sulfur contents of distillate fuel oil from Chevron, Phillips 66, and the American Society for Testing and Materials (ASTM) exactly match EPA's estimate, substantiating the use of the latter for the analysis. Considerable variation does exist among counties and states, especially in the Northeast. Nonetheless, EPA provides a reasonable estimate of emissions from residential oil-fired furnaces and boilers that are representative of the national average.

15-A.5 LPG

15-A.5.1 Oxides of Nitrogen

EPA estimates emissions for only propane and butane, fuels within the LPG family of gases. In the United States, the composition of LPG is typically 90 percent propane (C_3H_8) by liquid volume, 5 percent propylene (C_3H_6), and 2.5 percent butane (C_4H_{10}).[3, 4] This analysis uses EPA's propane emissions estimate to verify its comparability with LPG combustion or determines a more suitable estimate from other sources that best represents LPG emissions rates.

EPA estimates an emissions factor of 66 g of NO_x/GJ of energy input from propane-fired furnaces and boilers, which is slightly higher than the natural gas estimate. The University of New Hampshire's Energy Office estimates an emissions factor of 43 g/GJ from LPG combustion for the state of New Hampshire. In contrast, the state of New Jersey's EPA establishes an 86 g/GJ emissions factor. Both sources, therefore, support EPA's national assessment of NO_x emissions from residential propane combustion.

15-A.5.2 Sulfur Dioxide

The sulfur content of LPG is very low[5], although a few regulations exist in certain parts of the country. EPA's SO_2 emissions estimate is derived from the sulfur content of the propane fuel. With 90% of LPG comprised of propane, the EPA's propane emissions factor is a reasonable value for LPG emissions rates. Under the New Hampshire Department of Environmental Services (DES) regulation, the maximum sulfur content allowable is 13.3 g/GJ of SO_2 from LPG combustion. The San Diego County Air Pollution Control District enforces a stricter limit of only 8.8 g of SO_2/GJ of energy input using EPA's recommended value. Both the ASTM and Santa Barbara County Air Pollution Control District specify a sulfur standard of 0.0185 percent sulfur by weight, which approximates an emissions factor of 4.0 g of SO_2/GJ of

energy input. This calculation is based on an LPG weight per unit energy of 21,756 g/GJ. Even lower, Nett Technologies Inc. estimates a 0.012 percent sulfur content by mass LPG average for the United States as well as Canada, which is approximately 2.6 g of SO_2/GJ of heat input.

The wide range of emissions factors for SO_2 makes it difficult to determine a representative estimate for the emissions factor and the very small net effect of any energy-efficiency standard argue against making a significant research effort. The obtained estimates range in magnitude from approximately 4 to 13 g/GJ of energy input. The statistical average or arithmetic mean of these four estimates is 7.2 g/GJ, the value provided in Table 15-A.1.1. The averaged emissions factor estimate of 7.2 g/GJ energy input is reasonable to explain three of the five sources presented and suitably accounts for the average among the two extreme estimates. Table 15-A.1.1 therefore adequately represents national SO_2 emissions from residential LPG combustion.

15-A.6 SUMMARY

This investigation of emissions factors from natural gas-, fuel oil-, and LPG-fired residential furnaces and boilers indicates that using the values estimated by EPA's AP-42 is a robust and credible basis for analysis with NES output. This analysis indicates that regulations at the state and county level, especially in the northeastern region of the United States, are generally not good estimators of the national average set forth by the EPA AP-42 report. This is especially true for SO_2 emissions factors from fuel oil combustion where individual state and county regulations are highly variable. Thus, although it is worthwhile examining regional legislation to support the national average, this analysis demonstrates the complexity that would be required to establish a weighted regional calculation for each emission. The EPA's own lack of data on the sulfur content of LPG made it difficult to derive a nationally representative emissions factor for the country as a whole. External sources were therefore incorporated in the Table 15-A.1.1 estimate for SO_2 emissions from LPG combustion.

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APPENDIX 17-A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

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APPENDIX 17-A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

17-A.1 INTRODUCTION

The U.S. Department of Energy's regulatory impact analysis (RIA) evaluated the effects and effectiveness of various policies that might be established in place of mandatory standards. DOE estimated increases in market shares of residential clothes washers meeting target efficiency levels for each alternative policy. The non-regulatory alternatives described in chapter 17 are:

- No new regulatory action,
- Consumer rebates,
- Consumer tax credits,
- Manufacturer tax credits,
- Voluntary energy efficiency targets,
- Early replacement, and
- Bulk government purchases.

This appendix presents details on the following topics related to performing the RIA.

- The integrated model based on the national impacts analysis (NIA) model.
- XENERGY penetration curves used to analyze consumer rebates, including:
    - background material,
    - DOE's adjustment of the curves for this analysis, and
    - DOE's method for interpolating the curves.
- Projections of increases in annual market share for the alternative policies.
- Rebates offered for the considered products.
- Background on Federal and State tax credits for appliances.

17-A.2 ANNUAL INCREASES IN MARKET SHARE BY POLICY

Table 17-A.2.1 shows the annual increases in market shares attributable to the consumer rebate, consumer tax credit, and manufacturer tax credit policies for residential clothes washers meeting target efficiency levels. DOE used these increases in market share as inputs to the integrated (NIA-RIA) spreadsheet model.

Table 17-A.2.1 Annual Increases in Market Shares Attributable to Rebate and Tax Credit Policies for Residential Clothes Washers

Year	Consumer Rebates		Consumer Tax Credits		Manufacturer Tax Credits	
	Front-Loading %	Top-Loading %	Front-Loading %	Top-Loading %	Front-Loading %	Top-Loading %
2015	5	20	3	12	2	6
2016	5	20	3	12	2	6
2017	5	20	3	12	2	6
2018	5	20	3	12	2	6
2019	5	20	3	12	2	6
2020	5	20	3	12	2	6
2021	5	20	3	12	2	6
2022	5	20	3	12	2	6
2023	5	20	3	12	2	6
2024	5	20	3	12	2	6
2025	5	20	3	12	2	6
2026	5	20	3	12	2	6
2027	5	20	3	12	2	6
2028	5	20	3	12	2	6
2029	5	20	3	12	2	6
2030	5	20	3	12	2	6
2031	5	20	3	12	2	6
2032	5	20	3	12	2	6
2033	5	20	3	12	2	6
2034	5	20	3	12	2	6
2035	5	20	3	12	2	6
2036	5	20	3	12	2	6
2037	5	20	3	12	2	6
2038	5	20	3	12	2	6
2039	5	20	3	12	2	6
2040	5	20	3	12	2	6
2041	5	20	3	12	2	6
2042	5	20	3	12	2	6
2043	5	20	3	12	2	6
2044	5	20	3	12	2	6

Table 17-A.2.2 shows the annual increases in market shares attributable to policies involving voluntary efficiency targets, early replacements, and bulk government purchases for residential clothes washers meeting target efficiency levels. DOE used these increases in market share as inputs to the NIA-RIA spreadsheet model.

