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

## RESIDENTIAL DEHUMIDIFIERS

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**U.S. Department of Energy**
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# CHAPTER 1. INTRODUCTION

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# CHAPTER 1. INTRODUCTION

## 1.1 PURPOSE OF THE DOCUMENT

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

## 1.2 OVERVIEW OF STANDARDS FOR RESIDENTIAL DEHUMIDIFIERS

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 U.S. Department of Energy (DOE) the authority to regulate the energy efficiency of several products, including residential dehumidifiers—the products that are the focus of this document. The amendments to EPCA in the Energy Policy Act of 2005 (EPACT 2005) (P.L. 109-58), established energy conservation standards for residential dehumidifiers[b] manufactured as of October 1, 2007. (Section 135(c)(4)) EPACT 2005 also required that DOE issue a final rule by October 1, 2009, to determine whether these standards should be amended. (*Id.*) Compliance with any amended standards would be required for dehumidifiers manufactured as of October 1, 2012. (*Id.*) In the event that DOE did not publish a final rule, EPACT 2005 specified a new set of amended standards with a compliance date of October 1, 2012. (*Id.*)

DOE issued an advance notice of proposed rulemaking (ANOPR) to consider energy conservation standards for dehumidifiers and other products. 72 FR 64432 (Nov. 15, 2007). The Energy Independence and Security Act of 2007 (EISA 2007), Pub. L 110-140 subsequently amended EPCA to prescribe new energy conservation standards for dehumidifiers manufactured on or after October 1, 2012. DOE codified the EISA 2007 standards at 10 Code of Federal Regulations (CFR) 430.32(v)(2). 74 FR 12058 (Mar. 23, 2009).

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

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

[b] Dehumidifiers are defined as self-contained, electrically operated, and mechanically encased assemblies consisting of: (1) a refrigerated surface (evaporator) that condenses moisture from the atmosphere; (2) a refrigerating system, including an electric motor; (3) an air-circulating fan; and (4) a means for collecting or disposing of the condensate. (42 U.S.C. 6291(34))

## 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).

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)) 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 NOPR stage. The second notice is the 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.

In August 2012, DOE published a notice of public meeting and availability of the framework document. 77 FR 49739 (Aug. 17, 2009) The framework document, *Energy Conservation Standards Rulemaking Framework Document for Residential Dehumidifiers*, describes the procedural and analytical approaches DOE anticipated using to evaluate the establishment of amended energy conservation standards for these products. This document is available at: *http://www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0027-0003*.

Subsequently, DOE held a public meeting on September 24, 2012, ("September 2012 public meeting") to discuss procedural and analytical approaches to the rulemaking. In addition, DOE used the public meeting to inform and facilitate involvement of interested parties in the rulemaking process. The analytical framework presented at the public meeting described the different analyses, such as the engineering analysis and the consumer economic analyses (*i.e.*, the life-cycle cost (LCC) and payback period (PBB) analyses), the methods proposed for conducting them, and the relationships among the various analyses.

**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 | |
| Markups analysis | Emissions analysis | |
| Energy use analysis | Emissions Monetization Impact analysis | |
| Life-cycle cost and payback period analysis | Utility impact analysis | |
| Shipments analysis | Employment impact analysis | |
| National impact analysis | Regulatory impact analysis | |
| Preliminary manufacturer impact analysis | | |

During the September 2012 public meeting, interested parties commented about numerous issues relating to each one of the analyses listed in Table 1.3.1. Comments from interested parties submitted during the framework document comment period elaborated on the issues raised during the public meeting. DOE attempted to address these issues during its preliminary analyses and summarized the comments and DOE's responses in chapter 2 of the preliminary TSD.

As part of the information gathering and sharing process, DOE organized and held interviews with manufacturers of the residential dehumidifiers 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 preliminary manufacturer impact analysis (chapter 12).

DOE developed spreadsheets for the engineering, LCC, PBP (chapter 8), and national impact analyses (chapter 10) for each product. For each product, DOE developed an LCC spreadsheet that calculates the LCC and PBP at various energy efficiency levels. DOE also developed a national impact analysis spreadsheet that calculates the national energy savings (NES) and national net present values (NPVs) 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 dehumidifiers at: *http://www1.eere.energy.gov/buildings/appliance_standards/residential/dehumidifiers.html*.

On May 21, 2014, DOE published the NOPM and availability of the preliminary TSD. 77 FR 29380. The preliminary TSD provides technical analyses and results that support the information presented in the preliminary NOPM and the executive summary for residential heating products. The preliminary TSD also provides a detailed description of all of the analyses discussed in the paragraphs above. The preliminary TSD is available at: *http://www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0027-0015*.

Following publication of the NOPM and the preliminary TSD, DOE held a public meeting on June 13, 2014, to facilitate discussion about the preliminary analyses that were performed for the NOPM and described in the preliminary TSD. In addition to the public meeting, a written comment period was open until July 21, 2014, to allow interested parties to provide new comments or elaborate on any comments made at the public meeting.

After receiving these comments, DOE revised the preliminary analyses for the NOPR phase of this rulemaking based on the feedback from interested parties. DOE organized and held a second round of interviews with manufacturers to gather additional feedback on the analyses and as part of the manufacturer impact analysis conducted for the NOPR phase of the rulemaking.

In addition to revising the various preliminary analyses, DOE also performed a consumer subgroup analysis, manufacturer impact analysis, utility impact analysis, employment impact analysis, and regulatory impact analysis for the NOPR stage of this rulemaking.

## 1.4 STRUCTURE OF THE DOCUMENT

This NOPR TSD outlines the analytical approaches used in this rulemaking. The NOPR TSD consists of 17 chapters (including an environmental assessment and regulatory impact 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: discusses the methods used for forecasting shipments with and without higher efficiency standards, including how product purchase decisions are economically influenced and how DOE models this relationship with econometric equations. |

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|---|---|
| Chapter 10 | National Impact Analysis: Discusses the methods used for forecasting national energy consumption and national economic impacts based on annual product shipments and estimates of future product energy efficiency distributions in the absence and presence of amended energy conservation standards. |
| Chapter 11 | Consumer Subgroup Analysis: discusses the effects of standards on different subgroups of consumers. |
| Chapter 12 | Manufacturer Impact Analysis: discusses the effects of standards on the finances and profitability of product manufacturers. |
| Chapter 13 | Emissions Analysis: discusses the effects of standards on three pollutants—sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$), and mercury—as well as carbon dioxide emissions. |
| Chapter 14 | Monetization of Emission Reductions Benefits. |
| Chapter 15 | Utility Impact Analysis: discusses certain effects of the considered on electric and gas utilities. |
| Chapter 16 | Employment Impact Analysis: discusses the effects of standards on national employment. |
| Chapter 17 | Regulatory Impact Analysis: discusses the impact of non-regulatory alternatives to efficiency standards. |
| Appendix 3A | AHAM Data Submittal |
| Appendix 5A | Engineering Analysis Interview Guide |
| Appendix 6A | Detailed Data for Product Price Markups |
| Appendix 7A | Housing Variables |
| Appendix 7B | Weather Station Data Mapping to RECS Households |
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| Appendix 10A | User Instructions for National Impact Analysis Spreadsheet Model |
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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 dehumidifiers. 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.

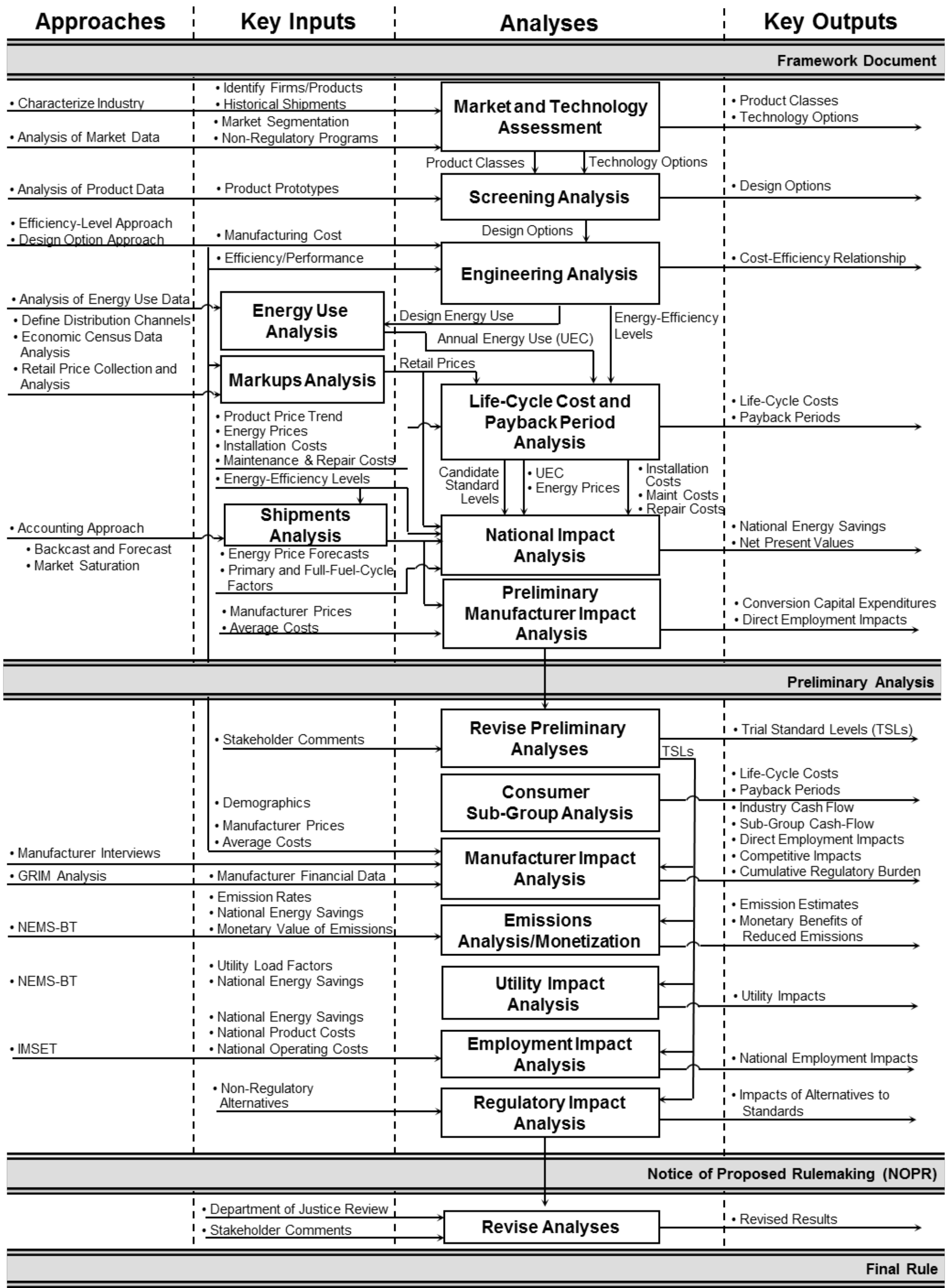


**Figure 2.1.1 Flow Diagram of Analyses for the Rulemaking Process**

The analyses performed as part of this notice of proposed rulemaking (NOPR) and reported in this NOPR technical support document (NOPR 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 and determine if it is technologically feasible; is practical to manufacture, install, and service; would adversely affect product utility or product availability; or would have adverse impacts on health and safety.
- An engineering analysis to develop cost-efficiency relationships that show the manufacturer's cost of achieving increased efficiency.
- A markups analysis to develop distribution channel markups that relate the manufacturer production cost (MPC) to the cost to the consumer.
- An energy use analysis to determine the annual energy use of the considered products in a representative set of users.
- A life-cycle cost (LCC) and payback period (PBP) analysis to calculate the savings in operating costs at the consumer level throughout the life of the covered products compared with any increase in the installed cost for the products likely to result directly from imposition of a standard.
- A shipments analysis to forecast product shipments, which are then used to calculate the national impacts of standards on energy, net present value (NPV), and future manufacturer cash flows.
- A national impact analysis (NIA) to assess the aggregate impacts at the national level of potential energy conservation standards for the considered products, as measured by the NPV of total consumer economic impacts and the national energy savings (NES).
- An LCC subgroup analysis to evaluate variations in customer characteristics that might cause a standard to disproportionately affect particular customer subpopulations.
- A manufacturer impact analysis (MIA) to estimate the financial impact of standards on manufacturers and to calculate impacts on costs, shipments, competition, employment, and manufacturing capacity.
- An emissions analysis to assess the impacts of amended energy conservation standards on the environment.
- An emissions monetization to assess the benefits associated with emissions reductions.
- A utility impact analysis to estimate the effects of potential standards on electric, gas, or oil utilities.
- An employment impact analysis to assess the aggregate impacts on national employment.
- A regulatory impact analysis to examine major alternatives to amended energy conservation standards that potentially could achieve substantially the same regulatory goal at a lower cost.

DOE developed this analytical framework and documented its initial findings in the *Energy Conservation Standards Rulemaking Framework Document for Residential Dehumidifiers* (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 17, 2012. 77 FR 49739. DOE presented the analytical approach to interested parties during a public meeting on September 24, 2012. The framework document is available at *http://www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0027-0003*.

DOE received numerous comments from interested parties regarding DOE's analytical approach. In the preliminary analysis, DOE: (1) summarized the key comments received from interested parties and describes DOE's responses to those comments; (2) summarized any significant changes in the analytical approach made since publishing the framework document; and (3) explained in further detail each of the issues for which DOE sought public comment in the executive summary. DOE announced the availability of the preliminary TSD in a *Federal Register* notice published on May 22, 2014. 79 FR 29380. The preliminary TSD is available at *http://www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0027-0015*.

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

## 2.2 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the relevant product markets and existing technology options, including working 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 include 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 manufacturers. DOE also examined publicly available data from the key trade association for this product category. DOE reviewed shipment data to evaluate annual shipment trends. Finally, DOE reviewed other energy efficiency programs from utilities, individual States, and other organizations. Chapter 3 of the NOPR TSD provides additional details on the market and technology assessment.

### 2.2.2 Technology Assessment

DOE typically uses information relating to existing and past technology options and prototype designs as inputs to determine what technologies manufacturers 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 through consultation with manufacturers of components and systems, and from trade publications and technical papers. Because many options for improving product efficiency are available in existing units, product literature and direct examination provided additional information. Chapter 3 of the NOPR TSD includes the detailed list of all the technology options.

## 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 the engineering analysis, DOE further considered efficiency enhancement options that it did not screen out in the screening analysis. Chapter 4 of the NOPR TSD contains details on the screening analysis.

## 2.4 ENGINEERING ANALYSIS

The engineering analysis establishes the relationship between the manufacturing production cost (MPC) and the efficiency for each class of products. 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 used a combination of these approaches for this rulemaking, as described in further detail in chapter 5 of the NOPR TSD.

## 2.5 MARKUPS ANALYSIS

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

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

## 2.6 ENERGY USE ANALYSIS

DOE establishes the annual energy consumption of a product and assesses the energy-savings potential of various product efficiencies. As part of the energy use analysis, certain engineering assumptions may be required regarding product application, including how often the product is operated and under what conditions. DOE uses the annual energy consumption and energy-savings potential in the LCC and PBP analyses to establish the savings in consumer operating costs at various product efficiency levels.

DOE used the Energy Information Administration's (EIA) 2009 *Residential Energy Consumption Survey* (*RECS 2009*) to establish a sample of households using dehumidifiers for each dehumidifier product class.[1] The *RECS* data provides information on dehumidifier ownership and frequency of dehumidifier use by monthly range in each household. The survey also includes household information such as the physical characteristics of housing units, household demographics, information about cooling products, and other relevant data. DOE used the household samples and publically available dehumidifier energy use data to determine dehumidifier annual energy consumption, but also as the basis for conducting the LCC and PBP analysis. See chapter 7 of the NOPR TSD for more information.

## 2.7 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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

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

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

DOE performed the LCC and PBP analyses using a spreadsheet model combined with Crystal Ball (a commercially-available software program used to conduct stochastic analysis using Monte Carlo simulation and probability distributions) to account for uncertainty and variability among the input variables. Each Monte Carlo simulation consists of 10,000 LCC and PBP calculations. The model performs each calculation using input values that are either sampled from probability distributions and household samples or characterized with single point values. The analytical results include a distribution of 10,000 data points showing the range of LCC savings and PBPs for a given efficiency level relative to the base case efficiency forecast. In performing an iteration of the Monte Carlo simulation for a given consumer, product efficiency is chosen based on its probability. If the chosen product efficiency is greater than or equal to the efficiency of the standard level under consideration, the LCC and PBP calculation reveals that a consumer is not impacted by the standard level. By accounting for consumers who already purchase more-efficient products, DOE avoids overstating the potential benefits from increasing product efficiency.

DOE is also required to perform a PBP analysis to determine whether the rebuttable presumption of economic justification applies (where the higher installed cost of more energy-efficient equipment is less than three times the value of the lowered operating costs in the first year of the energy conservation standard). (42 U.S.C. 6295(o)(2)(B)(iii)) The results of this analysis serve as the basis for DOE to evaluate the economic justification for a potential standard level (thereby supporting or rebutting the results of any NOPR determination of economic justification).

### 2.7.1 Inputs to First Costs

*Installation Costs*

Typically, small incremental changes in product efficiency incur little or no change in installation costs over baseline products. Based on available information, DOE did not include any installation costs from either a portable or whole-home dehumidifier with an increased product efficiency.

*Product Costs*

To calculate the product costs paid by dehumidifier purchasers, DOE multiplied the manufacturing product costs (MPCs) developed from the engineering analysis by industry markups to derive manufacturers' selling prices (MSPs). The MSPs in turn are multiplied by supply chain markups (along with sales taxes) to estimate the initial cost to the consumer. DOE used the supply chain markups that include separate markups on the baseline MSP and the incremental cost of each higher efficiency level considered.

### 2.7.2 Inputs to Operating Cost

*Energy Prices*

DOE derived average monthly electricity prices for the 27 geographic areas in *RECS 2009* by using the latest data from EIA. DOE assigned an appropriate energy price to each household in the sample, depending on its location. For future prices, DOE used the projected annual changes in average residential electricity prices in EIA's 2015 *Annual Energy Outlook* (*AEO 2015*).

*Maintenance and Repair Costs*

Typically, small incremental changes in product efficiency incur little or no change in installation, repair and maintenance costs over baseline products. Having no information to conclude otherwise, DOE did not include any maintenance or repair costs from either a portable or whole-home dehumidifier with an increased product efficiency.

*Product Lifetime*

Product lifetime is the age at which an appliance is retired from service. Based on information from the American Council for an Energy Efficiency Economy and the Northeast Energy Star Lighting and Appliance data, DOE identified an average dehumidifier lifetime of 11 years for portable dehumidifiers. DOE estimated lifetime for whole-home dehumidifiers based on data from central air conditioner information and identified an average lifetime of 19 years. DOE characterized dehumidifier survival functions using Weibull distributions.

### 2.7.3 Other Inputs

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

To estimate the share of consumers affected by a standard at a particular efficiency level, DOE's LCC and PBP analysis considers the projected distribution (*i.e.*, market shares) of product efficiencies that consumers will purchase in the first compliance year under the base case (the case without amended energy conservation standards).

## 2.8 SHIPMENTS ANALYSIS

DOE used forecasts of product shipments to calculate the national impacts of standards and also in its manufacturer impact analysis. DOE developed these shipment forecasts based on an analysis of key market drivers for each product.

DOE estimated portable dehumidifier shipments by projecting shipments in two market segments: (1) replacements; (2) homeowners that did not previously have a dehumidifier, *i.e.*, first time owners.

To project portable dehumidifier replacement shipments, DOE developed retirement functions for dehumidifiers from the lifetime estimates and applied them to the existing products in the stock. The existing stock of products is tracked by vintage and developed from historical shipments data. To project shipments to the first time owner market, DOE calibrated the estimated shipments with the historical data by introducing into the model a market segment identified as existing households without dehumidifiers. DOE estimated that 0.34 percent of existing households without a dehumidifier would annually purchase this product over the period 2019–2048. DOE estimated whole-home shipments at 1 percent of the total portable dehumidifier shipment volume. See chapter 9 of this NOPR TSD for more details regarding the projection of dehumidifier shipments.

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[a] The consumer discount rate differs from the discount rates used in the national impact analysis, which are intended to represent the rate of return on capital in the U.S. economy, as well as the societal rate of return on private consumption.

[b] Available at http://www.federalreserve.gov/econresdata/scf/scfindex.htm.

## 2.9 NATIONAL IMPACT ANALYSIS

The NIA assesses the NES and the NPV from a national perspective of total consumer costs and savings expected to result from new or amended energy conservation standards at specific efficiency levels. DOE determined the NPV and NES for the standard levels considered for the dehumidifier product classes analyzed. DOE prepared a Microsoft Excel spreadsheet that uses typical values (as opposed to probability distributions) as inputs. To assess the effect of input uncertainty on NES and NPV results, DOE has developed its spreadsheet model to conduct sensitivity analyses by running scenarios on specific input variables.

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

A key component of DOE's NIA is the energy efficiency forecasted over time for the base case (without new standards) and each of the standards cases. The forecasted efficiencies represent the annual shipment-weighted energy efficiency of the products under consideration during the forecast period (*i.e.*, from the assumed compliance date of a new standard to 30 years after compliance is required).

DOE developed a distribution of efficiencies in the base case for 2019 (the assumed compliance date for amended standards) for each dehumidifier product class. In each standards case, a "roll-up" scenario approach was applied to establish the efficiency distribution for 2019. Under the "roll-up" scenario, product efficiencies in the base case that do not meet the standard level under consideration would "roll-up" to meet the new standard level; and product efficiencies above the standard level under consideration would not be affected. In addition to a "roll-up" scenario, DOE developed a shift scenario. In the shift scenario DOE applied an annual growth rate in average energy efficiency, as it is done in the base case. To develop standards case forecasted shipments-weighted integrated energy factors (SWIEFs), DOE developed growth trends for each trial standard level that maintained the same per-unit average total installed cost difference for the year 2019 between the base case and each standards case over the entire forecast period (2019–2048). DOE's approach for developing standards case SWIEFs in this manner assumes that the rate of adoption of more efficient products under the standards case can occur only at a rate which ensures that the average total installed cost difference between the standards case and base case over the entire forecast period is held constant. Because the total installed cost versus efficiency relationship for each product class demonstrates an increasing cost rate for more efficient products, the SWIEF growth rate for each standards case is lower than the SWIEF growth rate for the base case.

DOE assumed that energy efficiencies for all dehumidifier product classes will increase at a rate of 0.25 percent per year in absence of standard. The growth rates in the standard cases are slightly lower than in the base case. Note that for the standards cases, the efficiency trend does not increase past the max tech level.

### 2.9.1 National Energy Savings Analysis

The inputs for determining the national energy savings for each product analyzed are: (1) annual energy consumption per unit; (2) shipments; (3) product or equipment stock; (4) national energy consumption; and (5) site-to-source conversion factors. DOE calculated the national energy consumption by multiplying the number of units (stock) of each product (by vintage or age) by the unit energy consumption (also by vintage). Vintage represents the age of the product. DOE calculated annual NES based on the difference in national energy consumption for the base case (without new efficiency standards) and for each higher efficiency standard. DOE estimated energy consumption and savings based on site energy and converted the electricity consumption and savings to source (primary) energy using annual conversion factors derived from the most recent version of the National Energy Modeling System (NEMS). Cumulative energy savings are the sum of the NES for each year over the timeframe of the analysis. Chapter 10 of this NOPR TSD presents primary energy savings for the considered efficiency levels.

### 2.9.2 Net Present Value Analysis

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

For the NPV analysis, DOE calculates increases in total installed costs as the difference in total installed cost between the base case and standards case (*i.e.*, once the standards take effect). Because the 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 expresses savings in operating costs as decreases associated with the lower energy consumption of products bought in the standards case compared to the base case. Total savings in operating costs are the product of savings per unit and the number of units of each vintage that survive in a given year.

DOE used the most recent available edition of EIA's *Annual Energy Outlook* (*AEO 2015*) as the default source of projections for future energy prices and total housing stock. It will also calculate the NPV assuming higher and lower economy growth scenarios from the *AEO*.

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

## 2.10 CONSUMER SUBGROUP ANALYSIS

During the NOPR stage of this rulemaking, DOE conducted a consumer subgroup analysis. A consumer subgroup comprises a subset of the population that may be affected disproportionately by new or revised energy conservation standards (*e.g.*, low-income consumers, seniors). The purpose of a subgroup analysis is to determine the extent of any such disproportional impacts. More information can be found in chapter 11 of the NOPR TSD.

## 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 NOPR TSD.

## 2.12 EMISSIONS ANALYSIS

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

DOE primarily conducted the emissions analysis using emissions factors for $CO_2$ and most of the other gases derived from data in the latest version of EIA's *Annual Energy Outlook*

*(AEO)*. Combustion emissions of $CH_4$ and $N_2O$ are estimated using emissions intensity factors published by the Environmental Protection Agency (EPA), GHG Emissions Factors Hub.[c]

EIA prepares the *Annual Energy Outlook* using the National Energy Modeling System (NEMS). Each annual version of NEMS incorporates the projected impacts of existing air quality regulations on emissions. The text below refers to *AEO 2014,* which generally represents current legislation and environmental regulations, including recent government actions, for which implementing regulations were available as of October 31, 2015.

$SO_2$ emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap and trading programs. Title IV of the Clean Air Act sets an annual emissions cap on $SO_2$ for affected EGUs in the 48 contiguous states and the District of Columbia (D.C.). $SO_2$ emissions from 28 eastern states and D.C. were also limited under the Clean Air Interstate Rule (CAIR), which created an allowance-based trading program that operates along with the Title IV program in those States and D.C. 70 FR 25162 (May 12, 2005). CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit), but it remained in effect.[d] On July 6, 2011 EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule (CSAPR). 76 FR 48208 (Aug. 8, 2011). On August 21, 2012, the D.C. Circuit issued a decision to vacate CSAPR.[e] The court ordered EPA to continue administering CAIR. *AEO 2014* assumes that CAIR remains a binding regulation through 2040.[f]

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

Beginning in 2016, however, $SO_2$ emissions will fall as a result of the Mercury and Air Toxics Standards (MATS) for power plants. 77 FR 9304 (Feb. 16, 2012). In the final MATS rule, EPA established a standard for hydrogen chloride (HCl) as a surrogate for acid gas

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

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

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

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

hazardous air pollutants (HAP), and also established a standard for $SO_2$ (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, $SO_2$ emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO 2014* assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2016. Both technologies, which are used to reduce acid gas emissions, also reduce $SO_2$ emissions. Under the MATS, emissions will be far below the cap that would be established by CAIR, so it is unlikely that excess $SO_2$ emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in $SO_2$ emissions by any regulated EGU. Therefore, DOE believes that energy efficiency standards will reduce $SO_2$ emissions in 2016 and beyond.

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

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

Power plants may emit particulates from the smoke stack, which are known as direct particulate matter (PM) emissions. NEMS does not account for direct PM emissions from power plants. DOE is investigating the possibility of using other methods to estimate reduction in PM emissions due to standards. The great majority of ambient PM associated with power plants is in the form of secondary sulfates and nitrates, which are produced at a significant distance from power plants by complex atmospheric chemical reactions that often involve the gaseous emissions of power plants, mainly $SO_2$ and $NO_x$. The monetary benefits that DOE estimates for reductions in $NO_x$ emissions resulting from standards are in fact primarily related to the health benefits of reduced ambient PM. Further detail is provided in chapter 13 of the NOPR TSD.

## 2.13 MONETIZING REDUCED CO2 AND OTHER EMISSIONS

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

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

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

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

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

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

DOE is investigating appropriate valuation of Hg and $SO_2$ emissions. DOE has not monetized estimates of $SO_2$ and Hg reduction in this rulemaking. Further detail on the emissions monetization is provided in chapter 14 of the NOPR TSD.

## 2.14 UTILITY IMPACT ANALYSIS

In the utility impact analysis, DOE analyzes the changes in electric installed capacity and generation that result for each trial standard level (TSL). The utility impact analysis is based on output of the DOE/ EIA's NEMS. NEMS is a public domain, multi-sectored, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce an energy forecast for the United States, the AEO. The EIA publishes a reference case, which incorporates all

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

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

existing energy-related policies at the time of publication, and a variety of side cases which analyze the impact of different policies, energy price and market trends. As of 2014, DOE is using a new methodology based on results published for the *AEO 2014* Reference case and a set of side cases that implement a variety of efficiency-related policies. Further detail is provided in chapter 15 of the NOPR TSD.

## 2.15 EMPLOYMENT IMPACT ANALYSIS

The adoption of energy conservation standards can affect employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the plants that produce the covered products. DOE evaluates direct employment impacts in the MIA. Indirect employment impacts may result from expenditures shifting between goods (the substitution effect) and changes in income and overall expenditure levels (the income effect) that occur due to standards. DOE defines indirect employment impacts from standards as net jobs eliminated or created in the general economy as a result of increased spending driven by increased product prices and reduced spending on energy.

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

## 2.16 REGULATORY IMPACT ANALYSIS

In the NOPR stage, DOE prepared a regulatory impact analysis (RIA) pursuant to Executive Order 12866, Regulatory Planning and Review, 58 FR 51735, October 4, 1993. The RIA addresses the potential for non-regulatory approaches to supplant or augment energy conservation standards in order to improve the energy efficiency or reduce the energy consumption of the product covered under this rulemaking. DOE recognizes that voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties can substantially affect energy efficiency or reduce energy consumption. DOE bases its assessment on the actual impacts of any such initiatives to date, but also considers information presented by interested parties regarding the impacts existing initiatives might have in the future. Further detail is provided in chapter 17 of the NOPR TSD.

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

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[1] "Residential Energy Consumption Survey: 2009 RECS Survey Data," 2013. U.S. Department of Energy: Energy Information Administration. Available online at: *http://www.eia.gov/consumption/residential/data/2009/*. (Accessed November 30, 2013).

# 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 dehumidifier industry in the United States. The 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 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 DEFINITION

The EPACT 2005 (P.L. 109-58) amended the EPCA, Pub. L. 94-163, 42 U.S.C. 6291 *et seq*. in relevant part to establish the definition of a dehumidifier as "a self-contained, electrically operated, and mechanically encased assembly consisting of -

A. a refrigerated surface (evaporator) that condenses moisture from the atmosphere;
B. a refrigerating system, including an electric motor;
C. an air-circulating fan; and
D. means for collecting or disposing of the condensate.

42 U.S.C. 6291(34)

On May 21, 2014 DOE published a test procedure NOPR in which it proposed definitions for portable and whole-home dehumidifiers, in addition to other clarifications and corrections to the current dehumidifier test procedure. 79 FR 29272. On February 4, 2015, DOE published a supplemental notice of proposed rulemaking (SNOPR), in which the previous definition proposals were maintained and DOE further proposed additional modifications and clarifications to the test procedure. 80 FR 5994. In the final rule for the test procedure rulemaking, DOE established the test procedure currently found at 10 CFR part 430, subpart B, appendix X1 (appendix X1) as well as the following product definitions in 10 CFR 430.2:

*Dehumidifier* means product, other than a portable air conditioner, room air conditioner, or packaged terminal air conditioner, that is a self-contained, electrically operated, and mechanically encased assembly consisting of—

1) A refrigerated surface (evaporator) that condenses moisture from the atmosphere;
2) A refrigerating system, including an electric motor;
3) An air-circulating fan; and
4) A means for collecting or disposing of the condensate.

*Portable dehumidifier* means a dehumidifier designed to operate within the dehumidified space without the attachment of additional ducting, although means may be provided for optional duct attachment.

*Whole-home dehumidifier* means a dehumidifier designed to be installed with ducting to deliver return process air to its inlet and to supply dehumidified process air from its outlet to one or more locations in the dehumidified space.

*Refrigerant-desiccant dehumidifier* means a whole-home dehumidifier that removes moisture from the process air by means of a desiccant material in addition to a refrigeration system.

## 3.3 PRODUCT CLASSES

When evaluating and establishing energy conservation standards, DOE generally divides covered products into product classes by the type of energy used or by capacity or other performance-related features that affect efficiency. Different energy conservation standards may apply to different product classes. (42 U.S.C. 6295(q))

For residential dehumidifiers, the EISA 2007, Pub. L 110-140 amendments to EPCA established product classes based on the capacity of the unit as measured in pints of water extracted per day (pints/day), for dehumidifiers manufactured on or after October 1, 2012. (42 U.S.C. 6295(cc)(2)):[a]

- Less than 35.00 pints/day
- 35.01 to 45.00 pints/day
- 45.01 to 54.00 pints/day
- 54.01 to 75.00 pints/day
- Greater than 75.00 pints /day

Among residential dehumidifiers there are also two general types, differentiated by the primary installation configuration: portable dehumidifiers and whole-home dehumidifiers, as described in section 3.2. Portable dehumidifiers are the most common type of dehumidifier sold in the United States, representing more than 95 percent of residential dehumidifier shipments. Consumers typically purchase portable dehumidifiers to reduce the relative humidity in one room or area of a living space less than 2,500 square feet, and may move these units from room to room to selectively reduce humidity where necessary. These units may also be located in an unconditioned space where moisture control is desired, such as a basement. Portable units currently on the market have rated capacities ranging from 25 pints/day to more than 120 pints/day, as determined by the test procedure at 10 CFR part 430, subpart B, appendix X (appendix X). Portable units are standalone appliances that are designed to operate independent of any other air treatment devices, and do not require attachment to ducting, although certain models may have optional provisions to do so (*i.e.*, “convertible” units).

Whole-home dehumidifiers are designed to be attached to ducting that supplies conditioned air to multiple or large living spaces in a residence and that returns humid air to the

[a] For standards effective October 1, 2007, EPACT 2005, in section 135(c), specified five product classes for dehumidifiers based on capacity as measured by the test procedure at appendix X: 25.00 pints/day or less, 25.01–35.00 pints/day, 35.01–54.00 pints/day, 54.01–74.99 pints/day, and 75.00 pints/day or more. EISA 2007, in section 311(a)(1), prescribed a new set of standards for dehumidifiers to take effect on October 1, 2012. In providing a new set of standards, EISA 2007 consolidated the two smallest product classes (25.00 pints/day or less and 25.01–35.00 pints/day) and subdivided the 35.01–54.00 pints/day product class into two product classes: 35.01–45.00 pints/day and 45.01–54.00 pints/day.

dehumidifier inlet. Whole-home dehumidifiers are often installed in conjunction with an existing heating, ventilation, or central air-conditioning (HVAC) system, and may utilize certain components of the HVAC equipment such as the air-handling blower, but can operate independently as well. Whole-home dehumidifiers typically use the same dehumidification system as portable units; however, to effectively dehumidify a large area, these units are manufactured with larger components than portable dehumidifiers, and may include additional features, such as pre-coolers or desiccant wheels, which may be difficult to incorporate into portable units due to volume and weight constraints. Whole-home product capacities range from approximately 65 pints/day to more than 200 pints/day. However, the current DOE dehumidifier test procedure at appendix X does not require testing these units with ducting in place, as they would be installed in the field. The lack of ducting allows higher airflow through the dehumidifier than would be experienced in real-world installations, which in turn affects the measured capacity and energy efficiency. Accordingly, the newly established appendix X1 test procedure includes provisions to require testing the energy use of whole-home dehumidifiers in dehumidification mode using a representative ducted configuration.

In the preliminary analysis for this rulemaking, DOE considered product classes that address both portable and whole-home dehumidifiers. DOE used the current product classes established by EISA 2007 as the basis for the analysis for portable dehumidifiers, with the capacities adjusted to account for the test procedure updates in appendix X1. In particular, appendix X1 requires that testing for portable dehumidifiers be conducted at an ambient temperature of 65 degrees Fahrenheit (°F) instead of the current 80 °F. DOE considered how the change in ambient temperatures would affect measured product capacities, and adjusted the capacity ranges in each of the portable product classes accordingly.

DOE also conducted its preliminary analysis on two whole-home dehumidifier product classes. DOE separated these two product classes based on case volume, one for products with volumes less than or equal to 8.0 cubic feet and another for products with volumes greater than 8.0 cubic feet, because it determined that capacity did not inherently impact efficiency for these products but that case volume affected consumer utility in terms of potential installation configurations.

DOE considered the following dehumidifier product classes in the preliminary analysis:

- Portable, less than 20.00 pints/day
- Portable, 20.01 to 30.00 pints/day
- Portable, 30.01 to 35.00 pints/day
- Portable, 35.01 to 45.00 pints/day
- Portable, 45.01 or more pints /day
- Whole-home, case volume less than or equal to 8.0 cubic feet
- Whole-home, case volume greater than 8.0 cubic feet

In the analysis for this NOPR, DOE combined four of the portable dehumidifier product classes considered in the preliminary analysis into two product classes due to similarities and trends observed in performance at these four product classes. Chapter 5 of this NOPR TSD includes more information about the portable dehumidifier product classes proposed in the NOPR, and listed below:

- Portable, less than 30.00 pints/day
- Portable, 30.01 to 45.00 pints/day
- Portable, 45.01 or more pints /day
- Whole-home, case volume less than or equal to 8.0 cubic feet
- Whole-home, case volume greater than 8.0 cubic feet

## 3.4 PRODUCT TEST PROCEDURES

EPACT 2005 amended EPCA to specify that the test criteria used under the ENERGY STAR[b] program must serve as the basis for the DOE test procedure for dehumidifiers. (EPACT 2005, section 135(b); 42 U.S.C. 6293(b)(13)) Prior to October 2012, the ENERGY STAR test criteria required that American National Standards Institute (ANSI)/ AHAM Standard DH-1-2003, *Dehumidifiers*, be used to measure energy use while the Canadian Standards Association (CAN/CSA) standard CAN/CSA-C749-1994 (R2005), *Performance of Dehumidifiers*, be used to calculate the energy factor (EF). DOE adopted these test criteria, along with related definitions and tolerances, as its test procedure for dehumidifiers in 2006 at 10 CFR part 430, subpart B, appendix X (appendix X). 71 FR 71340, 71347, 71366, 713667-68 (Dec. 8, 2006).

On October 31, 2012, DOE published a final rule to establish a new test procedure for dehumidifiers that references ANSI/AHAM Standard DH-1-2008, *Dehumidifiers* (ANSI/AHAM DH-1-2008), rather than the ENERGY STAR test criteria, and establishes a new energy efficiency metric, integrated energy factor (IEF), which incorporates measures of energy use in active mode, standby mode, and off mode. 77 FR 65995 (Oct. 31, 2012). The new DOE test procedure was codified at that time at 10 CFR part 430, subpart B, appendix X1 (appendix X1).

On February 7, 2014, DOE published a final rule removing the existing test procedure at appendix X and redesignating the test procedure at appendix X1 as appendix X. Manufacturers are currently required to test using only the active mode provisions in the redesignated appendix X to determine compliance with existing dehumidifier energy conservation standards. Appendix X must be used in its entirety if manufacturers make representations of standby mode or off mode energy use. 79 FR 7366 (Feb. 7, 2014).

On May 21, 2014, DOE published a test procedure NOPR (the May 2014 Test Procedure NOPR) in which it proposed to establish a new dehumidifier test procedure at appendix X1, which would include: (1) dehumidification mode test conditions requiring a lower ambient temperature to more accurately reflect conditions during consumer use; (2) a measure of fan-only mode energy consumption for dehumidifiers that operate the blower continuously or cyclically when the ambient air relative humidity is below the humidity setpoint, rather than enter off-cycle mode; (3) new definitions for portable, whole-home, and refrigerant-desiccant dehumidifiers; (4)

[b] For more information, please visit [http://www.energystar.gov/](http://www.energystar.gov/).

testing methodology and calculations for whole-home dehumidifiers; (5) additional clarifications and editorial corrections. 79 FR 29271.

On February 4, 2015, DOE subsequently published a SNOPR (the February 2015 Test Procedure SNOPR), to propose additional changes to the test procedure proposed in the May 2014 Test Procedure NOPR, including: (1) various adjustments and clarifications to the whole-home dehumidifier test setup and conduct; (2) a method to determine whole-home dehumidifier case volume; (3) a revision to the method for measuring energy use in fan-only operation; (4) a clarification to the relative humidity and capacity equations in ANSI/AHAM DH-1-2008; and (5) additional technical corrections and clarifications. 80 FR 5994.

In response to the May 2014 Test Procedure NOPR, June 2014 public meeting, and February 2015 Test Procedure SNOPR, DOE received comments from interested parties related to the test procedure. In the final rule that concluded the recent test procedure rulemaking, DOE addressed those comments and made certain modifications to its previous proposals. The final rule incorporated the proposed amendments to appendix X and established the new test procedure in appendix X1. The analysis conducted in support of this NOPR is based on capacities and efficiencies determined according to the test procedure in appendix X1.

## 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 dehumidifier 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.

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. 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 dehumidifiers, 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).

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

### 3.6.1 Manufacturers and Market Shares

The majority of residential dehumidifiers are manufactured overseas by three original equipment manufacturers (OEMs). These products are then imported to the United States and sold under a variety of brands belonging to both appliance manufacturers and importers. Additionally, some foreign OEMs sell dehumidifiers directly into the U.S. market under their own brands.

For residential dehumidifiers, DOE estimates that there are approximately 25 entities selling dehumidifiers in the United States, 17 of which sell portable dehumidifiers. The remaining 8 entities sell whole-home dehumidifiers. Table 3.6.1 lists these manufacturers and importers.

**Table 3.6.1 Residential Dehumidifier Original Equipment Manufacturers and Importers**

| Portable Dehumidifiers | Whole-Home Dehumidifiers** |
|---|---|
| Desert Aire* | Aprilaire* |
| Gree Electric Appliances Inc. of Zhuhai/SoleusAir* | Lennox |
| Hisense Kelon Electrical Holdings Limited* | Munters* |
| Haier America Trading LLC* | NovelAire* |
| LG Electronics, Inc.* | Therma-Stor* |
| Midea USA Inc.* | Williams Furnace Company* |
| Therma-Stor* | The General Filters, Inc. |
| Crosley | Healthy Air & Water Systems LLC |
| Danby Products Inc. | |
| De'Longhi America | |
| Friedrich Air Conditioning Co. | |
| GE Appliances | |
| Heat Controller | |
| Oscar Air | |
| Osram Sylvania | |
| Perfect Aire LLC | |
| Whynter LLC | |

* Original equipment manufacturers
**Some of these manufacturers and importers also sell high-capacity portable dehumidifiers with construction similar to that of their whole-home products.

Using publicly available data, DOE estimated the market shares of entities responsible for the sale of residential portable dehumidifiers in the United States. DOE estimates that over 50 percent of residential portable dehumidifier market share is held by Midea USA, Inc.[d],

[d] The U.S. division of Guangdong Midea Electric Appliances Co. Ltd., based in China.

De'Longhi America[e], Danby Products Inc., and GE Appliances. Figure 3.6.1 illustrates the estimated market shares for the residential portable dehumidifier market in the United States.

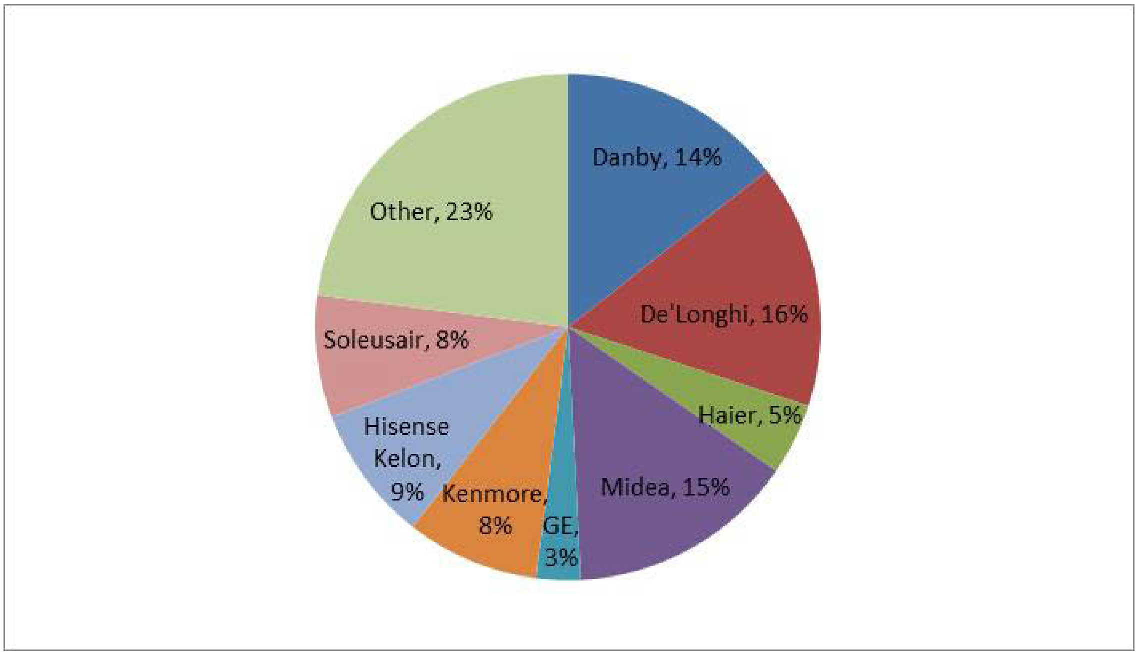



**Figure 3.6.1 Estimated U.S. Market Share for Residential Portable Dehumidifiers**

The majority of the whole-home dehumidifier segment is held by Therma-Stor LLC and Aprilaire (Research Products Corporation). Other producers of whole-home dehumidifiers include Munters, NovelAire, and Williams Furnace Company.

### 3.6.2 Mergers and Acquisitions

As described in Section 3.6.1, the major manufacturers and importers of residential dehumidifiers sold into the U.S. market include Midea, Gree, Haier, De'Longhi S.p.A., Danby Products Limited, and GE Appliances.

Recent merger and acquisition activities relating to the U.S. residential dehumidifier market include the joint venture formed between Chinese manufacturer Gree and U.S.-based SoleusAir in 2011, which led to the creation of Gree USA, headquartered in City of Industry, CA. Gree USA manufactures its own brands of HVAC products and OEM private labels, and sells directly to wholesalers. This collaboration has opened the way for Gree to have a presence in the United States.[1] Also in 2011, LG Electronics acquired LS Mtron's Air-Conditioning unit, and in November 2012, Corinthian Capital Group acquired Friedrich Air Conditioning Co. from U.S. Natural Resources Inc.[2] Finally, in September of 2014, Electrolux bought GE's appliances

[e] The U.S. division of De'Longhi S.p.A., based in Italy.

business for $3.3 billion. This move will double Electrolux's annual appliance sales in North America, to over $10 billion.[3]

### 3.6.3 Small Business Impacts

DOE considers the possible impact of energy conservation standards on small businesses. The products covered by this rulemaking are classified under the North American Industry Classification System (NAICS) codes 333415: Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing and 335210: Small Electrical Appliance Manufacturing. The Small Business Association (SBA) defines a small business as a company that has fewer than 750 employees for both NAICS codes. The 750-employee threshold includes all employees in a business's parent company and any other subsidiaries. Using this classification in conjunction with information from industry databases, the SBA member directory, and reports from vendors such as Dun & Bradstreet, DOE has identified five small business manufacturers which are based in the United States and produce one or more of the covered products. Further analysis of potential impacts on this manufacturer subgroup can be found in section VI.B of the NOPR notice and chapter 12 of this NOPR TSD.

### 3.6.4 Distribution Channels

Understanding the distribution channels through which residential dehumidifiers are sold is an important facet of the market assessment, because it helps to define the constraints or motivators manufacturers face from its customer base. DOE gathered information regarding the distribution channels for dehumidifiers from publicly available sources, as well as from preliminary interviews with manufacturers.

Because major OEMs of residential dehumidifiers are based overseas, the distribution channel for portable dehumidifiers is often multi-tiered. Typically, foreign OEMs sell their products to a sourcing company with a greater U.S. presence, which in turn sells the products to retailers. For a segment of the market, OEMs sell their products under their own brands either to distributors or directly to retailers. In either arrangement, these retailers include large discount stores, home improvement stores, and department stores, and to a lesser extent independent appliance retailors, internet retailers, membership warehouse clubs, electronics stores, and office supply stores.[4] The AHAM *2003 Fact Book* reports that home improvement stores claimed nearly one out of every four dollars spent on appliances in 2003.[5]

The distribution channel for whole-home dehumidifiers differs from that of the portable dehumidifiers. The majority of whole-dehumidifiers are sold directly to home builders or contractors, as they are intended to be integrated into a residence's HVAC system, and as such require system design and more complex installation.

## 3.7 REGULATORY PROGRAMS

The following section details current regulatory programs mandating energy conservation standards for dehumidifiers. Section 3.7.1 discusses Federal energy conservation standards, and section 3.7.2 reviews standards in Canada that may impact the companies servicing the North American market.

### 3.7.1 Federal Energy Conservation Standards

On August 8, 2005 EPACT 2005 established energy conservation standards for several residential and commercial products, including residential dehumidifiers. Section 135(c)(4) of EPACT 2005 amends section 325 of EPCA, 42 U.S.C. 6295, to add subsection (cc) for dehumidifiers. This subsection establishes energy conservation standards for dehumidifiers based on the unit's EF measured in liters (L) of water removed per kilowatt-hour (kWh) for product classes based on the unit's capacity to extract moisture from the surrounding air (in pints/day). These Federally mandated standards took effect for dehumidifiers manufactured after October 1, 2007. Table 3.7.1 provides the EPACT 2005 standards for residential dehumidifiers.

**Table 3.7.1 Energy Conservation Standards for Residential Dehumidifiers Established by EPACT 2005**

| Dehumidifier Capacity | Standards Effective October 1, 2007 |
|---|---|
| | **EF** *(L/kWh)* |
| 25.00 pints/day or less | 1.00 |
| 25.01–35.00 pints/day | 1.20 |
| 35.01–54.00 pints/day | 1.30 |
| 54.01–74.99 pints/day | 1.50 |
| 75.00 pints/day or more | 2.25 |

In addition, EPACT 2005 required that DOE issue a final rule for dehumidifiers to determine whether these standards should be amended by October 1, 2009. (EPACT 2005, section 135(c)(4)). In the event that DOE did not publish a final rule, EPACT 2005 specified a new set of amended standards with a compliance date of October 1, 2012. (*Id.*)

DOE issued an advance notice of proposed rulemaking (ANOPR) to consider energy conservation standards for dehumidifiers and other products (hereafter referred to as the "2007 ANOPR"). 72 FR 64432 (Nov. 15, 2007). EISA 2007 subsequently amended section 325(cc) of EPCA to prescribe new energy conservation standards for dehumidifiers manufactured on or after October 1, 2012. DOE codified the EISA 2007 standards at 10 CFR 430.32(v)(2). 74 FR 12058 (Mar. 23, 2009). Table 3.7.2 summarizes the October 1, 2012, standards prescribed by EISA 2007.

**Table 3.7.2 Energy Conservation Standards for Residential Dehumidifiers Established by EISA 2007**

| Dehumidifier Capacity | Standards Effective October 1, 2012 |
|---|---|
| | **EF** *(L/kWh)* |
| 35.00 pints/day or less | 1.35 |
| 35.01–45.00 pints/day | 1.50 |
| 45.01–54.00 pints/day | 1.60 |
| 54.01–75.00 pints/day | 1.70 |
| 75.01 pints/day or more | 2.50 |

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

### 3.7.2 Canadian Energy Conservation Standards

Canada's Energy Efficiency Regulations (hereafter "Canada's Regulations") mandate minimum energy conservation standards for dehumidifiers. Canada's Regulations refer to CAN/CSA-C749-07 (2007), "Performance of Dehumidifiers," for determining compliance with Canada's Regulations.[f] Canada's Regulations are comparable to DOE standards effective as of October 1, 2012, except capacity is expressed in terms of liters/day instead of pints/day, as seen in Table 3.7.3.

**Table 3.7.3 Canadian Regulations for Residential Dehumidifiers**

| Dehumidifier Capacity | Regulations Effective October 1, 2012 |
|---|---|
| | **EF** *(L/kWh)* |
| 16.6 liters/day or less | 1.35 |
| 16.6 – 21.3 liters/day | 1.50 |
| 21.3 – 25.5 liters/day | 1.60 |
| 25.5 – 35.5 liters/day | 1.70 |
| Greater than 35.5 liters/day | 2.50 |

[f] For more information, please visit: http://oee.nrcan.gc.ca/regulations/products/14452.

## 3.8 VOLUNTARY PROGRAMS

DOE reviewed several voluntary programs promoting energy efficient appliances and found that ENERGY STAR is the primary voluntary program that establishes energy efficiency criteria for dehumidifiers in the United States. 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. 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 should meet or exceed the ENERGY STAR levels. ENERGY STAR specifications exist for several products, including dehumidifiers.

On October 1, 2012, the current ENERGY STAR dehumidifier qualifying criteria became effective. The ENERGY STAR criteria divide products into two classes: less than 75 pints/day and greater than or equal to 75 pints/day, as measured by appendix X. The efficiency qualification criteria are listed in Table 3.8.1.