Table 17-A.2.2 Annual Increases in Market Shares Attributable to Voluntary Energy Efficiency Targets, Early Replacement, and Bulk Government Purchases Policies for Residential Clothes Washers

Year	Voluntary Energy Efficiency Targets		Early Replacement		Bulk Government Purchases	
	Front-Loading %	Top-Loading %	Front-Loading %	Top-Loading %	Front-Loading %	Top-Loading %
2015	1	1			0.0	0.0
2016	5	5			0.0	0.1
2017	8	8			0.0	0.1
2018	9	9			0.0	0.2
2019	10	10			0.0	0.2
2020	10	10			0.0	0.2
2021	10	10			0.0	0.3
2022	10	10			0.0	0.3
2023	10	10			0.0	0.3
2024	10	10			0.0	0.4
2025	10	10			0.0	0.4
2026	10	10			0.0	0.4
2027	10	10			0.0	0.4
2028	10	10			0.0	0.4
2029	10	10			0.0	0.4
2030	10	10			0.0	0.4
2031	10	10			0.0	0.4
2032	11	11			0.0	0.4
2033	11	11			0.0	0.4
2034	11	11			0.0	0.4
2035	11	11			0.0	0.4
2036	11	11			0.0	0.4
2037	12	12			0.0	0.4
2038	12	12			0.0	0.4
2039	12	12			0.0	0.4
2040	12	12			0.0	0.4
2041	12	12			0.0	0.4
2042	13	13			0.0	0.4
2043	13	13			0.0	0.4
2044	13	13			0.0	0.4

17-A.3 INTEGRATED MODEL

For this RIA, DOE developed an integrated model that built on the NIA model described in chapter 10 and documented in appendix 10-A.The resulting NIA-RIA model, which features both the NIA analysis inputs and results and the RIA inputs, has the capability to generate results for each RIA policy. DOE used a separate module to produce summaries of inputs for the rebate policy, generate their penetration curves (discussed in section 17-A.4), report data on increases

in shipments and market shares by product class, and produce the national energy savings and net present values reported in chapter 17, section 17.4. This module generated tables of increases in market share for the policies introduced previously in this appendix.

17-A.4 CONSUMER REBATE POLICY: MARKET PENETRATION CURVES

This section first discusses the theoretical basis for the market penetration curves DOE used to analyze the consumer rebates policy. Next it describes the adjustments it made to the maximum penetration rates. It then presents the method DOE developed to create interpolated penetration curves for each product class and efficiency level in the analysis. The resulting curves for the two residential clothes washer product classes are given in chapter 17, section 17.3.2.2.

17-A.4.1 Introduction

Extensive economic literature describes the diffusion of new products as technologies evolve. Some research focuses on developing analytical models of diffusion patterns applicable to individual consumers or to technologies from competing firms.[1, 2, 3] One study records researchers' attempts to investigate the factors that drive diffusion processes.[4] Because a new product generally has its own distinct characteristics, few studies have been able to 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. Rather, a ceiling usually 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, used widely in marketing and social studies, 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.[2] In 2002 XENERGY, Inc.,[a] developed a re-parameterized, mixed-source information diffusion model to estimate market impacts induced by financial incentives for purchasing energy efficient appliances.[5] The mixed-source model incorporates information diffusion from both internal sources (spread by word of mouth from early adopters to prospective adopters) and external sources (the so-called announcement effect produced by government agencies, institutions, or commercial advertising). The model incorporates both sources by combining a logistic function with an exponential function.[3, 4]

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[a] XENERGY is now owned by KEMA, Inc. (www.kema.com).

The relative degree of influence from the internal and external sources determines the general shape of the diffusion curve for a specific product.[3, 4] If a product's adoption is influenced primarily by external sources of information (the announcement effect), for instance, a high rate of diffusion occurs initially as 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 limited 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 17-A.4.1). If adoption of a new product is influenced more strongly by internal sources, the number of adopters increases gradually, forming a convex curve (the logistic curve in Figure 17-A.4.1).

Figure 17-A.4.1 S-Curves Showing Effects of External and Internal Sources on Adoption of New Technologies

17-A.4.2 XENERGY Penetration Curves

The XENERGY penetration (implementation) curves follow a functional form to estimate the rate of market implementation produced by measures such as consumer rebates.[b]

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[b] The RIA chapter refers to these curves as *penetration curves*. When referring to the original source, this section uses the term *implementation curves*.

The 2002 XENERGY report presents five implementation curves that differ according to the level of market barriers to technology penetration.[5] The curves reflect five reference levels of market barriers: *No Barriers*, *Low Barriers*, *Moderate Barriers*, *High Barriers*, and *Extremely High Barriers*. DOE has used similar curves in appliance standards rulemakings to estimate increases in market share in response to rebate programs.[c] The curves provide a framework for evaluating technology penetration, yet require matching the studied market to the curve that best represents it.

17-A.4.3 XENERGY Rate Function and Curves

The XENERGY curves employ the following functional form to estimate the percentage of the informed market[d] that will accept each energy efficiency measure based on the consumer's benefit/cost ratio:

$$imp(bc) = \frac{max}{\left(1 + \mathrm{e}^{-\ln\left(\frac{bc}{4}\right)}\right) \cdot \left(1 + \mathrm{e}^{-fit \cdot \ln(mid \cdot bc)}\right)} \qquad [1]$$

Where:

imp = implementation rate,
bc = benefit/cost ratio,
max = maximum annual acceptance rate for the technology,
mid = inflection point of the curve, and
fit = parameter that determines the general shape (slope) of the curve.

XENERGY uses Eq. [1] to generate its five primary (reference) curves. The curves, generated using distinct values of the parameters *max*, *mid*, *fit*, and *r*, reflect the five levels of market barriers to efficiency measures. Figure 17-A.4.2 presents the five reference curves. These initial, theoretical results are calibrated to actual implementation results associated with the first year of major utility energy efficiency programs.

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[c] DOE has also used this method to estimate market share increases resulting from consumer tax credit and manufacturer tax credit programs, because the effects of tax credits on markets can be considered proportional to the effects of rebates.

[d] The *informed market* refers to that part of the market aware and informed about the energy efficiency measure.

Figure 17-A.4.2 Market Implementation Curves for Five Market Barriers Reference Levels

17-A.4.4 Modifications to XENERGY Curves

In consultation with the primary authors of the 2002 XENERGY study, who continued to conduct similar studies, DOE made some adjustments to XENERGY's original implementation curves.[6] Experiences with utility programs since the 2002 XENERGY study indicate that incentive programs have difficulty achieving penetration rates as high as 80 percent. Consumer response is limited by 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 maximum penetration rates for the *low barriers* and *no barriers* curves (the latter used only when a product has a very high base-case-market share) remained 80 percent and 100 percent, respectively. 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 market penetration. It set another constraint such that the policy-case market share cannot exceed 100 percent, as might occur for products having high base-case market shares of the target-level technology.