**Table 3.8.1 ENERGY STAR Qualifying Criteria for Dehumidifiers**

| **Dehumidifier Capacity** | **Qualification Criteria Effective October 1, 2012** |
|---|---|
| | **EF** *(L/kWh)* |
| Less than 75 pints/day | 1.85 |
| 75 pints/day or greater | 2.80 |

## 3.9 HISTORICAL SHIPMENTS

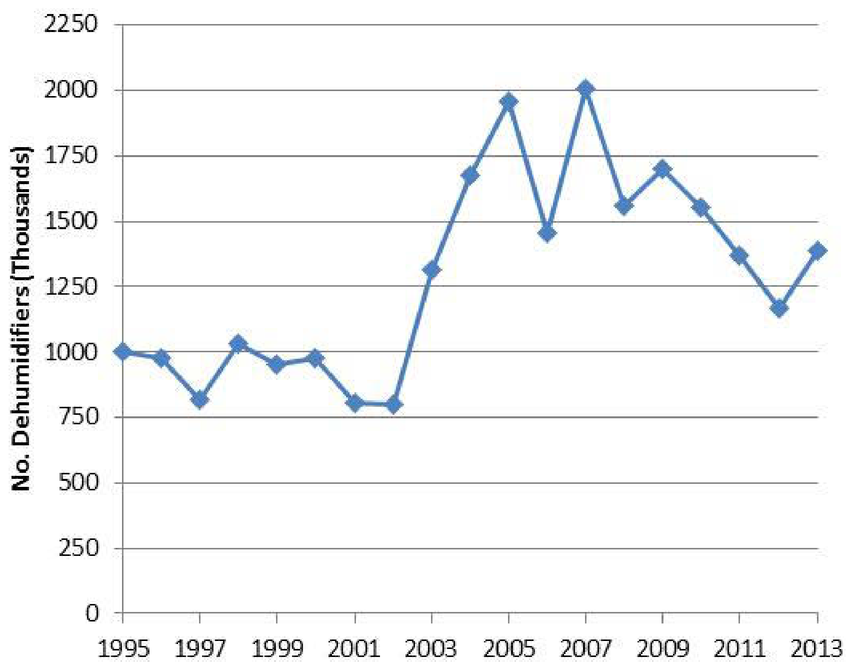
Awareness of annual product shipment trends is an important aspect of the market assessment and in the development of the standards rulemaking. DOE reviewed data collected by the U.S. Census Bureau and AHAM to evaluate dehumidifier shipment trends and the value of these shipments. Knowledge of such trends will be used during the shipments analysis (chapter 9 of this NOPR TSD).

### 3.9.1 Unit Shipments

AHAM's *2005 Fact Book* provides annual unit shipments for dehumidifiers from 1995 to 2005. In response to a data request, AHAM provided additional shipment information for 2006 through 2011. Table 3.9.1 presents the annual shipments of dehumidifiers for the 17-year period from 1995 to 2011. The complete AHAM data submittal is included in appendix 3A of this TSD.

**Table 3.9.1 Industry Shipments of Dehumidifiers (Domestic and Import)**[6, 7, 8]

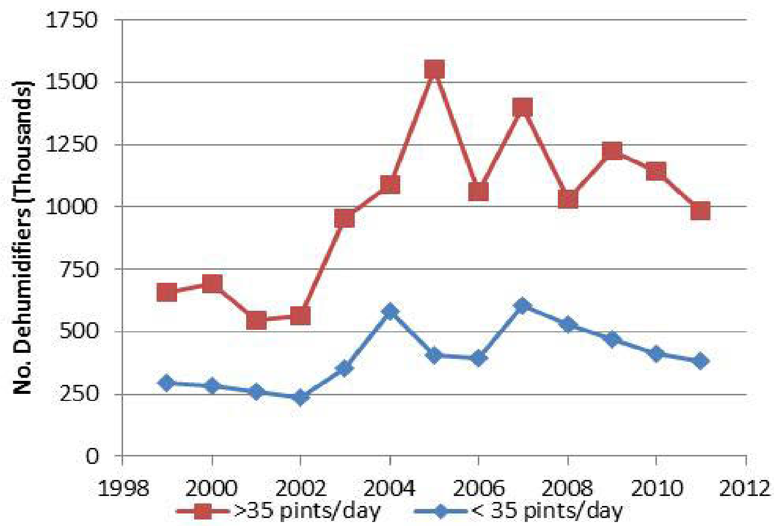
| Year | Shipments *(Thousands)* |
|---|---|
| 2013 | 1,385 |
| 2012 | 1,168 |
| 2011 | 1,368 |
| 2010 | 1,552 |
| 2009 | 1,700 |
| 2008 | 1,558 |
| 2007 | 2,004 |
| 2006 | 1,456 |
| 2005 | 1,957 |
| 2004 | 1,672 |
| 2003 | 1,311 |
| 2002 | 799 |
| 2001 | 806 |
| 2000 | 975 |
| 1999 | 950 |
| 1998 | 1,031 |
| 1997 | 820 |
| 1996 | 977 |
| 1995 | 1,003 |




In its data submittal, AHAM also provided capacity-specific shipment data for dehumidifiers. Table 3.9.2 presents a breakdown of the shipments of units greater than 35 pints/day and less than 35 pints/day, as measured by appendix X, from 1999 to 2011. DOE notes that Federal energy conservation standards took effect in 2007, and ENERGY STAR qualification criteria took effect in both 2006 and 2008. The implementation of these programs could have caused some of the year-to-year variation in shipments observed during that time period.

**Table 3.9.2 Dehumidifier Capacity-Specific Shipments (Domestic and Import)[9]**

| | Shipments *(Thousands)* | |
|---|---|---|
| **Year** | **Less than 35 pints/day** | **More than 35 pints/day** |
| 2011 | 384 | 984 |
| 2010 | 409 | 1,143 |
| 2009 | 472 | 1,227 |
| 2008[a] | 527 | 1,031 |
| 2007 | 603 | 1,401 |
| 2006[b] | 395 | 1,061 |
| 2005 | 406 | 1,551 |
| 2004 | 584 | 1,089 |
| 2003 | 353 | 958 |
| 2002 | 236 | 563 |
| 2001 | 260 | 545 |
| 2000 | 281 | 695 |
| 1999 | 294 | 656 |




a) ENERGY STAR criteria (effective June 1, 2008)
b) ENERGY STAR criteria (effective October 1, 2006)

### 3.9.2 Value of Shipments

Table 3.9.3 provides the value of shipments for the manufacturers in the NAICS category of small electric household appliances excluding fans (product class code 3352114) from 2003 to 2010. The values are based on data from the U.S. Census Bureau's *Current Industrial Reports*[g] (*CIR*) and *Annual Survey of Manufacturers*[h] (*ASM*). This NAICS category includes companies primarily engaged in manufacturing small electric household appliances such as coffee makers, toaster ovens, portable room heaters, mixers, air purifiers, food processors, and portable dehumidifiers. The U.S. Census Bureau reports all shipment values in nominal dollars, *i.e.*, 2010 data are expressed in 2010 dollars and 2009 data are expressed in 2009 dollars. Using the Gross Domestic Product Implicit Price Deflator (GDPIPD) published by the U.S. Bureau of Economic Analysis[i], DOE converted each year's value of shipments to 2013 dollars.

[g] Available online at *www.census.gov/manufacturing/cir/index.html*
[h] Available online at *www.census.gov/manufacturing/asm/index.html*
[i] Available online at *www.bea.gov/itable/*

**Table 3.9.3 Annual Shipment Value of Small Electric Household Appliances**[10, 11, 12,]

| | Annual Shipment Value *($ millions)* | |
|---|---|---|
| **Year** | **Nominal Dollars** | **2013 Dollars** |
| 2011 | 1,043 | 1,078 |
| 2010 | 1,107 | 1,167 |
| 2009 | 1,337 | 1,427 |
| 2008 | 1,098 | 1,181 |
| 2007 | 1,115 | 1,223 |
| 2006 | 1,206 | 1,358 |
| 2005 | 1,338 | 1,552 |
| 2004 | 1,254 | 1,502 |
| 2003 | 1,080 | 1,329 |

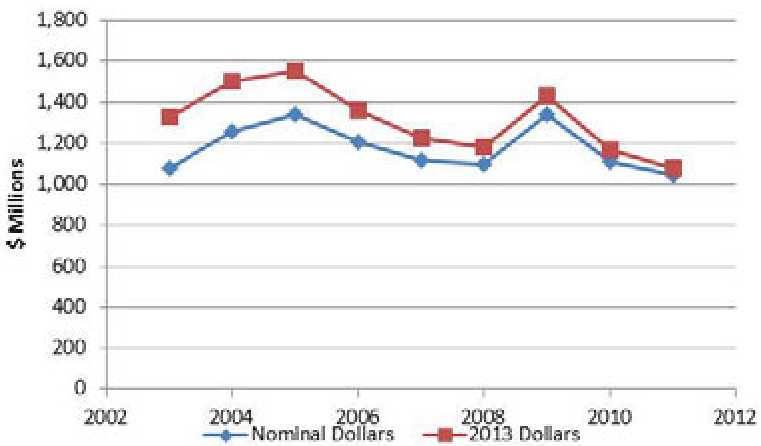



Table 3.9.4 provides the annual shipment value for the NAICS product class for "Small Electromechanical Household Appliances" (product class code 3352114150), which includes cordless household food preparation appliances, portable dehumidifiers, air purifiers, and other small appliances, from 2006 to 2010 based upon data from the U.S. Census Bureau's *CIR* and *ASM*. The U.S. Census Bureau shipment values are expressed in nominal dollars. DOE used the GDPIPD to convert each year's value of shipments to 2013 dollars.

**Table 3.9.4 Annual Shipment Value of Small Electromechanical Household Appliances**[13, 14, 15, 16, 17]

| | Annual Shipment Value *($ millions)* | |
|---|---|---|
| **Year** | **Nominal Dollars** | **2013 Dollars** |
| 2010 | 632 | 666 |
| 2009 | 653 | 697 |
| 2008 | 558 | 600 |
| 2007 | 595 | 652 |
| 2006 | 731 | 823 |

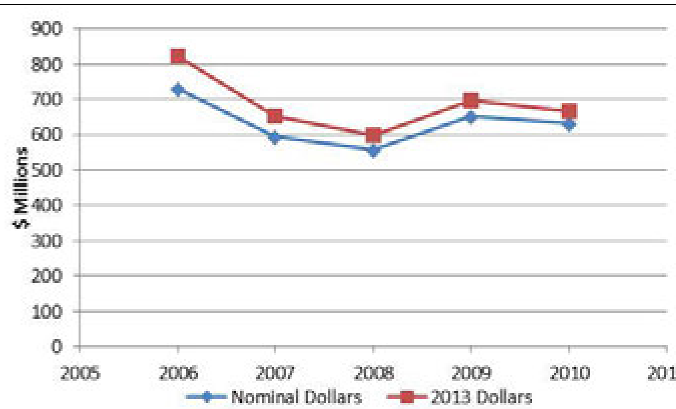
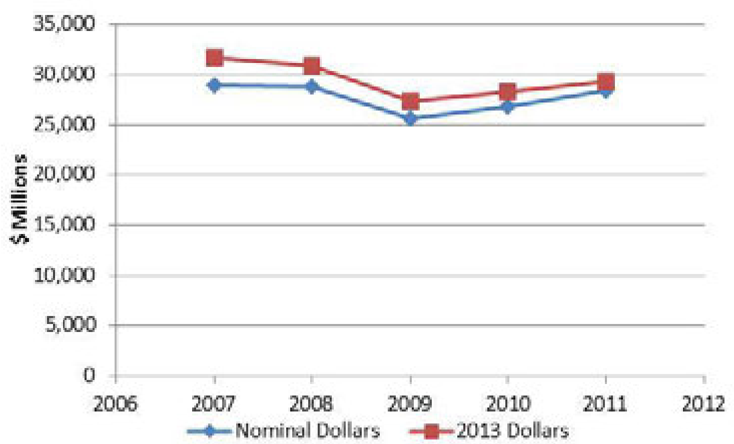



Table 3.9.5 provides the annual shipment value for the NAICS product class for "air-conditioning and warm air heating equipment and commercial and industrial refrigeration equipment manufacturer" (product class code 333415), which includes various air-conditioning equipment, refrigerated drinking fountains, whole-home humidifying equipment, and whole home dehumidifiers, and others from 2007 to 2011 based upon data from the U.S. Census

Bureau's *CIR* and *ASM*. The U.S. Census Bureau shipment values are expressed in nominal dollars. DOE used the GDPIPD to convert each year's value of shipments to 2013 dollars.

**Table 3.9.5 Annual Shipment Value of Air Conditioning Equipment**[18, 19, 20, 21]

| Year | Annual Shipment Value *($ millions)* Nominal Dollars | 2013 Dollars |
|---|---|---|
| 2011 | 28,407 | 29,348 |
| 2010 | 26,823 | 28,284 |
| 2009 | 25,688 | 27,418 |
| 2008 | 28,774 | 30,945 |
| 2007 | 28,939 | 31,733 |




According to data presented in the AHAM *2003 Fact Book*, many old appliances are still being used after consumers purchase new units of same product. Table 3.9.6 presents the various methods by which consumers dispose of their older dehumidifiers.

**Table 3.9.6 Disposition of Previous Dehumidifiers**[22]

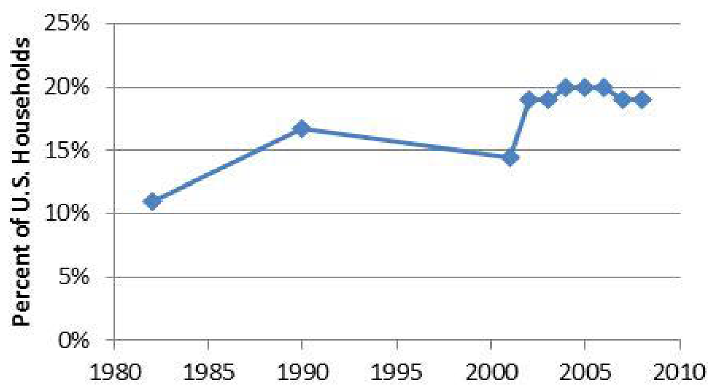
| Product | Kept It | Left with Previous Home | Sold / Gave Away | Recycling Facility | Left at Curb for Disposal | Retailer Took Away |
|---|---|---|---|---|---|---|
| Dehumidifiers | 18% | 14% | 23% | 13% | 24% | 4% |

## 3.10 MARKET SATURATION

AHAM's *2005 Fact Book* and the January 2010 *Appliance Market Research Report* present the market saturation for dehumidifiers. The market saturation of dehumidifiers has gradually increased and doubled since 1982. However, from 1990 through 2001 the market saturation decreased by 2 percent. For the 6 years from 2003 through 2008, the market saturation remained constant at around 20 percent. Table 3.10.1 presents the percentage of U.S. households with dehumidifiers.

**Table 3.10.1 Percentage of U.S. Households with Dehumidifiers[23, 24]**

| Year | % of U.S. Households |
|---|---|
| 2008 | 19 |
| 2007 | 19 |
| 2006 | 20 |
| 2005 | 20 |
| 2004 | 20 |
| 2003 | 19 |
| 2002 | 16 |
| 2001 | 15 |
| 1990 | 17 |
| 1982 | 11 |




## 3.11 PRODUCT RETAIL PRICES

For the preliminary analysis, DOE used the DOE Compliance Certification Management System (CCMS)[j] database, along with the California Energy Commission (CEC)[k] and ENERGY STAR[l] product databases, to identify a total of 214 portable and whole-home models of residential dehumidifiers on the market in the United States at that time, which encompassed 56 different brands. DOE collected consumer retail price data for these products from the websites of seven types of retailers: home improvement stores, discount retail stores, discount department stores, national office supply stores, national hardware stores, manufacturer websites, and online appliance retailers.

Figure 3.11.1 and Figure 3.11.2 summarize the data collected by DOE. These figures suggest that retail price is positively related to capacity for both portable and whole-home dehumidifiers. The consumer retail prices for portable dehumidifiers[m] ranged from $128 to $410, with an average of $240 (this is the average across all portable models and does not reflect the shipment-weighted average). Portable dehumidifiers are available with capacities ranging from 30 pints/day to 71 pints/day,[n] as measured by the current dehumidifier test procedure, with an average capacity of 52 pints/day.

The consumer retail prices for whole-home and high-capacity portable (greater than 75 pints/day capacity) dehumidifiers ranged from $1,000 to $5,499, with a model-based average of $1,979. Whole-home and high-capacity portable units range in capacity from 61 pints/day to 205 pints/day, with an average of 112 pints/day.

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[j] For more information, please visit www.regulations.doe.gov

[k] CEC appliance efficiency database available online at: http://www.energy.ca.gov/appliances/database/.

[l] ENERGY STAR database available online at http://www.energystar.gov/productfinder/product/certified-dehumidifiers/results

[m] High-capacity portable dehumidifiers (rated capacities greater than 75 pints/day) are excluded from these statistics.

[n] A 74 pint/day portable unit is also commercially available, but was excluded as an outlier from this retail price summary.

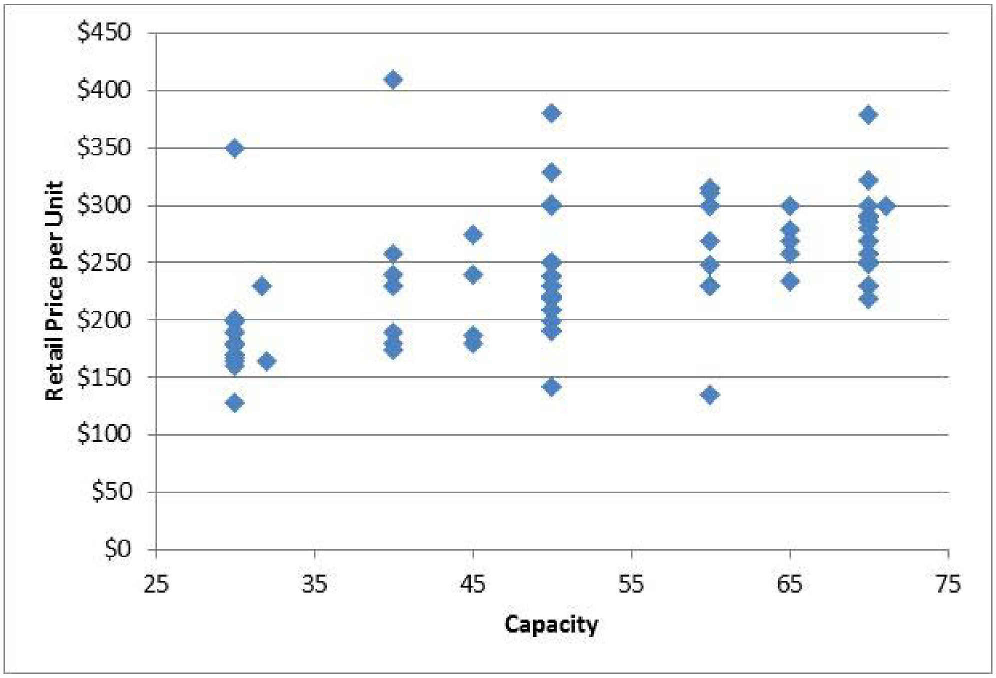


**Figure 3.11.1 Portable Residential Dehumidifier Retail Price versus Capacity**

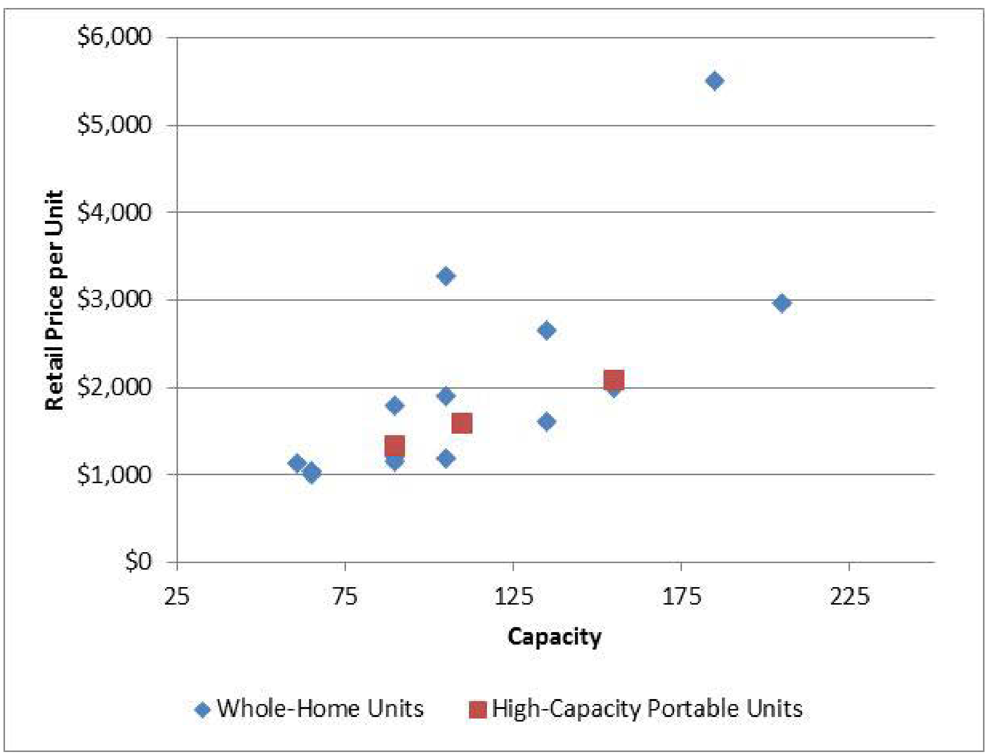


**Figure 3.11.2 Whole-Home and High-Capacity Portable Residential Dehumidifier Retail Price versus Capacity**

Other factors besides capacity and product type, such as efficiency, ENERGY STAR rating, and retailer, also may impact residential dehumidifier price.

## 3.12 INDUSTRY COST STRUCTURE

DOE developed the cost structure for two industry classifications associated with the residential dehumidifier industry from publicly available information from the *ASM* and Economic Census and the U.S. Securities and Exchange Commission (SEC) 10-K reports filed by publicly-owned manufacturers. **Table** 3.12.1 presents the small electrical appliance manufacturing industry (NAICS code 33521) employment levels and earnings from 2002–2011. The statistics illustrate a steady decline in the number of production and non-production workers in the industry since 2002, except during the period from 2005 to 2007 in which there was a slight increase.

DOE converted the payroll data to constant 2013 dollars using the GDPIPD published by the U.S. Bureau of Economic Analysis[o]. Table 3.12.1 shows that as industry employment levels decline, the industry payroll in constant 2013 dollars also decreases from 2002 to 2011, with a slight rebound from 2005 to 2007. The percent decrease in total industry employees tracks relatively closely with the percent decrease (increase) in payroll for all employees.

**Table 3.12.1 Small Electrical Appliance Manufacturing Industry Employment and Earnings[25]**

| Year | Production Workers | All Employees | Total Payroll *(2013 $ Mil)* |
|---|---|---|---|
| 2011 | 5,713 | 7,619 | 348 |
| 2010 | 6,383 | 8,536 | 385 |
| 2009 | 7,609 | 10,072 | 434 |
| 2008 | 9,905 | 12,809 | 546 |
| 2007 | 10,816 | 13,502 | 577 |
| 2006 | 9,870 | 12,715 | 533 |
| 2005 | 9,680 | 13,297 | 538 |
| 2004 | 11,770 | 15,533 | 636 |
| 2003 | 12,682 | 16,752 | 685 |
| 2002 | 14,293 | 18,781 | 761 |

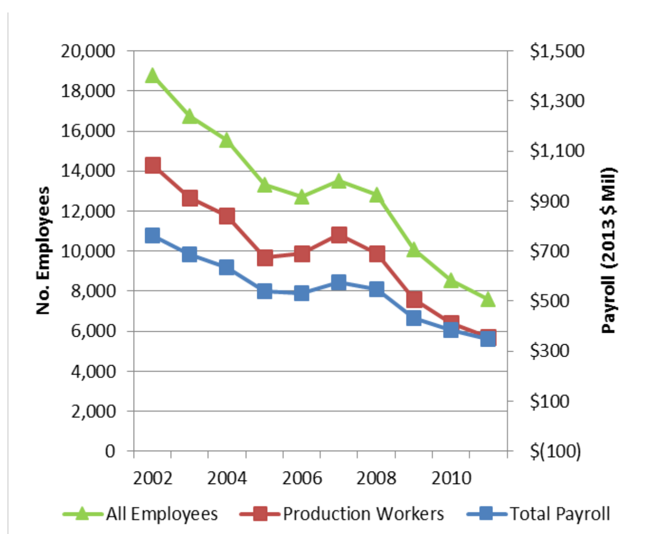


Table 3.12.2 presents the employments levels and payroll for NAICS code 333415, corresponding with "air-conditioning and warm air heating equipment and commercial and industrial refrigeration equipment manufacturing"[p], which includes whole-home dehumidifiers.

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

[p] Four out of five small business manufacturers identified and discussed in section 3.6.3 of this chapter are classified under this NAICS code.

Both employment and earnings statistics show a decline between 2007 and 2009 with levels remaining largely flat thereafter through 2011.

**Table 3.12.2 Air-Conditioning and Warm Air Heating Equipment Manufacturing Industry Employment and Earnings[26]**

| Year | Production Workers | All Employees | Total Payroll *(2013 $ Mil)* |
|---|---|---|---|
| 2011 | 62,009 | 83,969 | $3,764 |
| 2010 | 61,380 | 83,054 | $3,979 |
| 2009 | 60,041 | 86,454 | $3,913 |
| 2008 | 70,787 | 96,610 | $4,324 |
| 2007 | 74,728 | 101,485 | $4,423 |
| 2006 | 74,909 | 102,354 | $4,525 |
| 2005 | 76,011 | 98,097 | $4,423 |

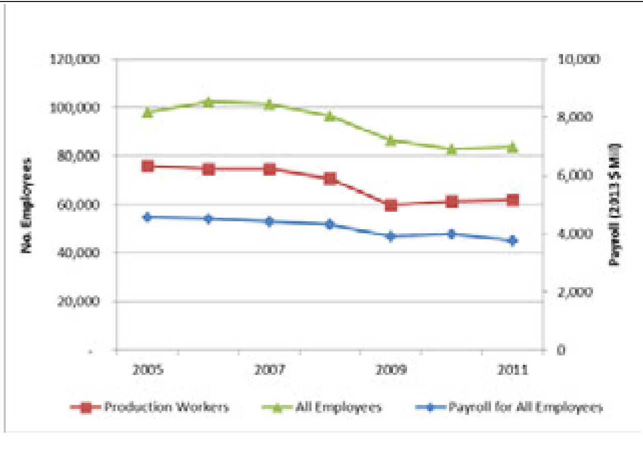



Table 3.12.3 presents the costs of materials and industry payroll as a percentage of value of shipments from 2002–2011 for the small electrical appliance manufacturing industry. The cost of materials as a percentage of value of shipments has remained fairly constant over the 10-year period, with some notable fluctuations, particularly an increase from 2002 to 2003 and a decrease between 2008 and 2010. DOE notes that fluctuations in raw material costs are common from year to year. The payroll for both production and non-production workers as a percentage of value of shipments has remained relatively stable since 2002.

**Table 3.12.3 Small Electrical Appliance Manufacturing Industry Materials and Wages Cost[27]**

| | Cost as a Percentage of Value of Shipments *(%)* | | |
|---|---|---|---|
| **Year** | **Materials** | **Payroll for Production Workers** | **Payroll for All Other Employees** |
| 2011 | 53% | 7% | 5% |
| 2010 | 49% | 6% | 5% |
| 2009 | 51% | 6% | 5% |
| 2008 | 54% | 7% | 5% |
| 2007 | 55% | 8% | 5% |
| 2006 | 54% | 8% | 5% |
| 2005 | 53% | 7% | 5% |
| 2004 | 52% | 7% | 5% |
| 2003 | 52% | 8% | 5% |
| 2002 | 47% | 8% | 5% |

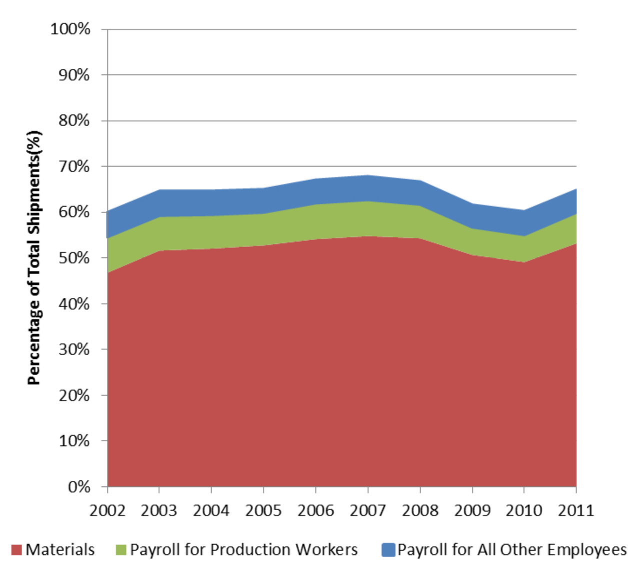


Table 3.12.4 shows the cost of materials and industry payroll as a percentage of value of shipments for the air-conditioning and warm air heating equipment and commercial and industrial refrigeration equipment manufacturing industry from 2005–2011. Material prices as a percentage of value of shipments have remained relatively constant over the 5-year period, with fluctuations from year to year. The cost of payroll for production workers as a percentage of value of shipments has decreased slightly since 2005. Finally, the cost of non-production payroll has remained relatively constant over the 7-year period, with fluctuations from year to year. DOE notes that, overall, wages and cost of materials combined represent approximately the same percentage of the total shipments value for the air-conditioning and warm air heating equipment industry and for the small electrical appliance industry.

**Table 3.12.4 Air-Conditioning and Warm Air Heating Equipment Manufacturing Industry Materials and Wages Cost[28]**

| | **Cost as a Percentage of Value of Shipments (%)** | | |
|---|---|---|---|
| **Year** | **Materials** | **Payroll for Production Workers** | **Payroll for All Other Employees** |
| 2011 | 55% | 8% | 5% |
| 2010 | 53% | 8% | 6% |
| 2009 | 55% | 8% | 6% |
| 2008 | 55% | 8% | 5% |
| 2007 | 56% | 8% | 5% |
| 2006 | 53% | 9% | 5% |
| 2005 | 54% | 9% | 5% |

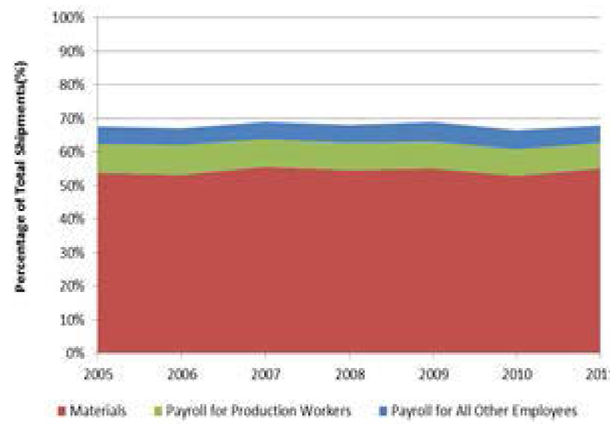



Table 3.12.5 presents the industry cost structure derived from SEC 10-K reports of publicly-owned dehumidifier manufacturers. DOE averaged the financial data from 2006–2012 of U.S.-based appliance manufacturers to obtain an industry average. Each financial statement entry is presented as a percentage of total revenues.

**Table 3.12.5 Industry Cost Structure Using SEC Data, Average 2006–2012**

| **Financial Statement Entry** | **Percent of Revenues** |
|---|---|
| Cost of sales | 71.7% |
| EBIT | 7.5% |
| Selling, general and administrative | 20.9% |
| Capital expenditure | 2.7% |
| Research and development | 1.3% |
| Depreciation and amortization | 2.5% |
| Net plant, property and equipment | 13.4% |
| Working capital | 11.28% |

A detailed financial analysis is presented in the manufacturer impact analysis (MIA, chapter 12 of this NOPR TSD). This analysis identifies key financial inputs including cost of capital, working capital, depreciation, capital expenditures, *etc*.

## 3.13 INVENTORY LEVELS AND CAPACITY UTILIZATION RATES

Table 3.13.1 and Table 3.13.2 show the year-end inventory for the small electrical appliance manufacturing and air-conditioning and warm air heating industries, according to the *ASM*. The trend in the value of end-of-year inventory in dollars for the small electrical appliance industry was relatively variable between 2005 and 2011, notably increasing 34 percent from 2006 to 2007, and decreasing 22 percent between 2008 and 2009. The decrease in inventories of small electrical appliance manufacturers from 2007 to 2009 aligns with the end of the 2007 to 2009 recession, and was likely a reaction to the decline in new orders during that period. From 2005 to 2011, inventories as a percentage of the value of shipments tracked ending inventories fairly closely until 2009, when it began to increase steadily, indicating that small electrical appliance shipments have decreased in recent years. For the air-conditioning and warm air heating equipment manufacturing industry, the value of the end-of-year inventories was less volatile than that for the small electrical appliance manufacturing industry, increasing from 2005 to 2007 and decreasing from 2007 to 2011. Inventory as a percentage of the value of shipments followed a similar trend, increasing from 2005 to 2007 and decreasing thereafter.

**Table 3.13.1 Small Electrical Appliance Manufacturing Industry Inventory Levels[29]**

| **Year** | **End-of-Year Inventory** (*2013 $ Mil*) | **EOY inventory as % of Shipments Value** |
|---|---|---|
| 2011 | 424 | 14.1% |
| 2010 | 457 | 13.0% |
| 2009 | 457 | 11.4% |
| 2008 | 583 | 13.1% |
| 2007 | 586 | 13.2% |
| 2006 | 436 | 10.5% |
| 2005 | 439 | 9.9% |

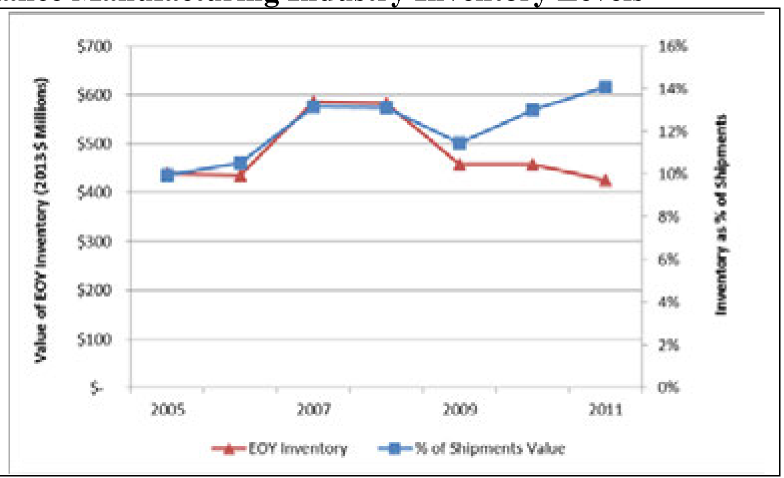
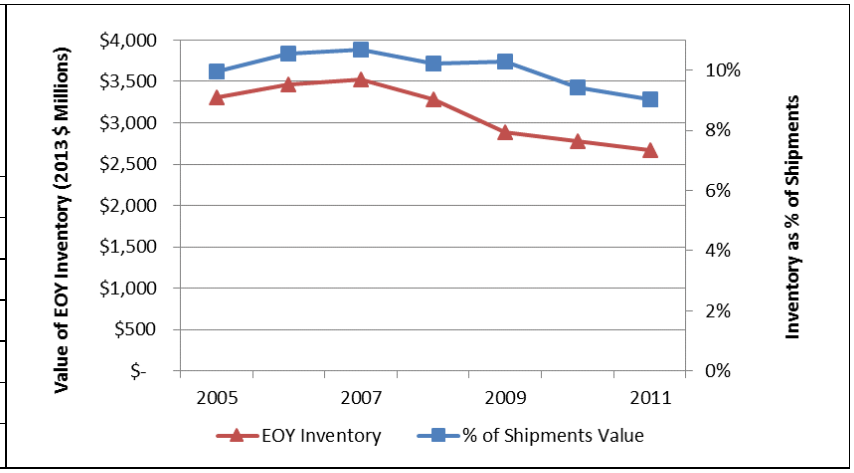


**Table** 3.13.2 **Air-Conditioning and Warm Air Heating Equipment Manufacturing Industry Inventory Levels**[30]

| Year | End-of-Year Inventory *(2013 $ Mil)* | EOY inventory as % of Shipments Value |
|---|---|---|
| 2011 | 2,667 | 9% |
| 2010 | 2,775 | 9% |
| 2009 | 2,888 | 10% |
| 2008 | 3,277 | 10% |
| 2007 | 3,523 | 11% |
| 2006 | 3,458 | 11% |
| 2005 | 3,307 | 10% |

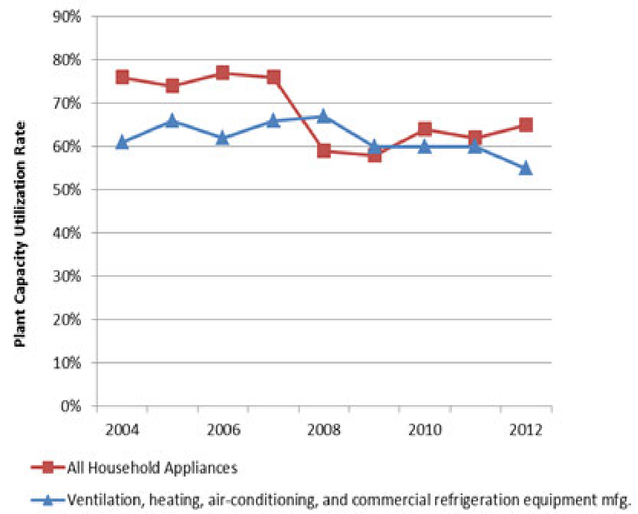



DOE obtained full production capacity utilization rates from the U.S. Census Bureau's *Survey of Plant Capacity* from 2004–2006. After 2006, the Census Bureau discontinued this survey, and began a new *Quarterly Survey of Plant Capacity Utilization*. However, this survey does not collect utilization data beyond the 4 digit NAICS codes for the "all household appliances"[q] and "ventilation, heating, air-conditioning, and commercial refrigeration equipment"[r] industries. Table 3.13.3 presents utilization rates for these umbrella industries.

Full production capacity is defined as the maximum level of production an establishment could attain under normal operating conditions.[s] 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 capacity. The full production utilization rate for all household appliances shows fairly steady utilization between 74 and 77 percent from 2004 through 2007, with a significant decrease to less than 60 percent from 2008 through 2009, and then a partial rebound from 2010 to 2012. Plant capacity utilization for ventilation, heating, air-conditioning, and commercial refrigeration manufacturers reached a peak in 2008, at 67 percent, and hit a low of 55 percent in 2012.

[q] "All Home Appliances" is the umbrella NAICS category 3352 that includes NAICS code 33521 for "Small Electrical Appliances."
[r] "Ventilation, heating, air-conditioning, and commercial refrigeration equipment" is the umbrella NAICS category 3334 that includes NAICS code 333415 for "air-conditioning and warm air heating equipment and commercial and industrial refrigeration equipment."
[s] For more information, please visit: http://www.census.gov/manufacturing/capacity/definitions/index.html

**Table 3.13.3 Full Production Capacity Utilization Rates**[31, 32]

| | Plant Capacity Utilization Rates *(%)* | | |
|---|---|---|---|
| **Year** | **All Household Appliances** | **Ventilation, heating, air-conditioning, and commercial refrigeration equipment mfg.** | |
| 2012 | 65% | 55% |  |
| 2011 | 62% | 60% | |
| 2010 | 64% | 60% | |
| 2009 | 58% | 60% | |
| 2008 | 59% | 67% | |
| 2007 | 76% | 66% | |
| 2006 | 77% | 62% | |
| 2005 | 74% | 66% | |
| 2004 | 76% | 61% | |



## 3.14 TECHNOLOGY ASSESSMENT

This section provides a technology assessment for dehumidifiers. Contained in this technology assessment are details about product characteristics and operation (section 3.14.1), an examination of possible technological improvements (section 3.14.2), and a characterization of the product efficiency levels currently commercially available (section 3.14.3).

### 3.14.1 Dehumidifier Operations and Components

Dehumidifiers are refrigeration-based appliances that enable homeowners to reduce indoor relative humidity (RH). RH is defined as the amount of water vapor present in the air compared to the maximum amount of water vapor the air can hold at that temperature. A desirable indoor RH is typically between 30 and 60 percent.

Dehumidifiers contain refrigeration systems that remove latent heat, and therefore moisture, from ambient air. Components of the refrigeration system include an evaporator, an expansion valve or capillary tube, a condenser, and a compressor.

Refrigeration-based dehumidifiers operate as follows:

1. A circulating fan draws air into the dehumidifier via an intake vent, or in the case of whole-home dehumidifiers, via an inlet air duct, typically in the front or on the sides of the unit;
2. The air is pulled across an evaporator heat exchanger that is cooled by an electrically-powered vapor compression refrigeration system;
3. The evaporator cools the air, and moisture from the air condenses on the surface of the evaporator and drips either into a bin or out a drain; and

4. The drier air is then typically pulled over a warm condenser heat exchanger and exits the dehumidifier via an outlet grille, or in the case of whole-home dehumidifiers, via an outlet air duct, typically on the top or sides of the unit.

This process is illustrated in Figure 3.14.1.

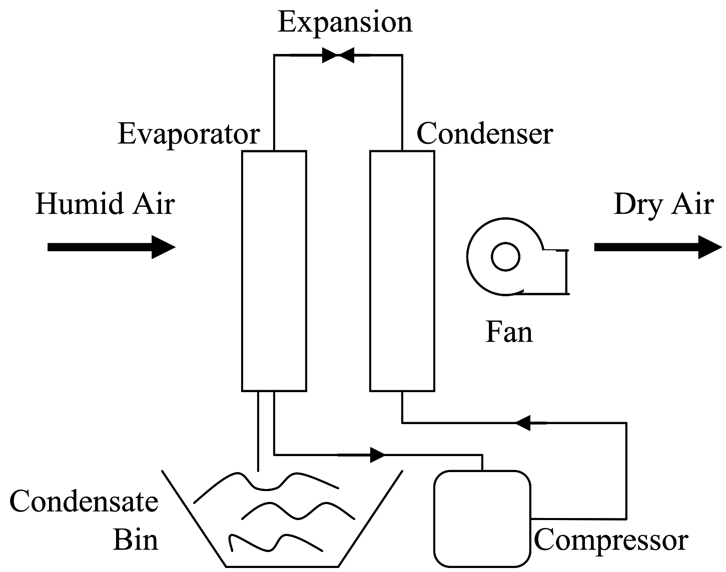



**Figure 3.14.1 Dehumidifier Operation Schematic**

When the surface temperature of the evaporator is lower than the dew point of the air passing over it, the removal of latent heat occurs through condensation. All residential portable dehumidifiers are equipped with an automatic shut-off function that halts operation of the device once the condensate collection tank is full. They may also include a direct drain hose connection and occasionally an internal pump for direct drainage of condensate into a sump pump or floor drain. Whole-home dehumidifiers typically only include a direct drain hose connection and no internal condensate collection tank. This allows for continuous operation without the need for user intervention to periodically empty the condensate collection tank.

There is a wide scope of control strategies, ranging from simple on/off mechanical humidistats and single-speed fans to electronic controllers that use multiple sensors, liquid-solenoid controls, and other devices to maximize unit performance. All dehumidifiers sense the evaporator coil or liquid line temperature to prevent icing, though some units may include sensors in multiple locations to avoid ice accumulation.

The electrically-powered components of the refrigeration-based dehumidifier system include the fan motor, the compressor that powers the refrigeration system, any electronic sensors or controls, and a (optional) built-in sump pump or similar accessory.

### 3.14.2 Dehumidifier Technology Options

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

DOE identified design options to improve dehumidifier efficiency during the preliminary analysis. DOE relied on previous rulemaking TSDs and information gathered during testing and teardowns to develop the list of technology options. DOE again considered these technology options in this NOPR analysis. For more details on the reverse-engineering teardown activities, see chapter 5 of this NOPR TSD.

The technology options for dehumidifiers are listed in Table 3.14.1. They are features that can be incorporated into the design of a dehumidifier to improve its efficiency. Based on product literature research, stakeholder interviews, and teardown analysis, DOE has identified compressor, heat exchanger, and fan motor improvements as the most common ways by which manufacturers may improve the energy efficiency of their dehumidifiers as measured by the DOE test procedure.

**Table 3.14.1 Technology Options for Dehumidifiers**

| |
|---|
| 1. Built-in hygrometer/humidistat |
| 2. Improved compressor efficiency |
| 3. Improved condenser and evaporator performance |
| 4. Improved controls |
| 5. Improved defrost methods |
| 6. Improved demand-defrost controls |
| 7. Improved fan and fan-motor efficiency |
| 8. Improved flow-control devices |
| 9. Low-standby-loss electronic controls |
| 10. Washable air filters |
| 11. Pre-cooling air-to-air heat exchanger |
| 12. Heat pipes |
| 13. Improved refrigeration system insulation |
| 14. Refrigerant-desiccant systems |

***Built-in hygrometer/humidistat***

All portable dehumidifiers subjected to DOE teardowns featured some type of built-in humidity controller. For all units in the teardown sample, DOE observed electronic controls, but DOE is aware that certain units may still feature electromechanical humidistats. The humidistat cycles the compressor and fan power supply as a function of relative humidity. Both electronic and electromechanical controllers measure the expansion of a reference material as a function of relative humidity. DOE notes that whole-home dehumidifiers are often designed to be used in conjunction with a remote humidistat. The humidistat is placed in the portion of the home that requires dehumidification, and cycles the whole-home dehumidifier compressor and fan power supply as needed. Although this control is external to the unit, DOE does not expect significant differences in efficiency or operation when compared to the built-in controls on portable units.

***Improved compressor efficiency***

Most dehumidifier manufacturers incorporate rotary R-410A compressors into their units. "Inertia" compressors, scroll compressors, and variable-speed compressors all have higher efficiencies than the traditional rotary compressors used in dehumidifiers. However, finding a suitable high-efficiency compressor at the capacities and price points needed for a dehumidifier is a challenge.

The "inertia" compressor is a technology that allows reciprocating compressors to approach an energy efficiency ratio (EER) of 12.0, where EER represents the cooling capacity in Btu/hr divided by the input wattage of the compressor. "Inertia" compressors utilize lightweight, responsive valve technology and an innovative refrigerant flow path to reduce losses and improve cylinder volumetric efficiency.

Scroll compressors require high precision to produce their internal components and are typically found in higher-efficiency central air-conditioning systems. Scroll compressors compress gas in a fundamentally different manner from traditional compressors — between two spirals, one fixed and one nutating. Scroll compression is inherently more efficient than traditional compression methods.

Both inertia and scroll compressors are, however, substantially larger, heavier, and sometimes noisier than their rotary counterparts, and, as such, are not well-suited for use in residential dehumidifiers.

Variable-speed compressors are typically implemented through the use of an electronic control that varies the input frequency of the power supply for the compressor motor. Variable-speed compressors enable modulation of the refrigeration-system cooling power beyond simple on/off control, allowing the dehumidifier to better match the compressor power to the load, increasing compression efficiency. Variable-speed compressor technology has not yet been implemented in residential dehumidifiers, and it is therefore difficult to predict the energy efficiency improvements that could be achieved through its use. However, DOE expects that a variable-speed compressor in a dehumidifier could provide more precise control of the evaporator coil temperature to ensure more efficient latent heat removal, especially at low temperatures where ice buildup is prevalent.

***Improved condenser and evaporator performance***

Improving the overall heat transfer capability of the dehumidifier condenser and evaporator coils would result in improved efficiency of the refrigeration system. DOE notes that many factors contribute to heat exchanger performance, including size, number of fins, type of fins, number of tube passes, etc. DOE notes that almost all dehumidifier models in its teardown sample had similarly constructed heat exchangers with "slit" aluminum fins for more turbulent airflow, roughly 20 fins per inch, and internally-rifled copper tubing for optimized refrigerant heat exchange, although the heat exchangers did vary in size from unit to unit.

### *Improved controls*

Manufacturers have increasingly adopted digital controllers for dehumidifiers due to consumer demand and because such controllers allow dehumidifiers to better respond to changing environmental conditions. Unlike the snap-action switches and fixed-RH electromechanical controllers they replace, digital controllers can measure multiple inputs and respond to present conditions as well as trends.

Digital controllers can use varying approaches, from rigid decision trees to fuzzy logic. During the reverse-engineering process, DOE observed that most electronic control boards were purchased parts that had been mass-customized for the specific dehumidifier. One advantage of digital controllers is the ease with which they can be reprogrammed, allowing a manufacturer to use one control board for its entire dehumidifier line, yet optimize its responses per dehumidifier model.

It is difficult to predict the amount of energy savings that could be achieved through the implementation of improved controllers because the current DOE test procedure evaluates continuous dehumidifier operation at constant ambient conditions.

### *Improved defrost methods*

As the air drawn into the dehumidifier is cooled, water vapor condenses on the surface of the evaporator coil. In some cases, typically when the ambient air is typically below 65 °F, this water can freeze as it collects and form a growing layer of frost. The frost reduces cooling performance by increasing the thermal resistance to heat transfer from the coil to the air and by obstructing air flow. Both the method by which defrost is performed and control of the defrost cycle can lead to substantial energy savings.

Many dehumidifiers incorporate defrost technology. In general, two types of defrost mechanisms are available: passive defrost and active defrost. According to market research and investigative testing, most dehumidifiers that feature defrost technology use active defrost. This is especially true for dehumidifiers that are designed and marketed for low-temperature operation (*i.e.*, for use in basements).

Dehumidifiers using passive defrost or off-cycle mode monitor the temperature of the evaporator and shut both the compressor and fan off if that temperature drops below the freezing point of water. This is not technically "defrost," as it actually prevents the formation of frost rather than eliminating frost after it forms. It is, however, an effective method of preventing the dehumidifier from operating under low-efficiency frosted conditions. This method is simple to implement and incurs no additional energy expenditure.

Active defrost in dehumidifiers is conducted in one of three ways: fan-only defrost, electric defrost, or hot-gas defrost.

Fan-only defrost involves shutting off the refrigeration system while keeping the air-circulation system running. The relatively warm ambient air melts the frost layer, and the dehumidifier subsequently resumes operation. Fan-only defrost may allow much of the frozen condensate to be reabsorbed into the ambient air as it melts, compromising the effectiveness of the dehumidifier.

Electric defrost involves melting frost by briefly activating an electric resistance heater, which is in contact with or near the evaporator. The heater melts frost quickly but consumes significant energy. Hot-gas defrost uses the hot compressor discharge gas to warm the evaporator from the refrigerant side. Electricity usage is reduced in comparison to the electric defrost method; however, this method necessitates more complicated piping and control than electric defrost systems. Neither of these defrost technologies were identified in dehumidifiers through market research, and were not present in any units that were disassembled during DOE's teardowns.

Defrost methods are not currently captured as part of the DOE test procedures because units are tested in dehumidification mode at 80 °F conditions where icing is unlikely to occur. At the 65 °F test conditions, which DOE established in appendix X1, however, certain dehumidifiers in DOE's test sample exhibited operational patterns that were indicative of fan-only defrost. For those units, actual energy savings will be a function of ambient conditions and usage patterns.

***Improved demand-defrost controls***

In all active-defrost systems, control of the defrost cycle may lead to substantial energy savings. Defrost-cycle control involves management of the initiation and termination of defrost cycles, and thereby management of the frequency and duration of defrost cycles. Two different defrost-cycle control designs are available: timer-controlled and temperature-sensor-controlled.

In a time-based defrost system, cycles are completely scheduled, and initiation and termination are timer-controlled. Cycles are initiated at regular intervals and terminated after a fixed amount of time or in response to low ambient temperatures. In these systems, cycle frequency and duration are not responsive to actual frost conditions. Under timer control, the frequency of defrost cycles is determined by the amount of time the manufacturer expects it to take for a large frost layer to develop in the worst-case scenario, and the cycle duration is long enough to ensure that the frost layer completely melts. Timer-based defrost can lead to unnecessarily frequent and unnecessarily long defrost cycles under anything but worst-case conditions.

Sensor-controlled defrost occurs as-needed based on evaporator coil temperatures. Defrost cycles are initiated in response to freezing temperatures at the evaporator coil or other area in the dehumidifier, and are terminated when the coil temperature reaches a value indicating complete defrost. This type of defrost control saves energy relative to timer-controlled defrost by varying cycle duration based upon defrost requirements. As with all defrost design options, actual energy savings will be a function of ambient conditions and usage patterns.

### *Improved fan and fan-motor efficiency*

The air-circulation system of a residential dehumidifier usually consists of a permanent split capacity (PSC) fan motor that drives either propeller-style blades or a tangential “squirrel cage” fan. These motors run on line voltage and typically feature one or two speeds. Multiple fan speeds are usually found on higher-end units. Some unit controllers can modulate fan speeds (high/low) whereas less complex models utilize a user-set switch.

Dehumidifiers are typically built using product platforms, where one enclosure serves multiple dehumidification capacities. As a result, the designers make tradeoffs to accommodate a wide range of capacities (35 to 65 pints/day, for example) within a single enclosure. While efficiency improvements could be achieved by optimizing fan blades for specific dehumidifier models, such a design change would add complexity to the manufacturing process by requiring a wider scope of fan blades to be stocked. Such steps would likely increase inventory, reduce fan blade purchase volumes and hence manufacturers see this as a relatively costly design option in relation to the efficiency benefit. Therefore, quantifying the efficiency improvements to the dehumidifier’s air-circulation system is restricted to analyzing the efficiency improvements to the fan motor only.