In recent rulemakings for efficiency standards, DOE has adopted a slightly different functional form of Eq. [1], whereby the constant value 1/4 is replaced by a parameter *r*. By introducing this parameter and rewriting Eq. [1] without the exponential and logarithmic operators, the following equation can be used to evaluate the market implementation rate of rebate programs.

$$imp(bc) = \frac{max}{(1 + r \cdot bc) \cdot (1 + (mid \cdot bc)^{-fit})} \qquad [2]$$

The reference curves build on the following functional form:

$$imp(b_d, bc) = \frac{max_d(b_d)}{(1 + r_d(b_d) \cdot bc) \cdot (1 + (mid_d(b_d) \cdot bc)^{-fit_d(b_d)})} \qquad [3]$$

Where:

b_d = [barrier type],

and $max_d(b_d)$, $mid_d(b_d)$, $fit_d(b_d)$, and $r_d(b_d)$ are as shown in Table 17-A.4.1. The four parameters are also presented as discrete-value functions in Figure 17-A.4.3.

Table 17-A.4.1 Parameter Values for Reference Curves

	Market Barriers Level				
Parameter	**No Barriers**	**Low Barriers**	**Moderate Barriers**	**High Barriers**	**Extremely High Barriers**
max_d	1.0	0.8	0.7[e]	0.6	0.5
mid_d	10	2.0	0.3	0.1	0.04
fit_d	1	1.7	1.7	1.7	1.7
r_d	1	0.5	0.25	0.25	0.25

[e] DOE adopted these parameters for the RIA analyses for refrigeration products and furnaces after consultation with the authors of the implementation curves. For the RIAs for the earlier rulemaking for cooking products and commercial clothes washers, the *max* value adopted for the *moderate barriers* and *high barriers* levels was 0.5. RIAs developed during prior rulemakings for furnaces and boilers, commercial unitary air conditioners, and heat pumps, and for distribution transformers used a *max* value of 0.8 for all but the *no barriers* curve, based on the original values from XENERGY's 2002 report.

Figure 17-A.4.3 Discrete-Value Functions of Parameters that Drive the Shape of an Implementation Curve

To estimate the barrier level of a given market, DOE previously sought the reference curve that most closely represented the pair (base-case market share, benefit/cost ratio) of the technology corresponding to the mandatory standard's efficiency level. It then used that curve to estimate the effect of a rebate program on the technology's market penetration. For that estimation, DOE calculated the increase in market share that an increase in the benefit/cost ratio —driven by a rebate program—would produce. It then assumed that the relative increase in market share calculated from the reference curve was a *proxy* for the effects of a rebate program on the studied market.

17-A.4.5 Interpolation of Penetration Curves

When a market is matched to the curve that best approximates it, some inaccuracy can be introduced into the analysis, especially if the actual benefit/cost ratio does not lie close to one of the reference curves. This section presents an alternative approach that can estimate market implementation rates more accurately by performing interpolations of the reference curves. The interpolation provides intermediate, continuous values for the four parameters that drive the market implementation curves (*max*, *mid*, *fit*, and *r*). These intermediate values are obtained after linear interpolation of their corresponding reference values.

To facilitate the interpolation, the four discrete-value functions listed in Table 17-A.4.1 and shown in Figure 17-A.4.3 must be transformed into continuous functions, which are capable of associating each of the four parameters to a real number denoting the market barrier level ($b_c \in \mathbf{R}$). A numeric, continuous scale for the market barriers level is applied, ranging from 0 to 5

($b_c \in [0,5]$). The correspondence between the discrete values of market barrier levels and b_c are shown in Table 17-A.4.2.

Table 17-A.4.2 Correspondence Between Discrete and Continuous Values of Market Barrier Levels

	Market Barriers Level				
	No Barriers	**Low Barriers**	**Moderate Barriers**	**High Barriers**	**Extremely High Barriers**
b_c	0.0	1.0	2.5	4.0	5.0

Based on the continuous-value market barriers level, the parameters *max*, *mid*, *fit*, and *r* are interpolated using the following functions:

$$max_c(b_c) = \propto_{max} (b_c) \cdot b_c + \beta_{max}(b_c) \quad [4]$$

$$mid_c(b_c) = \propto_{mid} (b_c) \cdot b_c + \beta_{mid}(b_c) \quad [5]$$

$$fit_c(b_c) = \propto_{fit} (b_c) \cdot b_c + \beta_{fit}(b_c) \quad [6]$$

$$r_c(b_c) = \propto_r (b_c) \cdot b_c + \beta_r(b_c) \quad [7]$$

For which $\propto_x (b_c)$ and $\beta_x(b_c)$ are shown in Table 17-A.4.3 for given intervals of market barrier levels.

Table 17-A.4.3 Coefficients of Continuous-Value Functions of *max, mid, fit,* and *r*

	Market Barriers Levels			
	No–Low Barriers	**Low–Moderate Barriers**	**Moderate–High Barriers**	**High–Extremely High Barriers**
	$b \in [0, 1]$	$b \in [1, 2.5]$	$b \in [2.5, 4]$	$b \in [4, 5]$
Max				
$\propto_{max}(b_c)$	-0.200	-0.075	-0.075	-0.075
$\beta_{max}(b_c)$	1.000	0.875	0.875	0.875
Mid				
$\propto_{mid}(b_c)$	-8.000	-1.133	-0.133	-0.060
$\beta_{mid}(b_c)$	10.000	3.133	0.633	0.340
Fit				
$\propto_{fit}(b_c)$	0.700	0.000	0.000	0.000
$\beta_{fit}(b_c)$	1.000	1.700	1.700	1.700
R				
$\propto_{r}(b_c)$	-0.500	-0.167	0.000	0.000
$\beta_{r}(b_c)$	1.000	0.667	0.250	0.250

The continuous-value functions defined for *max*, *mid*, *fit*, and *r*, as expressed by Eqs. [4] through [7], are substituted in Eq. [3], leading to the following functional form for the market implementation rate of rebate programs.

$$imp(b_c, bc) = \frac{max_c(b_c)}{(1 + r_c(b_c) \cdot bc) \cdot (1 + (mid_c(b_c) \cdot bc)^{-fit_c(b_c)})} \qquad [8]$$

Figure 17-A.4.4 presents the four continuous-value functions.

Figure 17-A.4.4 Continuous-Value Functions of Parameters that Drive the Shape of an Implementation Curve

Hence, estimating the market effects of a rebate program relies on finding the interpolated implementation curve that best represents the studied market. In other words, it involves finding b_c such that the pair ($imp(b_c,bc)$, bc) equals the pair (base case market share, benefit/cost ratio) of the technology that corresponds to the standard's efficiency level. After the appropriate value of b_c is found (*e.g.*, $b_c = \mathrm{b}_\mathrm{c}^*$), the market penetration of the technology under a rebate program can be calculated by the following equation.

$$imp(\mathrm{b}_\mathrm{c}^*, \mathrm{bc}^*) = \frac{max_c(\mathrm{b}_\mathrm{c}^*)}{(1 + r_c(\mathrm{b}_\mathrm{c}^*) \cdot \mathrm{bc}^*) \cdot (1 + (mid_c(\mathrm{b}_\mathrm{c}^*) \cdot \mathrm{bc}^*)^{-fit_c(\mathrm{b}_\mathrm{c}^*)})} \qquad [9]$$

Where:

b_c^* = market barriers level corresponding to the studied market, and
bc^* = benefit/cost ratio with rebate.