In a PSC motor, the start-up winding is electrically connected in parallel with the main winding and in series with a capacitor. At start-up, the interactions between the magnetic field generated by the start-up winding and that generated by the main winding induce rotation. As the capacitor charges, the current flowing through the start-up winding decreases and the start-up winding becomes an auxiliary winding after the motor reaches running speed. Consequently, the current to the start-up winding is cut off once the capacitor is fully charged and the motor reaches steady-state speed. Because of this, PSC motors are substantially more efficient than their shaded-pole counterparts, with motor efficiencies ranging from 60 to 65 percent.[33] Like shaded-pole motors, PSC motors are produced in large quantities and are relatively inexpensive.[34]

Electric motors with even higher efficiencies can be implemented by switching to permanent-magnet motors, which come in many varieties. The most widely-known variety is the electronically-commutated motor (ECM)[t], though DC-motors can also be used. Permanent magnet motors are less noisy and substantially more efficient than either shaded-pole or PSC motors. ECM motors convert single-phase AC input power into three-phase power, and have motor efficiencies approaching 80 percent.[35] However, ECM motors can weigh twice as much as equivalent PSC motors, potentially necessitating a redesign of the dehumidifier fan-motor chassis. In addition, ECM motors are complex, are not currently produced in large volumes, and can cost from 2.5 to 5 times as much as a PSC motor.[36]

### *Improved flow-control devices*

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[t] Also known as brushless permanent magnet (BPM) motors or electronically-commutated permanent magnet (ECPM) motors.

Nearly all portable dehumidifiers use capillary-tube expansion valves for flow control. The capillary-tube expansion valve is a pressure-reducing device that consists of a small-diameter line that connects the outlet of the condenser to the inlet of the evaporator. It is designed to provide optimum energy characteristics at one design point. If sized properly, the capillary-tube expansion valve compensates automatically for load and system variations and gives acceptable performance over a wide range of operating conditions. Because ambient temperature and humidity vary, however, dehumidifiers sometimes operate under conditions outside of the target conditions, leading to reduced efficiency.

The thermostatic expansion valve (TXV) — a flow-control alternative to the capillary tube — is commonly used in higher-efficiency central air-conditioning systems. TXVs regulate the flow of liquid refrigerant entering the evaporator in response to the superheat of the refrigerant leaving it. TXVs can adapt better to changes in operating conditions such as those due to variations in ambient temperature, which affect the condensing temperature. As a result, TXVs can lead to a somewhat increased seasonal operating efficiency.

Electronic expansion valves (EEVs) are similar to TXVs, but unlike TXVs, they can be actively controlled. While a TXV relies on a single temperature sensor for feedback, digital controllers can use multiple sensors for feedback control and respond using multiple approaches. For example, besides modulating the refrigerant flow, the controller may also vary the fan speed to optimize efficiency under varying conditions. As with TXVs, EEVs can use the superheat control method to regulate refrigerant flow. Other methods, such as controlling compressor discharge temperature, can also be used.

During the reverse-engineering analysis, DOE did not observe any units with either TXVs or EEVs. Given the cost of TXVs and EEVs, it is unlikely that manufacturers would implement them in residential dehumidifiers. Additionally, because dehumidifiers are tested during continuous operation under constant ambient conditions, the test procedure may not capture efficiency gains associated with these technologies.

***Low-standby-loss electronic controls***

Electronic controls may consume power even when the dehumidifier 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 will reduce the annual energy consumption of the dehumidifier, but will not impact the energy consumption of the dehumidifier during operation in dehumidification mode.

***Washable air filters***

The build-up of dust particles on the evaporator coil can lower the heat-transfer capability of the component. To minimize this possibility, most dehumidifiers incorporate an air filter at the air-intake vent. However, these filters can become clogged, obstructing air flow through the dehumidifier and reducing system performance. To prevent this, most manufacturers design the air filters to be removable and washable, which allows the consumer to clean the air filters on a regular basis. It is difficult to predict the amount of energy savings that could be realized with the addition of washable air filters, as it is dependent on the specific dehumidifier model and use characteristics, and on the degree to which the consumer takes advantage of this feature. Additionally, efficiency testing is often conducted on new dehumidifiers, so there would be likely be no clear efficiency impact due to dust build up in either the evaporator or in the air filter.

***Pre-cooling air-to-air heat exchanger***

The efficiency of a refrigeration-based dehumidification system may be increased by pre-cooling air prior to the evaporator inlet. With pre-cooled inlet air, the refrigeration system may consume less energy to maintain the proper evaporator temperature while removing additional condensate from the air. DOE found that many high-capacity dehumidifiers (greater than 75 pints/day) incorporate an air-to-air heat exchanger that transfers heat from the intake air to the air immediately exiting the evaporator. The energy savings that can be realized from this technology is dependent on a unit's specific airflow and component configuration. Based on DOE's analysis of existing models with and without air-to-air heat exchangers, DOE estimates that this technology option may result in a 10 to 25 percent reduction in active dehumidification mode energy use.

***Heat pipes***

Another method for increasing the efficiency of a refrigeration-based dehumidifier is to include a heat pipe system that acts as a pre-cooler for air entering the evaporator. A heat pipe system consists of a set of additional coils installed on each side of the evaporator. The coils are connected via a sealed refrigerant system, which is independent of the primary refrigeration system in the dehumidifier. The goal of the heat pipe is to passively transfer heat from the incoming air stream to the air stream exiting the evaporator.

The air entering the dehumidifier is pre-cooled by the refrigerant in the coil in front of the evaporator. The refrigerant in this section of the heat pipe evaporates as it gains heat from the inlet airstream and passively flows to the coil behind the evaporator. The pre-cooled air then passes through the evaporator, where the temperature of the air is decreased even further to condense moisture. Air exiting the evaporator is at a low temperature, so this air stream gains heat from the warmer refrigerant in the heat pipe coil behind the evaporator. As the refrigerant in this coil loses heat to the airstream, it condenses back to a liquid and passively flows back to the coil in front of the evaporator. As a result of this system, the evaporator is required to remove less heat from the incoming airstream, and less energy is required for the dehumidifier refrigeration system.

DOE was unable to identify any residential dehumidifiers that use heat pipes to boost performance by pre-cooling the inlet evaporator air. DOE is aware that units existed on the market until 2010, at which point the manufacturer chose to discontinue the product line for reasons unknown to DOE. DOE is, however, aware of packaged terminal air conditioners (PTACs) available on the market that incorporate heat pipe systems. The manufacturer for these products has provided limited information on their performance, including moisture removal. Based on a comparison of these products to similar PTACs without heat pipes, DOE estimates that heat pipes could produce as much as a 25-percent improvement in efficiency. DOE notes, however, that this estimate is based on products optimized for removing sensible heat from the airstream, and may not apply to dehumidifiers optimized for removing latent heat. DOE also notes that heat pipes may disrupt airflow to the evaporator. This could limit the effective heat transfer in the evaporator, decreasing or eliminating any efficiency gains associated with pre-cooling the inlet air.

***Improved refrigeration system insulation***

While conducting teardowns, DOE found that all products included refrigeration system insulation to a certain extent. The most commonly insulated parts of the system were the evaporator outlet and compressor inlet. Insulation helps contain heat loses throughout the refrigeration system and therefore improves the overall energy efficiency of the dehumidifier, but it is difficult to estimate the extent of the energy savings associated with improved insulation.

DOE also observed that whole-home dehumidifiers and the high-capacity portable dehumidifiers also typically featured insulated cases. However, DOE expects case insulation to primarily improve a unit's noise performance rather than its energy efficiency.

***Refrigerant-desiccant systems***

DOE is aware of certain products available on the market that meet the definition of whole-home dehumidifier, but also incorporate a desiccant system to aid in moisture removal. These dehumidifiers employ a combined moisture removal approach, where some of the moisture in the process air (*i.e.*, the air that is supplied from and returned to the conditioned space) is condensed on the evaporator, while additional moisture is removed via a porous desiccant material that adsorbs moisture when damp air passes through or over it. The desiccant material is typically configured in a circular or wheel structure. A portion of the wheel adsorbs moisture from the process air entering the unit, which is then delivered to the conditioned space. As the wheel rotates, the moisture in that segment is released into a separate heated reactivation air stream and exhausted out of the home. In addition to removing some moisture from the process air directly, the refrigeration system boosts the temperature of the reactivation air to more effectively remove moisture from the desiccant wheel, and cools the incoming air to improve the adsorptivity of the desiccant material.

The appendix X1 test procedure includes provisions to account for the unique setup and operation of these units compared to the typical refrigerant-based dehumidifiers. In particular, refrigerant-desiccant dehumidifiers require a separate inlet and exhaust duct for the intake of reactivation air that removes moisture from the desiccant wheel and discharge of the moist air to the outdoors, so not all moisture that is removed from the conditioned space will be accounted for by measurement of the condensate collected. DOE expects that refrigerant-desiccant systems can offer unique utility in certain conditions, particularly in very low-temperature installations where typical dehumidifiers may run into frosting issues. While refrigerant-desiccant dehumidifiers may provide additional utility compared to typical dehumidifiers under these lower temperature operating conditions, under the representative ambient conditions in appendix X1, DOE did not observe an efficiency improvement associated with refrigerant-desiccant systems.

### 3.14.3 Energy Efficiency

In preparation for the screening and engineering analyses, DOE gathered data on the energy efficiency of dehumidifiers currently available in the marketplace. This data is taken from DOE's CCMS database. Figure 3.14.2 plots the EF versus the capacity of each certified dehumidifier along with the current energy conservation standards and ENERGY STAR criteria for dehumidifiers, effective as of October 2012.[u]

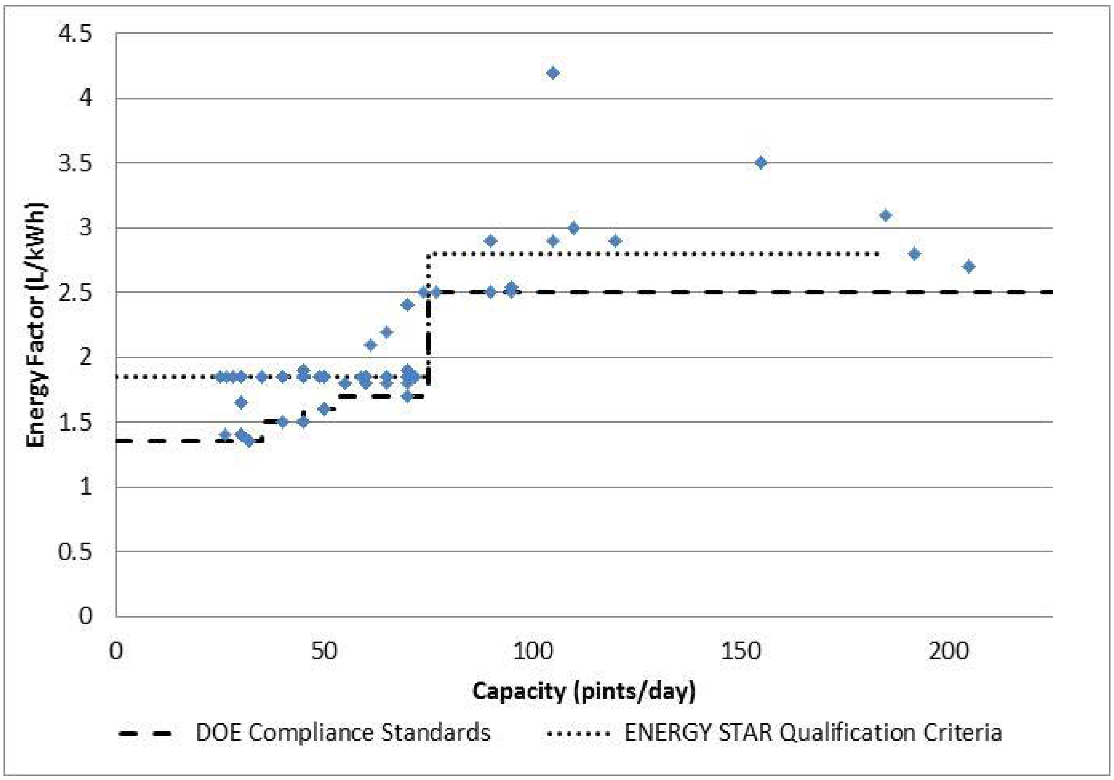


**Figure 3.14.2 DOE-Certified Dehumidifiers, DOE Standards, and ENERGY STAR Qualification Criteria[37]**

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

The candidate design options are assessed based on DOE analysis as well as inputs from interested parties including manufacturers, trade organizations, and energy efficiency advocates. Design options that are judged to be viable approaches for improving energy efficiency are retained as inputs to the subsequent engineering analysis. Design options that are not incorporated in commercial products or in working prototypes, or that fail to meet certain criteria as to practicability to manufacture, install and service, as to impacts on product utility or availability, or as to health or safety will be eliminated from consideration in accordance with *Energy Conservation Program for Consumer Products: Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products*. (61 FR 36974, section 4(a)(4) and 5(b)). The rationale for either screening out or retaining each design option is detailed in the following sections.

## 4.2 DISCUSSION OF DESIGN OPTIONS

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

### 4.2.1 Screened-Out Design Options

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

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

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

**(3) Impacts on product utility to consumers.** If a technology is determined to have significant adverse impact on the utility of the product to significant subgroups of consumers, or results in the unavailability of any covered product type with performance characteristics (including reliability), features, size, capacities, and volumes that are substantially the same as products generally available in the United States at the time, it will not be considered further.

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

The following sections detail the design options that were screened out for this rulemaking, and the reasons why they were eliminated.

***Pre-cooling Air-to-Air Heat Exchangers (for Portable Dehumidifiers up to 45 Pints/Day)***[a]

DOE is aware that certain whole-home dehumidifiers and portable dehumidifiers with capacities greater than 45 pints per day (pints/day) incorporate pre-cooling air-to-air heat exchangers, and thus DOE is retaining this technology as a design option for these product classes.

However, based on teardowns and research, DOE determined that portable dehumidifiers with capacities up to 45 pints/day have little room to incorporate additional components within the product case. Adding pre-cooling air-to-air heat exchangers to these products would require increases in case size to accommodate the additional heat exchanger, which would also increase product weight at the expense of consumer utility.

DOE observed that the pre-cooling air-to-air heat exchangers in high-capacity portable dehumidifiers and whole-home dehumidifiers typically occupied a volume of more than three times the combined evaporator and condenser volume. Although no low-capacity portable units on the market incorporate a pre-cooling air-to-air heat exchanger, DOE estimates that to achieve similar relative gains in efficiency as seen in larger units, portable units would incorporate a similar pre-cooling air-to-air heat exchanger size in proportion to the evaporator and condenser. DOE expects that with the addition of an effective pre-cooling air-to-air heat exchanger, case sizes would, at a minimum, roughly double for portable dehumidifiers up to 45 pints/day.

[a] As measured by DOE's dehumidifier test procedure at 10 CFR part 430, subpart B, appendix X1.

DOE believes the increased size and weight associated with incorporating a pre-cooling air-to-air heat exchanger in portable dehumidifiers with capacities up to 45 pints/day would have an adverse impact on product utility to consumers. Because this design option would result in the unavailability of products with the same size and volume as products currently available on the market, DOE screened out pre-cooling air-to-air heat exchangers as a design option for portable dehumidifiers with capacities up to 45 pints/day.

***Heat Pipes (for Portable Dehumidifiers up to 45 Pints/Day)***

DOE identified heat pipes as a potential technology to increase dehumidifier efficiency. Heat pipes perform a similar function as pre-cooling air-to-air heat exchangers; lowering the inlet air temperature to increase the efficiency of the refrigeration system, except that heat pipes use a phase-change fluid to transfer heat between the two air streams. Similar to the discussion above for pre-cooling air-to-air heat exchangers, DOE determined that the additional heat exchangers and fluid tubing for heat pipes would require increases in case size, overall weight, and cost for portable dehumidifiers up to 45 pints/day capacity. DOE is not aware of any units available on the market that incorporate the heat pipe design option; however, DOE expects the increases in case size necessary to accommodate heat pipes to be on the same order of magnitude as for pre-cooling air-to-air heat exchangers.

DOE believes the increased size and weight for portable dehumidifiers up to 45 pints/day capacity incorporating heat pipes would have an adverse impact on product utility to consumers. Because this design option would result in the unavailability of products with the same size and volume as products currently available on the market, DOE screened out heat pipes as a design option for portable dehumidifiers with capacities up to 45 pints/day.

However, DOE has retained heat pipes as a design option for whole-home and portable dehumidifiers with greater than 45 pints/day capacity. DOE notes that many of these products already use larger case sizes to accommodate pre-cooling air-to-air heat exchangers. Products incorporating heat pipes would likely require case volumes similar to the products available on the market that include pre-cooling air-to-air heat exchangers. Because heat pipes would not likely impact consumer utility for whole-home and portable dehumidifiers with greater than 45 pints/day capacity, DOE has retained this design option for these product classes.

### 4.2.2 Remaining Design Options

Table 4.2.1 lists the design options for dehumidifiers that were retained by DOE for at least one of the analyzed product classes. Each of these technologies will be evaluated further in the subsequent engineering analysis. DOE has retained each of these design options, with limitations to specific product class as appropriate, because they either are or have previously been available in commercially available equipment and also meet the criteria listed in section 4.2.1 relating to product utility, availability, and impacts on health and safety.

**Table 4.2.1 Retained Design Options for Dehumidifiers**

| |
|---|
| 1. Built-in hygrometer/humidistat |
| 2. Improved compressor efficiency |
| 3. Improved condenser performance |
| 4. Improved controls |
| 5. Improved defrost methods |
| 6. Improved demand-defrost controls |
| 7. Improved evaporator performance |
| 8. Improved fan and fan-motor efficiency |
| 9. Improved flow-control devices |
| 10. Low-standby-loss electronic controls |
| 11. Washable air filters |
| 12. Pre-cooling air-to-air heat exchanger (high-capacity portable and whole-home dehumidifiers) |
| 13. Heat pipes (high-capacity portable and whole-home dehumidifiers) |
| 14. Improved refrigeration system insulation |
| 15. Refrigerant-desiccant systems |

# CHAPTER 5. ENGINEERING ANALYSIS

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# CHAPTER 5. ENGINEERING ANALYSIS

## 5.1 INTRODUCTION

After conducting the screening analysis, the DOE performed an engineering analysis based on the remaining design options. The engineering analysis consists of estimating the energy consumption and costs of dehumidifiers at various levels of increased efficiency. This section provides an overview of the engineering analysis (section Chapter 5), discusses product classes (section 5.2), establishes baseline and incremental efficiency levels (section 5.3), explains the methodology used during data gathering (section 5.4) and discusses the analysis and results (section 5.5).

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

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

In the preliminary engineering analysis, DOE used a hybrid approach combining aspects of all three analysis methods described in the paragraph above. The efficiency-level approach for residential dehumidifiers, combined with the cost-assessment approach, allowed DOE to develop a cost for each product analyzed. DOE estimated that the costs for these products reflected the costs for typical units at their respective efficiency levels. This approach involved physically disassembling commercially available products, consulting with outside experts, reviewing publicly available cost and performance information, and modeling equipment cost. To ensure that DOE's analysis covered the entire range of capacities and efficiencies available on the market, DOE relied on the design-option approach to determine what changes would be needed for a particular unit to meet each incrementally higher efficiency level.

For this NOPR, DOE followed the same general approach as for the preliminary engineering analysis, but modified the analysis based on comments from interested parties and to reflect the most current available information.

## 5.2 PRODUCT CLASSES ANALYZED

The Energy Policy Act of 2005 (EPACT 2005), Pub. L. 109-58 (42 U.S.C. 6291–6309), amended the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163 (42 United States Code (U.S.C.) 6291–6309) to establish energy conservation standards for dehumidifiers manufactured as of October 1, 2007. (Section 135(c)(4)) These standards specified five product classes:

- 25.00 pints per day (pints/day) or less;
- 25.01–35.00 pints/day;
- 35.01–54.00 pints/day;
- 54.01–74.99 pints/day; and
- 75.00 or more pints/day.

The Energy Independence and Security Act of 2007 (EISA 2007), Pub. L. 110-140 (EISA 2007), in section 311(a)(1), amended EPCA to prescribe a new set of standards for dehumidifiers, which took effect on October 1, 2012. DOE codified the EISA 2007 standards at 10 CFR 430.32(v)(2). 74 FR 12058 (Mar. 23, 2009). These updated standards consolidated the two smallest product classes (25.00 pints/day or less and 25.01–35.00 pints/day) and subdivided the 35.01–54.00 pints/day product class into two product classes as follows:

- Up to 35.00 pints/day;
- 35.01 to 45.00 pints/day;
- 45.01 to 54.00 pints/day;
- 54.01 to 75.00 pints/day; and
- Greater than 75.00 pints/day.

In the preliminary analysis for this rulemaking, DOE considered portable dehumidifier product classes that were based on the existing product classes, but with capacities adjusted for the lower ambient temperature for testing as proposed in the test procedure NOPR published in the *Federal Register* on May 21, 2014 (May 2014 Test Procedure NOPR, 79 FR 29271), as follows:

- 20.00 pints/day or less;
- 20.01 to 30.00 pints/day;
- 30.01 to 35.00 pints/day;
- 35.01 to 45.00 pints/day; and
- 45.01 or more pints /day.

DOE considered separate portable product classes for the preliminary analysis because manufacturers typically offer multiple products over a range of capacities, but these products are generally constructed on one or two standardized chassis. These standardized chassis and case sizes may limit a manufacturer's ability to optimize blower or heat exchanger configuration for a particular capacity, and significant changes in efficiency may require a manufacturer to move to a larger case. By maintaining product classes over a range of capacities in the preliminary analysis, DOE considered the ability that manufacturers have to adjust capacity within a given case or chassis in order to meet the minimum energy conservation standards. Moving to a single portable dehumidifier product class may force manufacturers to limit the range of products available on the market, or require a substantial investment to establish new production lines for product classes in which their existing range of chassis sizes would not allow the standards to be met.

DOE also considered whole-home dehumidifiers as a separate product class for the preliminary analysis. DOE further divided the whole-home product class into two separate product classes by case volume: (1) less than or equal to 8.0 cubic feet ($ft^3$), and (2) greater than 8.0 $ft^3$. During interviews conducted in support of the preliminary analysis, manufacturers indicated that various installation locations, including attics, crawl spaces, utility closets, and others, impose case size restrictions for whole-home dehumidifiers. These spaces each impose different size restrictions on the dehumidifier floor footprint and overall case volume. The proposed product class case volume differentiation is intended to capture the various applications for these whole-home products where installation location may impose certain size restrictions and associated performance restrictions. Based on teardowns and market research, DOE concluded that 8.0 $ft^3$ is an appropriate threshold case volume for models that represent different utility in terms of installation location.

In response to the proposed product classes on which DOE based the preliminary analysis, several interested parties commented that DOE should not consider separate product classes for portable units with capacities less than or equal to 45 pints/day because units in this product class are all capable of achieving similar maximum efficiencies, and because there should be no product class differentiation based on product chassis size. Other interested parties commented that DOE should maintain several portable product classes to consider the appropriate efficiency levels for each capacity and to account for unique performance and costs associated with each capacity range. DOE considered these comments, and proposes in this NOPR to classify portable products into three product classes based on capacity, as measured by the test procedure at 10 CFR part 430, subpart B, appendix X1 (appendix X1), as follows:

- 30.00 pints/day or less;
- 30.01 to 45.00 pints/day; and
- 45.01 pints/day or more.

DOE's considered several factors in proposing this revised classification. Although portable dehumidifiers within the first two product classes are able to reach similar maximum efficiencies when tested under the currently applicable test procedure at 10 CFR part 430, subpart B, appendix X (appendix X), DOE observed that testing according to the newly established appendix X1 resulted in lower maximum efficiencies for products within the lowest-capacity portable product class. These results suggest an inherent relationship between capacity and efficiency at the lower ambient test temperature specified in appendix X1 that is not apparent at the ambient temperature specified in appendix X.

In addition, product sizes and weights vary between products currently available on the market. Lower-capacity units typically use a smaller chassis that limits the sizes of internal components such as heat exchangers. In its test and teardown sample, DOE observed that products with capacities below 30 pints/day[a] and typically on the smaller chassis had an average weight of 33 pounds. Portable dehumidifiers with capacities between 30 pints/day and 45 pints/day and in larger product cases had an average weight of 45 pounds. DOE concluded that the 12-pound average increase in product weight in moving to a larger case would result in less portable units (*i.e.*, more difficulty moving the unit within the home), which would negatively impact consumer utility.

DOE also observed no key difference in product characteristics for the separate product classes initially analyzed for the preliminary analysis that DOE is proposing to combine into a single product class in this NOPR. The units in the 20.00 pints/day or less and 20.01 to 30.00 pints/day product classes had similar sizes and weights, and were able to achieve similar efficiency levels under both appendix X and appendix X1 testing. Similarly, units in the 30.01 to 35.00 pints/day and 35.01 to 45.00 pints/day product classes had similar construction and measured efficiencies. For this NOPR analysis, DOE proposes combing the four lowest-capacity portable product classes analyzed in the preliminary analysis into two: 30.00 pints/day or less and 30.01 to 45.00 pints/day. DOE proposes maintaining the 45.01 pints/day or more product class as considered in the preliminary analysis because the larger chassis size and weight typically associated with these products would allow for consideration of certain design options, such as inlet pre-cooling heat exchangers, that would not be feasible in lower-capacity portable dehumidifiers.

For whole-home dehumidifiers, DOE maintained the product class differentiation based on products that may be installed in space-constrained locations. Many of the design options associated with improving efficiencies for these products, such as larger heat exchangers or an inlet pre-cooling heat exchanger, require increasing the unit case volume. Whole-home units that are not space constrained may incorporate all of these design options and reach higher efficiencies. DOE observed that products available on the market with case volumes greater than 8.0 $ft^3$ are able to incorporate additional design options and reach higher efficiencies than products with volumes at or less than 8.0 $ft^3$. DOE also expects that products with volumes of 8.0 $ft^3$ or less would be able to meet consumers' needs for space-constrained installations. DOE notes that switching to a capacity-based product class differentiation, as proposed for portable dehumidifier product classes, could result in products with smaller case sizes necessary for certain installations being eliminated from the market because lower capacity units would require a larger case volume to incorporate all available design options and maximize heat exchanger sizes to reach high efficiencies. For these reasons, DOE proposes in this NOPR to maintain the two whole-home dehumidifier product classes based on case volume: (1) less than or equal to 8.0 $ft^3$, and (2) greater than 8.0 $ft^3$.

## 5.3 EFFICIENCY LEVELS

For dehumidifiers, energy conservation standard levels are currently defined by the energy factor (EF) for each product class. However, EPCA, as amended by EISA 2007, requires

[a] For consistency, all capacities presented in the remainder of this chapter are expressed in pints/day as measured according to the test procedure in appendix X1 except where otherwise noted.

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))

The appendix X1 dehumidifier test procedure defines an integrated energy factor (IEF) metric that combines active mode energy consumption with low-power mode energy consumption, which includes standby mode or off mode energy consumption. In accordance with the EISA 2007 requirements, this NOPR analysis was conducted using efficiency levels based on IEF as measured by appendix X1.

### 5.3.1 Baseline Efficiency Levels

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

Table 5.3.1.1 summarizes the October 1, 2012, energy conservation standards prescribed by EISA 2007, with product class capacities measured according to appendix X. Each energy efficiency level is expressed as a minimum EF, which is defined in liters per kilowatt-hour (L/kWh).

**Table 5.3.1.1 Dehumidifier Baseline Unit Efficiencies Based on EISA 2007 Standards**

| **Product Class** (*Capacity*) | **EF** *(L/kWh)* |
|---|---|
| 35.00 pints/day or less | 1.35 |
| 35.01–45.00 pints/day | 1.50 |
| 45.01–54.00 pints/day | 1.60 |
| 54.01–75.00 pints/day | 1.70 |
| 75.01 pints/day or more | 2.50 |

For the preliminary analysis, DOE conducted its analysis on efficiency levels defined by IEF rather than EF. In addition to considering standby mode and off mode energy use, DOE adjusted IEF based on additional changes to the dehumidifier test procedure as proposed in the May 2014 Test Procedure NOPR. These included accounting for energy consumption in fan-only mode, modifying the active mode test conditions required in appendix X, and establishing separate installation requirements and test conditions for whole-home dehumidifiers. Based on the conversion from EF to IEF and on the proposed amendments in the May 2014 Test Procedure NOPR, DOE developed adjusted product classes and IEF baseline efficiency levels for the preliminary analysis, as shown in Table 5.3.1.2 and Table 5.3.1.3.

**Table 5.3.1.2 Preliminary Analysis Portable Dehumidifier Baseline Efficiency Levels**

| **Product Class** (*Capacity*) | **IEF** (*L/kWh*) |
|---|---|
| 20.00 pints/day or less | 0.77 |
| 20.01 – 30.00 pints/day | 0.80 |
| 30.01 – 35.00 pints/day | 0.94 |
| 35.01 – 45.00 pints/day | 1.00 |
| 45.01 pints/day or more | 2.07 |

**Table 5.3.1.3 Preliminary Analysis Whole-Home Dehumidifier Baseline Efficiency Levels**

| **Product Class** (*Case Volume*) | **IEF** (*L/kWh*) |
|---|---|
| Less than or equal to 8.0 $ft^3$ | 1.10 |
| Greater than 8.0 $ft^3$ | 1.68 |

Testing according to appendix X1 would not substantively change the IEF metric from the May 2014 Test Procedure NOPR or February 2015 Test Procedure SNOPR proposals for portable dehumidifiers. Therefore, for this NOPR, DOE maintained the portable dehumidifier baseline efficiencies determined for the preliminary analysis, with updates to reflect the combined product classes as discussed in section 5.2 of this chapter. DOE set the baseline efficiency level for the combined product classes at the lower of the two baseline IEF levels considered in the preliminary analysis for the two previously separate product classes because that IEF would be based on the minimum energy conservation standard currently applicable for any product within the combined product classes. Table 5.3.1.4 presents the portable dehumidifier baseline efficiency levels used in this NOPR analysis.

**Table 5.3.1.4 NOPR Analysis Portable Dehumidifier Baseline Efficiency Levels**

| **Product Class** (*Capacity*) | **IEF** (*L/kWh*) |
|---|---|
| 30.00 pints/day or less | 0.77 |
| 30.01 – 45.00 pints/day | 0.94 |
| 45.01 pints/day or more | 2.07 |

Appendix X1 does contain revisions to the whole-home testing conditions compared to those proposed in the May 20014 Test Procedure NOPR based on feedback from interested parties and available whole-home usage data. Appendix X1 requires an ambient dry-bulb temperature of 73 degrees Fahrenheit (°F) instead of 65 °F as proposed in the May 2014 Test Procedure NOPR. On the same basis, DOE also reduced the external static pressure requirements in the test ducting from the 0.5 inches of water column proposed in the May 2014 Test Procedure NOPR to 0.20 inches of water column. These test procedure changes would increase whole-home dehumidifier IEFs from the efficiency levels considered in the preliminary analysis. Using a combination of additional whole-home dehumidifier testing at the adjusted test conditions, interpolation of previous test data at 65 °F and 80 °F dry-bulb ambient temperatures, and data for a range of external static pressures, DOE established updated baseline efficiency levels for the two whole-home dehumidifier product classes that are consistent with the test procedure in appendix X1, as shown in Table 5.3.1.5.

**Table 5.3.1.5 NOPR Analysis Whole-Home Dehumidifier Baseline Efficiency Levels**

| **Product Class** (*Case Volume*) | **IEF** (*L/kWh*) |
|---|---|
| Less than or equal to 8.0 $ft^3$ | 1.77 |
| Greater than 8.0 $ft^3$ | 2.41 |

### 5.3.2 Incremental Efficiency Levels

DOE analyzed several efficiency levels beyond the baseline for both portable and whole-home dehumidifiers, and developed incremental manufacturing cost data at each of these levels in this engineering analysis.

#### 5.3.2.1 Portable Dehumidifiers

In the preliminary analysis, DOE established the first efficiency level beyond the baseline by assuming manufacturers would remove fan-only mode from the baseline products. DOE determined higher incremental efficiency levels by identifying relevant EF levels (*e.g.*, ENERGY STAR and maximum available) based on the appendix X test procedure, and then converting to IEF based on the test procedure proposals in the May 2014 Test Procedure NOPR. Table 5.3.2.1 shows the incremental efficiency levels analyzed for each portable dehumidifier product class in the preliminary analysis.

**Table 5.3.2.1 Portable Dehumidifier Efficiency Levels for the Preliminary Analysis**

| **Efficiency Level** | **Efficiency Level Source** | **IEF Efficiency Levels** (*L/kWh*) | | | | |
|---|---|---|---|---|---|---|
| | | **20.00 pints/day or less** | **20.01–30.00 pints/day** | **30.01–35.00 pints/day** | **35.01–45.00 pints/day** | **45.01 pints/day or more** |
| Baseline | Current Baseline with Fan-only Mode | 0.77 | 0.80 | 0.94 | 1.00 | 2.07 |
| 1 | Current Baseline with no Fan-only Mode | 1.10 | 1.10 | 1.20 | 1.30 | 2.40 |
| 2 | Gap Fill 1 | 1.20 | 1.20 | 1.40 | 1.40 | 2.80 |
| 3 | Gap Fill 2/ Maximum Available | 1.30 | 1.30 | 1.60 | 1.60 | 3.52 |
| 4 | Maximum Available | 1.42 | 1.52 | 1.75 | 1.75 | N/A |

DOE received comments in response to the preliminary analysis stating that DOE should establish the max-tech level based on the maximum efficiency that is technologically feasible rather than the maximum efficiency available. After further review, DOE determined that dehumidifiers commercially available at this time may not incorporate all design options that are technologically feasible, and therefore revised the max-tech efficiency levels to incorporate additional design options beyond those observed in its test sample. For a full description of the retained design options to meet the max-tech efficiency levels, see section 5.5.3.2. DOE then modeled the increased efficiency associated with these new max-tech levels.

For the NOPR analysis, another key change to the efficiency levels considered for the preliminary analysis was to combine the previous four lowest capacity portable product classes into two, as discussed in section 5.2. The two portable product classes from the preliminary analysis with capacities less than 30.00 pints/day each have three identical intermediate efficiency levels, and thus these same intermediate levels were maintained for the single combined product class. For the combined 30.01 to 45.00 pints/day product class, the IEF for Efficiency Level 1 was 1.20 L/kWh and 1.30 L/kWh for the 30.01 to 35.00 pints/day and 35.01-45.00 pints/day product classes, respectively. DOE selected the IEF of 1.20 L/kWh for Efficiency Level 1 of the combined product class because this represents the baseline IEF with no fan-only mode; therefore, DOE concluded it would be appropriate to maintain the lower of the two IEFs at this level for the combined product class. Efficiency Level 2 and Efficiency Level 3 were identical for the two previous product classes and thus were also maintained for the combined one.

Based on these revisions to the preliminary analysis, DOE conducted the NOPR analysis based on the portable dehumidifier efficiency levels presented in Table 5.3.2.2.

**Table 5.3.2.2 Portable Dehumidifier Efficiency Levels for the NOPR Analysis**

| Efficiency Level | Efficiency Level Source | IEF Efficiency Levels (*L/kWh*) | | |
|---|---|---|---|---|
| | | 30.00 pints/day or less | 30.01–45.00 pints/day | 45.01 pints/day or more |
| Baseline | Current Baseline with Fan-only Mode | 0.77 | 0.94 | 2.07 |
| 1 | Current Baseline with no Fan-only Mode | 1.10 | 1.2 | 2.40 |
| 2 | Gap Fill 1 | 1.20 | 1.4 | 2.80 |
| 3 | Gap Fill 2/ Max-Tech | 1.30 | 1.6 | 3.66 |
| 4 | Max-Tech | 1.57 | 1.8 | N/A |

#### 5.3.2.2 Whole-Home Dehumidifiers

In the preliminary analysis, DOE developed incremental whole-home dehumidifier efficiency levels based on IEF according to the procedure proposed in the May 2014 Test Procedure NOPR. DOE selected efficiency levels based on the range of efficiencies observed during investigative testing according to the May 2014 Test Procedure NOPR proposal. Unlike portable dehumidifiers, DOE did not observe any fan-only operation for whole-home dehumidifiers, so Efficiency Level 1 in the preliminary analysis represented an improvement in dehumidification mode efficiency rather than elimination of operation in fan-only mode. Table 5.3.2.3 includes the efficiency levels used as the basis of the preliminary analysis for the two whole-home dehumidifier product classes.

**Table 5.3.2.3 Whole-Home Dehumidifier Efficiency Levels for the Preliminary Analysis**

| Efficiency Level | Efficiency Level Source | IEF Efficiency Levels *(L/kWh)* | |
|---|---|---|---|
| | | Less than or equal to 8.0 $ft^3$ (Case Volume) | Greater than 8.0 $ft^3$ (Case Volume) |
| Baseline | Minimum Available | 1.10 | 1.68 |
| 1 | Gap Fill 1 | 1.40 | 1.90 |
| 2 | Gap Fill 2/Maximum Available | 1.59 | 2.80 |
| 3 | Maximum Available | N/A | 3.41 |

As discussed in section 5.3.1, appendix X1 requires whole-home testing conditions of 73 °F ambient dry-bulb temperature and external pressure of 0.20 inches of water column, instead of the 65 °F and 0.50 inches of water column proposed in the May 2014 Test Procedure NOPR (79 FR 29278, 29288). Accordingly, DOE adjusted the preliminary analysis IEF efficiency levels for this NOPR analysis.

Similar to portable dehumidifiers, DOE additionally revised the max-tech level from the maximum available to the maximum IEF that DOE concluded is technologically feasible. DOE determined that whole-home dehumidifiers commercially available at this time may not incorporate all design options that are technologically feasible, and therefore revised the max-tech efficiency levels to incorporate additional design options beyond those observed in its test sample. For a full description of the retained design options to meet the max-tech efficiency levels, see section 5.5.3.2. DOE then modeled the increased efficiency associated with these new max-tech levels.

Table 5.3.2.4 shows the efficiency levels DOE considered in this NOPR analysis based on the revisions to the preliminary analysis.

**Table 5.3.2.4 Whole-Home Dehumidifier Efficiency Levels for the NOPR Analysis**

| Efficiency Level | Efficiency Level Source | IEF Efficiency Levels *(L/kWh)* | |
|---|---|---|---|
| | | Less than or equal to 8.0 $ft^3$ (Case Volume) | Greater than 8.0 $ft^3$ (Case Volume) |
| Baseline | Minimum Available | 1.77 | 2.41 |
| 1 | Gap Fill 1 | 2.09 | 2.70 |
| 2 | Gap Fill 2/Max-Tech | 2.53 | 3.52 |
| 3 | Max-Tech | N/A | 4.50 |

## 5.4 METHODOLOGY OVERVIEW

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

### 5.4.1 Review of Previous Technical Support Documents and Models

DOE reviewed previous rulemaking TSDs to assess their applicability to the current standard setting process for residential dehumidifiers. These previous rulemaking TSDs served as a source for design options and energy consumption analysis, in addition to other sources. For dehumidifiers, the previous rulemaking TSD was developed in support of an advance notice of proposed rulemaking (ANOPR) published in 2007. 72 FR 64432 (Nov. 15, 2007). For this rulemaking, DOE developed a preliminary TSD available May 22, 2014. 79 FR 29380.

### 5.4.2 Manufacturer Interviews

DOE understands that there is variability among manufacturers in baseline units, design strategies, and cost structures. To better understand and explain these variances, DOE conducted manufacturer interviews. These confidential interviews provided a deeper understanding of the various combinations of technologies used to increase residential dehumidifier efficiency, and their associated manufacturing costs. DOE conducted interviews prior to the preliminary analysis stage of this rulemaking, and conducted an additional round of interviews in advance of this NOPR analysis. This allowed DOE an opportunity to receive confidential manufacturer feedback in response to the preliminary analysis. Sample questions from the NOPR phase interviews are contained in appendix 5A of this NOPR TSD.

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

### 5.4.3 Product Testing

Much of the analysis in this chapter incorporates data from publicly available sources such as the California Energy Commission (CEC), DOE Compliance Certification Management System (CCMS), and U.S. Environmental Protection Agency ENERGY STAR databases. However, DOE also conducted its own investigative testing 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;
- Investigate ducted performance for whole-home dehumidifiers; and
- Develop a better understanding of the operational characteristics of residential dehumidifiers.

### 5.4.4 Product Teardowns

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

#### 5.4.4.1 Selection of Units

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

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

#### 5.4.4.2 Generation of Bill of Materials

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

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

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

#### 5.4.4.3 Cost Structure of the Spreadsheet Models

The manufacturing cost assessment methodology used is a detailed, component-focused technique for rigorously calculating the manufacturing cost of a product (direct materials, direct labor and some overhead costs). Figure 5.4.4.1shows the three major steps in generating the manufacturing cost.

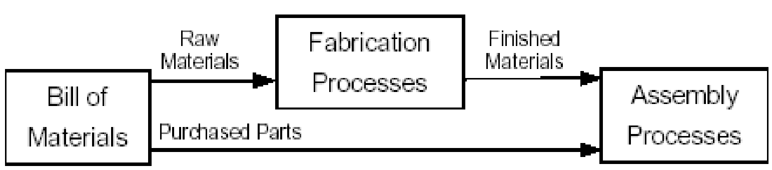


**Figure 5.4.4.1 Manufacturing Cost Assessment Stages**

The first step in the manufacturing cost assessment was the creation of a complete and structured BOM from the disassembly of the units selected for teardown. The units were dismantled, and each part was characterized according to weight, manufacturing processes used, dimensions, material, and quantity. The BOM incorporates all materials, components, and

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

fasteners with estimates of raw material costs and purchased part costs. Assumptions on the sourcing of parts and in-house fabrication were based on industry experience, information in trade publications, and discussions with manufacturers. Interviews and plant visits were conducted with manufacturers to ensure accuracy on methodology and pricing.

Following the development of a detailed BOM, the major manufacturing processes were identified and developed for the spreadsheet model. Some of these processes are listed in Table 5.4.4.1.

**Table 5.4.4.1 Major Manufacturing Processes**

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

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

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

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

#### 5.4.4.4 Cost Model and Definitions

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

- Materials: Purchased parts (*i.e.*, motors, valves, *etc*.), raw materials, (*i.e.*, cold rolled steel, copper tube, *etc*.), and indirect materials that are used for processing and fabrication.
- Labor: Fabrication, assembly, indirect, and supervisor labor. Fabrication and assembly labor cost are burdened with benefits and supervisory costs.

- Overhead: Equipment, tooling, and building depreciation, as well as utilities, equipment and tooling maintenance, insurance, and property taxes.

***Cost Definitions***

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

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

#### 5.4.4.5 Cost Model Assumptions

As discussed in the previous section, assumptions about manufacturer practices and cost structure played an important role in estimating the final product cost. In converting physical information about the product into cost information, DOE reconstructed manufacturing processes for each component using internal expertise and knowledge of the methods used by the industry. Site visits allowed DOE to confirm its cost model assumptions through direct observation of the manufacturing plant, as well as through manufacturer interviews, reviews of current Bureau of Labor Statistics data, etc.

## 5.5 ANALYSIS AND RESULTS

### 5.5.1 Manufacturer Interviews

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

- Product classes
- Design features of current baseline products
- Proposed incremental efficiency levels
- Design options required to meet each efficiency level
- Performance at reduced ambient temperatures
- Impacts on consumer utility
- Installation and repair costs as a function of efficiency

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

The discussion below represents a consolidation of the manufacturer responses.

#### 5.5.1.1 Product Classes

DOE asked manufacturers if the current product class divisions are appropriate. Manufacturers generally responded that the current product classes are too granular. Additionally, products with capacities near the end of the range of a product class are required to meet different minimum efficiency levels than similar units with slightly different capacities that would be classified in the adjacent product class. These products typically feature similar constructions and design features despite falling into separate product classes, so the units required to meet the higher minimum efficiency level may be penalized. Manufacturers noted that the product classes adjusted to the lower ambient temperature conditions result in smaller capacity ranges for each product class. This may force manufacturers to produce products only in the mid capacity for each product class due to verification concerns.

#### 5.5.1.2 Design Features of Current Baseline Products

DOE discussed with manufacturers the features of baseline products identified during the preliminary analysis. The manufacturers generally agreed with DOE’s assumptions for a baseline unit, discussed in section 5.5.3.1 although not all manufacturers produce products at the baseline efficiency level. Manufacturers indicated that baseline dehumidifiers typically include the same components as units at higher efficiencies, perhaps with smaller heat exchangers or less efficient compressors.

#### 5.5.1.3 Proposed Incremental Efficiency Levels

DOE asked manufacturers to comment on the efficiency levels DOE considered for the portable and whole-home product classes in the preliminary analysis. 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, manufacturers were not able to provide feedback on the proposed incremental efficiency levels due to lack of available data under the lower ambient test conditions. Also, some manufacturers were concerned about meeting the maximum IEF levels with current materials and components. They suggested that the necessary changes are not completely understood due to the (at that time) proposed revisions to the test conditions. Manufacturers also indicated that lower-capacity products may not be able to achieve as high efficiencies as higher capacity products, particularly at the lower ambient test conditions.

#### 5.5.1.4 Design Options Required to Meet Each 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. From the reverse-engineering analysis, DOE predicted the key design options would be increased compressor efficiency and heat exchanger sizes. DOE highlighted these options during discussions with manufacturers to determine the necessary design options to meet incrementally increased IEF levels.

Similar to the preliminary analysis, manufacturers generally agreed with DOE's initial association of design options with the efficiency levels. They confirmed that the primary changes required to meet higher efficiency levels will likely be more efficient compressors and optimized heat exchangers. Manufacturers stressed that making these changes would, for certain existing products, require a shift to larger cases and therefore would increase the manufacturing costs and also require investments to update the manufacturing facilities. Manufacturers indicated that fan motor improvements may result in small efficiency improvements, but at a high cost. These added costs would be passed down to the consumer, which could particularly impact low-income consumers.

#### 5.5.1.5 Performance at Reduced Ambient Temperatures

Manufacturers agreed that the current test conditions specify a higher dry-bulb temperature than those typically seen in the field, and they generally supported the ambient dry-bulb temperature in of 65 °F as proposed in the May 2014 Test Procedure NOPR. Manufacturers further indicated that they test their units at a range of ambient temperatures, including lower than 65 °F to ensure products will operate acceptably in low-temperature consumer installations. However, manufacturers also typically indicated that a single ambient test condition is appropriate for the DOE test procedure to limit test burden.

#### 5.5.1.6 Impact on Consumer Utility

DOE asked manufacturers how these design option changes may impact consumer utility. Manufacturers indicated that overall performance would not be impacted; however, larger fans may increase the fan operating noise, and larger components and cases would increase the overall unit weight. Manufacturers also noted that the lower ambient test temperatures may result in more frost on the evaporator coil. However, DOE notes that the change in test conditions better reflects actual consumer use, so any adjustments to avoid frosting during the test procedure (such as operating the evaporator coil at a higher temperature) would likely limit frosting during operation in the field and may improve consumer utility.

#### 5.5.1.7 Installation and Repair Costs as a Function of Efficiency

Manufacturers generally indicated that typical product lifetime was the same for all dehumidifiers regardless of efficiency and component size. They also stated that repair and maintenance costs would not significantly change with improvements in efficiency.

### 5.5.2 Product Testing

Prior to the preliminary analysis, DOE conducted extensive testing on dehumidifiers in each product class, including refrigerant-based and refrigerant-desiccant whole-home dehumidifiers. These units were tested under varying conditions and test setups to investigate how units perform under the lower ambient dry-bulb temperatures and the whole-home test setup. DOE used the data obtained during testing to identify appropriate test conditions and setups as discussed in the May 2014 Test Procedure NOPR. For the preliminary engineering analysis, DOE used the data to determine appropriate product classes, efficiency levels, and the design changes necessary to achieve those levels.

For portable dehumidifiers, the test data used in support of the preliminary analysis remain applicable for this NOPR analysis. DOE notes that the test procedure revisions between the May 2014 Test Procedure NOPR proposal and appendix X1 would not substantively affect the capacities or efficiencies considered in the preliminary analysis. For whole-home dehumidifiers, DOE revised the test conditions proposed in the May 2014 Test Procedure NOPR to a higher inlet air dry-bulb temperature (73 °F rather than 65 °F) and lower external static pressure (0.20 inches of water column rather than 0.5 inches of water column). To consider the effects of these changes on whole-home dehumidifier performance, DOE conducted additional testing on 5 whole-home units.

#### 5.5.2.1 Product Selection

For the portable dehumidifiers, DOE tested a total of 24 portable units with rated capacities up to 75 pints/day (as measured according to appendix X), 13 large-capacity (*i.e.*, portable dehumidifiers with rated capacities greater than 75 pints/day, as measured according to appendix X) and refrigerant-based whole-home units, and 2 refrigerant-desiccant whole-home dehumidifiers. The test units spanned the range of capacities and efficiencies available on the market from multiple manufacturers. The test results informed both the proposals presented in the May 2014 Test Procedure NOPR and in the preliminary engineering analysis.

For the additional whole-home dehumidifier testing conducted in support of this NOPR engineering analysis, DOE selected 5 units covering a range of capacities, efficiencies, configurations, and manufacturers. One of the 5 selected units was a refrigerant-desiccant dehumidifier.

#### 5.5.2.2 Test Approach and Results

A detailed description of the test approach and results for the testing conducted in support of the preliminary analysis is included in chapter 5 of the preliminary TSD and in the May 2014 Test Procedure NOPR. Figure 5.5.2.1 presents a summary of the portable dehumidifier test results from this testing at the appendix X ambient dry-bulb temperature (80 °F) and the appendix X1 ambient dry-bulb temperature (65 °F). The results are presented in terms of EF rather than IEF in order to isolate the effects of ambient temperature on dehumidification mode energy use.

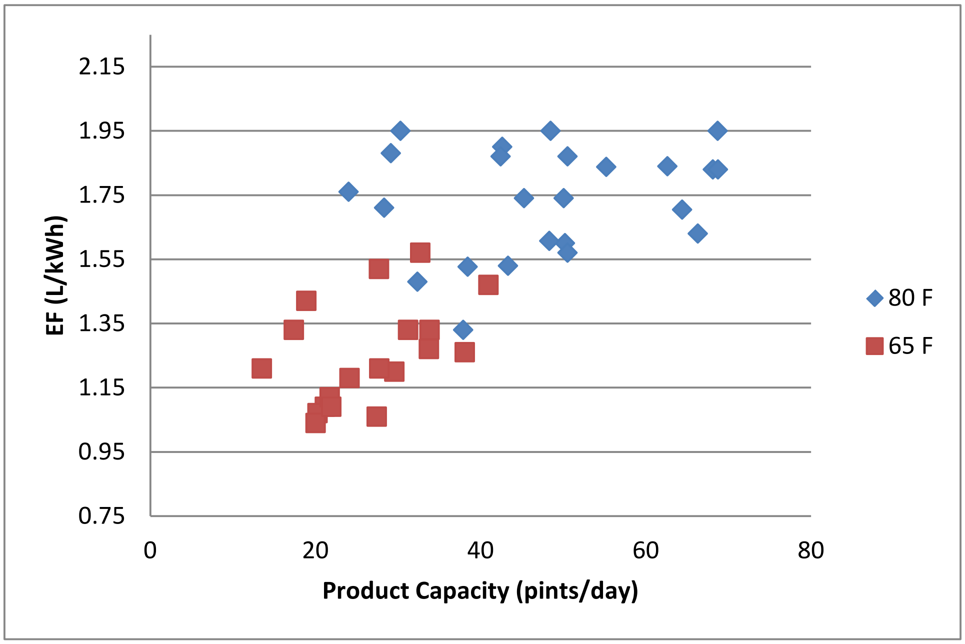


**Figure 5.5.2.1 Measured EF at 80 °F and 65 °F for Portable Dehumidifiers with Capacities Up to 75 pints/day (under Appendix X)**

As discussed in section 5.2, one reason for maintaining separate portable dehumidifier product classes for products with capacities less than 45 pints/day is that the maximum efficiencies observed for products with capacities of 30 pints/day or less are lower than those for products with capacities between 30 and 45 pints/day. Figure 5.5.2.1 shows that portable dehumidifiers are generally able to reach the same maximum efficiencies when tested under the appendix X conditions, but the lower ambient temperature in appendix X1 results in a greater decrease in efficiency for lower capacity units when tested under the new test procedure.

Figure 5.5.2.2 shows the test results from the preliminary analysis and May 2014 Test Procedure NOPR testing for whole-home dehumidifiers. The units were tested according to the ducted test setup proposed in the May 2014 Test Procedure NOPR with inlet air dry-bulb temperatures of 80 °F and 65 °F and external static pressure of 0.5 inches of water column. As observed with the portable units, both capacity and EF are reduced at lower ambient temperatures.