17-A.4.6 Limits to the Interpolation Approach

The approach described above increases the accuracy of the estimated market implementation rate attributable to a rebate program. Consequently, it improves the analysis of the market effects of rebate programs. Although it is feasible to develop interpolated

implementation curves between the reference ones, there is no empirical support to extrapolate them beyond the *No Barriers* and *Extremely High Barriers* curves. In fact, the theoretical boundaries for the market barriers level would be as follows.

(a) Zero Barriers (b_0): Assuming a rational consumer, a tiny increase in the benefit/cost ratio of a technology having a ratio greater than 1 would be sufficient to have the technology widely adopted.[f] This effect would result in the following implementation rate function:

$$imp(b_0, bc) = \begin{cases} 0, & bc < 1 \\ 1, & bc > 1 \end{cases}$$

(b) Infinite Barriers (b_∞): In this case, even an extremely high benefit/cost ratio would be insufficient to cause the market to adopt a technology. This effect would result in the following implementation rate function:

$$imp(b_\infty, bc) = 0, \forall bc$$

Notwithstanding the existence of such theoretical boundaries, the analysis of market implementation rates where the base-case market share is either higher than the market share in the *No Barriers* curve (for the corresponding benefit/cost ratio), or lower than in the *Extremely High Barriers* curve (for the corresponding benefit/cost ratio) should rely on the *No Barriers* or the *Extremely High Barriers* curves to estimate a relative market increase due to the rebate program.

17-A.5 UTILITY REBATE PROGRAMS

This section presents data on rebate programs for residential clothes washers offered by agencies and utilities nationwide. DOE found 119 organizations, comprising electric utilities and municipal and regional agencies that have rebate programs for residential clothes washers. The organizations offer 163 rebates for models that meet various efficiency criteria. Table 17-A.5.1 provides the organizations' names, States, rebate amounts, required modified energy factor (MEF) and water factor (WF) of qualifying units, and program websites. If there is more than one entry for an organization, that organization offers different rebate amounts depending on efficiency level. The average rebate amounts for clothes washers meeting an IMEF of 1.57 and 1.84 (the efficiency level for top-loading and front-loading washers in the proposed standards), is given in 2010$ at the end of the table.[g] It is a simple average of the individual amounts for units meeting the efficiency levels, rather than being population-weighted.

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[f] When the benefit/cost ratio is 1, the participant is indifferent to adopting the technology, and the implementation rate would be undetermined.

[g] DOE gathered rebate data for the two product classes during 2010. In the analysis, which assumes 2010$, it used the same rebate values, in the absence of a conversion factor for 2011$.

Table 17-A.5.1 Consumer Rebates for Residential Clothes Washers

Utility or Agency	State	Rebate $	MEF	WF	Website
Glendale Water and Power	CA	60	1.42		http://www.glendalewaterandpower.com/save_money/residential/sh_energy_saving_rebates.aspx
Glendale Water and Power	CA	80	1.42		http://www.glendalewaterandpower.com/save_money/residential/sh_energy_saving_rebates.aspx
Marblehead Light Department	MA	50	1.42		http://www.marbleheadelectric.com/9-6_Rebate_guide_for_MMLD.pdf
Kootenai Electric Cooperative	ID	70	1.72		http://www.kec.com/rebates.php
Kootenai Electric Cooperative	ID	25	1.72		http://www.kec.com/rebates.php
Rocky Mountain Power	ID	50	1.72		http://www.homeenergysavings.net/Downloads/ID_ApplianceForm2010.pdf
Central Lincoln People's Utility District	OR	70	1.72		http://www.clpud.org/pdf/Rebate%20Forms/CLPUD%20Applnc%20Rebate%20form%2008-10.pdf
Consumers Power, Inc	OR	60	1.72		http://www.cpi.coop/rebates/appliance.php
Forest Grove L&P	OR	70	1.72		http://www.forestgrove-or.gov/images/stories/services/lightandpower/pdf/mar2010appliancerebateform.pdf
Forest Grove L&P	OR	25	1.72		http://www.forestgrove-or.gov/images/stories/services/lightandpower/pdf/mar2010appliancerebateform.pdf
McMinnville Water and Light	OR	70	1.72	8	http://www.mc-power.com/rebates.aspx
McMinnville Water and Light	OR	25	1.72	8	http://www.mc-power.com/rebates.aspx
Midstate Electric Cooperative	OR	70	1.72	8	http://www.midstateelectric.coop/Washer%20Rebate.pdf
Monmouth Power & Light	OR	70	1.72		http://www.ci.monmouth.or.us/vertical/Sites/%7BCE78EAE1-6CA4-4610-BDB0-A9B3B0A8BB71%7D/uploads/%7BF66F3203-CD45-406C-89BF-ADE93D1D975D%7D.PDF
City of St.George	UT	25	1.72		http://www.sgcity.org/energyservices/ES%20Appliance%20Rebate%20Application.pdf
Clack Public Utilities	WA	50	1.72		http://www.clarkpublicutilities.com/yourhome/conservation/rebates
Cowlitz County PUD	WA	70	1.72		http://www.cowlitzpud.org/pdf/RebateBrochureRevised10-6-08.pdf
Pacific Power	WA	50	1.72		http://www.homeenergysavings.net/Washington/appliances/clotheswashers.html
Richland Energy Services	WA	25	1.72		http://www.ci.richland.wa.us/index.aspx?NID=178
SRP	AZ	50	1.8	7.5	http://www.srpnet.com/energy/powerwise/appliancerebate.aspx
Black Hills Energy	CO	100	1.8	7.5	http://www.blackhillsenergy.com/services/programs/builders-heateff-co.php#appliance
Black Hills Energy	IA	100	1.8	7.5	http://www.blackhillsenergy.com/services/programs/homes-heateff-ia.php#appliance
Marblehead Light Department	MA	100	1.8		http://www.marbleheadelectric.com/9-6_Rebate_guide_for_MMLD.pdf