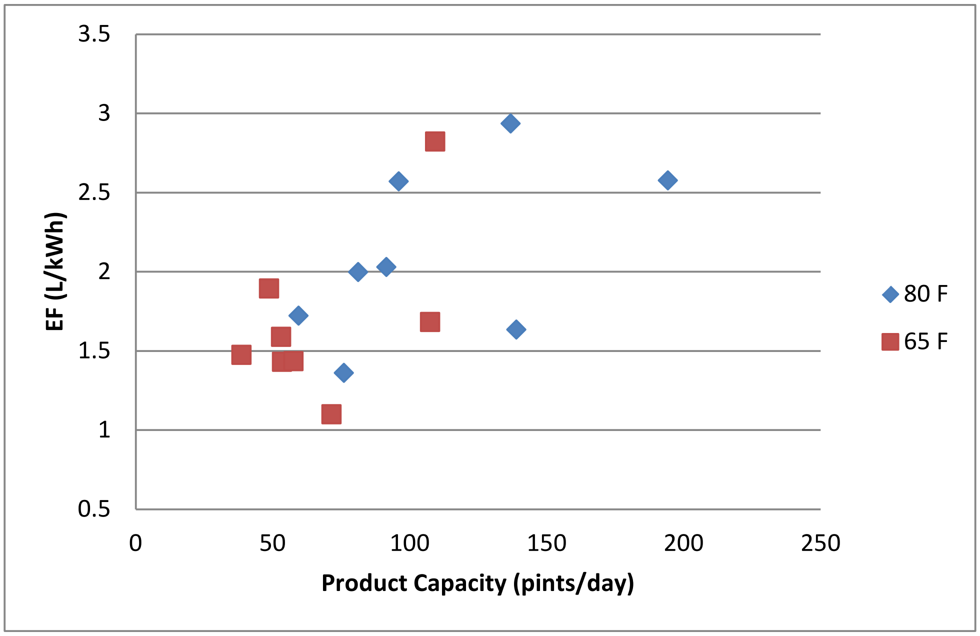

**Figure 5.5.2.2 Measured EF at 80 °F and 65 °F for Whole-Home Dehumidifiers**

As discussed in section 5.3, appendix X1 requires the whole-home units to be tested at an inlet air dry-bulb temperature of 73 °F and external static pressure of 0.20 inches of water column. DOE interpolated the preliminary analysis test results to these conditions to estimate performance at the conditions included in appendix X1. Table 5.5.2.1 presents the estimated performance at 73 °F, in addition to the measured performance at 80 °F and 65 °F dry-bulb temperature and 0.5 inches of water column, adjusted to reflect an external static pressure of 0.2 inches of water column. As expected, the estimated performance data fall between the test results from the two tested conditions.

**Table 5.5.2.1 Estimated Performance at Appendix X1 Conditions**

| Test Sample | Capacity (pints/day) | | | EF (L/kWh) | | |
|---|---|---|---|---|---|---|
| | 80 °F (Measured) | 73 °F (Estimated) | 65 °F (Measured) | 80 °F (Measured) | 73 °F (Estimated) | 65 °F (Measured) |
| 1 | 100.90 | 80.76 | 53.61 | 2.74 | 2.53 | 2.04 |
| 2 | 146.10 | 116.95 | 77.68 | 1.74 | 1.57 | 1.19 |
| 3 | 120.87 | 108.19 | 91.90 | 2.73 | 2.61 | 2.36 |
| 4 | 204.28 | 167.25 | 117.62 | 2.75 | 2.46 | 1.82 |
| 5 | 144.02 | 133.09 | 119.60 | 3.13 | 3.10 | 3.05 |
| 6 | 101.07 | 80.69 | 53.21 | 2.74 | 2.53 | 2.04 |
| 7 | 85.50 | 73.66 | 58.07 | 2.13 | 2.00 | 1.72 |
| 8 | 62.62 | 53.85 | 42.30 | 1.84 | 1.77 | 1.60 |
| 9 | 96.25 | 80.06 | 58.43 | 2.17 | 1.98 | 1.55 |
| 10 | 146.18 | 117.19 | 78.15 | 1.74 | 1.57 | 1.19 |

DOE also conducted additional testing on 5 whole-home units in accordance with the proposals in the February 2015 Test Procedure SNOPR, the most recent test procedure at the time of testing. These 5 units were selected to represent the entire market, spanning the capacities and efficiencies available in the market and varying configurations. Of the 5 test units, 3 were tested previously at both 80 °F and 65 °F dry-bulb temperature and 0.5 inches of water column, allowing a comparison of the numerically estimated results and measured data. As mentioned above, DOE notes that the units were tested at 0.25 inches of water column in accordance with the proposals in the February 2015 Test Procedure SNOPR instead of the 0.20 inches of water column established in appendix X1. DOE subsequently made numerical adjustments based on previous test data at various external static pressures to present data at the appendix X1 conditions. These results are shown below in Figure 5.5.2.3. DOE notes that the difference in EF between the tested and estimated performance at the appendix X1 conditions ranged from 3.1 percent to 8.2 percent, with an average agreement between the average and estimated performance within 6 percent. In lieu of a larger set of available performance data at the appendix X1 conditions, DOE proposes to proceed with the estimated performance data.

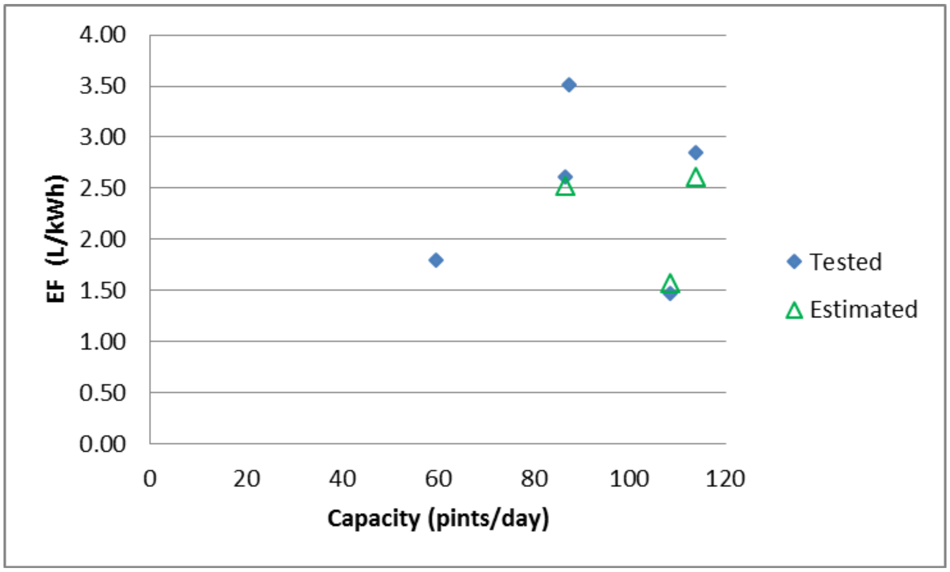

**Figure 5.5.2.3 Tested and Estimated Performance at Appendix X1 Conditions**

DOE used test data when conducting teardowns and modeling to correlate efficiency gains with certain design features or components included in the units in the test sample. In particular, the testing informed the appropriate capacity and efficiency effects of the design features at the lower ambient temperatures because there is limited publicly available information regarding dehumidifier operation at these temperatures.

### 5.5.3 Product Teardowns

After conducting the investigative testing for the preliminary analysis described in the previous section, DOE conducted teardowns on 32 out of its 39 test units, including both portable and whole-home dehumidifiers. The test units spanned the range of product efficiencies and features available on the market from multiple manufacturers. DOE relied on the dehumidifier teardowns to supplement the information gained through manufacturer interviews and to investigate performance observed during testing. Specifically, the teardowns allowed DOE to identify design features for improving efficiency and to develop corresponding manufacturing costs for products at different efficiency levels.

Because DOE's teardown sample in support of the preliminary analysis included a large number of units that spanned a full range of capacities and efficiencies, DOE did not conduct additional teardowns in support of the NOPR engineering analysis. Rather, DOE used the teardown information gathered during the preliminary analysis to determine new manufacturing cost information corresponding to the revisions in proposed product classes and efficiency levels, as described earlier in this chapter.

#### 5.5.3.1 Baseline Construction

Baseline portable dehumidifier construction for products with capacities up to 45.00 pints/day remains unchanged from the preliminary analysis. In the preliminary analysis, DOE observed that all of the units were housed in a plastic case with a removable bucket. They featured rotary R-410A compressors at the base of the unit, with the evaporator and condenser housed in the top of the unit along with the fan and air filter. DOE observed that the blowers all used permanent split capacitor (PSC) motors. The evaporator and condenser within a unit were similar in construction, with similar dimensions and number of tube passes, and they were connected via capillary tubes. The copper tubing exiting the evaporator and entering the compressor was typically insulated, though the thickness and length of insulation varied among units. All of the units in DOE's sample for these portable dehumidifiers with capacities up to 45.00 pints/day featured electronic controls, although DOE is aware that certain units may still use electromechanical controls.

Similarly, the baseline units for higher-capacity portable dehumidifiers (*i.e.*, those with capacities greater than 45.00 pints/day and both whole-home dehumidifier product classes remain unchanged from the preliminary analysis. Compared to the lower-capacity portable units, DOE observed that the baseline units for these product classes shifted to a different design, but still contained most of the same general components. As expected for these product classes, the internal components related to the product capacity were larger than for the lower-capacity portable product classes. In particular, these units used higher-capacity compressors, larger heat exchangers, and more powerful blowers. One key difference when compared to the other portable product classes is the elimination of the internal condensate collection bucket. All of the high-capacity portable units and whole-home units in DOE's teardown sample were designed to be connected to a drain. Also, the units in these product classes featured metal cases with more insulation than the plastic cases for the lower-capacity portable dehumidifier product classes.

DOE observed that manufacturers that produce high-capacity portable units also typically produce whole-home dehumidifiers. For products from the same manufacturer in the same capacity range, DOE observed that the high-capacity portable and whole-home products contained almost identical internal components. The only major differences between these products were the ducting attachments for whole-home units (and lack of ducting attachments for portable units) and the differences in controls. Whole-home products are typically controlled via a remote humidistat with no on-board user controls, while the portable products are controlled through the user interface on the unit. High-capacity portable products typically used electromechanical controls, unlike lower-capacity portables units, most likely due to simplicity, high reliability, and minimal expected consumer interaction.

#### 5.5.3.2 Design Options to Reach Higher Efficiency Levels

In chapter 3 of this NOPR TSD, DOE identified technology options that could potentially improve the efficiency of dehumidifiers. As discussed in chapter 4 of this NOPR TSD, a number of these technology options were eliminated from further consideration in the engineering analysis. DOE considered the technology options meeting all of the screening criteria in this engineering analysis, although not all of these design options factored into the final estimated incremental costs. This section explains how DOE addressed each of the technology options that were retained from the screening analysis.

***Retained Design Options to Meet Higher Efficiency Levels***

DOE maintained the findings of the preliminary engineering analysis when estimating typical dehumidifier construction at higher efficiency levels. In the preliminary analysis, DOE identified the following key design changes to reach higher efficiency levels: improved compressor efficiency, improved evaporator and condenser performance (*i.e.*, larger heat exchangers), and pre-cooling air-to-air heat exchangers. After considering feedback from interested parties on the preliminary analysis, DOE also incorporated improved fan-motor efficiency in this NOPR engineering analysis.

**Improved compressor efficiency**

Improved compressor efficiency is one of the primary means for dehumidifiers to achieve higher efficiencies. The compressor typically represents 80 to 90 percent of a dehumidifier's energy consumption, so small improvements in compressor efficiency translate directly to measurable improvements in IEF. DOE is aware that the rotary R-410A compressors widely used in dehumidifiers are available with a range of efficiencies, and manufacturers will likely move to a more efficient compressor of this type to achieve higher IEFs.

In chapter 3 of this NOPR TSD, DOE also identified inertia-reciprocating, scroll, and variable-speed compressors to further increase efficiency beyond that of traditional rotary compressors. DOE notes that inertia-reciprocating and scroll compressors are substantially larger, heavier, and noisier than rotary compressors, and therefore are not suited for residential dehumidifiers. Variable-speed compressors present an opportunity for a dehumidifier to adjust the compressor and refrigeration system operation to varying conditions. However, because the DOE test procedure is conducted at constant ambient conditions with continuous operation, it would not capture efficiency gains associated with variable-speed compressors. Therefore, DOE did not consider inertia-reciprocating, scroll, or variable-speed compressors in the remainder of its analysis.

**Improved condenser and evaporator performance**

DOE also observed during teardowns and received feedback during manufacturer interviews that manufacturers would likely use larger heat exchangers at the higher efficiency levels. Compressor efficiencies can only improve a dehumidifier's performance to a certain extent for a given refrigeration system. Larger heat exchangers can help to further improve the performance of the refrigeration system by more effectively converting the work performed by the compressor into heat transfer. As more heat is absorbed in the evaporator and rejected via the condenser, the refrigerant cycle operates more efficiently and less compressor power is required to achieve a similar capacity.

As discussed in chapter 3 of this NOPR TSD, many parameters affect a heat exchanger's performance. Based on manufacturer interviews and product teardowns, DOE found that manufacturers likely adjust the cross-sectional area of the heat exchangers to increase heat transfer. DOE observed that the condenser and evaporator in all of its teardown units had similar construction, but the cross-sectional area was the key parameter that changed from unit to unit. DOE verified through modeling that increasing heat exchanger cross-sectional area resulted in more significant efficiency improvements compared to other possible heat exchanger changes, such as increasing heat exchanger depth or fin density. In its analysis, DOE assumed that manufacturers would rely on increased heat exchanger cross-sectional areas to improve condenser and evaporator performance.

**Improved fan and fan-motor efficiency**

DOE is aware that efficiency gains may be possible through improvements to the fan and fan motor. DOE noted that all units in its teardown sample used PSC fan motors, which have improved efficiencies compared to shaded-pole motors. However, permanent-magnet motors would provide even higher motor efficiencies compared to PSC motors, but the overall improvements to IEF would be small due to the relatively small portion of energy consumed by the fan motor compared to the compressor. Manufacturers would also incur significant costs if employing permanent-magnet motors; the motors themselves cost approximately two times as much as a comparable PSC motor, and the different shape and weight of the motor may require product redesign.

Manufacturer interviews and product teardowns also showed that there were no significant changes to the blowers and fan motors at different product efficiencies. For these reasons, DOE did not further consider improved fan and fan-motor efficiency in developing the cost-efficiency relationships in the preliminary engineering analysis. However, after considering comments from interested parties, DOE determined that the small potential efficiency gains associated with improved fan motors should be incorporated into this NOPR analysis due to technological feasibility, as discussed in section 5.3.2.

**Pre-cooling air-to-air heat exchanger**

Pre-cooling air-to-air heat exchangers further increase the efficiency of whole-home and high-capacity portable dehumidifiers. By cooling the inlet air stream using the low-temperature air exiting the evaporator, the air-to-air heat exchanger decreases the amount of sensible heat the evaporator must remove from the air stream before condensation occurs. Because the heat exchanger uses evaporator outlet air to cool the inlet airstream, the air entering the condenser is at a higher temperature. The result is a slightly higher temperature exhaust air off of the condenser, but overall improved dehumidifier energy efficiency.

DOE considered pre-cooling air-to-air heat exchangers as a design option for the whole-home and high-capacity portable dehumidifier product classes in both the preliminary analysis and this NOPR analysis, but screened out this technology option for the lower-capacity portable dehumidifier product classes for the reasons discussed in chapter 4 of this NOPR TSD.

### *Design Options Not Used to Meet Higher Efficiency Levels*

Several of the technology options identified in chapter 3 of this NOPR TSD may produce energy savings in certain real-world situations, but DOE did not further consider them in this analysis because the dehumidifier test procedure would not capture the potential improvements and DOE does not expect manufacturers to rely on these features to meet higher efficiency levels. Accordingly, DOE did not specifically consider improvements associated with these design options when determining the manufacturer production costs at each efficiency level.

**Built-in hygrometer/humidistat**

All portable dehumidifiers in DOE's teardown sample featured a built-in humidity controller. These units all included electronic controls, but DOE is aware that certain units may still feature electromechanical humidistats. The humidistat cycles the compressor and fan power supply as a function of relative humidity. Both electronic and electromechanical controllers measure the expansion of a reference material as a function of relative humidity. DOE notes that whole-home dehumidifiers are often designed to be used in conjunction with a remote humidistat. The humidistat is placed in the portion of the home that requires dehumidification, and cycles the whole-home dehumidifier compressor and fan power supply as needed. Although this control is external to the unit, DOE does not expect significant differences in efficiency or operation when compared to the built-in controls on portable units.

While electronic humidistats may provide more flexible control in cycling the refrigeration system as needed in varying conditions, DOE does not expect the type or presence of a hygrometer or humidistat to affect dehumidifier efficiency. The DOE test procedure requires continuous unit operation at constant ambient conditions, and therefore does not reflect performance of the humidity sensor. Because DOE does not expect the type of humidity controller to result in efficiency gains, and because the test procedure would not capture any efficiency improvements, DOE did not further consider changes to the hygrometer or humidistat in this analysis.

**Improved controls**

Similar to the built-in hygrometer/humidistat discussed above, improved controls may allow dehumidifiers to better adjust their operation in response to changing conditions. Improved controllers may consider multiple inputs, such as ambient temperature, ambient humidity, and evaporator temperature, when adjusting unit operation. Because the DOE test procedure requires continuous unit operation at constant ambient conditions, it therefore would not reflect improved control schemes, and DOE did not further consider improved controls in this analysis.

**Improved defrost methods**

In chapter 3 of this NOPR TSD, DOE identified four defrost types: passive, fan-only, electric, and hot-gas. DOE is not aware of any units on the market that feature an electric or hot-gas defrost, although there are no technical limitations that would preclude these in dehumidifiers. DOE also did not observe passive defrost in its testing. DOE observed that units typically use a fan-only defrost when necessary.

DOE observed that some units in its test sample entered a defrost operation when tested in dehumidification mode at the 65 °F ambient dry-bulb temperature specified in appendix X1. While improved defrost methods could improve energy consumption in these units, DOE expects that manufacturers would likely adjust the unit controls or refrigeration system operation to avoid triggering defrost rather than improving performance during defrost. DOE did not observe different design features between the units that did or did not defrost at the reduced ambient temperature, so the difference in operation is likely due to different control schemes or refrigeration system operating parameters. Because manufacturers would likely adjust their units to avoid defrosts when operating at the appendix X1 test conditions, DOE did not further consider different defrost methods in determining how manufacturers may achieve higher efficiency levels.

**Improved demand-defrost controls**

Defrost controls determine if and when a defrost operation is needed and the duration of defrost. As described in chapter 3 of this NOPR TSD, time-based defrosts occur at regular intervals for constant duration as a unit operates. Sensor-controlled defrosts occur as needed based on evaporator coil temperatures. DOE observed that all units in the teardown sample featured temperature sensors on the evaporator coil, and therefore likely employ a sensor-controlled defrost. DOE also observed in its investigative testing that units did not enter defrost when tested at 80 °F ambient dry-bulb temperature, some units defrosted at 65 °F, and nearly all units defrosted at 55 °F. This also suggests sensor-based defrosts.

Because DOE expects that units available on the market already feature sensor-based defrost control, and the test procedure likely would not capture defrost operation as described in the section above, DOE did not further consider this design option in this analysis.

**Improved flow-control devices**

DOE observed that all units in the teardown sample used a wound capillary tube as the expansion device to control refrigerant flow to the evaporator, though the length and size of tubing varied. In chapter 3 of this NOPR TSD, DOE describes how thermostatic expansion valves or electronic expansion valves would allow dehumidifiers to regulate refrigerant flow to the evaporator based on changes in operating conditions.

As discussed for previous design options, the DOE test procedure is performed under constant ambient conditions, and any benefit associated with a unit's ability to adjust to varying ambient conditions would not be captured in the test. Therefore, DOE did not further consider improved flow-control devices as a design option in this analysis.

**Low-standby-loss electronic controls**

In the preliminary analysis, DOE observed that the presence of a fan-only mode had the most significant impact on the conversion from EF to IEF based on the calculations to incorporate low-power mode energy consumption as first proposed in the May 2014 Test Procedure NOPR. For units without a fan-only mode, DOE observed that low-power mode energy consumption resulted in an average decrease from EF to IEF of 0.02 L/kWh. For all units in the test sample, the average inactive mode or off mode power consumption was 0.9 Watts (W).

DOE observed two types of power supplies in its teardown sample: linear and switch-mode. Switch-mode power supplies typically require lower standby power compared to linear power supplies. In the test sample, DOE found an average off-mode power of 0.4 W for switch-mode power supplies compared to 1.2 W for linear power supplies. In off-cycle mode, for units without fan-only mode, units with switch-mode power supplies required on average 1.14 W compared to 1.63 W for units with linear power supplies. DOE notes that based on these average power inputs, the effect of changing from a linear to a switch-mode power supply has very little impact on IEF. For example, a baseline 50 pint/day unit with an EF of 1.6, at 80 °F ambient temperature, would have an IEF that rounded to 1.59 with either a linear or switch-mode power supply.

DOE also observed a range of power inputs for each power supply type. While switch-mode power supplies required less power on average than linear power supplies, DOE observed linear power supplies with off-mode and off-cycle mode power inputs as low as 0.51 W and 0.72 W, respectively.

Because of the relatively small impact of standby mode and off mode energy consumption on IEF, and the range of power inputs associated with each power supply, DOE did not consider this a specific design option in its preliminary analysis. However, because DOE relied on a hybrid analysis approach, including the efficiency-level approach, DOE's cost estimates reflect both power supply types based on the units torn down at each efficiency level and product class. DOE did not use low-standby controls as a design option in the design-option approach portion of the preliminary analysis because of the relatively large jumps in efficiency between the analyzed IEF levels. DOE concluded that manufacturers would rely on other changes, such as improved compressor efficiency and heat exchanger optimization, to achieve the higher efficiencies. For this NOPR analysis, DOE maintained this approach when considering low-standby-loss electronic controls as a design option.

**Washable air filters**

DOE found that all portable dehumidifiers in its test and teardown sample included washable air filters. Manufacturer instructions suggest that the consumer periodically clean the filter to minimize particulate build up and ensure optimal performance. However, because units typically already incorporate a washable air filter, DOE did not consider this as a design option to improve efficiency in this analysis.

**Heat pipes**

As discussed in chapter 4 of this NOPR TSD, DOE screened out heat pipes as a design option for portable dehumidifiers with capacity up to and including 45.00 pints/day. The size and weight of added heat pipes would have less of an impact on consumer utility for portable units with capacity more than 45.00 pints/day and for whole-home dehumidifiers.

DOE was unable to find any residential dehumidifiers that use heat pipes to boost performance by pre-cooling the inlet evaporator air. DOE is aware that units incorporating heat pipes existed on the market until 2010, at which point the manufacturer chose to discontinue the product line for reasons unknown to DOE. Although heat pipes have been incorporated in the past, DOE does not expect manufacturers to use this design option to achieve higher efficiencies because pre-cooling air-to-air heat exchangers accomplish the same function of pre-cooling the air entering the evaporator, likely with similar efficiency improvements. However, pre-cooling air-to-air heat exchangers lower the temperature of the incoming air using a simpler design. They do not require a heat transfer liquid and can be made of less costly materials. Accordingly, the air-to-air heat exchangers are likely lower cost than equivalent heat pipes that accomplish the same function. Therefore, DOE did not further consider heat pipes in its analysis because it tentatively concludes that manufacturers of whole-home and higher-capacity portable dehumidifiers would likely use pre-cooling air-to-air heat exchangers in their place.

**Improved refrigeration system insulation**

Through teardowns, DOE observed that manufacturers typically include insulation on the refrigeration system. The most commonly insulated parts of the system are the evaporator outlet and compressor inlet. However, DOE did not observe that the products at higher efficiency levels include different insulation types or quantities. Further, manufacturers did not indicate that higher efficiencies could be achieved with more insulation, although some manufacturers commented that insulating the product's case typically helps the unit's noise performance. Because DOE did not observe a relationship between product efficiency and refrigeration system insulation, it did not consider this as a design option when developing cost-efficiency curves in this NOPR analysis. However, because DOE used a hybrid approach for this analysis, the estimated costs for each product torn down reflect the type and quantity of insulation included in those products.

**Refrigerant-desiccant systems**

DOE is aware that refrigerant-desiccant systems may offer improved performance, particularly in low-temperature installations where defrosting may be a concern for refrigerant-only dehumidifiers. DOE investigated the potential improvements in efficiency and capacity from incorporating a desiccant wheel in a whole-home dehumidifier. Based on testing, DOE did not observe any efficiency or capacity improvement with incorporating a desiccant wheel. However, DOE notes that testing under appendix X1 is conducted at an ambient temperature where defrosting is likely not a concern, so it may not reflect the improvements associated with a refrigerant-desiccant system at low temperatures. Because DOE did not observe higher efficiencies for refrigerant-desiccant units under representative ambient conditions, it did not further consider refrigerant-desiccant systems as a design option in this analysis.

### 5.5.4 Numerical Model

Although DOE tested and tore down a large sample of units from different manufacturers at varying capacities and efficiencies in support of the preliminary analysis, the sample did not cover the entire range of capacities and efficiency levels that DOE analyzed for potential standards. To fill in gaps in the teardown sample, DOE used a numerical model to estimate unit performance at different efficiency levels and capacities. DOE continued to use the modeled performance results in support of this NOPR analysis.

#### 5.5.4.1 Summary

To conduct the energy modeling, DOE used the MarkN program developed for use in the most recent room air conditioner energy conservation standards direct final rule. 76 FR 22454 (Apr. 21, 2011). The MarkN program was itself an update of an adaptation to the Oak Ridge National Laboratory Mark III Heat Pump program for modeling room air conditioner cooling performance. This program was originally used in support of the 1997 room air conditioner standards final rule. 62 FR 50122 (Sep. 24, 1997). The 1997 final rule and 2011 TSD[c] provide further details regarding the use of these programs in support of the room air conditioner rulemakings.

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[c] The TSD in support of the 2011 room air conditioners final rule can be found at: *http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053*

DOE modified the room air conditioner numerical model for the dehumidifier analysis because both product types use similar technologies—an evaporator to absorb heat from an air stream, a compressor, a condenser to eject heat to an air stream, and an expansion device between the two heat exchangers. The only major difference in the operation of the two product types is the airflow through the unit. Room air conditioners have two separate air streams through the unit, one for the indoor air to be cooled over the evaporator and the other for the external air that absorbs the heat rejected by the condenser. Dehumidifiers pass the same air stream over the evaporator and condenser, first cooling the air on the evaporator to condense water, then re-heating the air over the condenser before exhausting the drier air back to the room or return air stream.

To account for this difference in operation, DOE adjusted the MarkN model to set the condenser inlet air conditions (typically the outdoor air conditions for room air conditioners) equal to the evaporator outlet air conditions (typically the indoor return air conditions for room air conditioners). Through an iterative process, the revised program adjusts the condenser inputs for the MarkN program until they are within a tolerance of the evaporator outlet conditions, effectively modeling one air stream through both heat exchangers.

#### 5.5.4.2 Analysis Method

In the preliminary analysis, DOE first used the numerical model to simulate unit performance for the models in the test and teardown sample. The model inputs include product component specifications and the ambient operating conditions. DOE obtained component information from the product teardowns, including heat exchanger construction (number of rows, tube passes, tube spacing, fin spacing, etc.), refrigerant tubing (lengths and diameters of inlet/outlet tubes and capillary tubes), and compressor specifications.

The model requires detailed compressor operating information, including the mapping coefficients for refrigerant mass flow and power input at varying evaporator and condenser operating temperatures. DOE lacked this information for most units in the teardown and test sample. However, DOE used the data from testing to calibrate the model for each individual unit using a base case of compressor mapping inputs. After calibrating the model, DOE achieved close agreement between the model outputs and test data at both 80 °F and 65 °F ambient dry-bulb temperatures.

DOE then used the model to determine the design changes necessary to reach different efficiency levels or capacity ranges not covered by the models in the teardown sample. For most portable dehumidifiers, DOE observed that manufacturers typically use two methods to increase product efficiency: (1) improving the compressor efficiency, and (2) increasing the heat exchanger cross-sectional areas. Based on inputs from manufacturer interviews, DOE is aware that improving compressor efficiency is likely the first option to improve a unit's efficiency before increasing the heat exchanger sizes. Increasing heat exchanger area could also require a change to a larger case size, which requires a higher material cost per unit, significant conversion costs to update the manufacturing facilities, and can increase shipping costs if fewer units can be transported in shipping containers. So, DOE assumed that manufacturers would first maximize the compressor efficiency within a unit to achieve higher efficiencies.

To determine appropriate ranges of compressor efficiencies, DOE surveyed available efficiencies for rotary R-410A compressors over the range of typical compressor capacities observed in dehumidifiers. As shown in Figure 5.5.4.1, compressors are available within this capacity range at rated energy efficiency ratios (EERs) ranging from roughly 8.5 to 10.5 British thermal units per hour per W (Btu/h/W). DOE notes that this range represents a limited number of compressors based on a survey of the market, not necessarily those observed during teardowns. DOE lacked rated information on the compressors found during teardowns, but expects the range presented in Figure 5.5.4.1 to be representative of compressors available to dehumidifier manufacturers.

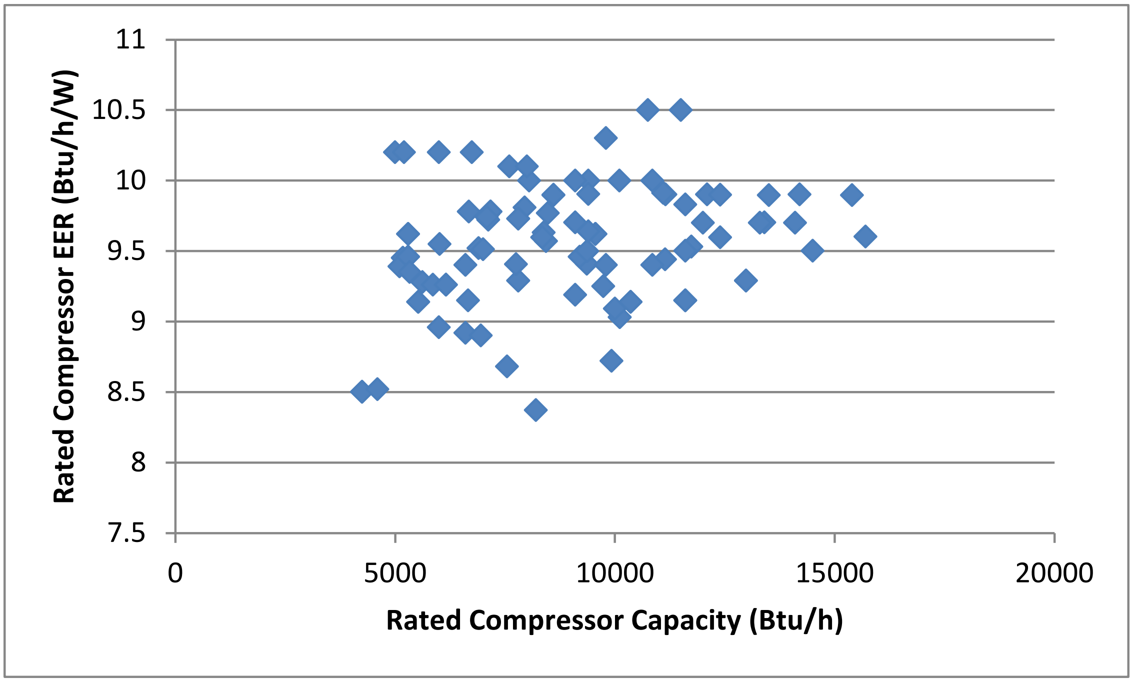


**Figure 5.5.4.1 R-410A Compressor Performance Characteristics**

In cases for which increasing compressor EER to 10.5 Btu/h/W did not result in a sufficient increase in IEF to reach a certain efficiency level, DOE additionally increased the condenser and evaporator cross-sectional areas in the model inputs. Improved compressor efficiencies and increased heat exchanger areas allowed DOE to analyze the design changes needed to meet each efficiency level for the lower-capacity portable and smaller-volume whole-home dehumidifier product classes. At higher efficiency levels, the highest-capacity portable and large-volume whole-home dehumidifier product classes incorporate inlet air-to-air heat exchangers. The numerical model did not incorporate a feature to simulate an inlet air-to-air heat exchanger, so DOE relied on unit teardowns for the analysis at these higher efficiency levels.

For this NOPR analysis, DOE incorporated further efficiency improvements to the modeled results from the preliminary analysis. As discussed in section 5.5.3.2, DOE included improved fan-motor efficiency at the max-tech efficiency level. To implement this design change, DOE decreased the fan power while keeping all other dehumidifier operation constant. DOE estimated that the permanent-magnet motors had an 80-percent efficiency compared to 60-percent efficiency for PSC motors.

### 5.5.5 Cost Estimates

For the models in the preliminary analysis teardown sample, DOE developed manufacturer cost estimates based on the method outlined in section 5.4.4. As discussed above, DOE did not tear down units from each manufacturer at each capacity and efficiency level. Instead, DOE relied on the numerical model to determine the design changes needed for a model in the teardown sample to reach a given efficiency or capacity level. DOE estimated that if a switch to a more efficient compressor was the only necessary design change, there would be no additional changes to the rest of the product. However, for units requiring larger heat exchangers, DOE scaled the size of the case and other related components to accommodate the larger coils.

In developing its cost estimates, DOE lacked detailed compressor pricing information. The compressor is often the most costly component in a dehumidifier, typically representing 20 to 30 percent of the product's material cost. DOE requested compressor pricing during manufacturer interviews, but did not receive enough detailed information to develop cost estimates for all of the compressors found during teardowns or specified through the numerical model.

DOE did, however, receive compressor pricing information from manufacturers during the 2011 energy conservation standards rulemaking for room air conditioners. Dehumidifiers and certain room air conditioners both use similar rotary compressors for R-410A refrigerant. Figure 5.5.5.1 presents the compressor cost information gathered during the room air conditioner rulemaking, and presented in chapter 5 of that direct final rule TSD.

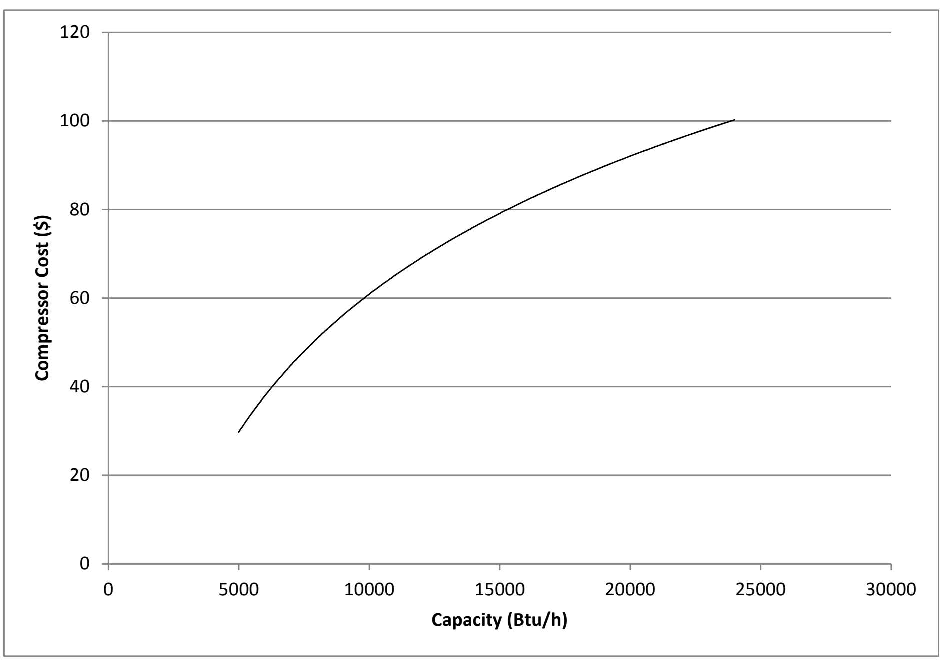


**Figure 5.5.5.1 R-410A Compressor Cost from Room Air Conditioner Energy Conservation Standards Direct Final Rule Analysis**

DOE observed that certain dehumidifiers use compressors with capacities less than 5,000 Btu/h, which are not represented by the curve. To model the costs of these lower compressor capacities, therefore, DOE extrapolated the curve using a linear relationship between $0 and 0 Btu/h capacity and the endpoint of the curve at 5,000 Btu/h capacity.

DOE used this same approach for developing cost estimates in the NOPR engineering analysis; however DOE updated its analysis to reflect costs in 2013 dollars and to account for the changes to product classes and efficiency levels as discussed earlier in this chapter.

#### 5.5.5.1 Cost Estimates

As discussed in the previous sections, DOE either tore down or developed models for units at each efficiency level for the different product classes. DOE developed manufacturing cost estimates for each product, and determined the incremental manufacturing cost needed to meet each efficiency level when compared to the baseline for a given product class. Table 5.5.5.1 presents the incremental manufacturing costs developed for the preliminary analysis.

**Table 5.5.5.1 Preliminary Analysis Manufacturer Production Costs (2012$)**

| | **Portable Product Class Capacity** *(pints/day)* | | | | | **Whole-Home Product Class Case Volume** *(ft³)* | |
|---|---|---|---|---|---|---|---|
| **Efficiency Level** | **≤ 20.00** | **20.01–30.00** | **30.01–35.00** | **35.01–45.00** | **> 45.00** | **≤ 8.0** | **> 8.0** |
| **EL1** | $- | $- | $- | $- | $38.40 | $15.22 | $6.14 |
| **EL2** | $1.56 | $1.85 | $2.94 | $1.98 | $49.16 | $76.18 | $37.05 |
| **EL3** | $4.64 | $3.78 | $8.72 | $7.56 | $100.13 | N/A | $112.01 |
| **EL4** | $7.77 | $10.82 | $13.40 | $11.24 | N/A | N/A | N/A |

Based on the updates to the engineering analysis made for this NOPR, DOE developed revised incremental manufacturing costs, as presented in Table 5.5.5.2.

**Table 5.5.5.2 NOPR Analysis Manufacturer Production Costs (2013$)**

| | **Portable Product Class Capacity** *(pints/day)* | | | **Whole-Home Product Class Case Volume** *(ft³)* | |
|---|---|---|---|---|---|
| **Efficiency Level** | **≤ 30.00** | **30.01–45.00** | **> 45.00** | **≤ 8.0** | **> 8.0** |
| **EL1** | $- | $- | $42.81 | $15.30 | $6.20 |
| **EL2** | $1.69 | $2.39 | $53.66 | $129.22 | $37.20 |
| **EL3** | $4.27 | $8.07 | $120.33 | N/A | $161.39 |
| **EL4** | $19.38 | $22.42 | N/A | N/A | N/A |

DOE notes that the portable dehumidifier product classes with capacities up to and including 45.00 pints/day have zero incremental cost for reaching the first efficiency level. As discussed in section 5.3.1, the baseline IEF's for these product classes assume the presence of fan operation in off-cycle mode. DOE did not observe any unique design features associated with the presence or absence of fan operation during off-cycle mode, and expects the only cost associated with eliminating fan operation to be the cost of reprogramming the unit controls. Because this is only a design cost, DOE does not expect any additional production cost for this change. Accordingly, DOE estimated zero incremental cost to reach EL1 for these product classes.

# CHAPTER 6. MARKUPS ANALYSIS

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# CHAPTER 6. MARKUPS ANALYSIS

## 6.1 INTRODUCTION

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

In the rulemaking for residential dehumidifiers, DOE is considering two product types: portable and whole-home dehumidifiers. The markups applied to the two product types differ because the products generally follow different distribution channels, as discussed below. Both product types, however, will receive manufacturer markups, as described in section 6.3.

DOE has identified three product classes of portable dehumidifiers, and two of whole-home dehumidifiers. In this analysis, DOE assumed that the market saturation rate for each of the five dehumidifier product classes varies by the geographical regions defined in the 2009 *Residential Energy Consumption Survey* (*RECS 2009*)[1] and based on the U.S. population projection for 2019. Therefore, DOE calculated regional markups for each dehumidifier product class.

## 6.2 MANUFACTURER MARKUP

A manufacturer applies a markup to transform production costs into a manufacturer selling price (MSP). DOE used the manufacturer's cost of goods sold (CGS) and gross margin (GM), along with the following equation, to calculate the manufacturer markup ($MU_{MFG}$).

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

Where:

| | |
|---|---|
| $MU_{MFG}$ = | manufacturer's markup, |
| $CGS_{MFG}$ = | manufacturer's cost of goods sold (or manufacturer production cost), and |
| $GM_{MFG}$ = | manufacturer's gross margin. |

The manufacturer's CGS plus its GM equals the MSP. Both baseline products and those produced under new energy conservation standards receive the same manufacturer markup. DOE determined the manufacturer markup for all five product classes of dehumidifiers to be 1.45. More detailed information on deriving manufacturer markups is described in chapter 5, Engineering Analysis.

## 6.3 DISTRIBUTION CHANNELS

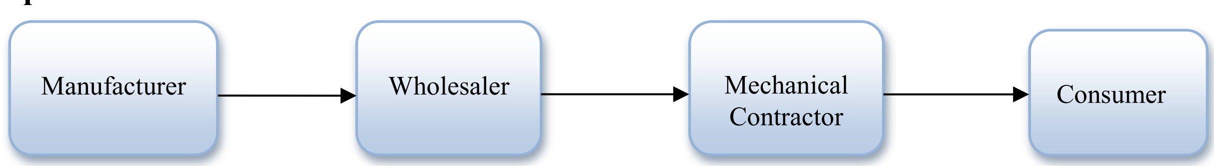
The final markups for determining consumer product prices depend on the type of distribution channels through which the products move from manufacturers to consumers. At each point in the distribution channel, companies mark up the price of a product to cover their business costs and profit margin. In the rulemaking for residential dehumidifiers, DOE is considering two product types, portable and whole-home dehumidifiers. Given the differences in their applications, the two product types likely follow different distribution channels from manufacturer to end user. Data from the AHAM[2] indicate that most portable dehumidifiers are sold through retail outlets, shown as in Figure 6.3.1.


**Figure 6.3.1 Distribution Channel for Portable Dehumidifiers**

Because whole-home dehumidifiers usually are installed as part of the residential cooling and heating system, DOE assumes they follow the same distribution channel as do central air conditioners and forced-air heating systems. There are two primary markets that determine how those products pass from the manufacturer to the consumer: one the replacement market and the other first time owners. In the distribution channel for replacements, the manufacturer generally sells the product to a wholesaler, who in turn sells it to a mechanical contractor, who in turn sells it to the consumer. The distribution channel for first time owners includes an additional step—the general contractor, who buys the product from the mechanical contractor and installs it in the home for the consumer.

Figure 6.3.2 illustrates the two primary distribution channels for whole-home dehumidifiers.

**Replacement:**




**First Time Owner:**

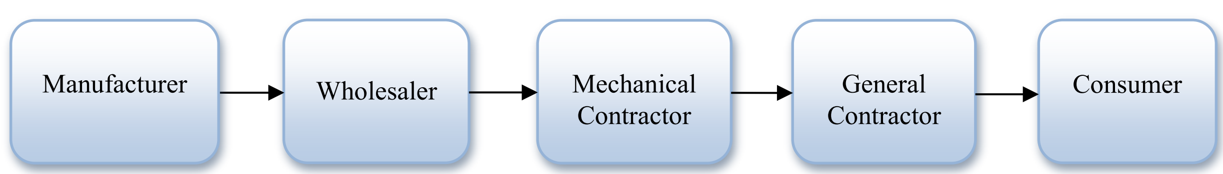



**Figure 6.3.2 Distribution Channels for Whole-Home Dehumidifiers**

### 6.3.1 Calculating Markups

At each point in a distribution channel, companies mark up the price of a product to cover their business costs and profit margin. In financial statements, GM is the difference between the company revenue and the company cost of sales, or CGS. A company's GM includes expenses associated with the distribution channel—overhead costs (sales, general, and administration); research and development; interest expenses; depreciation; 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 formulating markups for dehumidifiers, DOE obtained data about the revenue, CGS, and expenses of firms that produce and sell portable or whole-home dehumidifiers.

## 6.4 MARKUPS FOR PORTABLE DEHUMIDIFIERS

Consumers generally purchase portable dehumidifiers directly from retailers. Because they do not have to be installed in an air-conditioning or forced-air system, portable dehumidifiers incur no markups associated with contractors.

### 6.4.1 Methodology for Retailer Markups

DOE based the retailer markups for portable dehumidifiers on financial data for electronics and appliance stores from the 2012 U.S. Census *Annual Retail Trade Survey* (ARTS), which is the most recent survey that includes industry-wide detailed operating expenses for that economic sector.[3] DOE organized the financial data into statements that break down cost components incurred by firms in the sector. DOE assumes that the income statements faithfully represent the various average costs incurred by firms selling home appliances. Although electronics and appliance stores handle multiple commodity lines, the data provide the best available indication of expenses for selling portable dehumidifiers.

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

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

Where:

$MU_{BASE}$ = retailer's baseline markup,
$CGS_{RTL}$ = retailer's CGS, and
$GM_{RTL}$ = retailer's GM.

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

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

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

1. Changes in the efficiency of 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 channel (including changes in the cost of capital) without changes in company profits.
2. Efficiency improvements affect 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 approach to incremental markups is described in more detail in Dale and Fujita.[4] To estimate incremental retailer markups, DOE divides retailers' operating expenses into two categories: (1) those that do not change when CGS increases because of amended efficiency standards ("invariant"), and (2) those that increase proportionately with CGS ("variant"). DOE defines invariant costs as including labor and occupancy expenses, because those costs likely will not increase as a result of a rise in CGS. All other expenses, as well as net profit, are assumed to vary in proportion to CGS. Although it is possible that some other expenses may not scale with CGS, DOE takes a conservative position that includes other expenses as variant costs. (Note: under DOE's approach, a high fixed cost component yields a low incremental markup.)

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

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

Where:

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

In developing incremental markups, DOE 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, combined with relatively inelastic demand (*i.e.,* the demand is not expected to decrease significantly in response to a relatively small increase in price), will 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 materials and supplies dealers, and general merchandise stores. The FFCR represents the market share of the four largest firms in a given sector. Generally, an FFCR of less than 40 percent indicates that the sector is not concentrated; an FFCR of more than 70 percent indicates that a sector is highly concentrated.[a, b]

The FFCR of appliance sales within each retail channel is equal to the sector FFCR times the percent of total sales within each channel accounted for by major appliances. As shown in

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

Table 6.4.1, appliance sales in electronics and appliance stores, household appliance stores, building materials and supplies dealers, and general merchandise stores have a FFCR less than the 40-percent threshold. The electronics and appliance stores sector includes a subsector titled "household appliance stores." Because that subsector includes numerous stores, it has a FFCR of only 21.3 percent.

**Table 6.4.1 Four-Firm Concentration Ratio for Major Appliance Sales in Three Retail Channels**

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

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

### 6.4.2 Derivation of Retailer Markup for Portable Dehumidifiers

The 2012 ARTS data for electronics and appliance stores provide total sales data and detailed operating expenses. To construct a complete data set for estimating markups, DOE needed to estimate CGS and GM. The most recent 2012 ARTS publishes a separate document containing historical sales and gross margin from 1993 to 2012 for household appliance stores. DOE took the GM as a percent of sales reported for 2012 and combined that percent with detailed operating expenses data from 2012 ARTS to construct a complete income statement for electronics and appliance stores to estimate both baseline and incremental markups. Table 6.4.2 shows the calculation of the baseline retailer markup.

**Table 6.4.2 Data for Calculating Baseline Markup: Electronics and Appliance Stores**

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

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

Table 6.4.3 shows the breakdown of operating expenses for electronics and appliance stores based on the 2012 ARTS data. The incremental markup is calculated as 1.13.

**Table 6.4.3 Data for Calculating Incremental Markup: Electronics and Appliance**

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

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

## 6.5 MARKUPS FOR WHOLE-HOME DEHUMIDIFIERS

DOE examined the manner in which wholesaler and contractor markups may change in response to changes in whole-home dehumidifier efficiency levels and other factors. Using the available data, DOE estimated that there are differences between *incremental* markups on incremental equipment costs of higher efficiency products and the *baseline* markup on direct business costs of products with baseline efficiency. Since the whole-home dehumidifiers are normally handled and installed by the HVAC experts, the data collected for this product are based on HVAC industry.

DOE derived the wholesaler and contractor markups from three key assumptions about the costs associated with whole-home dehumidifiers. DOE based the wholesaler and mechanical contractor markups on firm-level income statement data, and based the general contractor markups on U.S. Census Bureau data for the residential building construction industry. DOE obtained the firm income statements from the Heating, Air-conditioning & Refrigeration Distributors International (HARDI) 2013 Profit Report and from the Air Conditioning Contractors of America (ACCA) 2005 Financial Analysis.[5, 6] HARDI and ACCA are trade associations representing wholesalers and mechanical contractors, respectively. DOE used the financial data from the 2007 U.S. Census of Business for developing general contractor markups in the same form as the income statement data for wholesalers and mechanical contractors. The key assumptions used to estimate markups using these financial data are:

1. Firm income statements faithfully represent the various average costs incurred by firms that distribute and install whole-home dehumidifiers.
2. Costs can be divided into two categories: (1) costs that vary in proportion to the MSP of dehumidifiers (variant costs); and (2) costs that do not vary with the MSP of dehumidifiers (invariant costs).
3. Overall, wholesale and contractor prices for dehumidifiers vary in proportion to the wholesaler and contractor costs for dehumidifiers included in the income statements.

In support of the first assumption, the income statements divide firm costs into various expense categories, including direct costs to purchase or install the product, labor and occupancy costs, and other operating costs and profit. Although wholesalers and contractors tend to handle multiple commodity lines, including room air conditioners, furnaces, central air conditioners, heat pumps, and boilers, the HARDI and ACCA data provide the best available indication of the expenses associated with wholesaling or installing dehumidifiers.

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

In support of the third assumption, the HVAC wholesaler and contractor industry is competitive, and consumer demand for heating and air conditioning is inelastic; that is, demand does not decrease significantly in response to an increase in product price. The large number of HVAC firms listed in the 2007 Census indicates the competitive nature of the market. The 2007 Census lists, for example, more than 700 HVAC manufacturers,[7] 5,300 wholesalers of heat pumps and air-conditioning equipment,[8] more than 170,000 general residential contractors,[9] and 91,000 HVAC contractors.[10] Following standard economic theory, competitive firms facing inelastic demand either set prices in line with costs or quickly go out of business.[11]

DOE concluded that markups for more efficient products are unlikely to be proportional to all direct costs. When the wholesaler's purchase price of products increases, for example, only a fraction of the business expenses increases, while the rest may remain relatively constant. If the unit price of a dehumidifier increases by 30 percent because of improved efficiency, for example, it is unlikely that the cost of secretarial support in an administrative office also will increase by

30 percent. Therefore, DOE assumed that incremental markups cover only those costs that scale with a change in the MSP (variant costs).

### 6.5.1 Methodology for Wholesaler Markups

Applying the assumptions described above, DOE developed baseline and incremental markups for wholesalers using the firm income statement from the HARDI *2013Profit Report.* Appendix 6A.1 presents the HARDI itemized revenues and costs in full. Baseline markups cover all the wholesaler's costs (both invariant and variant). DOE calculated the baseline markup for wholesalers using the following equation.

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

Where:

$MU_{BASE}$ = wholesaler's baseline markup,
$CGS_{WHOLE}$ = wholesaler's cost of goods sold,
$GM_{WHOLE}$ = wholesaler's gross margin,
$IVC_{WHOLE}$ = wholesaler's invariant costs, and
$VC_{WHOLE}$ = wholesaler's variant costs.

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

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

Where:

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

### 6.5.2 Derivation of Wholesaler Markups

Wholesalers reported median data in the confidential survey that HARDI conducted of member firms.[6] Table 6.5.1 summarizes the data as cost-per-dollar sales revenue and CGS.

**Table 6.5.1 Wholesaler Expenses and Markups**

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

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

Based on the information in Table 6.5.1, direct product expenses (cost of goods sold) represent about $0.74 per dollar sales revenue, so for every $1 wholesalers take in as sales revenue, $0.74 is used to pay CGS. Labor expenses represent $0.15 per dollar of sales revenue; occupancy expenses represent $0.04; other operating expenses represent $0.05; and profit accounts for $0.02 per dollar sales revenue.

DOE converted the expenses per dollar sales into expenses per dollar CGS by dividing each value in the first data column by $0.74 (*i.e.,* CGS per dollar of sales revenue). The data in column two show that, for every $1.00 spent on products, the wholesaler allocates $0.204 to cover labor costs, $0.049 to cover occupancy expenses, $0.070 for other operating expenses, and $0.031 in profits. A total of $1.353 in sales revenue is earned for every $1.00 spent on products. Therefore, the baseline wholesaler markup ($MU_{WHOLE\ BASE}$) is 1.353 ($1.353 ÷ $1.00).

DOE also used the data in column two to estimate the wholesaler's incremental markup. The incremental markup depends on which of the costs in Table 6.5.1 are variant and which are invariant with MSP. For example, for a $1.00 increase in MSP, if all the other costs scale with the MSP (*i.e.,* all costs are variant), the increase in wholesale price will be $1.353, implying that the incremental markup is 1.353, or the same as the baseline markup. At the other extreme, if none of the other costs are variant, then a $1.00 increase in MSP will lead to a $1.00 increase in the wholesale price, for an incremental markup of 1.0. DOE believes that the labor and occupancy costs will be invariant and that the other operating costs and profit will scale with the MSP. In this case, for a $1.00 increase in MSP, the wholesale price will increase to match changes in "other" operating costs and operating profit of $0.075, which when divided by 73.9 cents in CGS yields an increase of $0.103, for a wholesaler incremental markup ($MU_{WHOLE\ INCR}$) of 1.101.

### 6.5.3 Methodology for Contractor Markups

The type of financial data used to estimate markups for wholesalers is also available for mechanical and general contractors from the ACCA *Financial Analysis*[5] and the 2007 Economic Census. To estimate to mechanical contractors for whole-home dehumidifiers, DOE collected financial data from the *Plumbing and HVAC Contractors* (NAICS 23822) series from the 2007 Economic Census. To estimate general contractor markups for whole-home dehumidifiers, DOE collected data from the *Residential Building Construction* series from the 2007 Economic Census, which is the aggregation of *New Single-Family General Contractors* (NAICS 236115), *New Multifamily Housing Construction* (NAICS 236116), *New Housing Operative Builders* (NAICS 236117), and *Residential Remodelers* (NAICS 236118). ACCA financial data provide GM as a percent of sales for the mechanical contractor industry. Baseline markup can be derived using the following equation.

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

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

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

Where:

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

Analogously, DOE estimated the incremental mechanical and general contractor markups by marking up only those variant costs that scale with a change in the MSP for more energy efficient products. DOE categorized the Census cost data in each major category and used the following equation to estimate markups.

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

Where:

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

### 6.5.4 Derivation of Markups for Mechanical Contractors

This section describes markups for whole-home dehumidifiers applied by the mechanical contractor. After first presenting aggregate markups, this section divides those markups into categories of replacement and first time owner market.

#### 6.5.4.1 Aggregate Markups for Mechanical Contractors

The 2007 Economic Census provides a Geographic Area series for the *Plumbing and HVAC Contractors* (NAICS 23822) sector, which contains national average sales and cost data, including value of construction, cost of subcontract work, cost of materials, and payroll for construction workers. It also provides the cost breakdown of GM, including labor expenses, occupancy expenses, other operating expenses, and profit. The gross margin provided by the U.S. Census is disaggregated enough that DOE was able to determine the invariant and variant costs for the sector. By using the equations presented above, DOE estimated baseline and incremental markups, as shown in Table 6.5.2. (Appendix 6A.2 contains the full set of data.)

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

| Description | Mechanical Contractor Expenses and Revenue | |
|---|---|---|
| | Per Dollar Sales Revenue ($) | Per Dollar Cost of Goods ($) |
| Direct cost of products (CGS) | 0.68 | 1.00 |
| Labor expenses (salaries [indirect] and benefits) | 0.18 | 0.26 |
| Occupancy expenses (rent, maintenance, and utilities) | 0.02 | 0.03 |
| Other operating expenses (depreciation, advertising, and insurance) | 0.08 | 0.12 |
| Net profit before taxes | 0.04 | 0.06 |
| Baseline markup (*MUMECH BASE*): revenue per $ CGS | | 1.48 |
| Incremental markup (*MUMECH INCR*): increased revenue per $ increase in CGS | | 1.18 |

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

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

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

#### 6.5.4.2 Mechanical Contractor Markups in the Replacement and First Time Owner Markets

DOE derived the baseline and incremental markups for both replacement and new construction markets using the 2007 Economic Census industrial cost data[12] supplemented with the ACCA 2005 financial data.[5] The 2007 Economic Census provides a sufficiently detailed cost breakdown for the *Plumbing and HVAC Contractors* (NAICS 23822) sector to enable DOE to estimate baseline and incremental markups for mechanical contractors. The 2007 Economic Census does not separate the mechanical contractor market into replacement and first time owner markets, however. In order to calculate markups for the two markets, DOE utilized 2005 ACCA financial data, which reports GM data for the entire mechanical contractor market and for both the replacement and first time owner markets.

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

**Table 6.5.3 Baseline Markup, All Mechanical Contractors**

| Description | Contractor Expenses or Revenue | |
|---|---|---|
| | Per Dollar Sales Revenue ($) | Per Dollar Cost of Goods ($) |
| Direct cost of product sales (CGS) | 0.73 | 1.00 |
| Gross margin (labor, occupancy, operating expenses, and profit) | 0.27 | 0.37 |
| Revenue (baseline revenue earned per $ CGS) | | 1.37 |
| Baseline markup ($MU_{MECH\ CONT\ BASE}$) | | 1.37 |

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

Table 6.5.4 summarizes the GM and resulting baseline markup data for all mechanical contractors who serve the replacement and first time owner markets.

**Table 6.5.4 Baseline Markups for Replacement and First Time Owner Markets, All Mechanical Contractors**

| Description | Contractor Expenses or Revenue by Market Type | | | |
|---|---|---|---|---|
| | Replacement | | First Time Owners | |
| | Per Dollar Sales Revenue ($) | Per Dollar Cost of Goods ($) | Per Dollar Sales Revenue ($) | Per Dollar Cost of Goods ($) |
| Direct cost of product sales (CGS) | 0.703 | 1.000 | 0.745 | 1.000 |
| Gross margin (labor, occupancy, operating expenses, and profit) | 0.297 | 0.422 | 0.255 | 0.342 |
| Baseline markup (*MUMECH CONT BASE*), revenue per $ CGS | NA | 1.42 | NA | 1.34 |
| Difference compared to aggregate baseline markup (%) | NA | 3.6 | NA | -2.2 |

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

Using the baseline markup data from Table 6.5.4 and data from Table 6.5.3, DOE calculated that mechanical contractors' baseline markups for the replacement and first time owner markets for dehumidifiers are 3.6 percent higher and 2.2 percent lower, respectively, than for mechanical contractors serving all markets. DOE applied those markup deviations derived for all mechanical contractors to the baseline markup of 1.48 and the incremental markup of 1.18 estimated in Table 6.5.2. DOE assumed that the deviations apply equally to the baseline and incremental markups calculated from the 2007 Economic Census. The baseline and incremental markups for the replacement and first time owner markets served by mechanical contractors are shown in Table 6.5.5.

**Table 6.5.5 Markups for the Replacement and First Time Owner Markets**

| Market Sector | Baseline Markup | Incremental Markup |
|---|---|---|
| Replacement market | 1.53 | 1.22 |
| First time owner market | 1.45 | 1.15 |

### 6.5.5 Derivation of Markups for General Contractors

DOE derived markups for general contractors from U.S. Census Bureau data for the residential construction sector.[13] The residential construction sector includes establishments engaged primarily in construction work, including new construction, additions, alterations, and repairs of residential buildings. The U.S. Census data for the construction sector include detailed statistics for establishments that have payrolls, similar to the data reported by HARDI for wholesalers. The primary difference is that the U.S. Census Bureau reports itemized revenues and expenses for the construction industry as a whole in total dollars rather than in typical values for an average or representative business. Because of this difference, DOE assumed that the total dollar values reported by the U.S. Census, once converted to a percentage basis, represent revenues and expenses for an average or typical general contracting business. The first data column in Table 6.5.6 summarizes the expenses for general contractors in residential building construction as expenses per dollar sales revenue. (Table 6A.3 in appendix 6A.3 contains the full set of data.)

**Table 6.5.6 General Residential Building Contractor Expenses and Markups**

| Description | General Contractor Expenses or Revenue | |
|---|---|---|
| | **Per Dollar Sales Revenue ($)** | **Per Dollar Cost of Goods ($)** |
| Direct cost of product sales (CGS) | 0.68 | 1.00 |
| Labor expenses (salaries [indirect] and benefits) | 0.08 | 0.12 |
| Occupancy expenses (rent, maintenance, and utilities) | 0.01 | 0.01 |
| Other operating expenses (depreciation, advertising, and insurance) | 0.06 | 0.09 |
| Net profit before taxes | 0.17 | 0.25 |
| Baseline markup (*MUGEN CONT BASE*), revenue per dollar cost of goods | | 1.47 |
| Incremental markup (*MUGEN CONT INCR*), increased revenue per dollar increase in CGS | | 1.34 |

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

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

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

DOE used the data in column two of Table 6.5.6 to estimate incremental markups, after classifying the costs as either invariant or variant. At one extreme, if all of the other costs are variant, the increase in general contractor price would be $1.47, implying that the incremental markup is 1.48, or the same as the baseline markup. At the other extreme, if none of the other costs are variant, then a $1.00 increase in product cost leads to a $1.00 increase in the general contractor price, for an incremental markup of 1.0. DOE believes the labor and occupancy costs are invariant and the other operating costs and profit are variant. In this case, for a $1.00 increase in product cost, the general contractor's price would increase by $1.34, giving the general contractor an incremental markup ($MU_{GEN\ CONT\ INCR}$) of 1.34.

## 6.6 SALES TAXES

The sales tax comprises state and local taxes applied to the price a consumer pays for a product. The sales tax is a multiplicative factor that increases the consumer product price. DOE applied sales tax to the retail price of portable dehumidifiers and consumer price of whole-home dehumidifiers in the replacement market, not the new construction market. The common practice for selling larger appliances such as whole-home dehumidifiers in the new construction market is that general contractors (or builders) bear the added sales tax for the appliances, in addition to the cost of the units. Therefore, no specific sales tax is necessary to calculate the consumer product price for the first time owner market.

DOE derived state and local taxes from data provided by the Sales Tax Clearinghouse.[14] The data represent weighted averages that include county and city rates. DOE then derived population-weighted average tax values for each RECS region, as shown in Table 6.6.1.

**Table 6.6.1 Average Sales Tax Rates by Census Division and Large State**

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

## 6.7 OVERALL MARKUPS FOR DEHUMIDIFIERS

The overall markup for each distribution channel is the product of the appropriate markups, as well as the sales tax in the case of direct consumer purchases of portable dehumidifiers and replacement market of whole-home dehumidifiers.

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

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

Where:

$CPP_{BASE}$ = consumer product price for baseline model,
$COST_{MFG}$ = manufacturer's cost for baseline model,
$MU_{MFG}$ = manufacturer's markup,
$MU_{BASE}$ = baseline markup for portable dehumidifiers and whole-home dehumidifiers (replacement and new home markets),
$Tax_{SALES}$ = sales tax (portable dehumidifiers and replacement market of whole-home dehumidifiers), and
$MU_{OVERALL\_BASE}$ = overall baseline markup.

Similarly, DOE used the overall incremental markup to estimate changes in the consumer product price given changes in the manufacturer cost resulting from an energy conservation standard. The total consumer product price for more energy efficient models comprises two components: the consumer product price of the baseline model, and the change in consumer product price associated with the increase in manufacturer cost to meet the new energy conservation standard. The following equation shows how DOE used the overall incremental markup to determine the consumer product price for more energy efficient models.

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

Where:

$CPP_{STD}$ = consumer product price for models that meet new energy conservation standards,
$CPP_{BASE}$ = consumer product price for baseline model,
$COST_{MFG}$ = manufacturer's cost for baseline model,
$\Delta COST_{MFG}$ = change in manufacturer's cost for more energy efficient models,
$MU_{MFG}$ = manufacturer's markup,
$MU_{INCR}$ = incremental markup for portable dehumidifier and whole-home dehumidifiers (replacement and new home markets),
$Tax_{SALES}$ = sales tax (portable dehumidifiers and replacement market of whole-home dehumidifiers), and
$MU_{OVERALL\_BASE}$ = overall baseline markup (product of manufacturer markup, and
$MU_{OVERALL\_INCR}$ = overall incremental markup.

National average baseline and incremental markups for both portable and whole-home dehumidifiers are summarized in Table 6.7.1 and Table 6.7.2, respectively.

**Table 6.7.1 Summary of Markups for Portable Dehumidifiers**

| Markup | Baseline | Incremental |
|---|---|---|
| Manufacturer | 1.45 | |
| Retailer | 1.39 | 1.13 |
| Sales tax | 1.071 | |
| Overall | 2.16 | 1.75 |

**Table 6.7.2 Summary of Markups for Whole-Home Dehumidifiers**

| Markup | Replacement | | First Time Owner | |
|---|---|---|---|---|
| | Baseline | Incremental | Baseline | Incremental |
| Manufacturer | 1.45 | | 1.45 | |
| Wholesaler | 1.35 | 1.10 | 1.35 | 1.10 |
| Mechanical contractor | 1.53 | 1.22 | 1.45 | 1.15 |
| General contractor | -- | -- | 1.47 | 1.34 |
| Sales tax | 1.071 | | -- | -- |
| Overall | 3.21 | 2.08 | 4.17 | 2.46 |

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# CHAPTER 7. ENERGY USE ANALYSIS

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# CHAPTER 7. ENERGY USE ANALYSIS

## 7.1 INTRODUCTION

To perform the life-cycle cost and payback period calculations described in chapter 8 of this NOPR TSD, DOE determined the savings in operating costs that consumers would derive from more efficient products. DOE used consumer energy use data, along with energy prices, to develop the energy cost component of consumer operating costs determined in chapter 8 of the NOPR TSD. (Maintenance and repair costs are the other contributors to operating costs.) This chapter describes how DOE determined the annual energy consumption of residential dehumidifiers.

## 7.2 AVERAGE ANNUAL ENERGY USE EQUATION FOR DEHUMIDIFIERS

For the previous rulemaking regarding dehumidifiers, which went into effect in 2012, DOE based the annual energy use of a dehumidifier on the following equation.

$$DEH_{ENERGY} = \frac{CAP \times \left(0.473 / 24\right) \times Hours}{Eff}$$

Where:

| | |
|---|---|
| $DEH_{ENERGY}$ = | annual energy consumption of dehumidifier (kWh/year), |
| $CAP$ = | capacity of dehumidifier (pints/day), |
| 0.473 = | conversion factor for liters in a pint, |
| 24 = | number of hours in a day |
| $Hours$ = | annual operating hours for dehumidifier, and |
| $Eff$ = | dehumidifier efficiency (L/kWh). |

The above equation estimates the annual energy consumption associated with a dehumidifier's active mode, when the compressor operates. For the current rulemaking, DOE amended the above equation to accommodate three modes of dehumidifier operation: (1) standby/off mode, (2) fan-only mode, and (3) dehumidification (fan plus compressor) mode.

The following equation calculates the annual energy use of dehumidifiers as the product of the annual hours of operation multiplied by the energy use and percentage of time spent in each operational mode. The capacity and energy efficiency of the dehumidifier are relevant while the compressor is in operation. The energy used during standby mode and off mode is primarily for the display on the control panel and components on the control board, energy that is used during the other two modes as well.

$$DEH_{ENERGY} = \left(\frac{TotalHoursofUse}{Year}\right) \times \left[\left(\frac{CAP \times 0.473 \times X_{Dehum}}{Eff \times 24}\right) + \left(X_{Fan} \times kW_{Fan}\right) + \left(X_{Stby} \times kW_{Stby}\right)\right]$$

Where:

$DEH_{ENERGY}$ = annual energy consumption of dehumidifier (kWh/year),

$\frac{TotalHoursofUse}{Year}$ = number of hours the dehumidifier is used per year (at >0 W),

$CAP$ = dehumidifier capacity (pints of condensate removed/day),
0.473 = conversion factor for liters in a pint,
24 = number of hours in a day
$Eff$ = dehumidifier efficiency (liters of condensate removed/$kWh_{Dehum}$),
$X_{Dehum}$ = fraction of time in dehumidification mode,
$X_{Fan}$ = fraction of time in fan-only mode,
$X_{Stby}$ = fraction of time in standby/off mode,
$kW_{Dehum}$ = kW of dehumidification mode,
$kW_{Fan}$ = kW of fan-only mode, and
$kW_{Stby}$ = kW of standby/off mode.

Note:

$$\frac{Cap \times 0.473 \times X_{Dehum}}{Eff \times 24} = \boldsymbol{X_{Dehum}} \textbf{ X } \boldsymbol{kW_{Dehum}} \qquad \textbf{Eq. 7.1}$$

## 7.3 INPUTS TO AVERAGE ANNUAL ENERGY USE

The expanded equation for calculating average annual energy use includes parameters for dehumidifier capacity and efficiency, as well as fractions of operating hours and power use in dehumidification, fan-only, and standby/off modes.

### 7.3.1 Capacity and Efficiency

Values for capacity and efficiency, presented in Table 7.3.1, were obtained from the engineering analysis described in chapter 5 of the NOPR TSD. The average capacity sizes were determined from the tear-down process for the engineering analysis. See chapter 5 of the NOPR TSD for details.

**Table 7.3.1 Efficiency Levels for Various Dehumidifier Capacities**

| | Portable | | | Whole-Home | |
|---|---|---|---|---|---|
| | ≤30.00 Pints/Day | 30.01–45.00 Pints/Day | >45.00 Pints/Day | ≤8.0 $ft^3$ Case Volume | >8.0 $ft^3$ Case Volume |
| **Average Capacity** | 21 | 38 | 73 | 56 | 92 |
| **Efficiency Level** | | | | | |
| **Baseline** | 0.77 | 0.94 | 2.07 | 1.77 | 2.41 |
| 1 | 1.10 | 1.20 | 2.40 | 2.09 | 2.70 |
| 2 | 1.20 | 1.40 | 2.80 | 2.53 | 3.52 |
| 3 | 1.30 | 1.60 | 3.66 | - | 4.50 |
| 4 | 1.57 | 1.80 | - | - | - |

The next sections describe dehumidifier energy use and fraction of time spent in each mode of operation.

## 7.3.2 Energy Use for Operating Modes

For determining energy use, DOE defines three modes of dehumidifier operation.

- *Dehumidification mode:* is the mode in which the dehumidifier performs its primary function of removing moisture from the air by using a fan to draw moist air over a refrigerated coil.
- *Fan-only mode:* is when the fan circulates air without activating the compressor.
- *Standby/off mode:* standby mode facilitates the initiation of active mode via remote switch, internal sensor, or timer, and/or provides continuous status display, and off mode is the mode in which the dehumidifier is connected to power but is not in dehumidification mode, fan-only mode, or standby mode.

### 7.3.2.1 Power for Dehumidification Mode

DOE calculated the power of the dehumidification mode ($kW_{Dehum}$) using the rated capacity and rated efficiency at each efficiency level for each product class. Calculating the dehumidification mode power in this manner assumes that it is the same at all temperatures and relative humidities, which may not be the case. As stipulated in the 2015 test procedure, the efficiency and capacity values were measured using a temperature of 65 degrees Fahrenheit (°F) and humidity set point of 60 percent for portable dehumidifiers, and a temperature of 73 degrees °F and humidity set point of 60 percent for whole home dehumidifiers.

### 7.3.2.2 Fan-Only Mode Power and Standby/Off Mode Power

Two recent field studies[1,2] (Willem *et al*., 2013, Burke *et al*., 2014) measured energy use in three operating modes for both portable and whole-home dehumidifiers. Because DOE found no other studies that disaggregated energy use by mode, DOE used the values reported in the Willem studies (see Table 7.3.2). The studies' authors observed no relationship between the capacity of a portable dehumidifier and its fan-only mode or standby/off mode energy use.

**Table 7.3.2 Standby/Off Mode and Fan-Only Mode Power Consumption by Dehumidifier Type**

| Mode | Portable (W) | | | Whole-Home (W) | | |
|---|---|---|---|---|---|---|
| | Min | Median | Max | Min | Median | Max |
| Standby/Off | 0.3 | 1.0 | 12.3 | 1.0 | 4.5 | 49.5 |
| Fan-only | 21.4 | 51.2 | 80.9 | 50.2 | 141.7 | 497.0 |

Source: Willem *et al.*, 2013, Burke *et al.*, 2014.

## 7.3.3 Fractions of Operating Hours by Mode

A dehumidifier uses energy when the compressor is operating to remove moisture from the air. When the compressor is not operating, the dehumidifier may use energy for a fan-only mode that circulates air through the unit to sample the ambient relative humidity and to defrost the condenser coils. When neither the fan nor the compressor is operating, energy is used for standby mode or off mode power for functions such as keeping a user panel lit.

### 7.3.3.1 Fraction of Operating Hours in Dehumidification Mode

Table 7.3.3 summarizes information on annual dehumidification mode operating hours by portable and whole-home dehumidifiers derived from several studies and sources. Two of the studies utilized metered data from portable units. One study reports metered data for whole-home dehumidifiers. The other sources rely on power measurements and assumptions regarding usage to estimate values for annual energy use.

**Table 7.3.3 Data on Annual Dehumidification Mode Hours**

| Study/Source | Dehumidification Mode Operating Hours (*For portable units unless noted*) Average Hours/Year | |
|---|---|---|
| ADL (1998)[3] | 1,620 | |
| AHAM (2005)[4] | 1,095 | |
| ENERGY STAR fact sheet (2006)[5] | 1,620 | |
| ENERGY STAR calculator (2006)[6] | 2,851 | |
| The Cadmus Group, Inc. (2012)[7] | 2,160 | |
| Willem (2013) | CCB | 1,136 |
| | CCDD | 1,078 |
| | NCCB | 1,267 |
| | NCCDD | 1,785 |
| Burke (2014) | Whole-home | 2,542 |

CCB = Climate controlled space, bucket catches dehumidifier condensate.
CCDD = Climate controlled space, dehumidifier has a direct drain.
NCCB = Non-climate controlled space, bucket catches dehumidifier condensate.
NCCDD = Non-climate controlled space, dehumidifier has a direct drain.

The reports and studies are listed from oldest to most recent. The study by The Cadmus Group based annual average dehumidification mode hours on several months of metered data, extrapolating from those to an entire year. The second study that metered portable units (Willem *et al.*, 2013) estimated operating hours by correlating outside vapor density with compressor use. The Willem study found energy use depended on two factors: (1) whether the room in which the dehumidifier operated was climate controlled, and (2) how the condensate was removed (*i.e.*, manually by emptying a bucket, or via a direct drain). The following sections describe annual dehumidification mode energy use for units operating in climate-controlled versus non-climate controlled spaces and for the method of condensate removal.

***Portable Units— Minutes per Hour in Dehumidification Mode***

Four equations from Willem *et al.* (2013) correlate compressor run time with outdoor vapor density. Although individual dehumidifiers may differ greatly from the models, the equations describe, on average, the manner in which large numbers of dehumidifier units would operate.

Equation for climate-controlled dehumidifiers with bucket:

$$CC(B) Compressor\ Run\ Time\ \left(\frac{mins}{hour}\right) = (0.4141 * VD_{out} + 28.729) * (-0.0005 * VD_{out}{}^{2} - 0.0246 * VD_{out} + 0.7264)$$

Equation for climate-controlled, direct-drain dehumidifiers:

$$CC(DD) Compressor\ Run\ Time\ \left(\frac{mins}{hour}\right) = (-0.4966 * VD_{out} + 46.463) * (-0.0032 * VD_{out}^{2} + 0.1239 * VD_{out} + 0.4914)$$

Equation for non-climate controlled dehumidifiers with bucket:

$$NCC(B) Compressor\ Run\ Time\ \left(\frac{mins}{hour}\right) = (-0.1186 * VD_{out} + 49.389) * (-0.0011 * VD_{out}^{2} + 0.016 * VD_{out} + 0.4091)$$

Equation for non-climate controlled, direct-drain dehumidifiers:

$$NCC(DD) Compressor\ Run\ Time\ \left(\frac{mins}{hour}\right) = (1.5535 * VD_{out} + 27.778) * (-0.0013 * VD_{out}^{2} + 0.0265 * VD_{out} + 0.5783)$$

Where:

$VD_{out}$ = vapor density.

***Portable Units—Fraction of Hours in Fan-only Mode***

Willem *et al*., 2013, predicted fan-only run time as a function of dehumidification mode time. The following equation describes that relationship as applied to a large data set. The equation is not meant to be representative of individual dehumidifier units because fan use can vary widely among dehumidifiers.

$$Fan\ Run\ Time\ \left(\frac{mins}{hour}\right) = (.2518) * (-0.0265 * \mathrm{t_{Dehum}}^{2} + 1.6385 * (\mathrm{t_{Dehum}}) - 6.1693)$$

Where;

$t_{Dehum} = time\ in\ dehumidification\ mode\ \left(\frac{mins}{hour}\right)$

***Portable Units— Fraction of Hours in Standby/Off Mode***

DOE determined the amount of time in standby/off mode by subtracting both the compressor and the fan-only run times from the total time of dehumidifier use.

***Whole-Home Units— Fraction of Hours in Fan-only and Standby/Off Modes***

The small sample size in the whole-home dehumidifier study made it impossible to correlate vapor density to compressor use (Burke *et al.*, 2014). The authors were, however, able to develop time fractions for all operating modes. DOE used the average amount of time a dehumidifier operated during a 24-hour period. As shown in Table 7.3.4, the compressors in the whole-home dehumidifiers in the study did not operate all day long.

**Table 7.3.4 Fractions of Hours for Whole-Home Dehumidifiers Operated in Different Modes**

| Mode | Percent of Operating Hours (%) Mean |
|---|---|
| Dehumidification | 50 |
| Fan-only | 0.2 |
| Standby/Off | 49.0 |

## 7.4 ENERGY USE BY EFFICIENCY LEVEL AND PRODUCT CLASS

DOE calculated the annual energy use for the five product classes of dehumidifiers based on the assumptions and findings presented in Section 7.3. To calculate annual energy use, DOE used Eq. 7.2 in section 7.2 and assumed an average of 5.2 months of annual usage for portable dehumidifiers and 5.6 months of annual usage for whole-home dehumidifiers. Efficiencies are given in terms of integrated energy factor, which divides the amount of condensate removed divided by a sum of energy use in dehumidification, fan-only, and standby/off modes.

**Table 7.4.1 Portable Dehumidifiers ≤30.00 Pints/Day: Annual Energy Use by Efficiency Level**

| Level | Integrated Energy Factor (L/kWh) | Annual Energy Use* (kWh/year) |
|---|---|---|
| Baseline | 0.77 | 739.4 |
| 1 | 1.10 | 523.0 |
| 2 | 1.20 | 481.0 |
| 3 | 1.30 | 445.4 |
| 4 | 1.57 | 371.9 |

* Capacity = 21.0 pints/day; annual usage = 3,799 hours; $X_{Dehum}$ = 35.3%; $X_{Fan}$ = 6.5%; $X_{Stby}$ = 58.2%, $W_{Fan}$ = 65 W; $W_{Stby}$ = 1 W.

**Table 7.4.2 Portable Dehumidifiers 30.01–45.00 Pints/Day: Annual Energy Use by Efficiency Level**

| Level | Integrated Energy Factor (L/kWh) | Annual Energy Use* (kWh/year) |
|---|---|---|
| Baseline | 0.94 | 1073.2 |
| 1 | 1.20 | 844.7 |
| 2 | 1.40 | 726.6 |
| 3 | 1.60 | 638.0 |
| 4 | 1.80 | 569.2 |

* Capacity = 37.5 pints/day; annual usage = 3,799 hours; $X_{Dehum}$ = 35.3%; $X_{Fan}$ = 6.5%; $X_{Stby}$ = 58.2%, $W_{Fan}$ = 65 W; $W_{Stby}$ = 1 W.

**Table 7.4.3 Portable Dehumidifiers >45.00 Pints/Day: Annual Energy Use by Efficiency Level**

| Level | Integrated Energy Factor (L/kWh) | Annual Energy Use* (kWh/year) |
|---|---|---|
| Baseline | 2.07 | 944.3 |
| 1 | 2.40 | 817.0 |
| 2 | 2.80 | 702.9 |
| 3 | 3.66 | 542.0 |

* Capacity = 72.5 pints/day; annual usage = 3,799 hours; $X_{Dehum}$ = 35.3%; $X_{Fan}$ = 6.5%; $X_{Stby}$ = 58.2%, $W_{Fan}$ = 65 W; $W_{Stby}$ = 1 W.

**Table 7.4.4 Whole-Home Dehumidifiers ≤ 8.0 ft3 Case Volume: Annual Energy Use by Efficiency Level**

| Level | Integrated Energy Factor (L/kWh) | Annual Energy Use* (kWh/year) |
|---|---|---|
| Baseline | 1.77 | 1289.0 |
| 1 | 2.09 | 1093.0 |
| 2 | 2.53 | 904.5 |

* Capacity = 56.2 pints/day; annual usage = 4,091 hours; $X_{Dehum}$ = 50%; $X_{Fan}$ =0.2%; $X_{Stby}$ = 49%; $W_{Fan}$ = 142 W; $W_{Stby}$ = 4.5 W.

**Table 7.4.5 Whole-Home Dehumidifiers >8.0 ft3 Case Volume: Annual Energy Use by Efficiency Level**

| Level | Integrated Energy Factor (L/kWh) | Annual Energy Use* (kWh/year) |
|---|---|---|
| Baseline | 2.41 | 1542.9 |
| 1 | 2.70 | 1378.1 |
| 2 | 3.52 | 1059.2 |
| 3 | 4.50 | 830.5 |

* Capacity = 91.7 pints/day; annual usage = 4,091 hours; $X_{Dehum}$ = 50%; $X_{Fan}$ =0.2%; $X_{Stby}$ = 49%; $W_{Fan}$ = 142 W; $W_{Stby}$ = 4.5 W.

## 7.5 VARIABILITY OF ANNUAL DEHUMIDIFIER ENERGY USE

The EIA performs the RECS, collecting information for developing a national database of characteristics of a range of representative housing units, appliance usage patterns, and household demographics. The RECS reports on the presence of dehumidifiers in households and the amount of time the dehumidifiers are used. DOE used the 2009 version of RECS to determine the variability of dehumidifiers' annual energy consumption.

### 7.5.1 Monthly Dehumidifier Usage

*RECS 2009* questioned each household on two aspects of dehumidifier use: (1) ownership and (2) monthly use. Of the 12,083 household records contained in *RECS 2009*, 1,621 indicate use of dehumidifiers, which represents 13.2 percent of the households nationwide. *RECS 2009* provides five categories for how long a household's dehumidifier is in use (plugged in): 1 to 3, 4 to 6, 7 to 9, 10 to 11, or 12 months.

Of the 1,621 households that use dehumidifiers, most are located in the Northeast or upper Midwest regions of the country. *RECS 2009* disaggregates the households that have dehumidifiers into 10 regions based on the 10 Census divisions. Within each region, the data further show the percentages of households that do and do not have basements. The RECS data seem to confirm conventional wisdom that dehumidifiers are used primarily in basements (76 percent of dehumidifiers are in households that have basements). Figure 7.5.1 shows both where the households that have dehumidifiers are located geographically, and where in the house the dehumidifier is located. The blue bars show that of all the census divisions, the East North Central has the highest percentage of dehumidifiers (30 percent). The red and green bars show the percentage of homes having basement dehumidifiers within any one census division. More than 90 percent of the households that have a dehumidifier in the West North Central census division locate it in the basement.

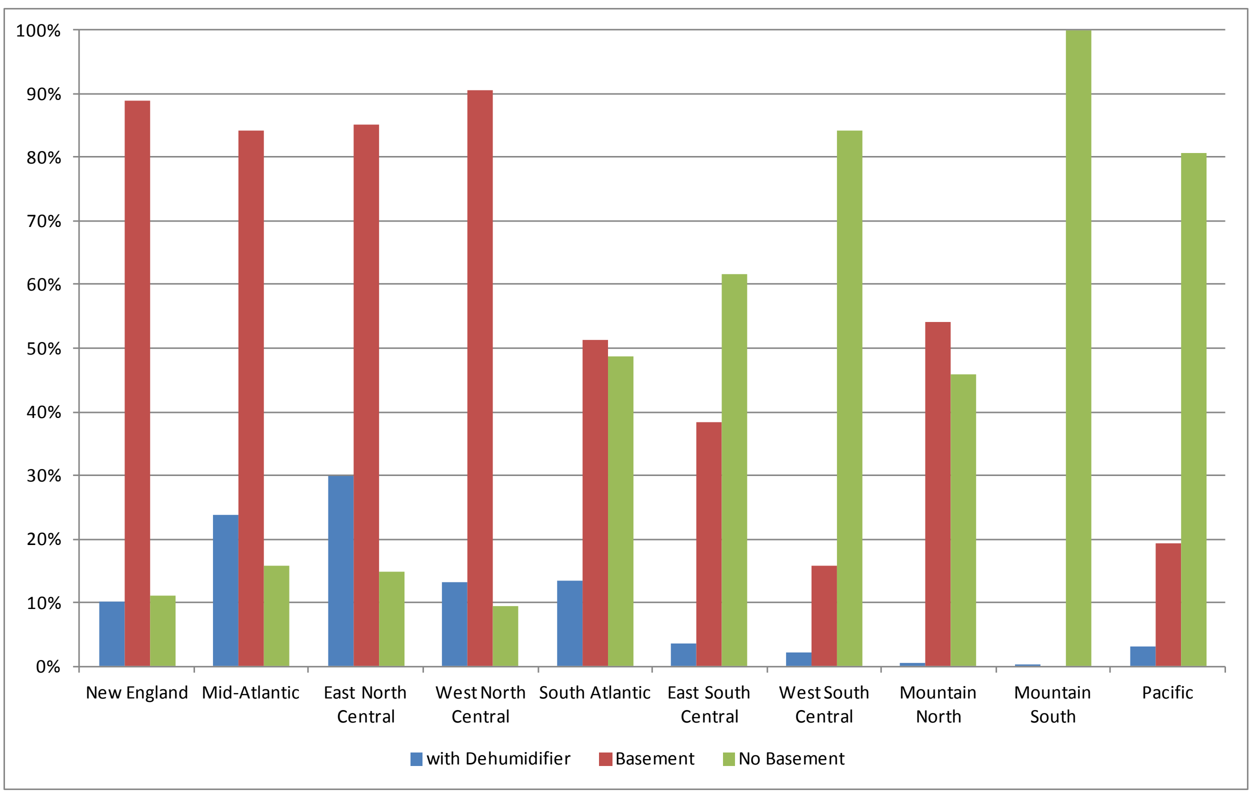


**Figure 7.5.1 Percent of Households that Have Dehumidifiers by Region and Presence of Basement**

### 7.5.2 Applications of Whole-Home Dehumidifiers

Although RECS itself does not distinguish between dehumidifier types, RECS variables can be used to approximate which households use portable dehumidifiers, and which use whole-home dehumidifiers. DOE assumed that households use whole-home dehumidifiers if they:

- are located in the Northeast, Midwest, or South Census regions;
- are located in the Building America Climate region categorized as "mixed humid";
- are single-family homes, either attached or detached;
- have a central air conditioner, and
- have duct work.

### 7.5.3 Annual Monthly Use

RECS collected data on annual use aggregated into monthly ranges. Table 7.5.1 shows the weighted number of households in each group of months. The maximum number in each range was used to more closely approximate the usage assumptions in DOE's dehumidifier test procedure.

**Table 7.5.1 Dehumidifier Use by Range of Months**

| Use Range | Portable | | Whole-Home | |
|---|---|---|---|---|
| (Months) | RECS Record Count | Total Estimated Households | RECS Record Count | Total Estimated Households |
| 1–3 | 708 | 6,479,451 | 6 | 58,569 |
| 4–6 | 492 | 4,456,581 | 9 | 99,188 |
| 7–9 | 116 | 1,056,969 | 2 | 23,390 |
| 10–11 | 36 | 382,792 | -- | -- |
| 12 | 249 | 2,414,801 | 3 | 32,862 |
| Total | 1,601 | 14,790,595 | 20 | 214,009 |

## 7.6 LINKING RECS HOUSEHOLDS TO CLIMATE PARAMETERS

To apply dehumidifier energy use data from the Willem field study, DOE matched the locations of RECS households having portable dehumidifiers with those of National Climatic Data Center (NCDC) weather stations. The match enabled DOE to include, for each RECS household, vapor density, hourly temperature and relative humidity parameters that could be used to estimate portable dehumidifier operation and energy use for the RECS household sample. See appendix 7B for more details.

### 7.6.1 Derivation of Outdoor Air Temperatures

*RECS 2009* reports both heating and cooling degree-days at a base temperature of 65 °F for each housing record, but provides no monthly data or humidity data. To obtain more precise temperature information for the households in the RECS sample, DOE assigned a physical location to each RECS household. DOE took the following steps.

1. There are 151 NCDC weather stations that provide hourly outdoor air temperatures and humidity. Those weather stations also provided the 2009 heating and cooling degree-days at a base temperature of 65 °F. The period covered by the 2009 heating and cooling degree-days from the weather stations matched the period used to determine degree-days in *RECS 2009*.
2. DOE assigned each RECS household to one of the 151 weather stations by calculating which weather station (within the appropriate census region or large state) best matched the 2009 heating and cooling degree-days in the RECS data set.

The following equation calculates the degree-day distance between the 2009 weather station data and *RECS 2009* data.

$$DDD = \sqrt{(HDD_2 - HDD_1)^2 + (CDD_2 - CDD_1)^2}$$

Where:

$DDD$ = degree-day distance,
$HDD_1$ = heating degree-days from 2009 weather station data,
$HDD_2$ = heating degree-days from *RECS 2009* data,
$CDD_1$ = cooling degree-days from 2009 weather station data, and
$CDD_2$ = cooling degree-days from *RECS 2009* data.

DOE then took the following steps to develop energy use profiles for portable dehumidifiers in U.S. households.

1. Used field-metered data from 2012 and 2013 paired with NCDC weather station data to determine the relationship between outdoor and indoor conditions and the time lag between them.
2. Developed models to predict dehumidifier operation based on hourly (lagged) outdoor conditions.
3. Used the models developed in step 2 and the NCDC weather data to estimate dehumidifiers' hours of operation for RECS households. The dehumidifier's relative humidity set point was not recorded for every field-metered dehumidifier.
4. Calculated annual dehumidifier energy use for RECS households.

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# CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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# CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

## 8.1 INTRODUCTION

This chapter of the NOPR TSD describes the DOE's method for analyzing the economic impacts of new energy conservation standards on individual consumers. The effects of standards on individual consumers include a change in operating expense (usually decreased) and a change in purchase price (usually increased). This chapter describes three metrics DOE used to determine the effects of standards on individual consumers of dehumidifiers.

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

Inputs to the LCC and PBP calculations are discussed in section 8.2 of this chapter. Results are presented in section 8.3. The rebuttable PBP is discussed in section 8.4. Key variables and calculations are presented for each metric. DOE performed the calculations discussed herein using a series of Microsoft Excel spreadsheets, which are accessible on the Internet.
(http://www1.eere.energy.gov/buildings/appliance_standards/residential/dehumidifiers.html)
Details and instructions for using the spreadsheets are presented in appendix 8A.

### 8.1.1 General Approach to Analysis

DOE uses the following equation to calculate LCC, the total consumer expense throughout the life of an appliance.

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

Where:

| | |
|---|---|
| *LCC* = | life-cycle cost in dollars, |
| *IC* = | total installed cost in dollars, |
| $\sum$ = | sum over the appliance lifetime, from year 1 to year N, |
| N = | lifetime of the appliance in years, |
| *OC* = | operating cost in dollars, |
| *r* = | discount rate, and |

$t$ = year for which operating cost is being determined.

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

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

Where:

$\Delta IC$ = difference in total installed cost between the more energy efficient design and the baseline design, and

$\Delta OC$ = difference in annual operating expenses.

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

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

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

As described in chapter 7 of this NOPR TSD, DOE used the EIA's *RECS 2009* to develop household samples for both portable and whole-home dehumidifiers.[1] The EIA designed *RECS 2009,* which consists of 12,083 housing units, to be a national representation of household population in the United States. DOE used the subset of *RECS 2009* records in which the household has a portable dehumidifier. Because *RECS 2009* does not provides stock and usage information for whole-home dehumidifiers, DOE used some of the variables that were assigned to central air-conditioners as the sample variables for whole-home dehumidifiers. Refer to chapter 7 of this NOPR TSD for details. DOE used RECS to establish the variability of annual dehumidifier use and of energy prices. DOE assigned unique annual hours of operation to each household in the sample. The variability among households in annual dehumidifier use and/or energy pricing contributes to the range of LCCs and PBPs calculated for the baseline efficiency level and each increased efficiency level.

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

### 8.1.2 Overview of Inputs to Analysis

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

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

The primary inputs for calculating operating costs are listed below.

- *Product energy consumption*: The on-site energy use associated with operating a product.
- *Product efficiency*: The product energy consumption associated with standard-level products (*i.e.*, products having efficiencies greater than those of baseline products).
- *Energy prices*: The prices consumers pay for energy (*e.g.*, electricity or natural gas).
- *Energy price trends*: DOE used the EIA's *AEO 2015* [2] to project energy prices.
- *Repair and maintenance costs*: Repair costs are associated with repairing or replacing components that have failed. Maintenance costs are associated with maintaining the operation of the product.
- *Lifetime*: The age at which the product is retired from service.
- *Discount rate*: The rate at which DOE discounts future expenditures to establish their present value.

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

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

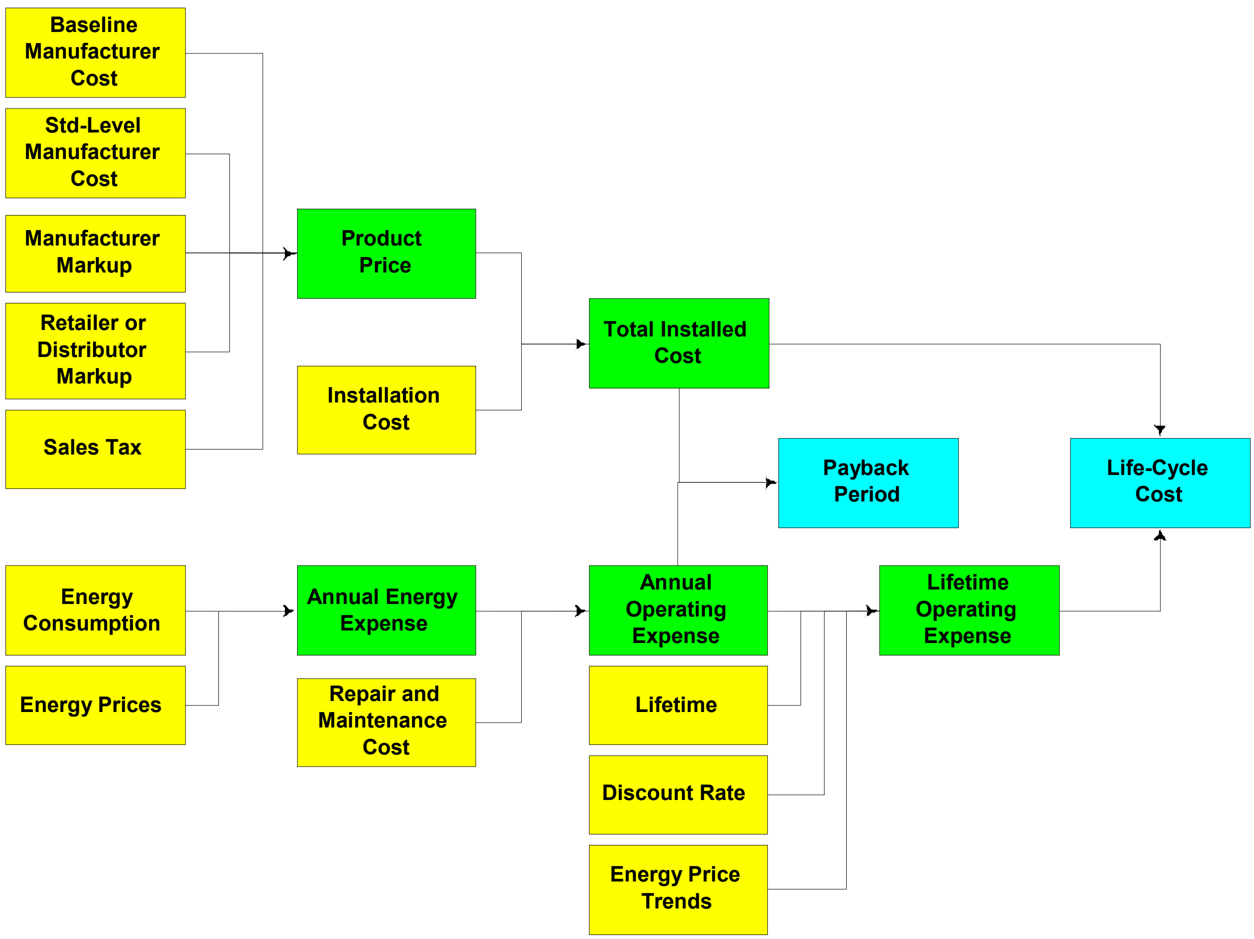


**Figure 8.1.1 Flow Diagram of Inputs for Determining LCC and PBP**

## 8.2 INPUTS TO LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

DOE gathered most of the data for performing the LCC and PBP analysis in 2014. DOE expresses dollar values in 2013$.

### 8.2.1 Inputs to Total Installed Cost

DOE uses the following equation to define the total installed cost (IC).

$$IC = CPC + INST$$

Where:

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

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

**Table 8.2.1 Inputs to Total Installed Cost**

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

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

DOE calculated the IC for baseline products based on the following equation.

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

Where:

| | |
|---|---|
| $IC_{BASE}$ = | total installed cost for baseline model, |
| $CPC_{BASE}$ = | consumer product cost for baseline model, |
| $INST_{BASE}$ = | installation cost for baseline model, |
| $COST_{MFG}$ = | manufacturer cost for baseline model, and |
| $MU_{OVERALL\_BASE}$ = | overall baseline markup (product of manufacturer markup, baseline |

retailer or distributor markup, and sales tax).

DOE used the following equation to calculate the IC for standard-level products.

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

Where:

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

The rest of this section provides information about each of the above input variables, which DOE used to calculate the IC for dehumidifiers.

#### 8.2.1.1 Forecasting Future Product Prices

Historical price data for certain appliances and equipment that have been subject to energy conservation standards indicate that the assumption of constant real prices and costs may overestimate long-term trends in appliance and equipment prices. Economic literature and historical data suggest that the real costs of products may trend downward over time in response to "learning" or "experience" curves.

An extensive body of literature discusses the learning or experience curve phenomenon, typically based on observations in the manufacturing sector[a]. Based on the experience curve approach, the real cost of production is related to the cumulative production, or experience, of a product. Typically, DOE uses historical shipments data to estimate cumulative shipments (production). However, the historical shipment data for portable and whole-home dehumidifiers are too limited to construct robust cumulative production estimation for the products. Therefore,

[a] Margaret Taylor and K. Sydny Fujita. Accounting for Technological Change in Regulatory Impact Analyses: The Learning Curve Technique. Lawrence Berkeley National Laboratory. April 2013. LBNL-6195E. (Available at: http://eetd.lbl.gov/publications/accounting-for-technological-change-0)

DOE used the appropriate Producer Price Index (PPI) series fit to an exponential model having *year* as the explanatory variable. In this case, the exponential function takes the form of:

$$Y = a \cdot e^{bX}$$

where Y is the dehumidifier price index, X is the time variable, *a* is the constant, and *b* is the slope parameter of the time variable.

To derive the exponential parameters for portable dehumidifiers and whole-home dehumidifiers, DOE obtained historical PPI data for "small electric household appliances" and for "room air conditioners and dehumidifiers" from the Bureau of Labor Statistics, respectively. Although the two PPI series encompass much more than portable and whole-home dehumidifiers, no PPI data specific to the two products were available. The PPI data reflect nominal prices, adjusted for changes in product quality. DOE calculated an inflation-adjusted (deflated) price index by dividing the PPI series by the Gross Domestic Product Chained Price Index for each product. The deflated price index is presented in 2012 dollar values.

For portable dehumidifiers, the regression performed as an exponential trend line fit results in an R-square of 0.99, which indicates a superior fit to the data. The fit results in a 2.02-percent annual rate of price decline. The final estimated exponential function for portable dehumidifiers is:

$$Y = 6.266 \times 10^{17} \cdot e^{(-0.0204)X}$$

For whole-home dehumidifiers, the regression performed as an exponential trend line fit results in an R-square of 0.96, which also indicates an excellent fit to the data. The fit results in a 2.32-percent annual rate of price decline. The final estimated exponential function for whole-home dehumidifiers is:

$$Y = 2.949 \times 10^{20} \cdot e^{(-0.0235)X}$$

Based on the fitted regressions, DOE derived separate price factor indexes for portable and whole-home dehumidifiers for each future year in the analysis. For the LCC and PBP analysis, DOE renormalized the price factor index, setting 2012 equal to 1, to estimate the price of portable and whole-home dehumidifiers in 2019.

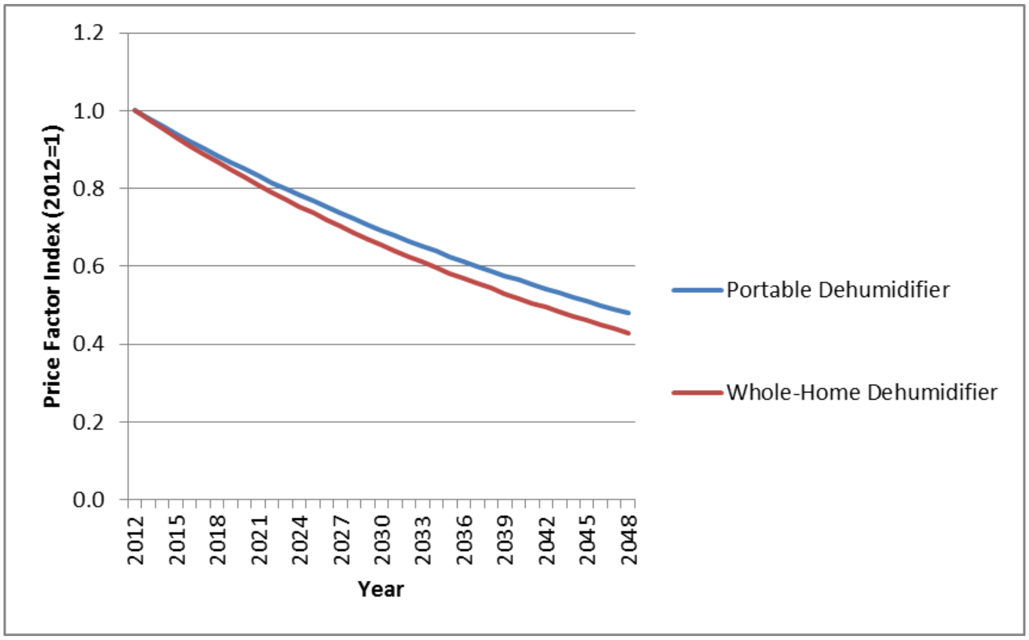


**Figure 8.2.1 Future Price Projection for Portable Dehumidifiers and Whole-Home Dehumidifier**

### 8.2.1.2 Baseline Manufacturer Cost

DOE developed the baseline manufacturer costs for all five product classes of dehumidifiers (described in chapter 5 of this NOPR TSD, Engineering Analysis). Baseline manufacturer costs are shown in Table 8.2.2.

**Table 8.2.2 Baseline Manufacturer Costs**

| Product Class (Pints/Day) | Baseline Integrated Energy Factor (L/kWh)* | Baseline Manufacturer Cost (2013$) |
|---|---|---|
| ≤ 30.00 | 0.77 | $113.38 |
| 30.01–45.00 | 0.94 | $136.99 |
| > 45.00 | 2.07 | $428.90 |
| ≤ 8.0 $ft^3$ case volume (whole-home) | 1.77 | $397.75 |
| >8.0 $ft^3$ case volume (whole-home) | 2.41 | $537.96 |

* L/kWh = liters (of moisture removed) per kilowatt-hour (of energy consumed).

### 8.2.1.3 Incremental Manufacturer Cost by Efficiency Level

DOE used a reverse-engineering analysis to develop manufacturer cost increases associated with increases in dehumidifier efficiency. Refer to chapter 5 of this NOPR TSD for details. Table 8.2.3 through Table 8.2.7 present the incremental manufacturer costs at each efficiency level for all five product classes of dehumidifiers.

**Table 8.2.3 Portable Dehumidifiers ≤30.00 Pints/Day: Incremental Manufacturer Cost by Efficiency Level**

| Efficiency Level | Integrated Energy Factor (L/kWh) | Manufacturer Cost Increase (2013$) |
|---|---|---|
| Baseline | 0.77 | - |
| 1 | 1.10 | $0 |
| 2 | 1.20 | $1.69 |
| 3 | 1.30 | $4.27 |
| 4 | 1.57 | $19.38 |

**Table 8.2.4 Portable Dehumidifiers 30.01–45.00 Pints/Day: Incremental Manufacturer Cost by Efficiency Level**

| Efficiency Level | Integrated Energy Factor (L/kWh) | Manufacturer Cost Increase (2013$) |
|---|---|---|
| Baseline | 0.94 | - |
| 1 | 1.20 | $0 |
| 2 | 1.40 | $2.39 |
| 3 | 1.60 | $8.07 |
| 4 | 1.80 | $22.42 |

**Table 8.2.5 Portable Dehumidifiers >45.00 Pints/Day: Incremental Manufacturer Cost by Efficiency Level**

| Efficiency Level | Integrated Energy Factor (L/kWh) | Manufacturer Cost Increase (2013$) |
|---|---|---|
| Baseline | 2.07 | - |
| 1 | 2.40 | $42.81 |
| 2 | 2.80 | $53.66 |
| 3 | 3.66 | $120.33 |

**Table 8.2.6 Dehumidifiers ≤8.0 ft3 Case Volume (Whole-Home): Incremental Manufacturer Cost by Efficiency Level**

| Efficiency Level | Integrated Energy Factor (L/kWh) | Manufacturer Cost Increase (2013$) |
|---|---|---|
| Baseline | 1.77 | - |
| 1 | 2.09 | $15.30 |
| 2 | 2.53 | $129.22 |

**Table 8.2.7 Dehumidifiers >8.0 ft3 Case Volume (Whole-Home): Incremental Manufacturer Cost by Efficiency Level**

| Efficiency Level | Integrated Energy Factor (L/kWh) | Manufacturer Cost Increase (2013$) |
|---|---|---|
| Baseline | 2.41 | - |
| 1 | 2.70 | $6.20 |
| 2 | 3.52 | $37.20 |
| 3 | 4.50 | $161.39 |

#### 8.2.1.4 Overall Markup

**The overall markup is the value determined by multiplying the manufacturer and retailer markups and the sales tax together to arrive at a single markup value. *Table 8.2.8* and *Table 8.2.9* show the overall baseline and incremental markups for portable and whole-home dehumidifiers, respectively. Refer to chapter 6 of this NOPR TSD for details.**

**Table 8.2.8 Portable Dehumidifiers: Overall Markup**

| Markup | Baseline | Incremental |
|---|---|---|
| Manufacturer | 1.45 | |
| Retailer | 1.39 | 1.13 |
| Sales tax | 1.071 | |
| Overall markup | 2.16 | 1.75 |

**Table 8.2.9 Whole-Home Dehumidifiers: Overall Markup**

| Markup | Replacement | | New Construction | |
|---|---|---|---|---|
| | Baseline | Incremental | Baseline | Incremental |
| Manufacturer | 1.45 | | 1.45 | |
| Wholesaler | 1.35 | 1.10 | 1.35 | 1.10 |
| Mechanical contractor | 1.53 | 1.22 | 1.45 | 1.15 |
| General contractor | -- | -- | 1.47 | 1.34 |
| Sales tax | 1.071 | | -- | -- |
| Overall markup | 3.21 | 2.08 | 4.17 | 2.46 |

#### 8.2.1.5 Installation Costs

Based on the previous rulemaking conducted for dehumidifiers,[3] DOE determined that there are no installation costs for portable dehumidifiers.