Utility or Agency	State	Rebate $	MEF	WF	Website
Southwest Gas Corporation	NV	50	1.8	<7.5	http://www.conservationrebates.com/programs/swg/SWG_NV_Res.aspx
Emerald P.U.D.	OR	70	1.8	<7.5	http://www.epud.org/documents/ApplianceRebate_000.pdf
Questar Gas	UT	50	1.8		http://www.thermwise.com/home/ApplianceRebates.html
Benton PUD	WA	70	1.8		http://www.bentonpud.org/pdf/CRC/REEP/October%201,%202009/Appliance%20Rebate%20Application%209-1-09.pdf
Benton PUD	WA	25	1.8		http://www.bentonpud.org/pdf/CRC/REEP/October%201,%202009/Appliance%20Rebate%20Application%209-1-09.pdf
Franklin PUD	WA	70	1.8		http://www.franklinpud.com/pdfs/REBATE_PROGRAM_V_10.2.pdf
Franklin PUD	WA	25	1.8		http://www.franklinpud.com/pdfs/REBATE_PROGRAM_V_10.2.pdf
Waverly Light & Power	IA	150	1.84		http://wlp.waverlyia.com/appliance_programs.asp
SRP	AZ	75	2	6	http://www.srpnet.com/energy/powerwise/appliancerebate.aspx
Burbank Water & Power	CA	100	2	6	http://www.burbankwaterandpower.com/download/Home-Rewards-Rebate-Form-Web.pdf
Burbank Water & Power	CA	75	2	6	http://www.burbankwaterandpower.com/download/Home-Rewards-Rebate-Form-Web.pdf
Hercules Municipal Utility	CA	75	2	6	http://www.ci.hercules.ca.us/index.aspx?page=157
Lassen Municipal Utility District	CA	50	2	6	http://www.lmud.org/documents/appliancerebate.pdf
Lodi Electric Utility	CA	50	2	6	http://lodielectric.com/residential/rebateoffer.asp?id=2
Modesto Irrigation District	CA	35	2	6	http://www.mid.org/rebates/pkts/homeAppliance.pdf
Plumas-Sierra REC	CA	50	2	6	http://www.psrec.coop/energy_rebates.php?sec=enersol&pag=enerreb
Redding Electric	CA	25	2	6	http://www.reupower.com/energysvc/documents/2010/Jan10EnergyStar.pdf
Sacramento Municipal Utility District (SMUD)	CA	35	2	6	http://www.smud.org/en/rebates/Documents/Clothes-Washer-Fact-Sheet.pdf
SoCalGas	CA	35	2	6	http://www.socalgas.com/rebates/residential/furnace/
Truckee Donner Public Utility District	CA	100	2	6	http://www.tdpud.org/pdf/Rebate%20program%20pamphlet,5-09.pdf
Turlock Irrigation District	CA	35	2	6	http://www.tid.org/MyHome/Rebates/EnergyEfficiencyRebates/index.htm
City of Lompoc Utilities	CA	120	2	6	http://www.cityoflompoc.com/utilities/conservation/
Riverside Public Utilities	CA	75	2	4	http://www.riversideca.gov/utilities/resi-washerrebate.asp
Delta-Montrose Electric Association	CO	40	2	6	http://www.dmea.com/Portals/0/Applianceformsrebate.pdf
Fort Collins Utilities	CO	50	2	6	http://www.fcgov.com/conservation/res-frige.php

Utility or Agency	State	Rebate $	MEF	WF	Website
Gunnison County Electric	CO	20	2	6	http://www.gcea.coop/EE/rebate_program.cfm
Holy Cross Energy	CO	75	2	6	http://www.holycross.com/green-programs/appliance-rebates
Holy Cross Energy	CO	25	2	6	http://www.holycross.com/green-programs/appliance-rebates
Longmont Power & Communications	CO	50	2	6	http://www.ci.longmont.co.us/lpc/pdfs/rebate_appl.pdf
Morgan County REA	CO	50	2	6	http://www.mcrea.org/Services/Electric_Appliances.html
United Power	CO	40	2	6	http://www.unitedpower.com/ApplianceRebate.aspx#recycle
Groton Utilities	CT	60	2	6	http://www.grotonutilities.com/files/conservation_forms/Appliance_Rebate.pdf
Norwich Public Utilities	CT	60	2	6	http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CT54F&re=0&ee=1
City of Tallahassee Utilities	FL	100	2	6	http://www.talgov.com/you/energy/energy_programs.cfm#appl
Lake Worth Utilities	FL	100	2	6	http://www.lakeworth.org/vertical/Sites/%7B5E6FE119-0228-4C9B-B2DB-067168049C16%7D/uploads/%7B5348F2F5-5F25-464C-873C-87948A60D480%7D.PDF
Access Energy Coop	IA	100	2	6	http://www.accessenergycoop.com/Content/Residential/Rebates.aspx
Ames Electric Department	IA	50	2	6	http://www.cityofames.org/SmartEnergy/Documents/EfficientApplianceClaimForm%207.9.09.pdf
Cedar Falls Utilities	IA	100	2	6	http://www.cfu.net/save-energy/residential-rebates.aspx
Interstate Power and Light	IA	100	2	6	http://alliantenergy.com/wcm/groups/wcm_internet/@int/documents/contentpage/022811.pdf
Linn County REC	IA	25	2	6	http://www.linncountyrec.com/cgi-script/csarticles/uploads/334/Energy%20Star%20Appliances%20LCREC.pdf
MidAmerican Energy	IA	50	2	6	http://www.midamericanenergy.com/ee/include/pdf/ia_res_equip_brochure.pdf
Idaho Falls Power	ID	50	2	6	http://www.idahofallsidaho.gov/city/city-departments/idaho-falls-power/services-for-your-home/appliances.html
Idaho Power	ID	50	2	6	http://www.idahopower.com/EnergyEfficiency/Residential/Programs/HomeProducts/default.cfm
Rocky Mountain Power	ID	100	2		http://www.homeenergysavings.net/Downloads/ID_ApplianceForm2010.pdf
Munihelps	MA	50	2	6	http://www.munihelps.org/2010%20rebate%20forms/MailinformAshburnham.pdf
Belmont Municipal Light Department	MA	100	2	6	http://www.town.belmont.ma.us/public_documents/BelmontMA_LightNews/Announcements/2010%20Appliance%20Rebate%20Program%20&%20Form%20Brochure.pdf
Belmont Municipal Light Department	MA	50	2	6	http://www.town.belmont.ma.us/public_documents/BelmontMA_LightNews/Announcements/2010%20Appliance%20Rebate%20Program%20&%20Form%20Brochure.p