DOE derived baseline installation costs for whole-home dehumidifiers from data in the *RS Means Residential Cost Data, 2013*.[4] The book estimates the labor required to install room air conditioners. Table 8.2.10 summarizes the nationally representative average costs associated with installing split-system air conditioners as presented in *RS Means Residential Cost Data*. Table 8.2.10 provides both bare costs (*i.e*., costs before overhead and profit (O&P)), and installation costs including O&P. DOE determined that installation costs would not be affected by increased efficiency levels.

**Table 8.2.10 Whole-home Dehumidifiers: Baseline Installation Costs**

| Installation Type | Bare Costs (2013$) | | | Including Overhead & Profit (2013$) | | |
|---|---|---|---|---|---|---|
| | Material | Labor | Total | Total | Material* | Labor** |
| Average | $995 | $338 | $1,333 | $1,663 | $1,095 | $568 |
| **Average (2013$)** | | | | | | **$568** |

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

** DOE derived labor cost including O&P by subtracting materials plus O&P from total plus O&P.

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

#### 8.2.1.6 Total Installed Cost

**Total installed cost is the sum of the consumer product cost and installation cost. *Table 8.2.11* through *Table 8.2.15* present the total installed costs for each dehumidifier product class at each efficiency level examined.**

**Table 8.2.11 Portable Dehumidifiers ≤30.00 Pints/Day: Consumer Product Prices, Installation Costs, and Total Installed Costs**

| Efficiency Level | Integrated Energy Factor (L/kWh) | Product Price (2013$) | Installation Cost (2013$) | Total Installed Cost (2013$) |
|---|---|---|---|---|
| Baseline | 0.77 | 212 | 0.00 | 212 |
| 1 | 1.10 | 212 | 0.00 | 212 |
| 2 | 1.20 | 214 | 0.00 | 214 |
| 3 | 1.30 | 218 | 0.00 | 218 |
| 4 | 1.57 | 241 | 0.00 | 241 |

**Table 8.2.12 Portable Dehumidifiers 30.01–45.00 Pints/Day: Consumer Product Prices, Installation Costs, and Total Installed Costs**

| Efficiency Level | Integrated Energy Factor (L/kWh) | Product Price (2013$) | Installation Cost (2013$) | Total Installed Cost (2013$) |
|---|---|---|---|---|
| Baseline | 0.94 | 256 | 0.00 | 256 |
| 1 | 1.20 | 256 | 0.00 | 256 |
| 2 | 1.40 | 259 | 0.00 | 259 |
| 3 | 1.60 | 268 | 0.00 | 268 |
| 4 | 1.80 | 290 | 0.00 | 290 |

**Table 8.2.13 Portable Dehumidifiers >45.00 Pints/Day: Consumer Product Prices, Installation Costs, and Total Installed Costs**

| Efficiency Level | Integrated Energy Factor (L/kWh) | Product Price (2013$) | Installation Cost (2013$) | Total Installed Cost (2013$) |
|---|---|---|---|---|
| Baseline | 2.07 | 915 | 0.00 | 915 |
| 1 | 2.40 | 989 | 0.00 | 989 |
| 2 | 2.80 | 1,008 | 0.00 | 1,008 |
| 3 | 3.66 | 1,124 | 0.00 | 1,124 |

**Table 8.2.14 Dehumidifiers ≤8.0 ft3 Case Volume (Whole-Home): Consumer Product Prices, Installation Costs, and Total Installed Costs**

| Efficiency Level | Integrated Energy Factor (L/kWh) | Product Price (2013$) | Installation Cost (2013$) | Total Installed Cost (2013$) |
|---|---|---|---|---|
| Baseline | 1.77 | 1,094 | 568 | 1,662 |
| 1 | 2.09 | 1,121 | 568 | 1,689 |
| 2 | 2.53 | 1,322 | 568 | 1,890 |

**Table 8.2.15 Dehumidifiers >8.0 ft3 Case Volume (Whole-Home): Consumer Product Prices, Installation Costs, and Total Installed Costs**

| Efficiency Level | Integrated Energy Factor (L/kWh) | Product Price (2013$) | Installation Cost (2013$) | Total Installed Cost (2013$) |
|---|---|---|---|---|
| Baseline | 2.41 | 1,574 | 568 | 2,142 |
| 1 | 2.70 | 1,586 | 568 | 2,154 |
| 2 | 3.52 | 1,644 | 568 | 2,212 |
| 3 | 4.50 | 1,877 | 568 | 2,445 |

### 8.2.2 Inputs to Operating Cost

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

$$OC = EC + RC + MC$$

Where:

$EC$ = energy expenditure associated with operating the product,
$RC$ = repair cost associated with component failure, and
$MC$ = cost for maintaining product operation.

Table 8.2.16 shows the inputs for determining annual OCs and their discounted values throughout the product lifetime.

**Table 8.2.16 Inputs to Operating Cost**

| |
|---|
| Annual energy consumption |
| Energy prices and price trends |
| Repair and maintenance costs |

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

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

$$OC_{BASE} = (AEC_{BASE} \times PRICE_{ENERGY}) + RC_{BASE} + MC_{BASE}$$

Where:

$OC_{BASE}$ = operating cost for baseline product,
$AEC_{BASE}$ = annual energy consumption for baseline product,
$PRICE_{ENERGY}$ = energy price,
$RC_{BASE}$ = repair cost associated with component failure for baseline product, and
$MC_{BASE}$ = cost for maintaining operation of baseline product.

DOE calculated the annual OC for standard-level products based on the following equation.

$$OC_{STD} = (AEC_{STD} \times PRICE_{ENERGY}) + RC_{STD} + MC_{STD}$$

Where:

| | |
|---|---|
| $OC_{STD}$ = | operating cost for standard-level product, |
| $AEC_{STD}$ = | annual energy consumption for standard-level product, |
| $PRICE_{ENERGY}$ = | energy price, |
| $RC_{STD}$ = | repair cost associated with component failure for standard-level product, and |
| $MC_{STD}$ = | cost for maintaining operation of standard-level product. |

The rest of this section provides information about each of the above input variables that DOE used to calculate the OCs for all product classes of dehumidifiers.

#### 8.2.2.1 Annual Operating Hours

As described in chapter 7 of this NOPR TSD and in section 8.1.1, DOE utilized *RECS 2009* and the two recent field studies (Willem, et al., 2013, Burke, et al., 2014)[5,6] to develop samples of individual households that use either portable or whole-home dehumidifiers. By developing a household sample for each product type, DOE was able to perform the LCC and PBP calculations for each household to account for the variability in both energy use and energy price, as shown in Table 8.2.17 and Table 8.2.18. Refer to chapter 7 of the NOPR TSD for details.

**Table 8.2.17 Usage Data for RECS2009 Portable Dehumidifiers**

| Usage Bin (Months) | Share of RECS Households | |
|---|---|---|
| | Percentage* (%) | Number (n) |
| 1 to 3 months | 43.8 | 708 |
| 4 to 6 months | 30.1 | 492 |
| 7 to 9 months | 7.2 | 116 |
| 10 to 11 months | 2.6 | 36 |
| Turned on all year | 16.3 | 249 |
| **Total** | **100.0** | **1,601** |

*Percentages represent weighted values.
Source: *RECS 2009*.

**Table 8.2.18 Usage Data for Whole-Home Dehumidifiers**

| Usage Bin (Months) | Share of RECS Households | |
|---|---|---|
| | **Percentage* (%)** | **Number (n)** |
| 1 to 3 months | 27.4 | 6 |
| 4 to 6 months | 46.4 | 9 |
| 7 to 9 months | 10.9 | 2 |
| Turn on all year | 15.4 | 3 |
| **Total** | **100.0** | **20** |

*Percentages represent weighted values.
Source: *RECS 2009*.

#### 8.2.2.2 Operating Hours by Mode

The fraction of time a portable dehumidifier spends in each mode of operation (standby/off, fan-only, and dehumidification) affects the unit's energy use. To determine the fraction of time spent in each operational mode, DOE linked the RECS households having portable dehumidifiers to climate parameters. By linking the geographic locations of the RECS households with data on outdoor vapor density, DOE was able to calculate a sampled RECS household's dehumidification operating times for each month. DOE also disaggregated the portable dehumidifier usage into four installation categories based on climate type and type of condensate removal (manual emptying of a bucket or use of a direct drain). DOE assumed that market shares of portable dehumidifiers are divided 15% to 85% between direct-drain units and units having buckets. See chapter 7 of this NOPR TSD for more information.

To determine the fraction of time whole-home dehumidifiers spend in each mode of operation, DOE used the probability distribution of operating hours by mode from the Willem study (Burke, et al., 2014)[6]. DOE did not link the RECS data with outdoor vapor density for whole-home dehumidifiers because the sample size from the study is insufficient to apply results to U.S. households in general. Figure 8.2.2 through Figure 8.2.4 summarize the probability distributions of operating hours by mode for whole-home dehumidifiers. DOE assigned a probability distribution based on the frequency range for each mode.

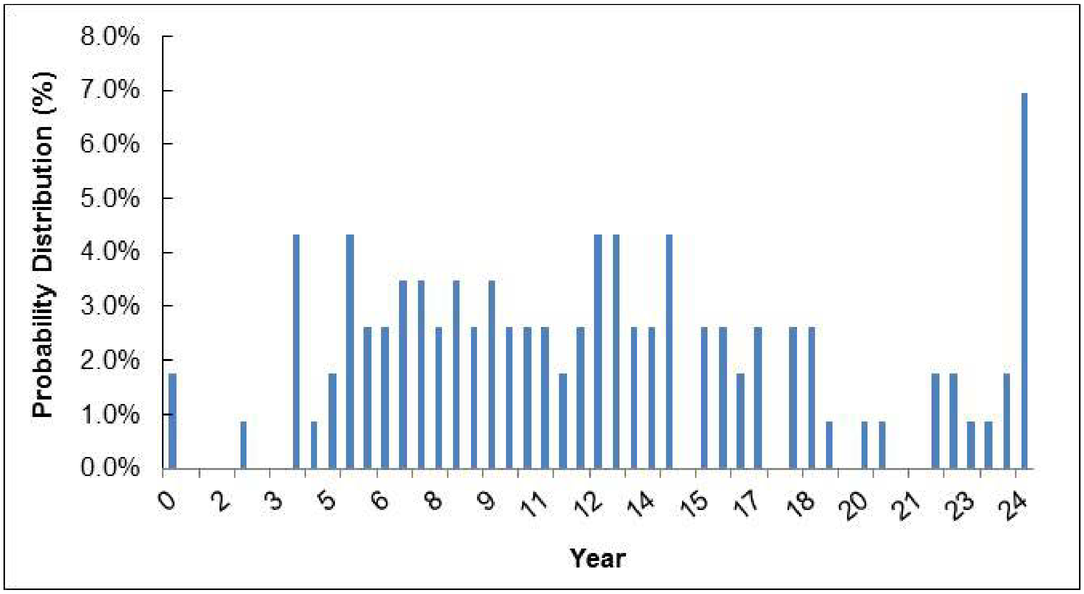


**Figure 8.2.2 Probability Distribution of Dehumidification Mode for Whole-Home Dehumidifiers**

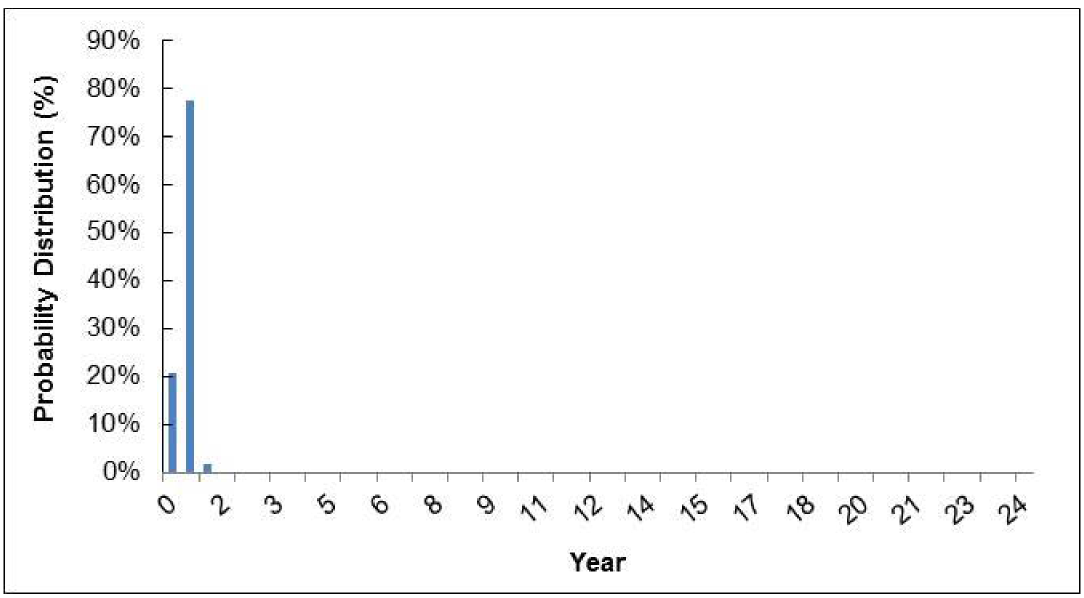


**Figure 8.2.3 Probability Distribution of Fan-Only Mode for Whole-Home Dehumidifiers**

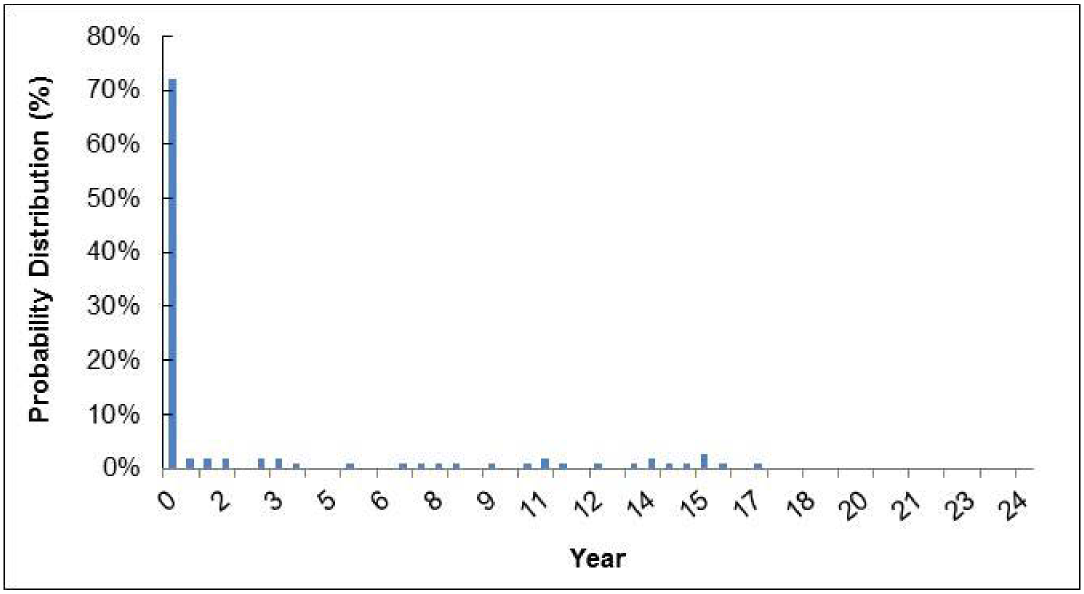


**Figure 8.2.4 Probability Distribution of Standby/Off Mode for Whole-Home Dehumidifiers**

#### 8.2.2.3 Power Use by Mode

To determine power use by mode for portable dehumidifiers, DOE used a single value from the Willem study (Willem, et al., 2013)[5] for fan-only mode and standby/off mode. To determine power use by mode for whole-home dehumidifiers, DOE used a range of power use associated with fan-only mode and standby/off mode from the Willem study (Burke, et al., 2014)[6], and assigned a probability distribution to each mode. Table 8.2.19 summarizes the power use by mode for portable and whole-home dehumidifiers.

**Table 8.2.19 Power Use by Mode**

| Product Type | Fan-Only Mode (W) | Standby/Off Mode (W) |
|---|---|---|
| Portable dehumidifier | 65 | 1 |
| Whole-home dehumidifier | 50.2-141.7 | 1-4.5 |

DOE used the following equation to determine power use by dehumidification mode.

$$kW_{Dehum} = \frac{Cap * 0.473}{IEF * 24}$$

#### 8.2.2.4 Residential Electricity Prices

DOE derived electricity prices for each of the 27 RECS Reportable Domain categories regions. Using those data, DOE analyzed the regional variability of electricity prices at the regional level.

DOE used data from EIA Form 861[7] to estimate electricity prices for residential consumers in each of the 27 geographic areas. Those data, published annually, include annual electricity sales in kilowatt-hours; revenues from electricity sales; and number of consumers in the residential, commercial, and industrial sectors for every utility that serves final consumers. DOE calculated average residential electricity prices in two steps.

1. For each utility, an average residential price was estimated by dividing residential revenues by residential sales.
2. An average regional price was calculated, weighting each utility having customers in a region by the total number of residential consumers served in that region.

Table 8.2.20 shows the average residential electricity price calculated for each geographic region.

**Table 8.2.20 Average Residential Electricity Prices in 2012**

| Geographic Area | Average Price (2013$/kWh) |
|---|---|
| Connecticut, Maine, New Hampshire, Rhode Island, Vermont | $0.164 |
| Massachusetts | $0.152 |
| New York | $0.190 |
| New Jersey | $0.161 |
| Pennsylvania | $0.131 |
| Illinois | $0.116 |
| Indiana, Ohio | $0.115 |
| Michigan | $0.144 |
| Wisconsin | $0.134 |
| Iowa, Minnesota, North Dakota, South Dakota | $0.111 |
| Kansas, Nebraska | $0.109 |
| Missouri | $0.104 |
| Virginia | $0.112 |
| Delaware, DC, Maryland, West Virginia | $0.131 |
| Georgia | $0.114 |
| North Carolina, South Carolina | $0.114 |
| Florida | $0.116 |
| Alabama, Kentucky, Mississippi | $0.106 |
| Tennessee | $0.103 |
| Arkansas, Louisiana, Oklahoma | $0.092 |
| Texas | $0.112 |
| Colorado | $0.116 |
| Idaho, Montana, Utah, Wyoming | $0.099 |
| Arizona | $0.114 |
| Nevada, New Mexico | $0.119 |
| California | $0.156 |
| Alaska, Hawaii, Oregon, Washington | $0.119 |

Source: EIA Form 861.

#### 8.2.2.5 Energy Price Trends

DOE used EIA's price forecasts to estimate future trends in electricity prices. To arrive at prices in future years, DOE multiplied the average prices listed in Table 8.2.20 by the forecast of annual average price changes based on the reference case in EIA's *AEO 2015*.[2] To estimate the trend after 2040, DOE followed the guidance EIA previously provided to the Federal Energy Management Program, to use the average rate of change during 2025–2040.

DOE calculated LCC and PBP based on three separate projections from the *AEO 2015*: reference case, low economic growth, and high economic growth. Those three cases reflect the uncertainty regarding economic growth during the forecast period. Figure 8.2.5 shows the three projected trends in residential electricity prices based on the three *AEO 2015* cases.

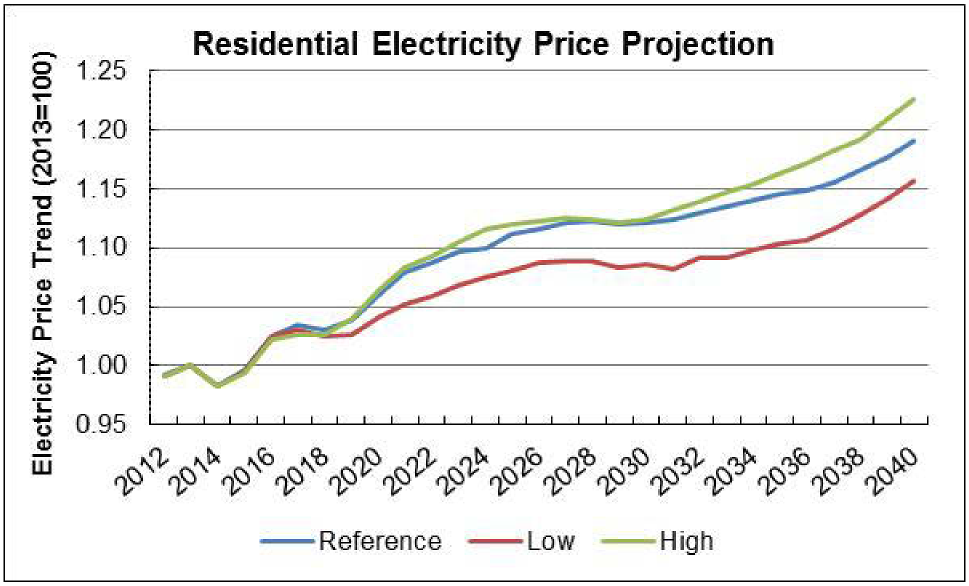


**Figure 8.2.5 Residential Electricity Price Trends**

### 8.2.2.6 Repair and Maintenance Costs

DOE included no changes to repair or maintenance costs for either portable or whole-home dehumidifiers that exceed baseline efficiency.

### 8.2.2.7 Product Lifetime

For portable dehumidifiers, DOE considered the sources listed in Table 8.2.21 to estimate product lifetime.

**Table 8.2.21 Dehumidifiers: Product Lifetime Estimates and Sources**

| Lifetime (years) | Source |
|---|---|
| Mean* = 8; Low* = 5; High* = 10 | Appliance Magazine (2005**) [8] |
| 10 | ACEEE (2001) [9] |
| 12 | Northeast Energy Star Lighting and Appliance [10] |

* Estimates are first-ownership length, not full product lifetime.
** Most current citation found.

The estimates from *Appliance Magazine* are "based on first-owner use of the product and does not necessarily mean the appliance is worn out." In other words, *Appliance Magazine*'s lifetime estimates underestimate the actual lifetime of the products in those cases where the product is used by two or more users. As a result, DOE excluded *Appliance Magazine* as a source for determining the average product lifetime. To determine the average product lifetime, DOE calculated the average value from estimates provided by the two remaining sources listed in the table above. The resulting average lifetime estimate is 11 years. DOE used the low estimate from *Appliance Magazine* to establish the minimum product lifetime and a triangular distribution to establish the maximum product lifetime.

**Table 8.2.22 Portable Dehumidifiers: Average, Minimum, and Maximum Product Lifetimes Used in LCC Analysis**

| **Product** | **Minimum** *years* | **Average** *years* | **Maximum** *years* |
|---|---|---|---|
| Dehumidifiers | 5.0 | 11.0 | 17.0 |

DOE assumed whole-home dehumidifiers have the same life span as residential room air conditioners. For the sources used to develop the room air conditioner lifetime parameters, see Table 8.2.23. The resulting lifetime parameters derived for room air conditioners for whole-home dehumidifiers are shown in Table 8.2.24.

**Table 8.2.23 Room Air Conditioners: Product Lifetime Estimates and Sources**

| **Typical Lifetime or Range (years)** | | **Source** |
|---|---|---|
| *Original Sources* | | |
| Average = 9; Low = 7 | | Appliance Magazine, September 2008[11] |
| 12.5 | | ASHRAE 2008[12] |
| 15 | | CEC 2005[13] |
| 12 | | European Rulemaking Draft Report[14] |
| Average = 15; High = 20 | | NRDC[15] |
| *Other Sources* | | |
| *Lifetime* | *Source* | |
| 9 | Appliance Magazine, 1997 | ENERGY STAR Savings Calculator[b] |
| 18 | EnerGuide 2005 | Natural Resources Canada, 2008[16] |
| 15 | NA | New Mexico Market Assessment, Itron 2006[17] |
| 18 | NA | Nebraska Public Power District[18] |
| 12 | See endnote | NYSERDA SBC, 2002[19] |
| 9 | NA | Regional Technical Form (Northwest), 2002[20] |
| 12.5 | DOE TSD 1997 | NCEP report, LBNL 2004[21] |
| 19 | Aspen Memo, 2002 | NYSERDA Deemed Savings Database: ENERGY STAR[22] |
| 13 (TTW) | DOE TSD 2005 | NYSERDA Deemed Savings Database: ENERGY STAR[23] |
| Low = 8, High =16 | | NEMS Residential Demand Module, 2008[24] |
| 13 | | LBNL 2008[25] |
| Average = 10–15, Low = 8-12, High = 14-18 | | LBNL 1994[26] |
| 10 | | Consortium for Energy Efficiency[27] |
| 10 - 12 | | American Council for an Energy Efficient Economy, 2007[28] |

Note: NA means the data source is not stated in the reference.

[b] ENERGY STAR Savings Calculator, Products, Room Air Conditioners. Efficient and conventional models.

**Table 8.2.24 Room Air Conditioner Lifetime Reference Values**

| Product Type | Minimum (Years) | Average (Years) | Maximum (Years) |
|---|---|---|---|
| Room Air Conditioners | 3.0 | 10.5 | 20.0 |

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

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

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

Where:

$P(x)$ = probability that the appliance is still in use at age $x$;
$x$ = age of appliance;
$\alpha$ = scale parameter, which would be the decay length in an exponential distribution;
$\beta$ = shape parameter, which determines the way in which the failure rate changes through time; and
$\theta$ = 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, $\beta$ commonly is greater than 1, reflecting an increasing failure rate as appliances age. Figure 8.2.6 and Figure 8.2.7 show the Weibull retirement and survival functions for portable and whole-home dehumidifiers, respectively. The results of DOE's analysis are shown in Table 8.2.25.

[c] For reference on the Weibull distribution, see sections 1.3.6.6.8 and 8.4.1.3 of the National Institute of Standards and Technology (*NIST)/SEMATECH e-Handbook of Statistical Methods*. <www.itl.nist.gov/div898/handbook/> (Last accessed August 21, 2012.)

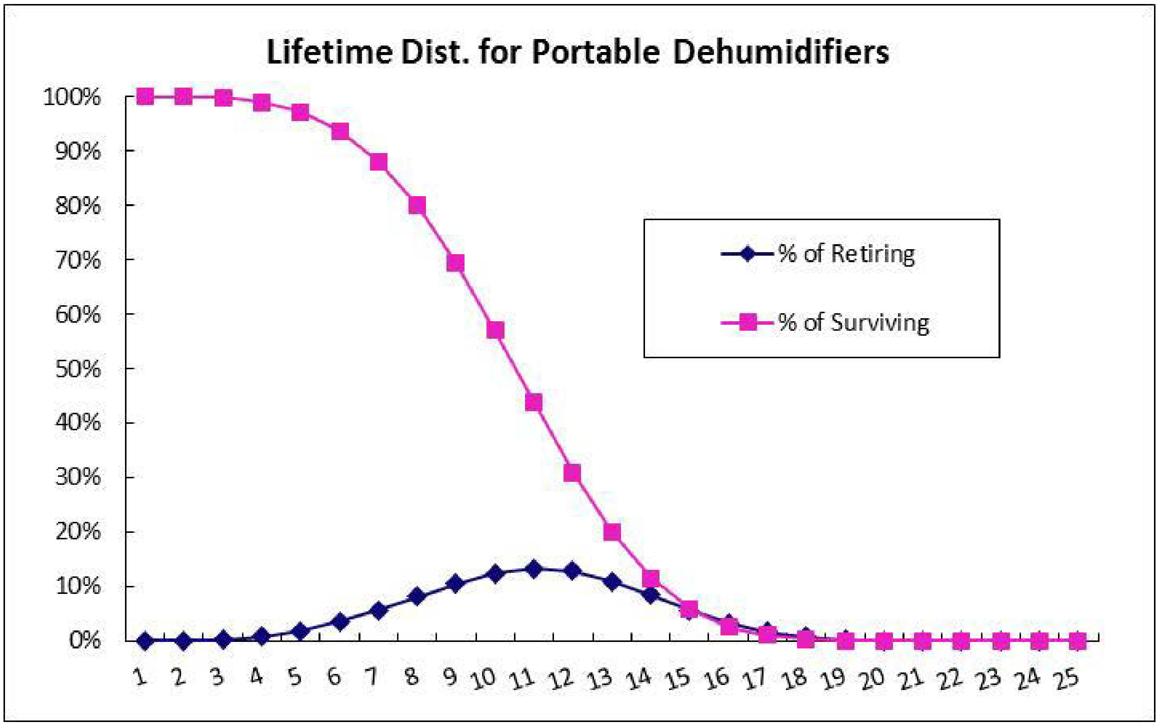


**Figure 8.2.6 Weibull Function for Lifetime of Portable Dehumidifiers**

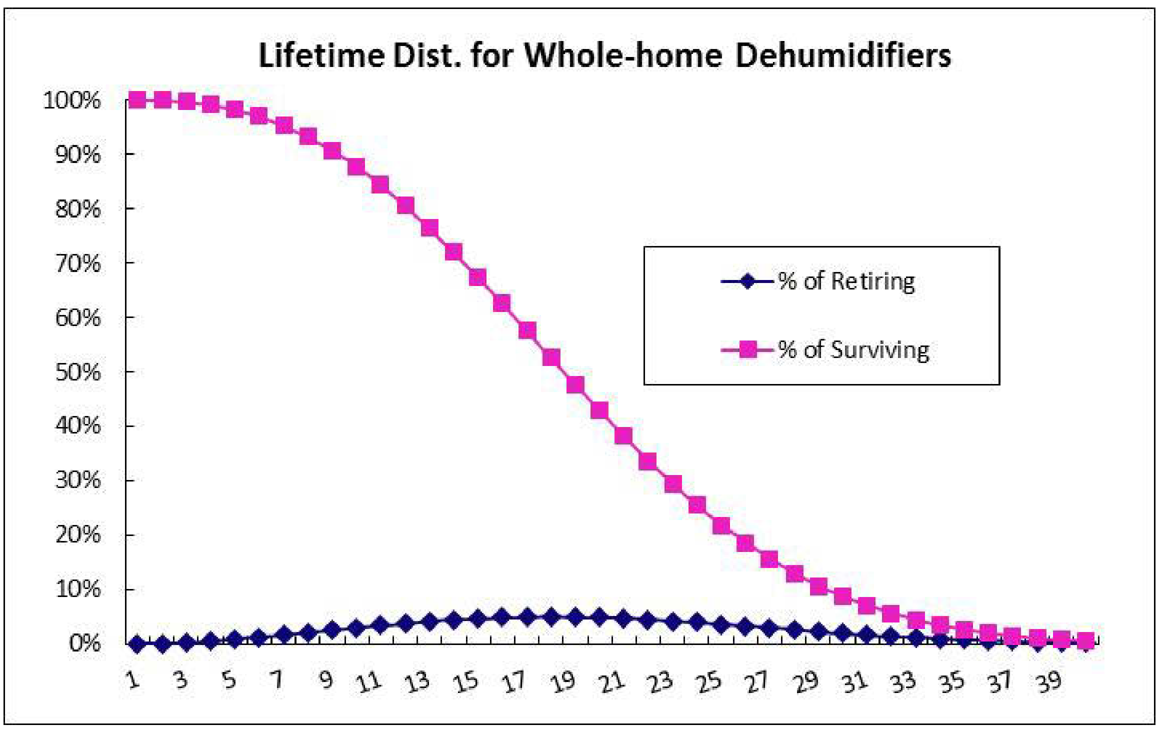


**Figure 8.2.7 Weibull Function for Lifetime of Whole-Home Dehumidifiers**

**Table 8.2.25 Lifetime Parameters**

| Product Type | Average (Years) | Weibull Parameters | |
|---|---|---|---|
| | | Alpha (Scale) | Beta (Shape) |
| Portable dehumidifiers | 11.0 | 11.00 | 4.20 |
| Whole-home dehumidifiers | 19.01 | 20.30 | 2.50 |

### 8.2.3 Discount Rates

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

DOE estimates separate discount rate distributions for six income groups, divided based on income percentile as reported in the Federal Reserve Board's SCF.[29] This disaggregation reflects the fact that low and high income consumers tend to have substantially different shares of debt and asset types and tend to face different rates on debts and assets. Summaries of shares and rates presented in this chapter are averages across the entire population.

**Table 8.2.26 Definitions of Income Groups**

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

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

***Shares of Debt and Asset Classes***

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

The average share of total debt plus equity and the associated rate of each asset and debt type are used to calculate a weighted average discount rate for each SCF household (Table 8.2.27). The household-level discount rates are then aggregated to form discount rate distributions for each of the six income groups. Note that previously DOE performed aggregation of asset and debt types over households by summing the dollar value across all households and then calculating shares. Weighting by dollar value gave disproportionate influence to the asset and debt shares and rates of higher income consumers. DOE has shifted to a household-level weighting to more accurately reflect the average consumer in each income group.

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

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

**Table 8.2.27 Types of Household Debt and Equity by Percentage Shares (%)**

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

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

***Rates for Types of Debt***

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

In calculating effective interest rates for home equity loans and mortgages, DOE accounted for the fact that interest on both such loans is tax deductible (Table 8.2.28). This rate corresponds to the interest rate after deduction of mortgage interest for income tax purposes and after adjusting for inflation (using the Fisher formula).[e] For example, a 6-percent nominal mortgage rate has an effective nominal rate of 4.5 percent for a household at the 25-percent marginal tax rate. When adjusted for an inflation rate of 2 percent, the effective real rate becomes 2.45 percent.

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

**Table 8.2.28 Data Used to Calculate Real Effective Mortgage Rates**

| Year | Mortgage Interest Rates in Selected Years (%) | | | |
|---|---|---|---|---|
| | Average Nominal Interest Rate | Inflation Rate[30] | Applicable Marginal Tax Rate[31] | Average Real Effective Interest Rate |
| 1995 | 8.2 | 2.83 | 24.2 | 3.3 |
| 1998 | 7.9 | 1.56 | 25.0 | 4.3 |
| 2001 | 7.6 | 2.85 | 24.2 | 2.8 |
| 2004 | 6.2 | 2.66 | 20.9 | 2.2 |
| 2007 | 6.3 | 2.85 | 20.6 | 2.1 |
| 2010 | 5.7 | 1.64 | 20.0 | 2.9 |

Table 8.2.29 shows the household-weighted average effective real rates for different types of household debt. Because the interest rates for each type of household debt reflect economic conditions throughout numerous years and various phases of economic growth and recession, they are expected to be representative of rates in effect in 2019.

**Table 8.2.29 Average Real Effective Interest Rates for Household Debt (%)**

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

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

***Rates for Types of Assets***

No similar rate data are available from the SCF for classes of assets, so DOE derived asset interest rates from various sources of national historical data (1983-2013). The interest rates associated with certificates of deposit,[32] savings bonds,[33] and bonds (AAA corporate bonds)[34] were collected from Federal Reserve Board time-series data. Rates on money market accounts came from Cost of Savings Index data.[35] Rates on savings accounts were estimated as one half of the rate for money market accounts, based on recent differentials between the return to each of these assets. The rates for stocks are the annual returns on the Standard and Poor's.[36] Rates for mutual funds are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year. DOE assumed rates on checking accounts to be zero.

DOE adjusted the nominal rates to real rates using the annual inflation rate for each year. Average nominal and real interest rates for the classes of household assets are listed in Table 8.2.30. Because the interest and return rates for each type of asset reflect economic conditions throughout numerous years, they are expected to be representative of rates that may be in effect in 2019. For each type, DOE developed a distribution of rates, as shown in appendix 8E.

**Table 8.2.30 Average Nominal and Real Interest Rates for Household Equity**

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

***Discount Rate Calculation and Summary***

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

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

Where:

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

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

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

Table 8.2.31 presents the average real effective discount rate and its standard deviation for each of the six income groups. To account for variation among households, DOE sampled a rate for each RECS household from the distributions for the appropriate income group. (RECS provides household income data.) Appendix 8F presents the full probability distributions for each income group that DOE used in the LCC and PBP analysis.

**Table 8.2.31 Average Real Effective Discount**

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

### 8.2.4 Compliance Date of Standard

The compliance date is the future date when manufacturers must comply with a new or amended standard. The compliance date of the potential energy conservation standards for dehumidifiers manufactured in, or imported into, the United States is March 11, 2019. DOE calculated the LCC for all consumers as if each would purchase a new product in 2019.

### 8.2.5 Product Energy Efficiency in the Base Case

To estimate the percentage of consumers who would be affected by a standard at any of the trial standard levels, DOE considered the projected distribution of efficiencies for products that consumers purchase under the base case (the case without new or amended energy conservation standards). DOE refers to this distribution of product efficiencies as the base-case efficiency distribution. Using the projected distribution of efficiencies for each product class, DOE randomly assigned a product efficiency to each sampled household. The energy efficiency distributions that DOE used in the LCC analysis are described below. For this NOPR analysis, DOE used the efficiency distributions calculated based on DOE's Certification Database for Dehumidifiers.[37] The energy factors for dehumidifiers listed in the DOE product database are determined by the current test procedure which took effect in 2007 and was updated in 2014. The current test procedure also defines IEF, which includes measures of standby mode and off mode energy use and is the basis of this NOPR analysis. Because the standby/off mode energy use is small compared to dehumidification mode energy use, DOE assumes that IEF as measured by the current test procedure is relatively equal to EF, and thus the base-case market shares would be similar. A proposed amendment to the test procedure would require dehumidification mode testing at an ambient temperature of 65 °F (for portable dehumidifiers) and of 73 °F (for whole-home dehumidifiers) rather than 80 °F and would include a measure of fan-only mode energy use. Although these changes may result in IEF values that are significantly lower than EF for certain dehumidifiers, DOE expects that the distribution of efficiencies among dehumidifier models will remain approximately the same.

DOE also projected efficiencies for the base case based on assumptions regarding future improvements in efficiency and assumed an annual growth rate of 0.25 percent between 2014 and 2048. Table 8.2.32 through Table 8.2.36 present market shares of the efficiency-levels being considered for each dehumidifier product class in 2019, based on IEF measured at 80 °F and on IEF measured at 65 °F (for portable dehumidifiers) and at 73 °F (for whole-home dehumidifiers) with fan-only mode energy use included.

**Table 8.2.32 Dehumidifiers ≤30.00 Pints/Day: Base-Case Market Shares**

| **Efficiency Level** | **80 °F** | **65 °F** | **Market Share (%)** |
|---|---|---|---|
| | **Integrated Energy Factor (L/kWh)** | **Integrated Energy Factor (L/kWh)** | |
| Baseline | 1.05 | 0.77 | 11 |
| 1 | 1.50 | 1.10 | 23 |
| 2 | 1.70 | 1.20 | 0 |
| 3 | 1.85 | 1.30 | 66 |
| 4 | 2.01 | 1.57 | 0 |

**Table 8.2.33 Dehumidifiers 30.01–45.00 Pints/Day: Base-Case Market Shares**

| **Efficiency Level** | **80 °F** | **65 °F** | **Market Share (%)** |
|---|---|---|---|
| | **Integrated Energy Factor (L/kWh)** | **Integrated Energy Factor (L/kWh)** | |
| Baseline | 1.29 | 0.94 | 0 |
| 1 | 1.60 | 1.20 | 0 |
| 2 | 1.85 | 1.40 | 94 |
| 3 | 1.95 | 1.60 | 2 |
| 4 | 2.13 | 1.80 | 4 |

**Table 8.2.34 Dehumidifiers >45.00 Pints/Day: Base-Case Market Shares**

| Efficiency Level | 80 °F | 65 °F | Market Share (%) |
|---|---|---|---|
| | Integrated Energy Factor (L/kWh) | Integrated Energy Factor (L/kWh) | |
| Baseline | 2.44 | 2.07 | 57 |
| 1 | 3.00 | 2.40 | 20 |
| 2 | 3.50 | 2.80 | 23 |
| 3 | 4.39 | 3.66 | 0 |

**Table 8.2.35 Dehumidifiers ≤8.0 ft3 Case Volume (Whole-Home): Base-Case Market Shares**

| Efficiency Level | 80 °F | 73 °F | Market Share (%) |
|---|---|---|---|
| | Integrated Energy Factor (L/kWh) | Integrated Energy Factor (L/kWh) | |
| Baseline | 1.90 | 1.77 | 75 |
| 1 | 2.20 | 2.09 | 25 |
| 2 | 2.67 | 2.53 | 0 |

**Table 8.2.36 Dehumidifiers >8.0 ft3 Case Volume (Whole-Home): Base-Case Market Shares**

| Efficiency Level | 80 °F | 73 °F | Market Share (%) |
|---|---|---|---|
| | Integrated Energy Factor (L/kWh) | Integrated Energy Factor (L/kWh) | |
| Baseline | 2.50 | 2.41 | 31 |
| 1 | 2.80 | 2.70 | 46 |
| 2 | 3.50 | 3.52 | 23 |
| 3 | 4.46 | 4.50 | 0 |

## 8.3 RESULTS OF LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

This section presents the results of the LCC and PBP analysis for all product classes of dehumidifiers. As discussed in section 8.1.1, DOE's approach to the LCC analysis relied on developing samples of households that use each of the product classes. DOE also used probability distributions to characterize the uncertainty in many of the inputs to the analysis. DOE used Monte Carlo simulation to perform the LCC calculations for the households in the sample. For each set of sample households that use the product in each product class, DOE calculated the average LCC and LCC savings and the median and average PBP for each the efficiency levels. These efficiency levels are also referred to as trial standard levels (TSLs).

DOE calculated LCC savings and PBPs relative to the base-case products that it assigned to sample households. For some consumers DOE assigned a base-case product that is more efficient than some of the TSLs. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific TSL and the LCC of the baseline product. DOE calculated the average LCC savings and the median PBP values by excluding the households that are not impacted by a standard at a given efficiency level.

LCC and PBP calculations were performed 10,000 times on the sample of consumers established for each product class. Each LCC and PBP calculation was performed on a single household selected from the sample. A household was selected based on its weight (*i.e.*, how representative it was of other households in the distribution). Each LCC and PBP calculation also sampled from the probability distributions that DOE developed to characterize many of the inputs to the analysis.

Using the Monte Carlo simulations for each TSL, DOE calculated the percent of consumers who experience a net LCC benefit, a net LCC cost, and no effect. DOE considered a consumer to receive no effect at a given standard level if DOE assigned it a baseline product having the same or higher efficiency than the standard level. The following sections present figures that illustrate the range of LCC and PBP effects among sample consumers.

### 8.3.1 Summary of Results

Table 8.3.1 through Table 8.3.10 show the LCC and simple PBP results by efficiency level for each dehumidifier product class. The average operating cost is the discounted sum.

**Table 8.3.1 Dehumidifiers ≤30.00 Pints/Day: LCC Results**

| Efficiency Level | IEF* (L/Day) | Average Life-Cycle Cost (2013$) | | | | Simple Payback Period |
|---|---|---|---|---|---|---|
| | | Installed Price | First Year's Operating Cost | Lifetime Operating Costs | Life-Cycle Cost | Years |
| 0 | 0.77 | 212 | 101 | 952 | 1,163 | -- |
| 1 | 1.10 | 212 | 71 | 668 | 879 | 0.0 |
| 2 | 1.20 | 214 | 65 | 612 | 826 | 0.1 |
| 3 | 1.30 | 218 | 60 | 566 | 784 | 0.2 |
| 4 | 1.57 | 241 | 50 | 469 | 710 | 0.6 |

* IEF = Integrated energy factor.
† Discounted.

**Table 8.3.2 Dehumidifiers ≤30.00 Pints/Day: Simple PBP Results**

| Efficiency Level | % of Consumers that Experience Net Cost | Average Savings 2013$ |
|---|---|---|
| 0 | -- | -- |
| 1 | 0 | 31 |
| 2 | 0 | 49 |
| 3 | 0 | 64 |
| 4 | 10.3 | 137 |

**Table 8.3.3 Dehumidifiers 30.01–45.00 Pints/Day: LCC Results**

| Efficiency Level | IEF* (L/Day) | Average Life-Cycle Cost (2013$) | | | | Simple Payback Period |
|---|---|---|---|---|---|---|
| | | Installed Price | First Year's Operating Cost | Lifetime Operating Costs | Life-Cycle Cost | Years |
| 0 | 0.94 | 256 | 145 | 1,361 | 1,617 | -- |
| 1 | 1.20 | 256 | 114 | 1,067 | 1,323 | 0.0 |
| 2 | 1.40 | 259 | 97 | 915 | 1,175 | 0.1 |
| 3 | 1.60 | 268 | 85 | 802 | 1,069 | 0.2 |
| 4 | 1.80 | 290 | 76 | 713 | 1,003 | 0.5 |

* IEF = Integrated energy factor.
† Discounted.

**Table 8.3.4 Dehumidifiers 30.01–45.00 Pints/Day: Simple PBP Results**

| Efficiency Level | % of Consumers that Experience Net Cost | Average Savings 2013$ |
|---|---|---|
| 0 | -- | -- |
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 0.5 | 99 |
| 4 | 5.4 | 164 |

**Table 8.3.5 Dehumidifiers >45.00 Pints/Day: LCC Results**

| Efficiency Level | IEF* (L/Day) | Average Life-Cycle Cost (2013$) | | | | Simple Payback Period |
|---|---|---|---|---|---|---|
| | | Installed Price | First Year's Operating Cost | Lifetime Operating Costs | Life-Cycle Cost | Years |
| 0 | 2.07 | 915 | 127 | 1,195 | 2,110 | -- |
| 1 | 2.40 | 989 | 110 | 1,032 | 2,021 | 4.3 |
| 2 | 2.80 | 1,008 | 94 | 885 | 1,893 | 2.8 |
| 3 | 3.66 | 1,124 | 72 | 678 | 1,802 | 3.8 |

* IEF = Integrated energy factor.
† Discounted.

**Table 8.3.6 Dehumidifiers >45.00 Pints/Day: Simple PBP Results**

| Efficiency Level | % of Consumers that Experience Net Cost | Average Savings 2013$ |
|---|---|---|
| 0 | -- | -- |
| 1 | 18.9 | 50 |
| 2 | 11.7 | 147 |
| 3 | 31.4 | 239 |

Table 8.3.7 **Dehumidifiers ≤8.0 ft3 Case Volume (Whole-Home): LCC Results**

| Efficiency Level | IEF* (L/Day) | Average Life-Cycle Cost (2013$) | | | | Simple Payback Period |
|---|---|---|---|---|---|---|
| | | Installed Price | First Year's Operating Cost | Lifetime Operating Costs | Life-Cycle Cost | Years |
| 0 | 1.77 | 1,662 | 139 | 2,048 | 3,710 | -- |
| 1 | 2.09 | 1,689 | 118 | 1,740 | 3,429 | 1.3 |
| 2 | 2.53 | 1,890 | 98 | 1,444 | 3,334 | 5.5 |

* IEF = Integrated energy factor.
† Discounted.

**Table 8.3.8 Dehumidifiers ≤8.0 ft3 Case Volume (Whole-Home): Simple PBP Results**

| Efficiency Level | % of Consumers that Experience Net Cost | Average Savings 2013$ |
|---|---|---|
| 0 | -- | -- |
| 1 | 8.4 | 207 |
| 2 | 44.4 | 302 |

**Table 8.3.9 Dehumidifiers >8.0 ft3 Case Volume (Whole-Home): LCC Results**

| Efficiency Level | IEF* (L/Day) | Average Life-Cycle Cost (2013$) | | | | Simple Payback Period |
|---|---|---|---|---|---|---|
| | | Installed Price | First Year's Operating Cost | Lifetime Operating Costs | Life-Cycle Cost | Years |
| 0 | 2.41 | 2,142 | 166 | 2,446 | 4,589 | -- |
| 1 | 2.70 | 2,154 | 149 | 2,188 | 4,342 | 0.7 |
| 2 | 3.52 | 2,212 | 115 | 1,687 | 3,899 | 1.4 |
| 3 | 4.50 | 2,445 | 90 | 1,328 | 3,773 | 4.0 |

* IEF = Integrated energy factor.
† Discounted.

**Table 8.3.10 Dehumidifiers >8.0 ft3 Case Volume (Whole-Home): Simple PBP Results**

| Efficiency Level | % of Consumers that Experience Net Cost | Average Savings 2013$ |
|---|---|---|
| 0 | -- | -- |
| 1 | 1.4 | 75 |
| 2 | 10.7 | 416 |
| 3 | 39.9 | 542 |

### 8.3.1.1 Distributions of Impacts

The figures in this section show the distribution of LCCs in the base case for each product class. Also presented are figures showing the distribution of LCC impacts for Efficiency Level 3. The figures are presented as frequency charts that show the distribution of LCCs, and LCC impacts with their corresponding probability of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples.

***Base-Case LCC Distributions.*** *Figure 8.3.1* through *Figure 8.3.5* show the base-case LCC distributions for each product class of dehumidifiers.

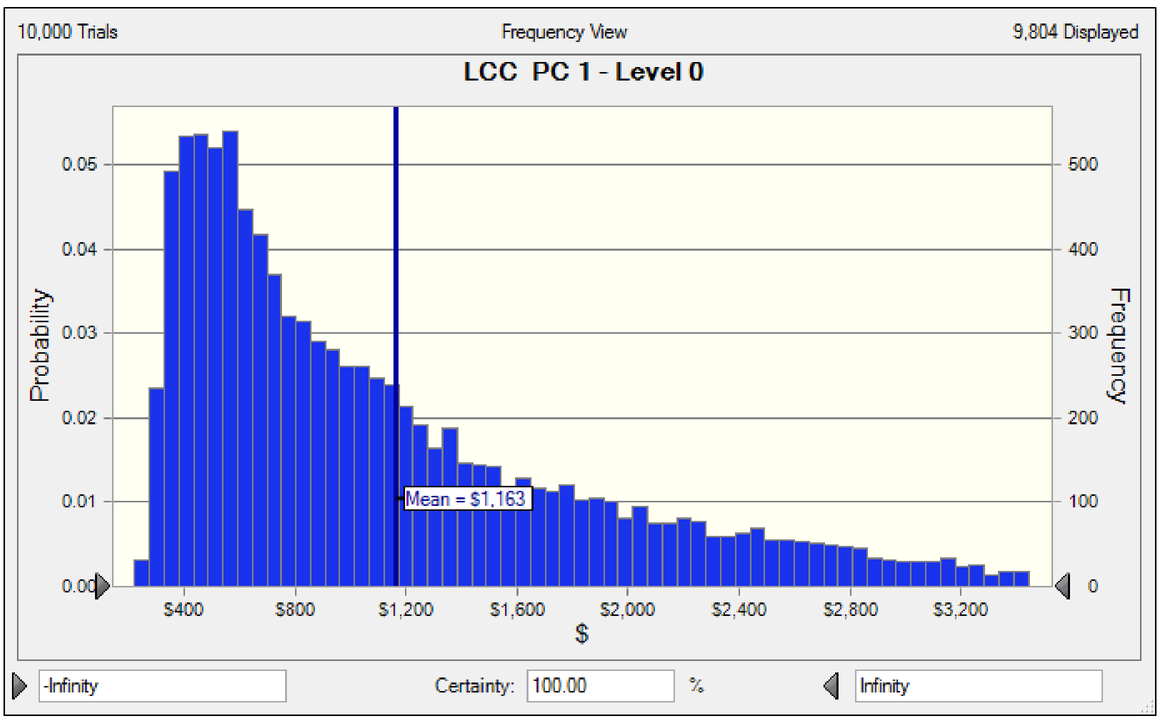


**Figure 8.3.1 Dehumidifiers ≤30.00 Pints/Day: Base-Case LCC Distribution**

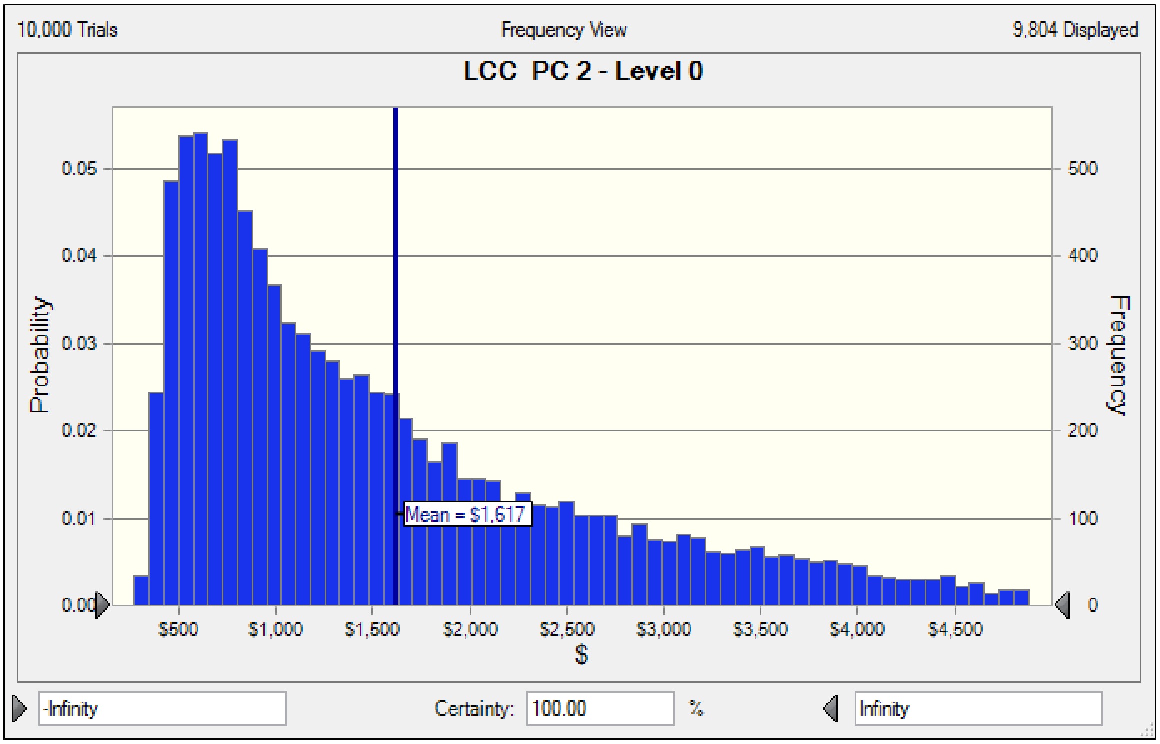


**Figure 8.3.2 Dehumidifiers 30.01–45.00 Pints/Day: Base-Case LCC Distribution**

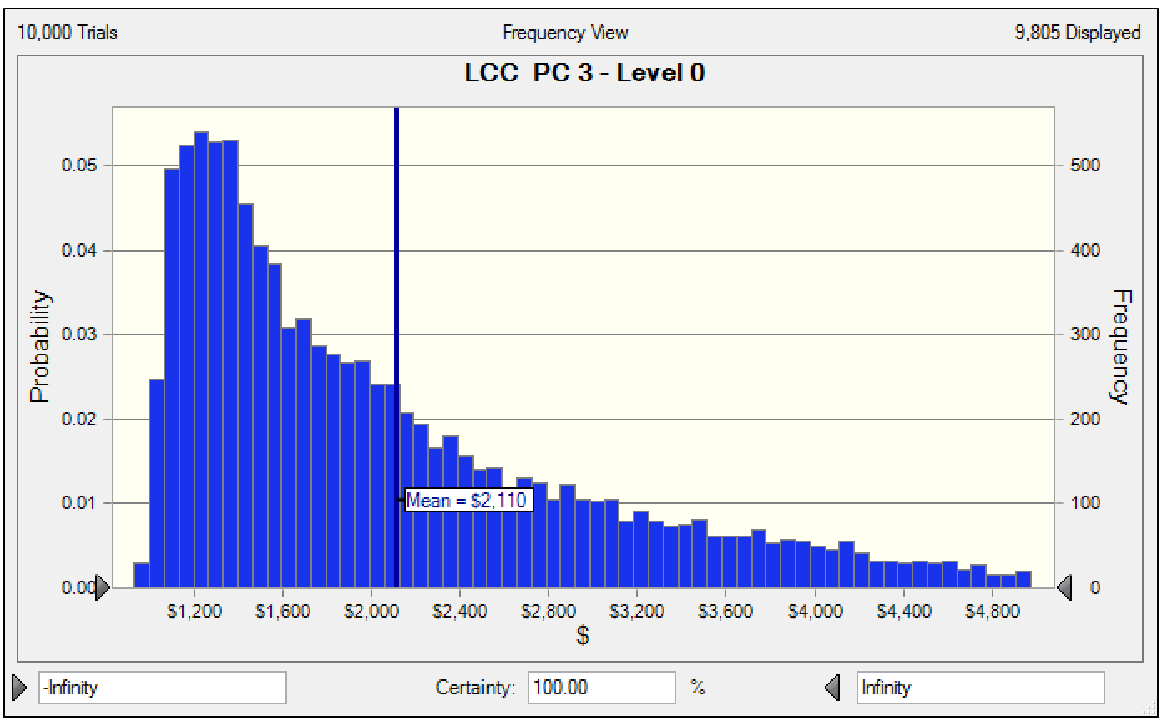


**Figure 8.3.3 Dehumidifiers >45.00 Pints/Day: Base-Case LCC Distribution**

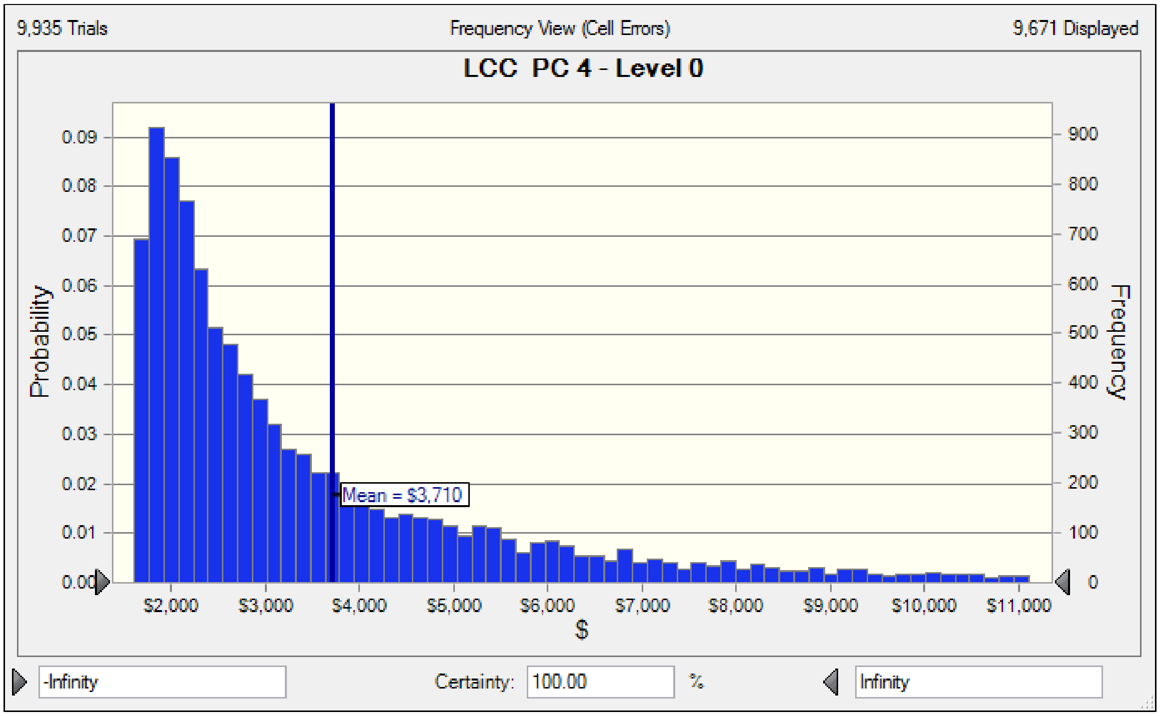


**Figure 8.3.4 Dehumidifiers ≤8.0 ft3 Case Volume (Whole-Home): Base-Case LCC Distribution**

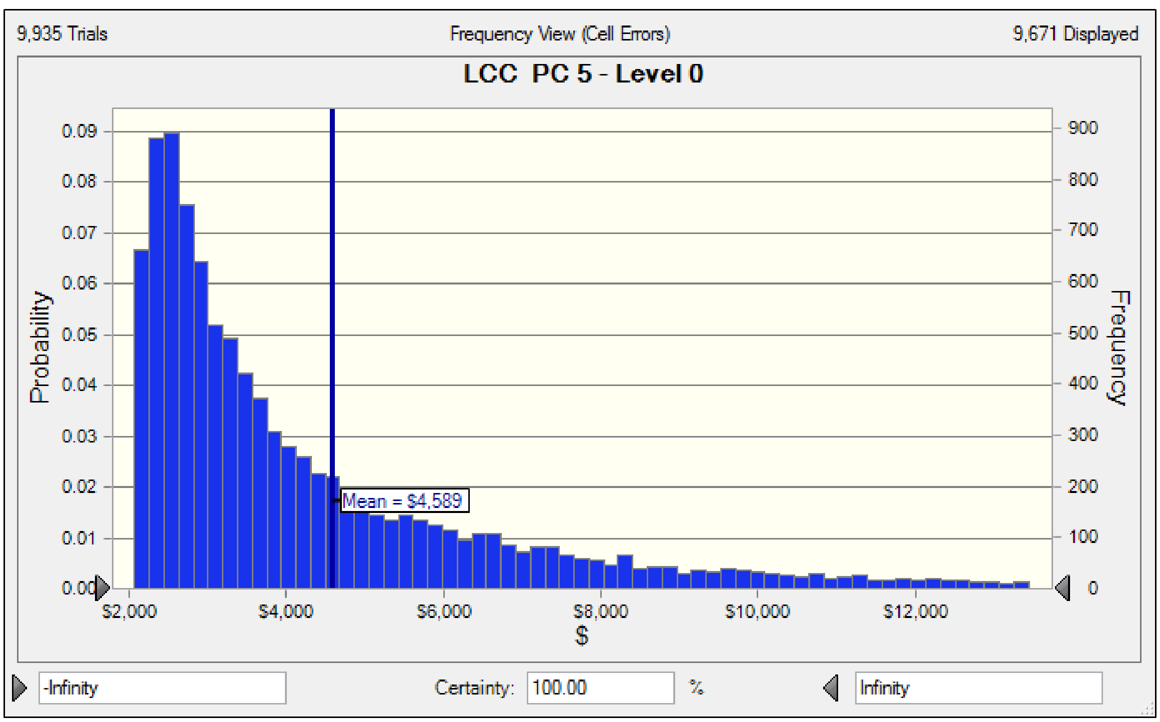


**Figure 8.3.5 Dehumidifiers >8.0 ft3 Case Volume (Whole-Home): Base-Case LCC Distribution**

***Standard-Level Distribution of Impacts.*** Figure 8.3.6 is an example of a frequency chart that shows the distribution of LCC differences for the case of Efficiency Level 3 for product class one (≤30.00 pints/day). In the figure, a text box next to a vertical line at a given value on the x-axis shows the mean change in LCC (a savings of $64 in the example here). The note, "Certainty is 100.00% from $0 to +Infinity," means that 100 percent of owners of dehumidifier units will have LCC savings or not be affected by the efficiency level compared to the base case. The large spike in Figure 8.3.6 represents the percentage of consumers who are not affected by an increase in the efficiency level, i.e., consumers who already use dehumidifiers that have efficiencies greater than or equal to the efficiency level. Refer to section 8.2.5 on the distribution of product efficiencies under the base case. DOE can generate a frequency chart like the one shown in Figure 8.3.6 for each efficiency level and product class.

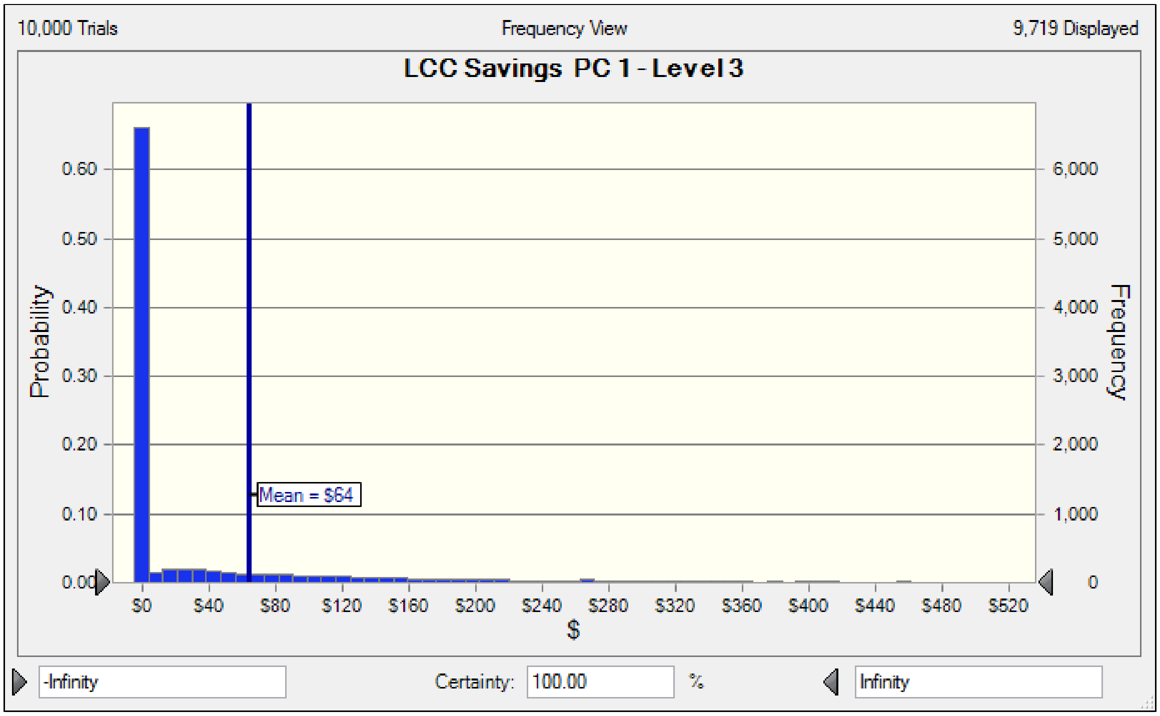


**Figure 8.3.6 Dehumidifiers ≤30.00 Pints/Day: LCC Savings Distribution for Efficiency Level 3**

#### 8.3.1.2 Range of Impacts

Figure 8.3.7 through Figure 8.3.11 show the range of LCC savings for all efficiency levels considered for each dehumidifier product class. For each efficiency level, the top and the bottom of the box indicate the 75$^{th}$ and 25$^{th}$ percentiles, respectively. The bar at the middle of the box indicates the median: 50 percent of households have LCC savings in excess of that value. The "whiskers" at the bottom and the top of the box indicate the 5$^{th}$ and 95$^{th}$ percentiles. The small box shows the average LCC savings for each standard level.

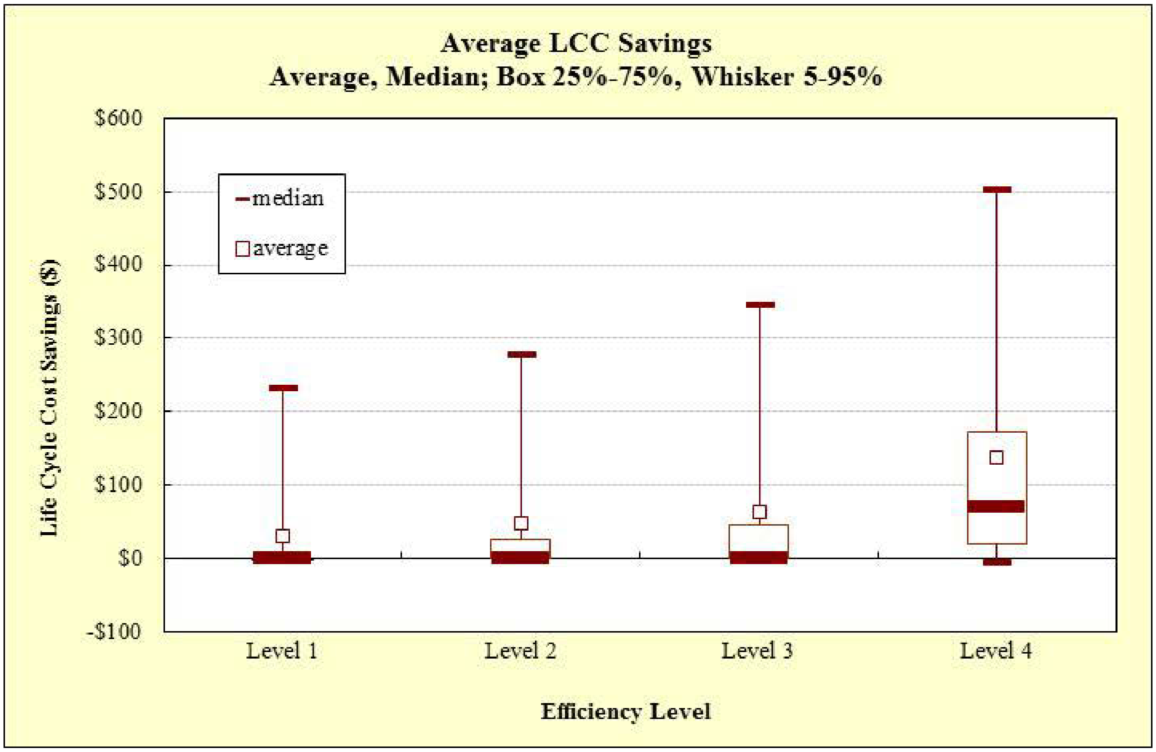


**Figure 8.3.7 Dehumidifiers ≤30.00 Pints/Day: Range of Average LCC Savings**

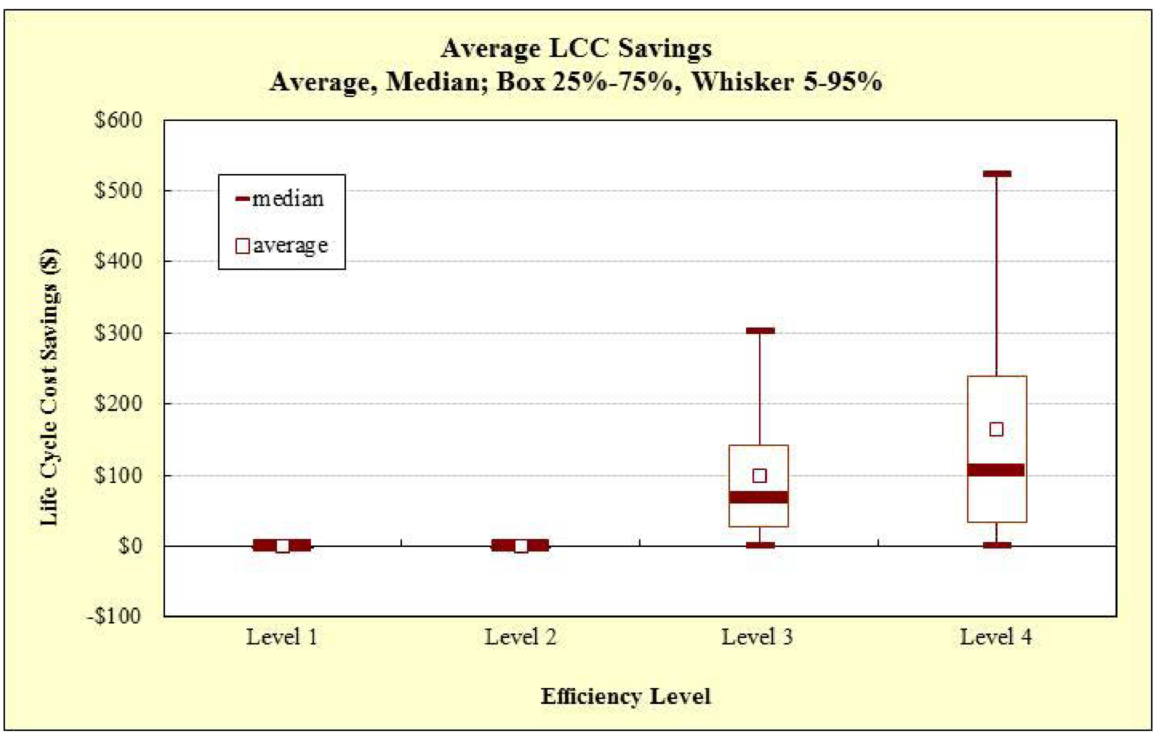


**Figure 8.3.8 Dehumidifiers 30.01–45.00 Pints/Day: Range of Average LCC Savings**

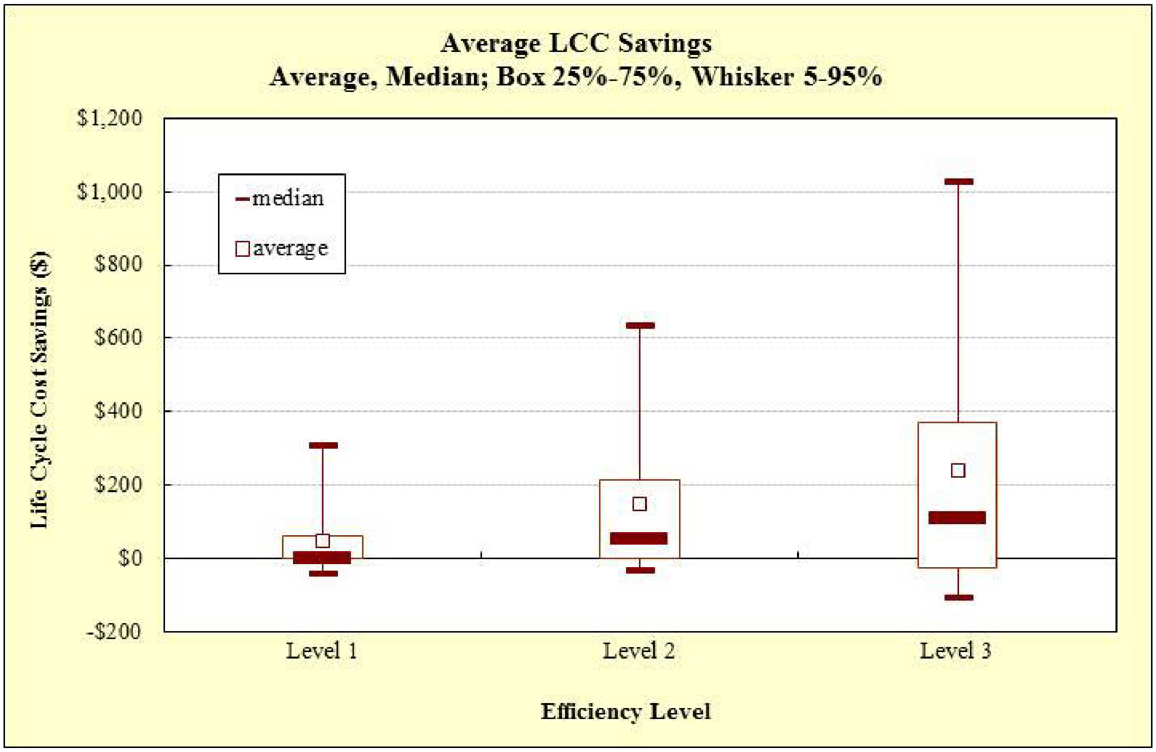


**Figure 8.3.9 Dehumidifiers >45.00 Pints/Day: Range of Average LCC Savings**

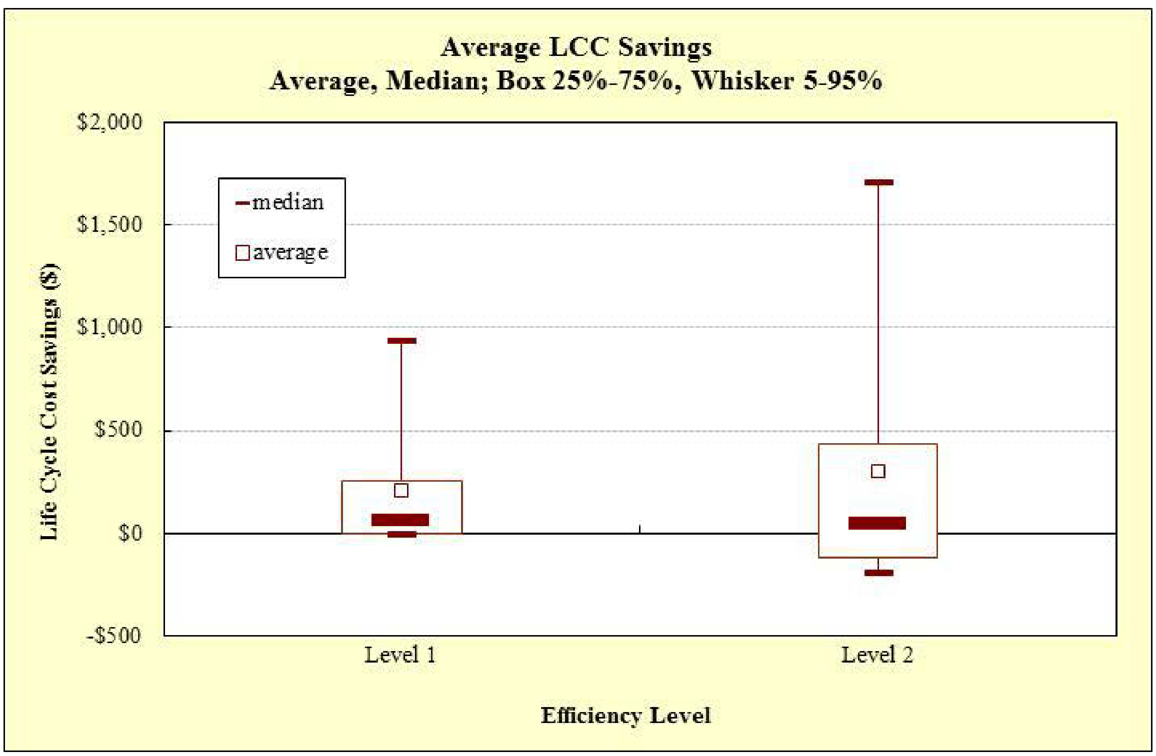


**Figure 8.3.10 Dehumidifiers ≤8.0 ft3 Case Volume (Whole-Home): Range of Average LCC Savings**

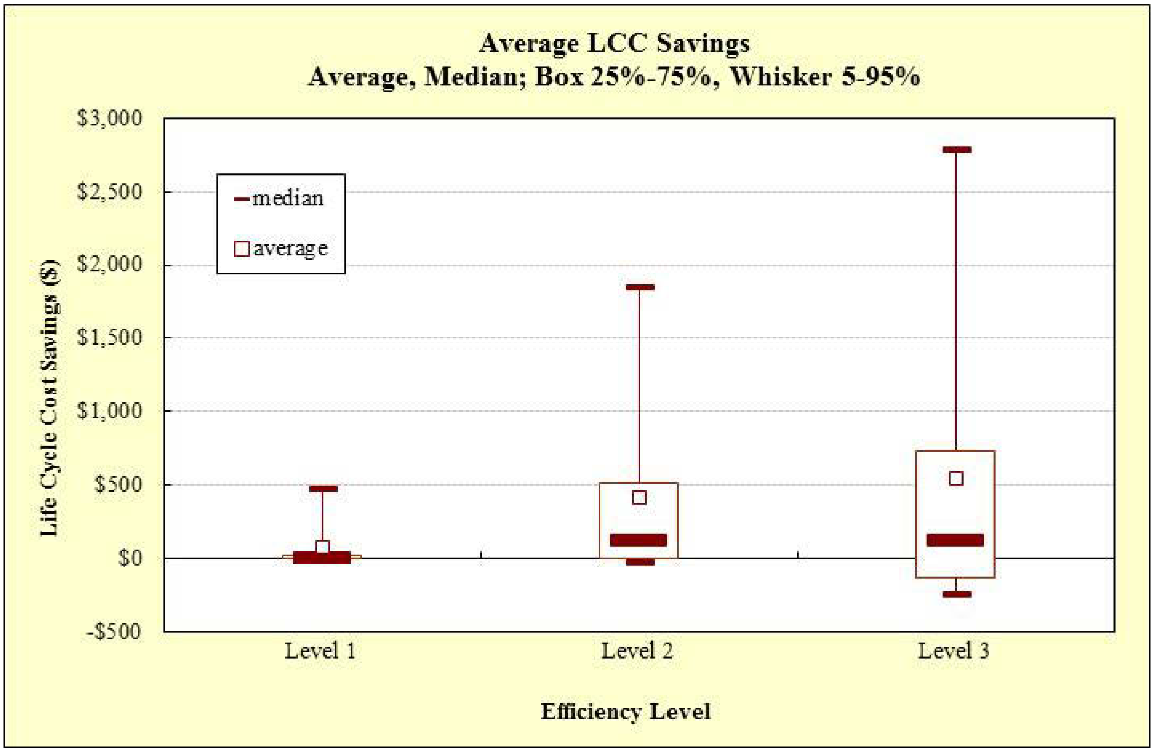


**Figure 8.3.11 Dehumidifiers >8.0 ft3 Case Volume (Whole-Home): Range of Average LCC Savings**

## 8.4 REBUTTABLE PAYBACK PERIOD

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

The basic equation for rebuttable PBP is the same as that shown for the PBP in section 8.1.1. Unlike the analyses described in section 8.2, however, the rebuttable PBP is not based on household samples and probability distributions. The rebuttable PBP is based instead on discrete, single-point values. For example, whereas DOE uses a probability distribution of regional energy prices in the distributional PBP analysis, it uses only the national average energy price to determine the rebuttable PBP.

Other than the use of single-point values, the most notable difference between the distributional PBP and the rebuttable PBP is the latter's reliance on the DOE test procedure to determine a product's annual energy consumption. DOE based the annual energy consumption for the rebuttable PBP on the number of operating hours per year specified in DOE's proposed test procedure for dehumidifiers[38]. The following sections identify the differences, if any, between the annual energy consumptions determined by the distributional PBP and the rebuttable PBP for all product classes of dehumidifiers.

### 8.4.1 Inputs to Rebuttable Payback Period Analysis

Because inputs for determining total installed cost for calculating the distributional PBP were based on single-point values, only the variability and/or uncertainty in the inputs for determining operating cost contributed to variability in the distributional PBPs. The following summarizes the single-point values that DOE used in determining the rebuttable PBP.

- Manufacturing costs, markups, sales taxes, and installation costs were based on the single-point values used in the distributional LCC and PBP analysis.
- Energy prices were based on national average values for the year that new standards would take effect.
- An average discount rate or lifetime is not required in calculating the rebuttable PBP.
- The effective date of any new standard is assumed to be 2019.

### 8.4.2 Results of Rebuttable Payback Period Analysis

DOE calculated rebuttable PBPs for each efficiency level relative to the distribution of product efficiencies estimated for the baseline. In other words, DOE did not determine the rebuttable PBP relative to the base case energy efficiency, but relative to the distribution of product energy efficiencies for the baseline (*i.e.*, the case without new energy conservation standards). Table 8.4.1 and Table 8.4.2 present the rebuttable PBPs for each product class of dehumidifiers.

**Table 8.4.1 Rebuttable Payback Periods: Portable Dehumidifiers**

| ≤30.00 Pints/Day | | 30.01–45.00 Pints/Day | | >45.00 Pints/Day | |
|---|---|---|---|---|---|
| **IEF (L/kWh)** | **PBP (Yrs)** | **IEF (L/kWh)** | **PBP (Yrs)** | **IEF (L/kWh)** | **PBP (Yrs)** |
| 0.77 | – | 0.94 | – | 2.07 | – |
| 1.10 | 0.0 | 1.20 | 0.0 | 2.40 | 5.6 |
| 1.20 | 0.1 | 1.40 | 0.1 | 2.80 | 3.7 |
| 1.30 | 0.2 | 1.60 | 0.3 | 3.66 | 5.0 |
| 1.57 | 0.8 | 1.80 | 0.7 | – | – |

Table 8.4.2 Rebuttable Payback Periods: Whole-Home Dehumidifiers

| ≤8.0 $ft^3$ Case Volume | | >8.0 $ft^3$ Case Volume | |
|---|---|---|---|
| **IEF (L/kWh)** | **RPBP (Years)** | **IEF (L/kWh)** | **RPBP (Years)** |
| 1.77 | – | 2.41 | – |
| 2.09 | 2.0 | 2.70 | 1.0 |
| 2.53 | 8.7 | 3.52 | 2.1 |
| – | – | 4.50 | 6.3 |

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# CHAPTER 9. SHIPMENTS ANALYSIS

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# CHAPTER 9. SHIPMENTS ANALYSIS

## 9.1 INTRODUCTION

Estimates of future product shipments are a necessary input to calculations of the NES and NPV, as well as to the manufacturer impact analysis. This chapter describes the data and methods the DOE used to project annual product shipments and presents results for dehumidifiers considered for this standards rulemaking. Because DOE did not have shipment data for each product classes, total historical shipments of portable and whole-home dehumidifiers were estimated and then separated by market share of each product classes.

To project shipments for dehumidifiers, DOE used a shipments model that is calibrated with historical shipments data. The shipments model estimates shipments to specific market segments, the results for which are then aggregated to estimate total product shipments. To estimate the impacts of potential standard levels on product shipments, the shipments model accounts for the combined effects of changes in purchase price, annual operating cost on the consumer purchase decision.

The shipments model was developed as a part of the NIA spreadsheet. Appendix 10A discusses how to access the NIA spreadsheet and provides basic instructions for its use.

The rest of this chapter explains the shipments models in more detail. Section 9.2 presents the methodology behind the shipments model; section 9.3 describes the data inputs and model calibration; section 9.4 discusses impacts on shipments from changes in product purchase price; and section 9.5 discusses the affected stock.

## 9.2 METHODOLOGY BEHIND SHIPMENTS MODEL

DOE developed a national stock model for estimating annual shipments for this standards rulemaking. The model considers market segmentation as a distinct input to the shipments projection. As represented by the following equation, the two primary market segments for dehumidifiers are installations in existing households without dehumidifiers, "first time owners," and replacements.

$$Ship_{DEF}(j) = Rpl_{DEH}\,(j) + FTO_{DEH}\,(j)$$

Where:

$Ship_{DEH}(j)$ = total shipments of dehumidifiers in year $j$,
$Rpl_{DEH}(j)$ = units of dehumidifiers retired and replaced in year $j$, and
$FTO_{DEH}(j)$ = shipments to existing households without dehumidifiers 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 first time ownership. The models estimate shipments due to replacements using sales in previous years and assumptions about the lifetime of dehumidifiers. Estimated sales attributable to replacements in a given year therefore are equal to the total stock of the appliance minus the sum of the appliances sold in previous years that remain in the stock. As described in chapter 8 of this NOPR TSD, DOE determined the useful service life of dehumidifiers. DOE then estimated how long the appliance is likely to remain in stock. The following equation represents how DOE estimated replacement shipments.

$$Rpl_p(j) = Stock_p(j-1) - \sum_{age=0}^{ageMax} \sum_{j=N}^{j-1} Ship_j \times prob_{Rtr}(age)$$

Where:

$Stock_p(j\text{-}1)$ = total stock of in-service appliances in year $j$-$1$,
$prob_{Rtr}(age)$ = probability that an appliance of a particular *age* will be retired, and
$N$ = start year for when the model begins its stock accounting (start year is specific to each product based on available historical shipments data).

Stock accounting takes product shipments, a retirement function, and initial in-service product stock as inputs 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 both the NES and NPV calculations—the operating costs for any year depend on the age distribution of the stock. The dependence of operating cost on the product age distribution occurs under a standards case scenario that produces increasing efficiency over time, whereby older, less efficient units may have higher operating costs, while younger, more-efficient units will have lower operating costs.

DOE estimated replacements using product retirement functions that it developed based on product lifetimes. DOE based the retirement function on a Weibull distribution for the product lifetime. The shipments model assumes that no units are retired below a minimum product lifetime and all units are retired before exceeding a maximum product lifetime. The models determine the probability of retirement at a certain age for all products using a Weibull equation:

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

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

Where:

$P(x)$ = probability that the appliance is still in use at age $x$;
$x$ = appliance age;
$\alpha$ = scale parameter, which would be the decay length in an exponential distribution;
$\beta$ = shape parameter, which determines the way in which the failure rate changes through time; and
$\theta$ = delay parameter, which allows for a delay before any failures occur.

The retirement probability is the difference in the survival function from one year to another year.

DOE calculated total in-service stock of a product by integrating historical shipments data starting from a specific year. The start year depends on the historical data available for the product. As units are added to the in-service stock, some of the older ones retire and exit the stock. To estimate future shipments, DOE developed a series of equations that define the dynamics and accounting of in-service stocks. For new units, the equation is:

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

Where:

*Stock(j, age)* = the population of in-service units of a particular age,
*j* = year for which the in-service stock is being estimated, and
*Ship (j)* = number of units purchased in year *j*.

The above equation states that the number of one-year-old units is simply equal to the number of new units purchased the previous year. The following equation describes the accounting of the existing in-service stock of units:

$$Stock(j+1, age+1) = Stock(j, age) \times \left[1 - prob_{Rtr}(age)\right]$$

In the above equation, as the year is incremented from *j* to *j+1*, the age is also incremented from *age* to *age+1*. With time, a fraction of the in-service stock is removed, that fraction being determined by a retirement probability function, $prob_{Rtr}(age)$, which is described in section 9.3. Most replacements are made when a product wears out and fails. Over time, some of the units will be retired and removed from the stock, triggering the shipment of a new unit.

## 9.3 DATA INPUTS AND MODEL CALIBRATION

The sections below describe the data inputs and market segments considered for dehumidifiers.

### 9.3.1 Historical Shipments

For portable dehumidifiers, DOE used data on historical shipments (domestic[a] shipments plus imports) to calibrate its shipments model for dehumidifiers. DOE's sources for historical shipments data were (1) data provided by the AHAM for the period 1999 – 2011[1], (2) data provided by AHAM for the period 1995 – 1998[2], (3) data from the 2000 AHAM *Factbook* for the period 1989–1994[3], and (4) data from *Appliance Magazine*[4,5,6] for the period 1972–1988.[b] Table 9.3.1 summarizes the historical data on portable dehumidifier shipments.

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[a] Domestic shipments include shipments to States and U.S. territories.
[b] Shipments estimates from *Appliance Magazine* included exports. However, DOE saw no difference between shipments in the AHAM *Fact Book* 2000, which exclude exports, and those reported in *Appliance Magazine* for almost all years. Thus, DOE made no adjustments to the *Appliance Magazine* shipments.

**Table 9.3.1 Portable Dehumidifiers: Historical Shipments, Domestic plus Imports**

| Year | Shipments (thousands) | Year | Shipments (thousands) | Year | Shipments (thousands) |
|---|---|---|---|---|---|
| 1972 | 461 | 1986 | 555 | 2000 | 975 |
| 1973 | 646 | 1987 | 704 | 2001 | 806 |
| 1974 | 586 | 1988 | 673 | 2002 | 799 |
| 1975 | 392 | 1989 | 605 | 2003 | 1,311 |
| 1976 | 440 | 1990 | 743 | 2004 | 1,672 |
| 1977 | 314 | 1991 | 745 | 2005 | 1,957 |
| 1978 | 442 | 1992 | 803 | 2006 | 1,456 |
| 1979 | 685 | 1993 | 983 | 2007 | 2,004 |
| 1980 | 673 | 1994 | 1,059 | 2008 | 1,558 |
| 1981 | 536 | 1995 | 1,003 | 2009 | 1,700 |
| 1982 | 440 | 1996 | 977 | 2010 | 1,552 |
| 1983 | 437 | 1997 | 820 | 2011 | 1,368 |
| 1984 | 591 | 1998 | 1,031 | | |
| 1985 | 588 | 1999 | 950 | | |

Source: 1999–2011: AHAM data submittal, 2012. 1995–1998: AHAM data submittal. 1989 – 1994: AHAM Factbook, 2000. 1972–1988: Appliance Magazine 1982, 1990, 1993.

DOE assumed that whole-home shipments started from 2004, and the shipments accounted for about 1 percent of the portable dehumidifiers market.

### 9.3.2 Markets and Model Calibration

The market for dehumidifiers is comprised primarily of replacement units for products that have been retired from service. Total dehumidifiers shipments are represented by the following equation:

$$Ship_{DEF}(j) = Rpl_{DEH}\,(j) + FTO_{DEH}\,(j)$$

Where:

$Ship_{DEH}\,(j)$ = total shipments of dehumidifiers in year $j$,
$Rpl_{DEH}(j)$ = units of dehumidifiers retired and replaced in year $j$, and
$FTO_{DEH}(j)$ = shipments to existing households without dehumidifiers in year $j$.

The sections below discuss these markets in further detail.

#### 9.3.2.1 Replacements

DOE used an accounting method that tracks the total stock of units by vintage to determine shipments to the replacement market. DOE estimated a stock of dehumidifiers 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 each type of unit will fail and need to be replaced. To determine when a portable dehumidifier fails, DOE used a product survival function based on a lifetime distribution having an average value of 11.0 years. To determine when a whole-home dehumidifier fails, DOE used a product survival function based on a lifetime distribution having an average value of 19.01 years. For a more complete discussion of dehumidifier lifetimes, refer to section 8.2.2.6 of chapter 8 and appendix 8C in this NOPR TSD. Figure 9.3.1 and Figure 9.3.2 show the survival and retirement function that DOE used to estimate replacement shipments for each dehumidifier type.

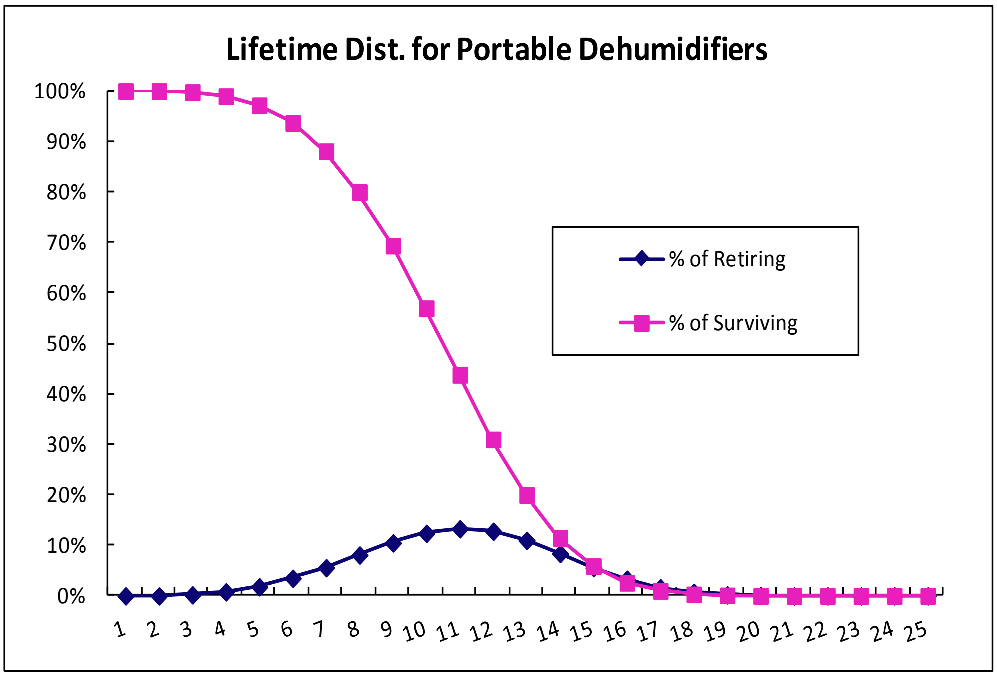


**Figure 9.3.1 Portable Dehumidifier: Survival and Retirement Functions**

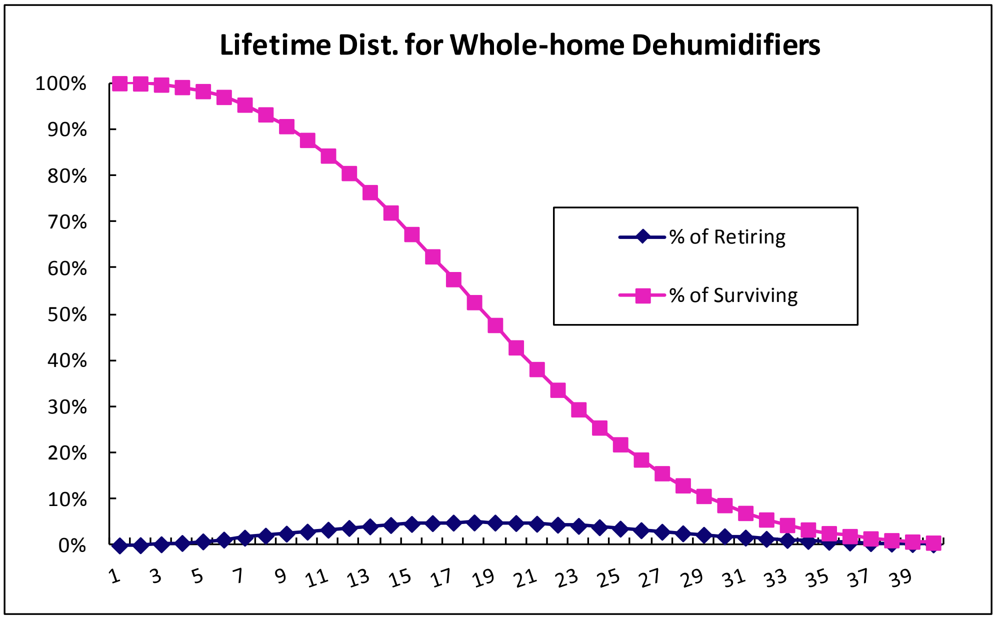


**Figure 9.3.2 Whole-home Dehumidifier: Survival and Retirement Functions**

#### 9.3.2.2 Model Calibration—Existing Households Without Appliance

To calibrate the estimated shipments with the historical data, DOE introduced into the model a market segment identified as existing households without dehumidifiers, also referred to as FTOs. Based on the calibration, DOE estimated that 0.35 percent of existing households without a dehumidifier would annually purchase this product over the period 2019–2048.

### 9.3.3 Base-Case Shipments

Figure 9.3.3 shows the projected shipments in the base case (*i.e.*, the case without new energy efficiency standards) and the historical shipments DOE used to calibrate the projection.

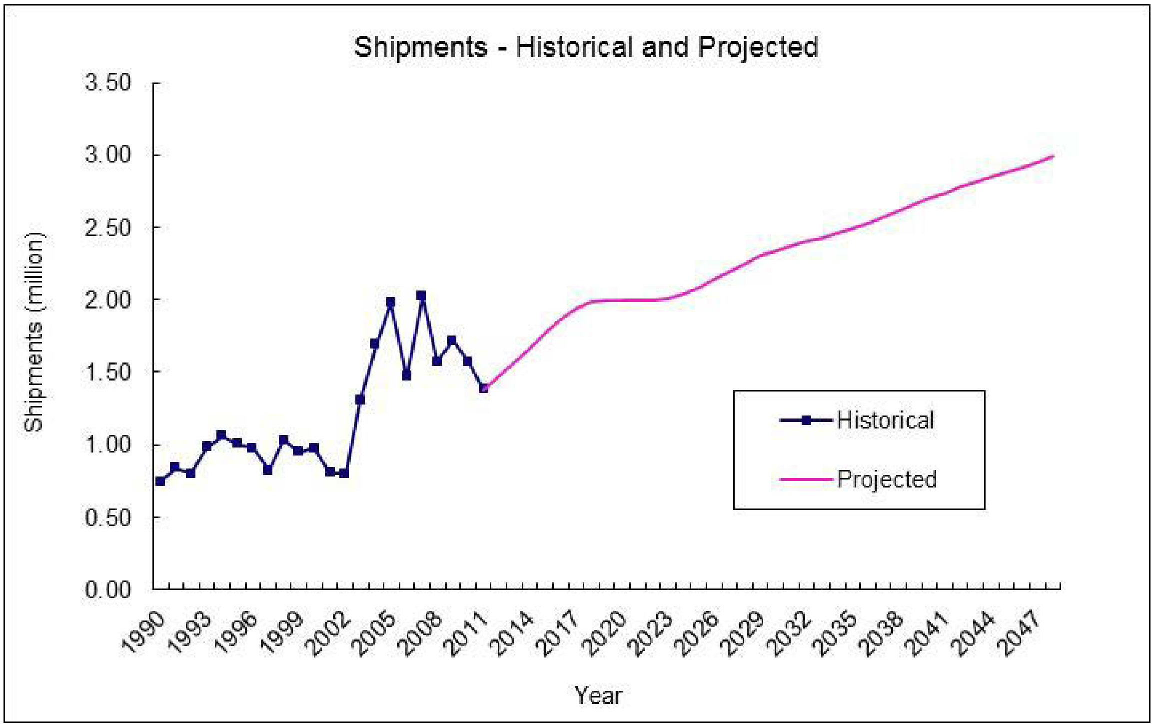


**Figure 9.3.3 Dehumidifiers: Historical and Base-Case Shipments Projection**

DOE's base-case shipments model for dehumidifiers used the aggregate shipments, i.e. the shipments for all five product classes, as the basis for its projection. In other words, DOE did not develop a separate shipments model for each dehumidifier product class. As provided in Table 9.3.2, DOE assumed market shares for each of the five product classes based on the engineering analysis in the preliminary analysis phase of the standards rulemaking.[7] DOE used the average market shares over the period 2012 – 2048 to disaggregate projected shipments into each of the five dehumidifier product classes.

**Table 9.3.2 Product Class Market Share of Dehumidifiers**

| Year | Product Class (pints/day) | | | | |
|---|---|---|---|---|---|
| | ≤30.00 | 30.01-35.00 | >45.00 | ≤ 8.0ft³ Case Volume (Whole-home) | >8.0ft³ Case Volume (Whole-home) |
| **Pre-2004** | 57.1% | 42.9% | 0.0% | 0.0% | 0.0% |
| **Post-2004** | 52.4% | 42.9% | 3.7% | 0.7% | 0.3% |

Source: DOE's Engineering Analysis of the Preliminary Analysis Technical Support Document for Residential Dehumidifiers.

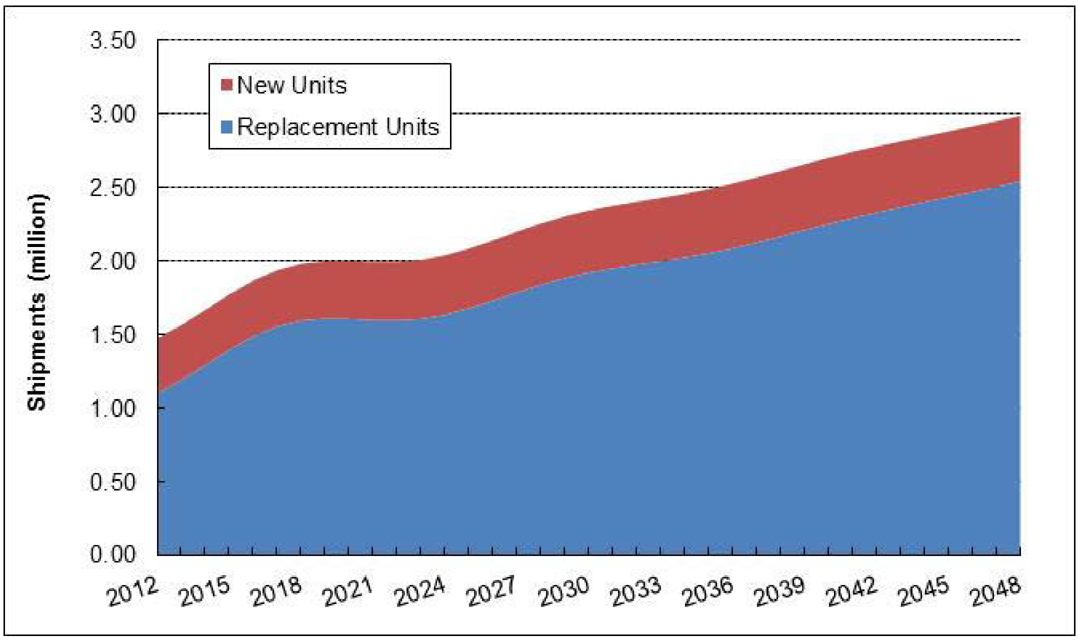


**Figure 9.3.4 Dehumidifiers: Disaggregated Shipments Projection for Base Case**

## 9.4 EFFECT OF INCREASED PURCHASE PRICE ON SHIPMENTS

Economic theory suggests that, all else being equal, an increase in the price of a good leads to a decrease in demand for it. Because DOE projects that appliance standards often result in an increase in the price of the product, DOE conducted a literature review and an analysis of appliance price and efficiency data to estimate the effects on product shipments from increases in product price. DOE also considered the decreases in operating costs from higher energy efficiency and changes over time in household income. Appendix 9A explains the method DOE used to quantify the effects of the above variables.

In the literature, DOE found only a few studies of appliance markets that are relevant to this rulemaking analysis and identified no studies that use time-series data of product prices and shipments after 1980. The information that can be summarized from the literature suggests that the demand for appliances is price-inelastic. Other information in the literature suggests that appliances are a normal good, such that rising incomes increase the demand for appliances. Finally, the literature suggests that consumers use relatively high implicit discount rates[c] when comparing appliance prices and operating costs.

DOE found insufficient data on product purchase price and operating cost 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 room air conditioners during 1980–2002 to evaluate broad market trends and conduct simple regression analyses. The data indicate that there has been an increase in appliance shipments and a decrease in appliance purchase price and operating costs during the period. Household income also increased during this time. To simplify the analysis, DOE combined the available economic information into one variable, termed the *relative price*, and used this variable in an analysis of market trends, as well as to conduct a regression analysis. The *relative price* is defined using the following expression.

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

Where:

*RP* = relative price,
*TP* = total price,
*Income* = household income,
*PP* = appliance purchase price, and
*PVOC* = present value of operating cost.

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 *relative price* elasticity of demand for the three appliances is relatively inelastic (that is, less than 1.0). DOE's regression analysis suggests that the *relative price* elasticity of demand, averaged for the three appliances, is -0.34. Thus a *relative price* increase of 10 percent results in a shipments decrease of 3.4 percent. Note that, because the *relative price* elasticity incorporates the effects of three factors (purchase price, operating cost, and household income), the effect of any single factor is mitigated by changes to the other two.

The *relative price* elasticity of -0.34 is consistent with estimates in the literature. Nevertheless, DOE stresses that the measure is based on a small data set subject to simple statistical analysis. More importantly, the measure is based on an assumption that economic variables, including purchase price, operating costs, and household income, explain most of the trend in appliances per household in the United States since 1980. Changes in appliance quality

[c] A high implicit discount rate with regard to operating costs means that consumers do not put much economic value on the operating cost savings realized from more efficient appliances. Consumers are much more concerned with the higher purchase prices.

and consumer preferences may have occurred during that period, but DOE did not account for them in this analysis. Despite these uncertainties, DOE believes that its estimate of the relative price elasticity of demand provides a reasonable assessment of the impact that purchase price, operating cost, and household income have on product shipments.