Utility or Agency	State	Rebate $	MEF	WF	Website
					df
Concord Municipal Light Plant	MA	50	2	6	http://www.concordma.gov/Pages/ConcordMA_LightPlant/appliance
Mansfield Municipal Electric	MA	100	2	6	http://www.mansfieldelectric.com/consumerforms/Appliance-Rebate-App.pdf
Reading Municipal Light	MA	50	2	6	http://www.rmld.com/Pages/rmldma_residential/rebate.pdf
Shrewsbury Electric & Cable Operations	MA	50	2	6	http://www.shrewsbury-ma.gov/egov/docs/1263402562_742065.pdf
Wakefield Municipal Gas & Light Department	MA	50	2	6	http://www.wakefield.ma.us/Public_Documents/WakefieldMA_MGLD/WMGLDRebateForm.pdf
Allegheny Power	MD	75	2		http://www.nxtbook.com/nxtbooks/garrisonhughes/empowermaryland2010/#/4
Baltimore Gas & Electric Company	MD	50	2	6	http://conservation.bgesmartenergy.com/residential/lighting-appliances/appliance-rebates
Efficiency United	MI	50	2	6	http://efficiencyunited.com/resources/Energy_Star_Incentive_Request_Form_Alpena.pdf
Consumers Energy	MI	25	2	6	http://www.consumersenergy.com/eeprograms/Landing.aspx?ID=802
Consumers Energy	MI	50	2	6	http://www.consumersenergy.com/eeprograms/Landing.aspx?ID=802
DTE Energy	MI	25	2	6	http://www.dteenergy.com/residentialCustomers/saveEnergy/rebates/energyStar/resEnergyStar.html
DTE Energy	MI	50	2	6	http://www.dteenergy.com/residentialCustomers/saveEnergy/rebates/energyStar/resEnergyStar.html
Alexandria Light and Power	MN	50	2	6	http://www.alputilities.com/forms/Energy%20Star%20Rebate%20Brochure%202010.pdf
Alexandria Light and Power	MN	75	2	6	http://www.alputilities.com/forms/Energy%20Star%20Rebate%20Brochure%202010.pdf
Anoka Municipal Utility	MN	25	2	6	http://www.ci.anoka.mn.us/index.asp?Type=B_BASIC&SEC={03DDAD7B-EC66-4214-97D8-EB42DA396059}
Southern Minnesota Municipal Power Agency	MN	50	2	6	http://www.smmpa.org/upload/Res%202010%20Rebate%20Program%20Fact%20Sheet-BP.pdf
City of North St. Paul Electric Utility	MN	50	2	6	http://www.ci.north-saint-paul.mn.us/index.asp?Type=B_BASIC&SEC={F5C1E5FE-1ADD-49AF-ACD8-59C3FB4192FF}
Crow Wing Power	MN	50	2	6	http://www.cwpower.com/heatingcoolingoptions.shtml
Minnesota Energy Resources	MN	35	2	6	http://www.minnesotaenergyresources.com/home/rebates.aspx#high_efficiency
Minnesota Energy Resources	MN	50	2	6	http://www.minnesotaenergyresources.com/home/rebates.aspx#high_efficiency

Utility or Agency	State	Rebate $	MEF	WF	Website
Minnesota Power	MN	40	2	6	http://www.mnpower.com/powerofone/one_home/energystar/special_offers/index.php
Shakopee Public Utilities	MN	35	2	6	http://www.shakopeeutilities.com/Residential_Rebate_Packet.pdf
Stearns Electric	MN	25	2	6	https://www.stearnselectric.org/energystarres.htm
Citizen's Electric Corporation	MO	50	2	6	http://www.citizenselectriccorp.com/documents/REBATEFORM2010.pdf
Co-Mo Electric Cooperative	MO	100	2	6	http://www.co-mo.coop/documents/HomeApplianceRebateApp_000.pdf
Intercounty Electric Cooperative	MO	100	2	6	http://www.ieca.coop/PROGRAMS/REBATES/tabid/116/Default.aspx
White River Valley Electric Cooperative	MO	100	2	6	http://whiteriver.org/RebateProgram.html
Flathead Electric	MT	70	2	6	http://www.flatheadelectric.com/energy/Rebates.html
Flathead Electric	MT	25	2	6	http://www.flatheadelectric.com/energy/Rebates.html
Yellowstone Valley Electric Cooperative	MT	50	2	6	http://www.yvec.com/UserFiles/File/Energy%20Star%20Rebate.pdf
Four-County EMC	NC	150	2	6	http://www.fourcty.org/news.php?id=39&p=7
South River EMC	NC	25	2	6	http://www.sremc.com/ESRebates.aspx
New Hampshire Electric Coop	NH	50	2	6	http://www.nhec.com/residential_energystar_appliances.php
Northern Utilities	NH	50	2	6	http://services.unitil.com/nh/energy_efficiency.asp?t=204
Public Service of New Hampshire	NH	50	2	6	http://www.psnh.com/Residential/Efficiency/Appliance.asp
Unitil	NH	50	2	6	http://services.unitil.com/nh/energy_efficiency.asp?t=204
Southwest Gas Corporation	NV	100	2	<6	http://www.conservationrebates.com/programs/swg/SWG_NV_Res.aspx
Central New Mexico Electric Cooperative	NY	40	2	6	http://www.cnmec.org/pdfs/waterheater_rebate_guidelines.pdf
NYSERDA	NY	75	2	6	http://www.nyserda.org/economicrecovery/appliance.asp
Verdigris Valley Electric Cooperative	OK	100	2	6	http://www.vvec.com/products_services/rebate_program.php
Ashland Electric Utility	OR	80	2	6	http://www.ashland.or.us/Page.asp?NavID=1366
Ashland Electric Utility	OR	40	2	6	http://www.ashland.or.us/Page.asp?NavID=1366
Ashland Electric Utility	OR	100	2	<6.5	http://www.ashland.or.us/Page.asp?NavID=1366
Ashland Electric Utility	OR	50	2	<6.5	http://www.ashland.or.us/Page.asp?NavID=1366
Central Electric Cooperative	OR	25	2	6	http://www.cec-co.com/custserv/energy_info/brochures/energy_star.pdf
Columbia River PUD	OR	75	2	6	http://www.crpud.net/residential/efficiency/appliances

Utility or Agency	State	Rebate $	MEF	WF	Website
Columbia River PUD	OR	25	2	6	http://www.crpud.net/residential/efficiency/appliances
Douglas Electric Cooperative	OR	70	2	6	http://www.douglaselectric.com/programs/Rebate_Form.pdf
Eugene Water & Electric Board	OR	35	2	6	http://www.eweb.org/public/documents/energy/home_appliance_rebate.pdf
Eugene Water & Electric Board	OR	70	2	6	http://www.eweb.org/public/documents/energy/home_appliance_rebate.pdf
Idaho Power	OR	50	2	6	http://www.idahopower.com/EnergyEfficiency/Residential/Programs/HomeProducts/default.cfm
Lane Electric	OR	75	2	6	http://www.laneelectric.com/conservation-renewables/rebates-credits/
OTEEC	OR	70	2	6	http://www.otecc.com/residentialprograms.aspx
OTEEC	OR	25	2	6	http://www.otecc.com/residentialprograms.aspx
Salem Electric	OR	60	2	6	http://www.salemelectric.com/residential/pdfs/rebates_programs/ApplianceBrochure.pdf
Springfield Utility Board	OR	70	2	6	http://www.subutil.com/files/static_page_files/E3DD085D-078B-420B-267070C0638CD317/RebateForm10.pdf
Tillamook County PUD	OR	70	2	6	http://www.tpud.org/nrg_appliance.html
Allegheny Power	PA	75	2		http://www.alleghenypower.com/EngConserv/PA/WattWatchers/RebateCW.asp
PPL Electric Utilities	PA	75	2	6	http://www.rebate-zone.com/ppl/pdf/PEJ.pdf
City of St.George	UT	50	2		http://www.sgcity.org/energyservices/ES%20Appliance%20Rebate%20Application.pdf
Questar Gas	UT	75	2		http://www.thermwise.com/home/ApplianceRebates.html
Rocky Mountain Power	UT	50	2	6	http://homeenergysavings.net/Utah/appliances/clotheswashers.html
Avista Utilities	WA	50	2	6	https://www.avistautilities.com/savings/rebates/Documents/HighEfficiencyRebate_OREnergyStar-R2.1.5.2009.pdf
Clallam PUD	WA	50	2	6	http://www.clallampud.net/uploadedFiles/conservation/documents/energy_star_appliance_rebate.pdf
Columbia Rural Electric Association	WA	70	2	6	http://www.columbiarea.com/programs/Res%20Rebate%20Application.pdf
Grant County Public Utility District	WA	70	2	6	http://www.gcpud.org/conservation/rebates/index.htm
Grays Harbor PUD	WA	75	2	6	https://www.ghpud.org/index.php?option=com_content&task=view&id=89&Itemid=113
Inland Power and Light Co	WA	50	2	6	http://www.inlandpower.com/pdf/appliancerebateform.pdf
Mason PUD	WA	50	2	6	http://www.masonpud3.org/powerSupply/applianceRebates.aspx
Modern Electric Water Company	WA	50	2	6	http://www.mewco.com/promotions/PDF/Rebate%20Flyer.pdf

Utility or Agency	State	Rebate $	MEF	WF	Website
Modern Electric Water Company	WA	25	2	6	http://www.mewco.com/promotions/PDF/Rebate%20Flyer.pdf
Modern Electric Water Company	WA	12.5	2	6	http://www.mewco.com/promotions/PDF/Rebate%20Flyer.pdf
Okanogan PUD	WA	50	2	6	http://www.okanoganpud.org/consrebates.htm
Orcas Power and Light Cooperative	WA	75	2	6	http://www.opalco.com/wp-content/uploads/2009/03/Rebate-Appliances-9-30-10.pdf
Pacific Power	WA	100	2		http://www.homeenergysavings.net/Washington/appliances/clotheswashers.html
Puget Sound Energy	WA	50	2	6	http://www.washwiserebate.com/docs/washwise-qualifying-products.pdf
Snohomish County Public Utility District No. 1	WA	50	2	6	http://www.washwiserebate.com/docs/washwise-qualifying-products.pdf
Tacoma Power	WA	50	2	6	http://www.washwiserebate.com/docs/washwise-qualifying-products.pdf
Barron Electric Cooperative	WI	25	2	6	http://www.barronelectric.com/Appliance%20&%20Lighting%20Program.pdf
Eau Claire Energy Cooperative	WI	25	2	6	http://www.ecec.com/programs/incentives
Riverland Energy Cooperative	WI	25	2	6	http://riverlandenergy.com/RIVERLAND%20HOMEPAGE/rebates.htm
Rocky Mountain Power	WY	75	2		http://www.homeenergysavings.net/Wyoming/appliances/clotheswashers.html
PG&E	CA	50	2.2	4.5	http://www.pge.com/myhome/saveenergymoney/rebates/appliance/clothes/index.shtml
City of Palo Alto Utilities	CA	125	2.2	4.5	http://www.cityofpaloalto.org/civica/filebank/blobdload.asp?BlobID=4365
Pacific Power	CA	50	2.2	4.5	http://www.homeenergysavings.net/California/appliances/clotheswashers.html
Sacramento Municipal Utility District (SMUD)	CA	75	2.2	4.5	http://www.smud.org/en/rebates/Documents/Clothes-Washer-Fact-Sheet.pdf
Energy Trust of Oregon	OR	50	2.2		http://energytrust.org/residential/incentives/Appliances/ENERGYSTARregClothesWashers1
Puget Sound Energy	WA	75	2.2	4.5	http://www.washwiserebate.com/docs/washwise-qualifying-products.pdf
Snohomish County Public Utility District No. 1	WA	75	2.2	4.5	http://www.washwiserebate.com/docs/washwise-qualifying-products.pdf
Tacoma Power	WA	75	2.2	4.5	http://www.washwiserebate.com/docs/washwise-qualifying-products.pdf
Pacific Power	CA	75	2.4	4	http://www.homeenergysavings.net/California/appliances/clotheswashers.html
Sacramento Municipal Utility District (SMUD)	CA	125	2.4	4	http://www.smud.org/en/rebates/Documents/Clothes-Washer-Fact-Sheet.pdf
New Braunfels Utilities	TX	100	2.4	4.5	http://www.nbutexas.com/Conservation/WaterUsage/WashingMachineRebateProgram/tabid/377/Default.aspx
Energy Trust of Oregon	OR	100	2.46		http://energytrust.org/residential/incentives/Appliances/ENERGYSTARregClothesW

Utility or Agency	State	Rebate $	MEF	WF	Website
					ashers1
Rocky Mountain Power	UT	75	2.46		http://www.homeenergysavings.net/Downloads/UT_ApplianceForm2010.pdf
Puget Sound Energy	WA	100	2.46	4	http://www.washwiserebate.com/docs/washwise-qualifying-products.pdf
Snohomish County Public Utility District No. 1	WA	100	2.46	4	http://www.washwiserebate.com/docs/washwise-qualifying-products.pdf
Tacoma Power	WA	100	2.46	4	http://www.washwiserebate.com/docs/washwise-qualifying-products.pdf
Rocky Mountain Power	WY	50	2.46		http://www.homeenergysavings.net/Wyoming/appliances/clotheswashers.html

Average Rebate Amount for MEF >/= 1.72 ($2010) **$ 61.16**

Average Rebate Amount for MEF >/= 2.2 ($2010) **$ 82.35**

17-A.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 that produce certain energy efficient appliances.

17-A.6.1 Federal Tax Credits for Consumers

The Energy Policy Act of 2005 (EPACT 2005) included Federal tax credits for consumers who installed efficient air conditioners or heat pumps; gas or oil furnaces; furnace fans; and/or gas, oil, or electric heat pump water heaters in new or existing homes.[7, 8] The 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.[9] Residential appliances must meet the following specifications, as applicable, to qualify for Federal tax credits.[6]

- Natural gas and propane furnaces must provide an annual fuel utilization efficiency (AFUE) of 95 or higher; oil furnaces and gas, oil, and propane boilers must provide an AFUE of 90 or higher.
- Central air conditioning units and air-source heat pumps must meet the highest tier (III) standards set by the Consortium for Energy Efficiency as of January 1, 2009. Table 15-A.5.1 shows the requirements for those equipment types.[9]
- Fans for heating and cooling systems may consume no more than 2 percent of total heating system energy, as defined by the DOE test procedure (may be revised because of the 2009 Federal stimulus legislation).
- Gas- or propane-fired water heaters must have an energy factor (EF) of at least 0.82 or a thermal efficiency of at least 90 percent; heat pump water heaters must have an EF of at least 2.0.

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 EPACT credits during tax years 2006 and 2007. DOE estimated the percentage of taxpayers who filed Form 5695, *Residential Energy Credits.*[10] It also estimated the percentage of taxpayers who made entries under Form 5695's section 3, *Residential energy property costs*, line 3b, *qualified natural gas, propane, or oil furnace or hot water boiler*. Although none of these three items incorporates clothes washers, DOE reasoned that the percentage of taxpayers making an entry on line 3b could serve as a rough indication of the taxpayer participation during the initial years of in a Federal tax credit program for an efficient appliance. DOE found that of all residential taxpayers filing tax returns, 0.8 percent in 2006 and 0.6 percent in 2007 claimed a credit for a furnace or boiler. DOE further found that the percentages of those filing Form 5695 for any qualifying expenditure (which included installation of efficient windows, doors, and roofs) were 3.1 percent in 2006 and 3.2 percent in 2007.

DOE also reviewed data from a Federal energy conservation tax credit program in place in the 1980s. Although this tax credit was available from 1979 through 1985, DOE could locate data for only the first three years of the program.[11, 12, 13] For those 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 purchase, they served only to indicate a possible trend of greatest participation in the initial program year, followed by slightly less participation in subsequent years. DOE did not find detailed analysis of the program, however, to identify the possible reasons for such a trend. This trend also differs from the more stable trend shown in the first program years of the EPACT 2005 tax credit program.

As discussed in chapter 17, section 17.3.3, DOE estimated the percentage of participation in consumer tax credit programs based on its estimates of consumer participation in rebate programs, which utilized benefit/cost data specific to each product class. It was difficult to compare the estimates derived from the detailed analysis of rebates to the more general data from the Federal tax credit program, or to use the IRS data in its analysis of consumer tax credits.

17-A.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.[14] The Emergency Economic Stabilization Act of 2008[15] amended the credits and extended them through 2010. Manufacturers receive the credits for increasing their production of qualifying appliances relative to a two-year rolling baseline. Each manufacturer is allowed a stipulated amount for all credits. Manufacturers were eligible for Energy Efficient Appliance Credits for qualifying models of residential refrigerators, residential and commercial clothes washers, and residential dishwashers. The credits were available for models produced in 2008, 2009, and 2010. The credit to manufacturers of qualifying clothes washers, refrigerators, and dishwashers was capped at $75 million for 2008–2010. The most efficient refrigerator (30%) and clothes washer (2.2 MEF/4.5 water consumption factor [wcf]) models were not subject to the cap. For 2011, the credit is capped at $25 million, with the most efficient refrigerators (35%) and clothes washers (2.8 MEF/3.5 wcf) are exempted from the cap.[16] The credits listed below were available to manufacturers for qualifying clothes washers manufactured from 2008 through 2011. The amounts listed are for each unit manufactured.

- $150 for residential or commercial clothes washers manufactured in 2008, 2009, and 2010 that meet/exceed a 2.0 MEF and do not exceed a 6.0 wcf.
- $250 for residential or commercial models manufactured in 2008, 2009, and 2010 that meet/exceed a 2.2 MEF and do not exceed a 4.5 wcf.
- $175 for residential or commercial, top-loading models manufactured in 2011 that meet/exceed 2.2 MEF and do not exceed 4.5 wcf.
- $225 for residential or commercial, top-loading models manufactured in 2011 that meet/exceed 2.4 MEF and do not exceed 4.2 wcf.
- $225 for residential or commercial, front-load-loading models manufactured in 2011 that meet/exceed 2.8 MEF and do not exceed a 3.5 wcf.

17-A.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 Indiana, Kentucky, and Michigan began offering such credits in 2009. The Oregon Department of Energy 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.) Although DOE reviewed Montana's overall participation trend in support of its analysis of Oregon's clothes washer tax credits, Montana's Department of Revenue does not disaggregate participation data by appliance. DOE was unable to obtain tax credit data from Indiana, Kentucky, or Michigan.

Oregon's Residential Energy Tax Credit (RETC) was created in 1977. After the Oregon legislature expanded the RETC program in 1997 to include residential refrigerators, clothes washers, and dishwashers, participation in the program increased significantly. The program offers two levels of rebates for standard-sized refrigerators having capacities between 12 and 30 cubic feet. One efficiency level is 20 percent above Federal standard (ENERGY STAR); the other is 30 percent above Federal standard (CEE Tier 3). 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. For heating, ventilating, and air conditioning equipment; residential appliances; and water heaters, the credit is $0.40 per kilowatt saved in the first year, or 25 percent of the net purchase price, whichever is less. The credit limit is $1,000 per calendar year; excess credit may be carried forward for 5 years.[17]

Montana has had an Energy Conservation Tax Credit for residential measures since 1998.[18, 19] The tax credit covers various energy and water efficient products, including ENERGY STAR heating/cooling equipment, water heaters, low-flow showerheads and faucets, and light fixtures and controls. In 2002 the credit amount 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. The tax credit covers only that part of the cost and materials that exceed established standards of construction.

Beginning in 2009, Indiana offered a tax credit to individuals and small businesses for costs associated with purchasing ENERGY STAR-qualified central air conditioners, room air conditioners, furnaces, programmable thermostats, and water heaters. The credit may be claimed against state income tax, insurance premium tax, or financial institutions tax. The amount of the credit is 20 percent of the expenditure for qualified heating and cooling equipment, to a maximum of $100 per taxable year. The credit applies to expenditures made in 2009 and 2010; there is no carryover.[20, 21]

Beginning in 2009, Kentucky began offering a 30-percent state income tax credit for taxpayers who install certain energy efficiency measures in their principal residence or residential rental property. Qualifying products include water heaters, heat pumps, central air conditioners, and advanced main air circulating fans. A product must meet the energy efficiency guidelines specified for the Federal tax credit for that product. The tax credit may not exceed

$250. The credit, which applies to products purchased in taxable years 2009–2015, may be carried forward for one year.[22, 23]

Beginning in 2009, certain low-income Michigan taxpayers became eligible for a tax credit for the purchase and installation of qualifying energy efficient home improvements. Qualifying improvements are limited to: insulation, water heaters, furnaces, windows, refrigerators, clothes washers, and dishwashers. All products must meet the ENERGY STAR efficiency criteria. The amount of the credit is 10 percent of the installed cost of each improvement, up to $75 for single filers and $150 for joint filers. A taxpayer may not make more than one claim under each product category during a single tax year. The credit applies only to products purchased in 2009–2011. If the amount of the credit exceeds a taxpayer's tax liability for a given year, the balance is refunded.[24, 25]

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