Because DOE's projections of shipments and national impacts due to standards consider 30-year period, it needed to consider how the *relative price* elasticity is affected once a new standard takes effect. DOE considered the *relative price* elasticity provided 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. To estimate how the *relative price* elasticity changes over time, therefore, DOE relied on a study pertaining to automobiles.[8,9] That study showed that the automobile price elasticity of demand changes following a change in purchase price. With increasing years after the purchase price change, the price elasticity becomes more inelastic until it reaches a terminal value around the tenth year after the price change. Table 9.4.1 shows the relative change in the price elasticity of demand for automobiles over time. DOE developed a time-series of *relative price* elasticities for home appliances based on the relative change in the automobile price elasticity of demand. For years not shown in Table 9.4.1, DOE performed a linear interpolation to obtain the *relative price* elasticity.

**Table 9.4.1 Change in Relative Price Elasticity After a Purchase Price Change**

| | **Number of Years After Price Change** | | | | | |
|---|---|---|---|---|---|---|
| Change in elasticity relative to first year | **1** | **2** | **3** | **5** | **10** | **20** |
| | 1.00 | 0.78 | 0.63 | 0.44 | 0.35 | 0.33 |
| Relative price elasticity | -0.34 | -0.26 | -0.21 | -0.16 | -0.12 | -0.11 |

Based on the following equation, DOE estimated standards case shipments by incorporating the impact of the *relative price* into the base-case shipments projection. Note that in the equation below, 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 the 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 home installations of product $p$ in year $j$ under the base case, |
| $M_{BASE\_p}(j)$ = | first-time owners market M of product $p$ in year $j$ 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 a standard level in year $j$. |

DOE determined the standards case shipments were not affected by the *relative price* impact on the base-case shipments projection. Because the incremental cost of dehumidifiers meeting the trial standard levels is low relative to the operating cost savings for portable dehumidifiers, and its market share accounts for approximately 95 percent of the total shipments, DOE assumed that consumer price elatisicity for this product is zero. Therefore, shipments would not be affected by standards.

## 9.5 AFFECTED STOCK

The affected stock is the in-service stock of a product that is affected by a standard level. In addition to the projection of product shipments under both the base case and the standards case, the affected stock (which represents the difference in the appliance stock between the base case and the standards case) is a key output of DOE's shipments models. The affected stock quantifies the effect that new product shipments have on the appliance stock because of a standard level. Therefore, the affected stock consists of those in-service units that are purchased in or after the year the 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 stock of units of product $p$ of all vintages that are operational in year $j$, |
| $Ship_p(j)$ = | shipments of product $p$ in year $j$, |
| $Stock_p(j)$ = | stock of units of product $p$ of all vintages that are operational in year $j$, |
| $age$ = | age of the units (years), and |
| $Std\_yr$ = | effective date of the standard. |

As noted for the above equation, to calculate the affected stock, DOE must define the effective date of the standard. For the NES and NPV results presented in chapter 10 of this NOPR TSD, DOE assumed that new energy efficiency standards will become effective in 2019. Thus, all appliances purchased starting in 2019 are affected by the standard level.

Because dehumidifiers meeting the standard levels have low incremental manufacturing costs and high operating cost savings, DOE estimated that the standards would have no impact on shipments. Thus, for all trial standards levels, shipments are projected to be the same as in the base case.

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# CHAPTER 10. NATIONAL IMPACT ANALYSIS

## 10.1 INTRODUCTION

This chapter of the NOPR TSD describes the method the DOE used to estimate the effects on national energy consumption of TSLs for dehumidifiers. DOE evaluated the following effects: (1) NES attributable to each potential standard; (2) the monetary value of energy savings to consumers of dehumidifiers; (3) increased total installed cost of the products because of standards; and (4) the NPV of energy savings (*i.e.*, the difference between the operational savings and increased total installed costs).

DOE determined both the NES and NPV for all the TSLs considered for the product classes of both portable and whole-home dehumidifiers. It performed all calculations using a Microsoft Excel spreadsheet model, which is accessible on the Internet (http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/47). The spreadsheets, which implement the NIA model, combine the calculations for determining the NES and NPV with input from the shipments model (chapter 9 of the NOPR TSD). Details and instructions for using the NIA model are provided in appendix 10A of this NOPR TSD.

Chapter 9 of this NOPR TSD provides a detailed description of the shipments model that DOE used to project future purchases of dehumidifiers. Chapter 9 includes detailed descriptions of consumers' sensitivities to total installed cost and operating cost, and how DOE captured those sensitivities within the model.

DOE analyzed the benefits and burdens of four TSLs for three product classes of portable dehumidifiers and two product classes of whole-home dehumidifiers. The TSLs were developed using combinations of efficiency levels for all five product classes that DOE analyzed. Table 10.1.1 presents the TSLs and the corresponding efficiency levels for dehumidifiers. TSL 4 represents the maximum technologically feasible ("max-tech") improvement in energy efficiency for dehumidifiers. TSLs 2 and 3 represent intermediate efficiency levels between TSLs 1 and 4. TSL 1 represents the first efficiency level considered that exceeds baseline efficiency.

**Table 10.1.1 Trial Standard Levels for Dehumidifiers—IEF* (Units: L/kWh†)**

| TSL | ≤30.00 pints/day | 30.01-45.00 pints/day | >45.00 pints/day | Whole-home - ≤8.0ft^3 Case Volume | Whole-home - >8.0ft^3 Case Volume |
|---|---|---|---|---|---|
| -- | 0.77 | 0.94 | 2.07 | 1.77 | 2.41 |
| TSL 1 | 1.10 | 1.20 | 2.40 | 2.09 | 2.70 |
| TSL 2 | 1.20 | 1.40 | 2.80 | 2.09 | 3.52 |
| TSL 3 | 1.30 | 1.60 | 2.80 | 2.09 | 3.52 |
| TSL 4 | 1.57 | 1.80 | 3.66 | 2.53 | 4.50 |

* IEF = Integrated energy factor, which includes energy consumed in standby, off, dehumidification, and fan-only modes.

† L/kWh = Liters (of moisture removed) per kilowatt-hour (of energy consumed).

## 10.2 PROJECTED EFFICIENCIES FOR BASE AND STANDARDS CASES

This section describes the method DOE used to project the energy efficiencies of dehumidifiers for the base case and for each of the trial standards cases. It provides efficiency distributions for all product classes of both portable and whole-home dehumidifiers.

A key factor in estimating NES and NPV is the trend in energy efficiency projected 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. Because it is a function of annual energy use, the per-unit annual operating cost depends indirectly on product efficiency.

To project the base-case energy efficiency for dehumidifiers, DOE used the shipments-weighted integrated energy factors (SWIEF) as a starting point for 2014 (see chapter 8). DOE also projected efficiencies for the base case based on assumptions regarding future improvements in efficiency and assumed an annual growth rate of 0.25 percent between 2014 and 2048.

DOE assumed a “roll-up” scenario to establish the shipment-weighted efficiency for the year that standards are assumed to become effective (2019). 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 level. For its projected efficiencies of TSLs, in addition to a “roll-up” scenario, DOE developed a shift scenario. In the shift scenario DOE applies an annual growth rate in average energy efficiency to the SWIEF, as it is done in the base case. To develop standards case projected SWIEFs, DOE developed growth trends for each trial standard level that maintained the same per-unit average total installed cost difference for the year 2019 between the base case and each standards case over the entire projection period (2019–2048). DOE’s approach for developing standards case SWIEFs in this manner assumes that the rate of adoption of more efficient products under the standards case can occur only at a rate which ensures that the average total installed cost difference between the standards case and base case over the entire projection period is held constant. Because the total installed cost versus efficiency relationship for each product class demonstrates an increasing cost rate for more efficient products, the SWIEF growth rate for each standards case is lower than the SWIEF growth rate for the base case. Note that for the standards cases, the efficiency trend does not increase past the max tech level.

Table 10.2.1 through Table 10.2.5 show the base-case and TSL product efficiency distributions in 2019, based on the IEF for each of the five product classes that DOE is considering. The TSLs are composed of efficiency levels analyzed in the life-cycle cost and payback period analysis (chapter 8 of the NOPR TSD). Also included in the tables are the SWIEFs associated with the base case and each TSL.

**Table 10.2.1 Portable Dehumidifiers ≤30.00 Pints/Day: Base- and Standards-Case Efficiency Distributions in 2019**

| EL | TSL | IEF | Market Shares (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Base Case | Trial Standard Level | | | |
| | | (L/kWh) | | 1 | 2 | 3 | 4 |
| Baseline | - | 0.77 | 11 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1.10 | 23 | 34 | 0 | 0 | 0 |
| 2 | 2 | 1.20 | 0 | 0 | 34 | 0 | 0 |
| 3 | 3 | 1.30 | 66 | 66 | 66 | 100 | 0 |
| 4 | 4 | 1.57 | 0 | 0 | 0 | 0 | 100 |
| **SWIEF (L/kWh)** | | | 1.20 | 1.23 | 1.27 | 1.30 | 1.57 |

**Table 10.2.2 Portable Dehumidifiers 30.01–45.00 Pints/Day: Base- and Standards-Case Efficiency Distributions in 2019**

| EL | TSL | IEF (L/kWh) | Market Share (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Base Case | Trial Standard Level | | | |
| | | | | 1 | 2 | 3 | 4 |
| Baseline | - | 0.94 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1.20 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | 1.40 | 94 | 94 | 94 | 0 | 0 |
| 3 | 3 | 1.60 | 2 | 2 | 2 | 96 | 0 |
| 4 | 4 | 1.80 | 4 | 4 | 4 | 4 | 100 |
| **SWIEF (L/kWh)** | | | 1.42 | 1.42 | 1.42 | 1.61 | 1.80 |

**Table 10.2.3 Portable Dehumidifiers >45.00 Pints/Day: Base- and Standards-Case Efficiency Distributions in 2019**

| EL | TSL | IEF (L/kWh) | Market Share (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Base Case | Trial Standard Level | | | |
| | | | | 1 | 2 | 3 | 4 |
| Baseline | - | 2.07 | 57 | 0 | 0 | 0 | 0 |
| 1 | 1 | 2.40 | 20 | 77 | 0 | 0 | 0 |
| 2 | 2, 3 | 2.80 | 23 | 23 | 100 | 100 | 0 |
| 3 | 4 | 3.66 | 0 | 0 | 0 | 0 | 100 |
| SWIEF (L/kWh) | | | 2.30 | 2.49 | 2.80 | 2.80 | 3.66 |

**Table 10.2.4 Whole-Home Dehumidifiers ≤8.0 ft$^3$ Case Volume: Base- and Standards-Case Efficiency Distributions in 2019**

| EL | TSL | IEF (L/kWh) | Market Share (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Base Case | Trial Standard Level | | | |
| | | | | 1 | 2 | 3 | 4 |
| Baseline | - | 1.77 | 75 | 0 | 0 | 0 | 0 |
| 1 | 1, 2, 3 | 2.09 | 25 | 100 | 100 | 100 | 0 |
| 2 | 4 | 2.53 | 0 | 0 | 0 | 0 | 100 |
| SWIEF (L/kWh) | | | 1.85 | 2.09 | 2.09 | 2.09 | 2.53 |

**Table 10.2.5 Whole-Home Dehumidifiers >8.0 ft$^3$ Case Volume: Base- and Standards-Case Efficiency Distributions in 2019**

| EL | TSL | IEF (L/kWh) | Market Share (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Base Case | Trial Standard Level | | | |
| | | | | 1 | 2 | 3 | 4 |
| Baseline | - | 2.41 | 31 | 0 | 0 | 0 | 0 |
| 1 | 1 | 2.70 | 46 | 77 | 0 | 0 | 0 |
| 2 | 2, 3 | 3.52 | 23 | 23 | 100 | 100 | 0 |
| 3 | 4 | 4.50 | 0 | 0 | 0 | 0 | 100 |
| SWIEF (L/kWh) | | | 2.80 | 2.89 | 3.52 | 3.52 | 4.50 |

## 10.3 NATIONAL ENERGY SAVINGS

DOE calculated the NES associated with the difference between the base case and each of the potential standards cases for dehumidifiers. DOE calculated cumulative energy savings from 2019 to 2048.

### 10.3.1 Definition

DOE calculated annual NES as the difference between two projections: a base case (without new standards) and a standards case (with new standards). Positive values of NES represent energy savings (*i.e.*, national annual energy consumption under a standard is less than under the base case).

$$NES_y = AEC_{BASE} - AEC_{STD}$$

Cumulative energy savings are the sum of the national annual energy savings throughout the projection period, which starts in the compliance year (2019) and ends in the year when the last unit installed in 2048 is retired from service. The calculation is represented by the following equation.

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

DOE calculated the national annual energy consumption by multiplying the number or stock of each product class (by vintage) by its unit energy consumption (also by vintage). The calculation of the national annual energy consumption is performed using the following equation.

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

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, $STOCK_V$. |
| $NES_y$ = | national annual energy savings (quads). |
| $STOCK_V$ = | stock of product (millions of units) of vintage $V$ surviving in the year for which DOE calculated annual energy consumption. |
| $UEC_V$ = | annual energy consumption per product in either kilowatt-hours (kWh) or million Btus (MMBtu) (electricity and gas consumption are 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. |
| $y$ = | year in the forecast. |

The stock of a product depends on annual shipments and the lifetime of the product. As described in chapter 9 of the NOPR TSD, DOE projected dehumidifier shipments under the base and standards cases. To avoid including savings attributable to shipments displaced because of standards (consumers deciding not to buy higher-priced products), DOE used the projected standards-case shipments and, in turn, the standards-case stock, to calculate the AEC for the base case.

### 10.3.2 Inputs to National Energy Savings

The inputs to the calculation of NES are:

- shipments,
- product stock ($STOCK_V$),
- annual energy consumption per unit (*UE*C),
- national annual energy consumption (*AEC*),
- site-to-source conversion factor (src_conv), and
- primary energy to full fuel cycle multipliers (μ).

#### 10.3.2.1 Shipments

DOE projected shipments for the base case and all standards cases. Several factors, including total installed cost (purchase price plus installation costs), operating cost, and product lifetime, all affect projected shipments. Chapter 9 of the NOPR TSD, Shipments Analysis, details the method DOE used to calculate and generate the shipments projections for dehumidifiers.

#### 10.3.2.2 Product Stock

The product 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 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 of the NOPR TSD provides additional details on the survival functions that DOE used for portable and whole-home dehumidifiers.

#### 10.3.2.3 Annual Energy Consumption per Unit

DOE presented the per-unit annual energy consumption as a function of product efficiency in chapter 7, Energy Use Determination, and section 8.2.2 of chapter 8, Life-Cycle Cost and Payback Period Analysis.  Because the per-unit annual energy consumption is directly dependent on efficiency, DOE used the base case and standards case energy efficiency distribution presented in section 10.2, in combination with the annual energy use data presented in chapter 8, to estimate the shipment-weighted average annual per-unit energy consumption under the base case and standards cases.

Table 10.3.1 through Table 10.3.5 present the per-unit annual energy consumption based on the efficiency distribution corresponding to the base case and each TSL, resprectively.

**Table 10.3.1 Portable Dehumidifiers ≤30.00 Pints/Day: Base- and Standards-Case Efficiency Distributions in 2019**

| EL | TSL | IEF (L/kWh) | Market Shares (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Base Case | Trial Standard Level | | | |
| | | | | 1 | 2 | 3 | 4 |
| Baseline | - | 0.77 | 11 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1.10 | 23 | 34 | 0 | 0 | 0 |
| 2 | 2 | 1.20 | 0 | 0 | 34 | 0 | 0 |
| 3 | 3 | 1.30 | 66 | 66 | 66 | 100 | 0 |
| 4 | 4 | 1.57 | 0 | 0 | 0 | 0 | 100 |
| **SWAEU (kWh/yr)** | | | 477 | 454 | 440 | 428 | 355 |

**Table 10.3.2 Portable Dehumidifiers 30.01–45.00 Pints/Day: Base- and Standards-Case Efficiency Distributions in 2019**

| EL | TSL | IEF (L/kWh) | Market Share (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Base Case | Trial Standard Level | | | |
| | | | | 1 | 2 | 3 | 4 |
| Baseline | - | 0.94 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1.20 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | 1.40 | 94 | 94 | 94 | 0 | 0 |
| 3 | 3 | 1.60 | 2 | 2 | 2 | 96 | 0 |
| 4 | 4 | 1.80 | 4 | 4 | 4 | 4 | 100 |
| **SWAEU (kWh/yr)** | | | 685 | 685 | 685 | 604 | 540 |

**Table 10.3.3 Portable Dehumidifiers >45.00 Pints/Day: Base- and Standards-Case Efficiency Distributions in 2019**

| EL | TSL | IEF (L/kWh) | Market Share (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Base Case | Trial Standard Level | | | |
| | | | | 1 | 2 | 3 | 4 |
| Baseline | - | 2.07 | 57 | 0 | 0 | 0 | 0 |
| 1 | 1 | 2.40 | 20 | 77 | 0 | 0 | 0 |
| 2 | 2, 3 | 2.80 | 23 | 23 | 100 | 100 | 0 |
| 3 | 4 | 3.66 | 0 | 0 | 0 | 0 | 100 |
| **SWAEU (kWh/yr)** | | | 826 | 755 | 670 | 670 | 513 |

**Table 10.3.4 Whole-Home Dehumidifiers ≤8.0 ft$^3$ Case Volume: Base- and Standards-Case Efficiency Distributions in 2019**

| EL | TSL | IEF (L/kWh) | Market Share (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Base Case | Trial Standard Level | | | |
| | | | | 1 | 2 | 3 | 4 |
| Baseline | - | 1.77 | 75 | 0 | 0 | 0 | 0 |
| 1 | 1, 2, 3 | 2.09 | 25 | 100 | 100 | 100 | 0 |
| 2 | 4 | 2.53 | 0 | 0 | 0 | 0 | 100 |
| **SWAEU (kWh/yr)** | | | 916 | 809 | 809 | 809 | 671 |

**Table 10.3.5 Whole-Home Dehumidifiers >8.0 ft$^3$ Case Volume: Base- and Standards-Case Efficiency Distributions in 2019**

| EL | TSL | IEF (L/kWh) | Market Share (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Base Case | Trial Standard Level | | | |
| | | | | 1 | 2 | 3 | 4 |
| Baseline | - | 2.41 | 31 | 0 | 0 | 0 | 0 |
| 1 | 1 | 2.70 | 46 | 77 | 0 | 0 | 0 |
| 2 | 2, 3 | 3.52 | 23 | 23 | 100 | 100 | 0 |
| 3 | 4 | 4.50 | 0 | 0 | 0 | 0 | 100 |
| **SWAEU (kWh/yr)** | | | 1,000 | 963 | 784 | 784 | 617 |

#### 10.3.2.4 National Annual Energy Consumption

The national annual energy consumption is the product of the annual energy consumption per unit and the number of units of each vintage (V). The calculation of AEC accounts for differences in unit energy consumption from year to year. DOE used the equation below (as presented in section 10.3.1) to calculate annual energy consumption.

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

To determine national annual energy consumption, DOE calculated the annual energy consumption at the site and then applied a conversion factor to calculate primary energy consumption, as described below.

#### 10.3.2.5 Primary Energy Use Factors

For electricity use, the conversion from site kWh to power plant primary million Btu uses a marginal heat rate factor that accounts for losses associated with the generation, transmission, and distribution of electricity. DOE derived these marginal factors using data published with the EIA's *AEO2014*,[1] following the methodology outlined in appendix 15A. The factors depend on the sector and end-use, and also vary with time due to changes in the mix of fuels used for electric power generation. Figure 10.3.1 shows the site-to-power plant factors from 2019 to the end of the AEO analysis period (2040). For years after 2040, DOE held the factors constant and equal to their 2040 values.

For fossil fuels such as natural gas, fuel oil or propane, the site energy and primary energy are the same, as energy used in processing is captured in the FFC metric.

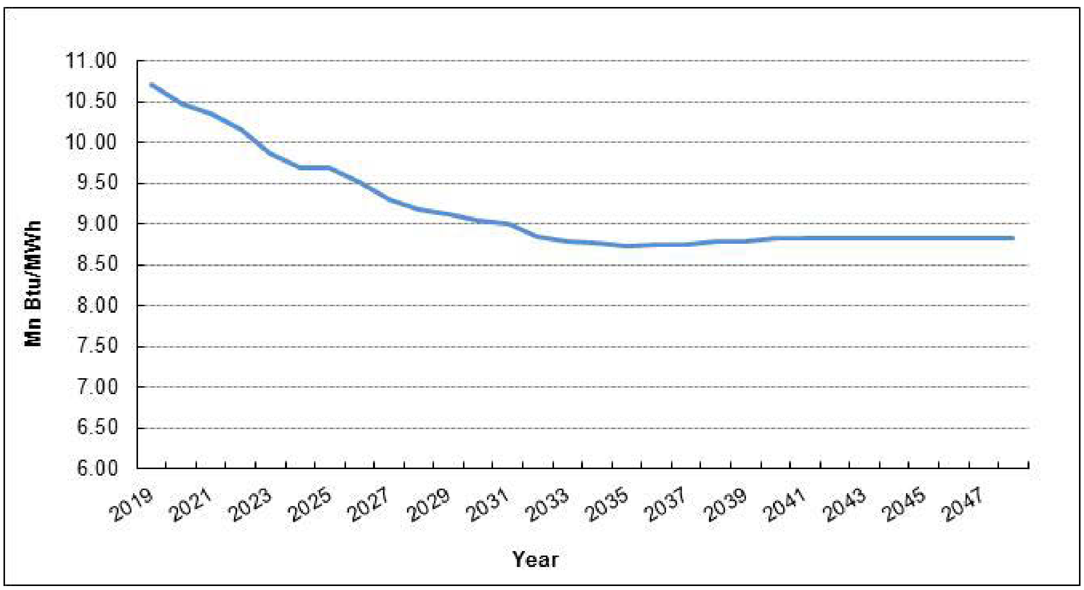


**Figure 10.3.1 Site-to-Power Plant Energy Conversion Factors for Dehumidifiers**

#### 10.3.2.6 Full-Fuel-Cycle Energy Factors

The full-fuel-cycle energy use is equal to the primary energy use plus the energy consumed "upstream" of the site in the extraction, processing and distribution of fuels. The FFC energy use was calculated by applying a fuel-specific FFC energy multiplier to the primary energy use. DOE developed FFC multipliers using the data and projections generated by the NEMS used for *AEO 2014*. The AEO provides extensive information about the energy system, including projections of future oil, natural gas and coal supply, energy use for oil and gas field and refinery operations, and fuel consumption and emissions related to electric power production. This information can be used to define a set of parameters representing the energy intensity of energy production. The multplier for electricity represents the energy needed to produce and deliver the fuels that are consumed in electricity generation. The multipliers are dimensionless numbers that express the upstream energy use as a percentage of the primary energy use.

Because the FFC energy multipliers depend on the fuel type, the FFC energy is calculated starting with the annual site energy numbers *ASEC*. The equation is:

$$FFC(L,y) = \sum_F ASEC(L,F,y) * h(F,y) * \mu(F,y).$$

Where:

| | |
|---|---|
| $ASEC$ = | annual site energy consumption |
| $L$ = | trial standard level |
| $F$ = | fuel type |
| $y$ = | analysis year |
| $h$ = | energy unit conversion factor |
| $\mu$ = | full fuel cycle multiplier |
| $FFC$ = | annual full fuel cycle energy consumption |

If a product uses only one fuel, then the FFC energy is equal to the primary energy *APEC* multiplied by the FFC multipler μ. For products that use multiple fuels, the relationship between the primary energy use and the FFC energy is less straight-forward.

As with the NES, DOE calculated cumulative, national level energy savings in the full-fuel-cycle metric by calculating the difference relative to the base case and summing over the analysis period:

$$NES\text{-}FFC(L,y) = FFC(L=0,y) - FFC(L,y),$$

$$NES\text{-}FFC_{cum}(L) = \sum_y NES\text{-}FFC(L,y)$$

The method used to calculate FFC energy multipliers and the derived values are described in appendix 10B.

Table 10.3.6 shows the FFC energy multipliers used for residential dehumidifers for selected years. The method used to calculate FFC energy multipliers is described in appendix 10B.

**Table 10.3.6 Full-Fuel-Cycle Energy Multipliers (Based on AEO 2014)**

| Electricity | **2019** | **2020** | **2025** | **2030** | **2035** | **2040** |
|---|---|---|---|---|---|---|
| Upstream to Power Plants | 1.043 | 1.044 | 1.045 | 1.046 | 1.047 | 1.047 |

## 10.4 NET PRESENT VALUE

DOE calculated the NPV of the increased product price and reduced operating cost associated with the difference between the base case and each potential standards case for the dehumidifier 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 operating cost savings, and
*PVC* = present value of increased total installed costs (including purchase price and installation costs).

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 costs each year summed over vintages of the product stock, $STOCK_V$;
*DF* = discount factor in each year;
*TIC* = total annual-increases in installed cost each year summed over vintages of the product stock, $STOCK_V$; 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 price 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 price increases are 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 operating cost savings per unit of vintage *V*, |
| $V$ = | 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 price in year *y*. |

DOE determined the total increased product price for each year from 2019 to 2048. DOE determined the present value of operating cost savings for each year from 2019 to the year when all units purchased in 2048 will 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" (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 to Net Present Value

The inputs to the calculation of NPV are:

- total installed cost per unit,
- annual operating cost savings per unit,
- total annual increases in product price,
- total annual savings in operating cost,
- discount factor,
- present value of costs, and
- present value of savings.

The increase in the total annual installed cost is equal to the annual change in the per-unit total installed cost (difference between base and standards case) multiplied by the shipments forecasted in the standards case.

The total annual operating cost savings are equal to the change in annual operating cost (difference between base and standards case) per unit multiplied by the shipments forecasted in the standards case. As noted, DOE did not calculate operating cost savings using base-case shipments. The annual operating cost includes energy costs.

#### 10.4.2.1 Total Installed Cost per Unit

The average annual product cost depends directly on efficiency. DOE therefore used the efficiency distributions presented in 0 through Table 10.2.5, along with the product price at various efficiency levels (presented in chapter 8 of the NOPR TSD), to estimate the shipment-weighted average annual product cost under the base and standards cases. Table 10.4.1 shows the shipment-weighted average installed cost of dehumidifiers in 2019 for the base and standards cases.

**Table 10.4.1 Shipment-Weighted Average Per-Unit Total Installed Costs for Base and Standards Cases (2013$)**

| Product Class | Base Case | Trial Standard Level | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| ≤30.00 pints/day | $216 | $216 | $217 | $218 | $241 |
| 30.01-45.00 pints/day | $260 | $260 | $260 | $269 | $290 |
| >45.00 pints/day | $951 | $994 | $1,008 | $1,008 | $1,124 |
| Whole-home - <8.0ft^3 Case Volume | $1,669 | $1,689 | $1,689 | $1,689 | $1,890 |
| Whole-home - >8.0ft^3 Case Volume | $2,164 | $2,167 | $2,212 | $2,212 | $2,445 |

To evaluate the effect of uncertainty regarding price trends, DOE examined the effect of various product price forecasts on the consumer NPV for the considered TSLs for residential dehumidifiers. In addition to the default price trend, DOE considered separate product price sensitivity cases for portable dehumidifiers and whole-home dehumidifiers. For portable dehumidifiers, DOE considered a case for a low price decline based on estimating an experience curve using Producer Price Index (PPI) data for "small electric household appliances" from 1983 to 2012. A case for high price decline was based on the price forecast of the "furniture and appliances" series from *AEO 2013*. For whole-home dehumidifiers, a case for a low price decline was based on an exponential fit to the PPI from 1978 to 2012 for "air-conditioning, refrigeration, and forced air heating equipment." The high price decline was based on the price forecast of the "furniture and appliances" series from *AEO 2013*. The approach used to forecast the price trends and the results of the sensitivity cases are described in appendix 10C of this NOPR TSD.

#### 10.4.2.2 Annual Operating Cost Savings per Unit

The per-unit annual operating cost includes the costs for energy, repair, and maintenance. As described in chapter 8 of the NOPR TSD, DOE assumed that potential standards would not increase maintenance and repair costs for any of the considered product classes. Therefore, DOE determined the per-unit annual operating cost savings based only on the energy cost savings attributable to a standard level. DOE determined the per-unit annual operating cost savings by multiplying the per-unit savings in annual energy consumption for each product class by the appropriate energy price.

As described in chapter 8, DOE forecasted energy prices based on EIA's *AEO 2015*. [2] The energy price trends are described in chapter 8 of this NOPR TSD.

#### 10.4.2.3 Total Annual Increases in Installed Cost

The total annual increase in installed cost for any given standards case is the product of the total per-unit increase in installed cost due to the standard and the number of units of each vintage. This approach accounts for differences in total installed cost from year to year. Below is the equation for calculating the increase in total annual installed cost for a given standards case (as introduced in section 10.4.1).

$$TIC = \sum STOCK_V \times UTIC_V$$

#### 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 operating cost savings per unit attributable to the standard and the number of units of each vintage. This approach accounts for differences in annual operating cost savings from year to year. Below is the equation for calculating the total annual operating cost savings for a given standards case (as introduced in section 10.4.1).

$$OCS = \sum STOCK_V \times UOCS_V$$

#### 10.4.2.5 Discount Factors

DOE multiplies monetary values in future years by a discount factor to determine the present value. The discount factor (DF) is described by the equation:

$$DF = \frac{1}{(1+r)^{(y-yp)}}$$

Where:

$R$ = discount rate,
$Y$ = year of the monetary value, and
$y_P$ = year in which the present value is being determined.

DOE estimated national impacts using both a 3-percent and a 7-percent real discount rate, in accordance with the Office of Management and Budget (OMB)'s guidance to Federal agencies on the development of regulatory analysis (*OMB Circular A-4*, September 17, 2003), and section E, "Identifying and Measuring Benefits and Costs," therein. DOE defines the present year as 2014.

#### 10.4.2.6 Present Value of Costs

The present value of increased installed costs is the increase in annual-installed cost in each year (*i.e.*, the difference between a standards case and base case), discounted to the present and summed over the period for which DOE is considering the installation of products (that is, from 2019 to 2048).

The increase in total installed cost refers to both product cost and installation cost associated with the higher energy efficiency of products purchased in the standards case compared to the base case. DOE calculated annual increases in installed costs as the difference in total installed cost for new products purchased each year multiplied by the shipments in the standards case.

#### 10.4.2.7 Present Value of Savings

The present value of operating cost savings is the annual operating cost savings (the difference between the base case and a standards case) discounted to the present and summed over the period from the compliance year, 2019, to the year when the last unit installed in 2048 is retired from service. Savings are decreases in operating costs associated with the higher energy efficiency of products purchased in the standards case compared to the base case. Total annual operating cost savings are the savings per unit multiplied by the number of units of each vintage that survive in a particular year.

## 10.5 RESULTS OF CALCULATIONS

The national impact analysis (NIA) model estimates the NES and NPV attributable to a given trial standard level. The inputs to the NIA model were discussed in sections 10.3.2 (NES inputs) and 10.4.2 (NPV inputs). DOE generated the NES and NPV results using a Microsoft Excel spreadsheet, which is accessible on the Internet (http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/47). Details and instructions for using the spreadsheet are provided in appendix 10A of this NOPR TSD.

### 10.5.1 Summary of Inputs

Table 10.5.1 summarizes the inputs to the NIA model. The data source for each input is described briefly.

**Table 10.5.1 Inputs to Calculation of National Energy Savings and Net Present Value**

| Input | Data Source |
|---|---|
| Shipments | Annual shipments from shipments model. (See chapter 9.) |
| Effective date of standard | 2019 |
| Base-case projected efficiencies | SWIEF determined in 2014 for each of the considered products classes. Annual growth rate of 0.25 percent assumed for determining SWIEF between 2014 and 2048. (See section 10.2) |
| Standards-case efficiencies | Roll-up scenario for 2019; efficiency improvement after 2019 based on 0.25 percent (See section 10.2.) |
| Annual energy consumption per unit | Annual weighted-average values are a function of cost at each TSL. (See section 10.3.2.3.) Incorporates forecast of future product prices based on historical data. |
| Total installed cost per unit | Annual weighted-average values are a function of the efficiency distribution. (See section 10.4.2.1.) |
| Energy cost per unit | Annual weighted-average values are a function of the annual energy consumption per unit and energy prices. (See chapter 8, for energy prices.) |
| Repair and maintenance costs per unit | Annual values do not change with efficiency level. |
| Projection of installed cost per unit | Price forecast based on historical PPI data. |
| Projection of energy prices | AEO 2015 forecasts (to 2040) and extrapolation through 2048 (See chapter 8.) |
| Energy site-to-power plant and FFC conversion | A time-series conversion factor derived from AEO 2014. |
| Discount rate | Three and seven percent real. |
| Present year | Future costs and savings are discounted to 2014. |

*Section 10.3.2.5 provides more detail on NEMS.

### 10.5.2 Results of National Energy Savings Calculations

Table 10.5.2 shows the NES results for the TSLs analyzed for dehumidifiers. NES results, which are cumulative to 2097, are shown as primary energy savings. DOE based the inputs to the NIA model on weighted-average values, yielding results that are discrete point values, rather than a distribution of values such as obtained in the LCC and PBP analysis (chapter 8 of the preliminary TSD).

**Table 10.5.2 Cumulative National Energy Savings (Unit: Quads)**

| TSL | ≤30.00 Pints/Day | 30.01-45.00 Pints/Day | >45.00 Pints/Day | ≤8.0 $ft^3$ Case Volume (Whole-Home) | >8.0 $ft^3$ Case Volume (Whole-home) | All |
|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.01 | 0.03 | 0.00 | 0.00 | 0.07 |
| 2 | 0.05 | 0.01 | 0.03 | 0.00 | 0.00 | 0.11 |
| 3 | 0.08 | 0.18 | 0.03 | 0.00 | 0.00 | 0.31 |
| 4 | 0.33 | 0.34 | 0.06 | 0.01 | 0.01 | 0.75 |

**Table 10.5.3 Full-Fuel-Cycle Energy Savings (Unit: Quads)**

| TSL | ≤30.00 Pints/Day | 30.01-45.00 Pints/Day | >45.00 Pints/Day | ≤8.0 $ft^3$ Case Volume (Whole-Home) | >8.0 $ft^3$ Case Volume (Whole-home) | All |
|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.01 | 0.03 | 0.00 | 0.00 | 0.07 |
| 2 | 0.06 | 0.01 | 0.04 | 0.00 | 0.00 | 0.11 |
| 3 | 0.09 | 0.19 | 0.04 | 0.00 | 0.00 | 0.32 |
| 4 | 0.35 | 0.36 | 0.07 | 0.01 | 0.01 | 0.79 |

### 10.5.3 Annual Costs and Savings

To illustrate the basic inputs to the NPV calculations, Figure 10.5.1 presents the non-discounted annual installed cost increases and annual operating cost savings nationwide for TSL 3 for dehumidifiers. The figure also shows the net savings, which represent the difference between the savings and costs for each year. The annual product cost is the increase in the total installed cost for products purchased each year during the projection period. The annual operating cost savings is the savings in operating costs for products operating in each year. The NPV is the difference between the cumulative annual discounted savings and the cumulative annual discounted costs. DOE could create figures like the one presented below for each TSL.

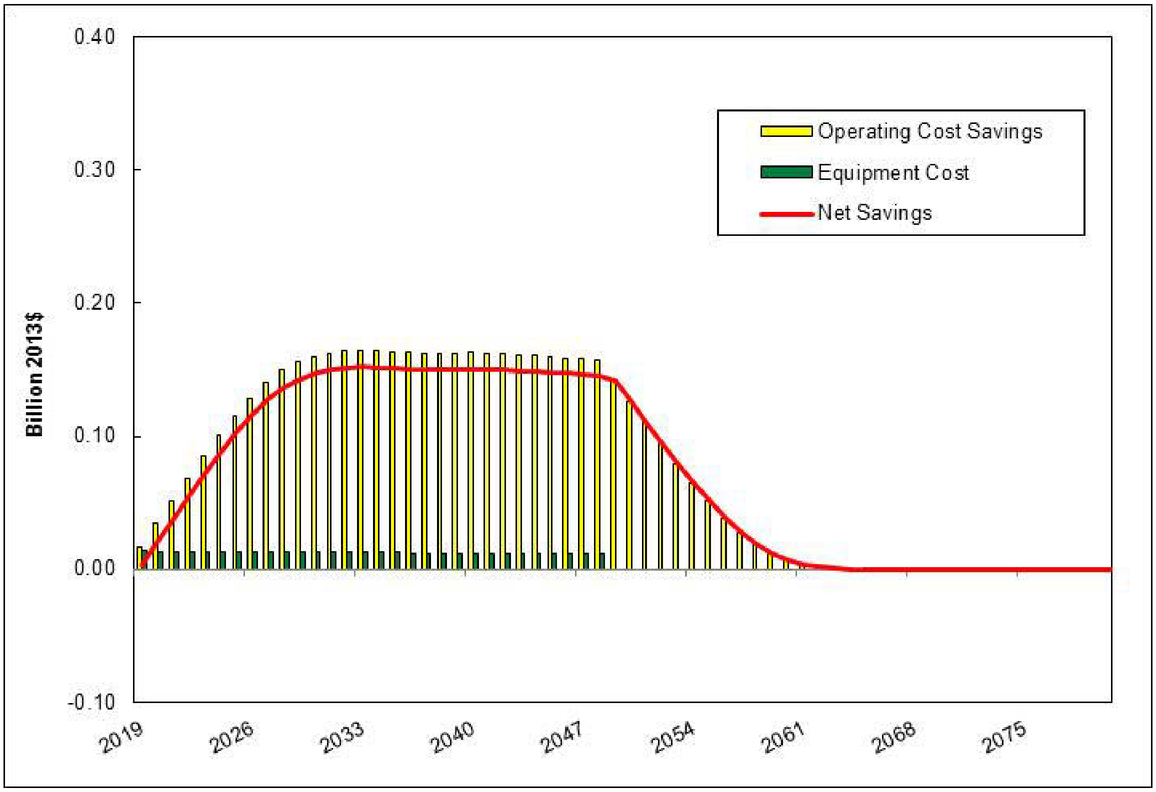


**Figure 10.5.1 Non-Discounted Annual Installed Cost Increases and Annual Operating Cost Savings for Dehumidifiers, TSL 3**

### 10.5.4 Results of Net Present Value Calculations

This section provides results from the calculation of NPV for the potential efficiency standards for dehumidifiers. Results, which are cumulative, are shown as the discounted value of 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 produced by the life-cycle cost and payback period analysis.

The present value of increased total installed costs is the increase in total annual installed cost (*i.e.*, the difference between the standards case and base case), discounted to the present and summed over the period in which DOE evaluated the impacts of standards (2019 to 2048).

Savings are decreases in operating costs associated with the higher energy efficiency of products purchased in a standards case as compared to the base case. Total savings in operating costs are the savings per unit multiplied by the number of units of each vintage (*i.e.*, the year of manufacture) that survive in a particular year. For units purchased through 2048, operating costs include energy consumed until the last unit is retired from service.

Table 10.5.4 and Table 10.5.5 presents NPV results for the trial standard levels considered for dehumidifiers.

**Table 10.5.4 Cumulative NPV Results Based on 3-Percent Discount Rate (Billion, 2013$)**

| TSL | ≤30.00 Pints/Day | 30.01-45.00 Pints/Day | >45.00 Pints/Day | ≤8.0 $ft^3$ Case Volume (Whole-Home) | >8.0 $ft^3$ Case Volume (Whole-Home) | All |
|---|---|---|---|---|---|---|
| 1 | 0.22 | 0.10 | 0.16 | 0.02 | 0.00 | 0.50 |
| 2 | 0.44 | 0.10 | 0.20 | 0.02 | 0.02 | 0.78 |
| 3 | 0.68 | 1.35 | 0.20 | 0.02 | 0.02 | 2.27 |
| 4 | 2.23 | 2.36 | 0.32 | 0.03 | 0.03 | 4.96 |

**Table 10.5.5 Cumulative NPV Results Based on 7-Percent Discount Rate (Billion, 2013$)**

| TSL | ≤30.00 Pints/Day | 30.01-45.00 Pints/Day | >45.00 Pints/Day | ≤8.0 $ft^3$ Case Volume (Whole-Home) | >8.0 $ft^3$ Case Volume (Whole-Home) | All |
|---|---|---|---|---|---|---|
| 1 | 0.13 | 0.04 | 0.06 | 0.01 | 0.00 | 0.24 |
| 2 | 0.23 | 0.04 | 0.08 | 0.01 | 0.01 | 0.37 |
| 3 | 0.33 | 0.60 | 0.08 | 0.01 | 0.01 | 1.04 |
| 4 | 0.97 | 1.02 | 0.12 | 0.01 | 0.01 | 2.13 |

## REFERENCES


1. U.S. Energy Information Administration. *Annual Energy Outlook 2014 with Projections to 2040*. 2014. Washington, DC. Report No. DOE/EIA-0383(2014). April. (Last accessed August 21, 2014.)
< http://www.eia.gov/forecasts/aeo/>

2. U.S. Energy Information Administration. *Annual Energy Outlook 2015 with Projections to 2040*. 2015. Washington, DC. Report No. DOE/EIA-0383(2015). April. (Last accessed April 20, 2015.)
< http://www.eia.gov/forecasts/aeo/>

# CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

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# CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

## 11.1 INTRODUCTION

Chapter 8 of this TSD describes the LCC and PBP analysis that examines energy savings and costs impacts of energy conservation standards on the U.S. population. In analyzing the potential impacts of new or amended standards on consumers, the DOE further evaluates the impacts on identifiable groups of consumers (subgroups) that may be disproportionately affected by a national standard level. The consumer subgroup analysis evaluates effects by analyzing the LCCs and PBPs for subgroups of residential consumers. For both portable and whole-home dehumidifiers, DOE identified two consumer subgroups that warranted further study: (1) senior-only households and (2) low-income households.

DOE determined the impact on consumer subgroups for portable and whole-home dehumidifiers using the LCC spreadsheet model, which enables DOE to analyze the LCC for any subgroup by sampling only the data that apply to that subgroup. (Chapter 8 explains in detail the inputs to the model used in determining LCCs and PBPs.) As described in section 11.3, the energy use and energy price characteristics of the two subgroups (senior-only and low-income) differ from those for the general population.

This chapter describes the identification of the two subgroups and gives the results of the LCC and PBP analysis for those subgroups.

## 11.2 IDENTIFIED SUBGROUPS

The following two sections describe how DOE defined the two consumer subgroups identified for further examination.

### 11.2.1 Senior-Only Households

Senior-only households comprise occupants who are all at least 65 years of age. Based on *RECS 2009*, senior-only households represent 17 percent of U.S. households.[1]

### 11.2.2 Low-Income Households

As defined in the RECS survey, low-income household residents are living at or below the poverty line. The poverty line varies with household size, age of head of household, and family income. The RECS survey classifies 15 percent of the country's households as low-income.

## 11.3 INPUTS TO CONSUMER SUBGROUP ANALYSIS

Table 11.3.1 summarizes the overall household populations and the populations of senior-only and low-income households in RECS. Table 11.3.2 through Table 11.3.6 summarize the weighted-average annual energy use for the households analyzed in the consumer subgroup analysis. These values are compared against the weighted-average values for the national sample.

**Table 11.3.1 Household Population**

| | Count | Sum |
|---|---|---|
| National | 12,083 | 113,616,229 |
| Senior-Only | 1,939 | 19,562,375 |
| Senior-Only (%) | 16.0 | 17.2 |
| Low-Income | 1675 | 16,867,387 |
| Low-Income (%) | 13.9 | 14.8 |

**Table 11.3.2 Portable Dehumidifiers ≤30.00 Pints/Day: Weighted-Average Annual Electricity Use**

| Efficiency Level | All Households | Senior-Only | Low-Income |
|---|---|---|---|
| | (kWh/year) | | |
| Baseline | 720 | 582 | 699 |
| 1 | 505 | 409 | 491 |
| 2 | 463 | 375 | 450 |
| 3 | 428 | 346 | 416 |
| 4 | 355 | 287 | 345 |

**Table 11.3.3 Portable Dehumidifiers 30.01–45.00 Pints/Day: Weighted-Average Annual Electricity Use**

| Efficiency Level | All Households | Senior-Only | Low-Income |
|---|---|---|---|
| | (kWh/year) | | |
| Baseline | 1,030 | 833 | 1,000 |
| 1 | 808 | 653 | 784 |
| 2 | 693 | 560 | 673 |
| 3 | 607 | 491 | 589 |
| 4 | 540 | 436 | 524 |

**Table 11.3.4 Portable Dehumidifiers >45.00 Pints/Day: Weighted-Average Annual Electricity Use**

| Efficiency Level | All Households | Senior-Only | Low-Income |
|---|---|---|---|
| | (kWh/year) | | |
| Baseline | 905 | 731 | 878 |
| 1 | 781 | 631 | 758 |
| 2 | 670 | 542 | 650 |
| 3 | 513 | 415 | 498 |

**Table 11.3.5 Dehumidifiers ≤8.0 ft$^3$ Case Volume (Whole-Home): Weighted-Average Annual Electricity Use**

| Efficiency Level | All Households | Senior-Only | Low-Income |
|---|---|---|---|
| | (kWh/year) | | |
| Baseline | 951 | 850 | 850 |
| 1 | 809 | 722 | 722 |
| 2 | 671 | 600 | 600 |

**Table 11.3.6 Dehumidifiers >8.0 ft$^3$ Case Volume (Whole-Home): Weighted-Average Annual Electricity Use**

| Efficiency Level | All Households | Senior-Only | Low-Income |
|---|---|---|---|
| | (kWh/year) | | |
| Baseline | 1,137 | 1,015 | 1,015 |
| 1 | 1,016 | 908 | 908 |
| 2 | 784 | 700 | 700 |
| 3 | 617 | 551 | 551 |

## 11.4 RESULTS

Table 11.4.1 through Table 11.4.20 summarize the LCC and PBP results from DOE’s subgroup analysis. The results describe the financial effects of potential standards on senior-only and low-income households. The tables present the average installed price; average lifetime operating cost (discounted); average life-cycle cost; average life-cycle cost savings; percentage of each subgroup who are burdened with net costs, realize net savings, or are not affected; and the simple payback period.

**Table 11.4.1 Senior-Only Households: Summary of LCC and PBP Results by Efficiency Level for Portable Dehumidifiers ≤30.00 Pints/Day**

| TSL | Efficiency Level | Average Costs 2013$ | | | | Simple Payback years |
|---|---|---|---|---|---|---|
| | | Installed Cost | First Year's Operating Cost | Lifetime Operating Cost | LCC | |
| -- | 0 | $212 | $84 | $786 | $998 | -- |
| 1 | 1 | $212 | $59 | $552 | $763 | 0.0 |
| 2 | 2 | $214 | $54 | $506 | $720 | 0.1 |
| 3 | 3 | $218 | $50 | $468 | $686 | 0.2 |
| 4 | 4 | $241 | $41 | $388 | $629 | 0.7 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.2 Senior-Only Households: Summary of LCC and PBP Results by Efficiency Level for Portable Dehumidifiers 30.01–45.00 Pints/Day**

| TSL | Efficiency Level | Average Costs 2013$ | | | | Simple Payback years |
|---|---|---|---|---|---|---|
| | | Installed Cost | First Year's Operating Cost | Lifetime Operating Cost | LCC | |
| -- | 0 | $256 | $120 | $1,124 | $1,380 | -- |
| 1 | 1 | $256 | $94 | $882 | $1,137 | 0.0 |
| 2 | 2 | $259 | $81 | $756 | $1,016 | 0.1 |
| 3 | 3 | $268 | $71 | $662 | $930 | 0.2 |
| 4 | 4 | $290 | $63 | $589 | $879 | 0.6 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.3 Senior-Only Households: Summary of LCC and PBP Results by Efficiency Level for Portable Dehumidifiers >45.00 Pints/Day**

| TSL | Efficiency Level | Average Costs 2013$ | | | | Simple Payback years |
|---|---|---|---|---|---|---|
| | | Installed Cost | First Year's Operating Cost | Lifetime Operating Cost | LCC | |
| -- | 0 | $915 | $105 | $987 | $1,903 | -- |
| 1 | 1 | $990 | $91 | $852 | $1,842 | 5.2 |
| 2, 3 | 2 | $1,008 | $78 | $731 | $1,739 | 3.4 |
| 4 | 3 | $1,124 | $60 | $560 | $1,684 | 4.6 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.4 Senior-Only Households: Summary of LCC and PBP Results by Efficiency Level for Dehumidifiers ≤8.0 ft$^3$ Case Volume (Whole-Home):**

| TSL | Efficiency Level | Average Costs 2013$ | | | | Simple Payback years |
|---|---|---|---|---|---|---|
| | | Installed Cost | First Year's Operating Cost | Lifetime Operating Cost | LCC | |
| -- | 0 | $1,643 | $126 | $1,826 | $3,469 | -- |
| 1, 2, 3 | 1 | $1,670 | $107 | $1,552 | $3,221 | 1.4 |
| 4 | 2 | $1,867 | $89 | $1,288 | $3,155 | 6.0 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.5 Senior-Only Households: Summary of LCC and PBP Results by Efficiency Level for Dehumidifiers >8.0 ft$^3$ Case Volume (Whole-Home):**

| TSL | Efficiency Level | Average Costs 2013$ | | | | Simple Payback years |
|---|---|---|---|---|---|---|
| | | Installed Cost | First Year's Operating Cost | Lifetime Operating Cost | LCC | |
| -- | 0 | $2,125 | $151 | $2,181 | $4,306 | -- |
| 1 | 1 | $2,136 | $135 | $1,950 | $4,087 | 0.7 |
| 2, 3 | 2 | $2,194 | $104 | $1,504 | $3,698 | 1.5 |
| 4 | 3 | $2,424 | $82 | $1,184 | $3,609 | 4.4 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.6 Senior-Only Households: Summary of Life-Cycle Cost Savings Relative to the Base Case Efficiency Distribution for Portable Dehumidifiers ≤30.00 Pints/Day**

| TSL | Efficiency Level | Life-Cycle Cost Savings | |
|---|---|---|---|
| | | % of Consumers that Experience Net Cost | Average Savings 2013$ |
| 1 | 1 | 0 | 24 |
| 2 | 3 | 0 | 39 |
| 3 | 3 | 0 | 51 |
| 4 | 4 | 12.0 | 107 |

Note: The LCC savings for each TSL are calculated relative to the base case efficiency distribution. The calculation includes households with zero LCC savings (no impact).

**Table 11.4.7 Senior-Only Households: Summary of Life-Cycle Cost Savings Relative to the Base Case Efficiency Distribution for Portable Dehumidifiers 30.01–45.00 Pints/Day**

| TSL | Efficiency Level | Life-Cycle Cost Savings | |
|---|---|---|---|
| | | % of Consumers that Experience Net Cost | Average Savings 2013$ |
| 1 | 1 | 0 | 0 |
| 2 | 3 | 0 | 0 |
| 3 | 3 | 0.5 | 81 |
| 4 | 4 | 6.1 | 130 |

Note: The LCC savings for each TSL are calculated relative to the base case efficiency distribution. The calculation includes households with zero LCC savings (no impact).

**Table 11.4.8 Senior-Only Households: Summary of Life-Cycle Cost Savings Relative to the Base Case Efficiency Distribution for Portable Dehumidifiers >45.00 Pints/Day**

| TSL | Efficiency Level | Life-Cycle Cost Savings | |
|---|---|---|---|
| | | % of Consumers that Experience Net Cost | Average Savings 2013$ |
| 1 | 1 | 21.6 | 36 |
| 2, 3 | 2 | 13.6 | 114 |
| 4 | 3 | 37.0 | 169 |

Note: The LCC savings for each TSL are calculated relative to the base case efficiency distribution. The calculation includes households with zero LCC savings (no impact).

**Table 11.4.9 Senior-Only Households: Summary of Life-Cycle Cost Savings Relative to the Base Case Efficiency Distribution for Dehumidifiers ≤8.0 ft$^3$ Case Volume (Whole-Home)**

| TSL | Efficiency Level | Life-Cycle Cost Savings | |
|---|---|---|---|
| | | % of Consumers that Experience Net Cost | Average Savings 2013$ |
| 1, 2, 3 | 1 | 5.5 | 182 |
| 4 | 2 | 40.3 | 248 |

Note: The LCC savings for each TSL are calculated relative to the base case efficiency distribution. The calculation includes households with zero LCC savings (no impact).

**Table 11.4.10 Senior-Only Households: Summary of Life-Cycle Cost Savings Relative to the Base Case Efficiency Distribution for Dehumidifiers >8.0 ft3 Case Volume (Whole-Home)**

| TSL | Efficiency Level | Life-Cycle Cost Savings | |
|---|---|---|---|
| | | % of Consumers that Experience Net Cost | Average Savings 2013$ |
| 1 | 1 | 0.7 | 67 |
| 2, 3 | 2 | 7.5 | 367 |
| 4 | 3 | 35.9 | 457 |

Note: The LCC savings for each TSL are calculated relative to the base case efficiency distribution. The calculation includes households with zero LCC savings (no impact).

**Table 11.4.11 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Portable Dehumidifiers ≤30.00 Pints/Day:**

| TSL | Efficiency Level | Average Costs 2013$ | | | | Simple Payback years |
|---|---|---|---|---|---|---|
| | | Installed Cost | First Year's Operating Cost | Lifetime Operating Cost | LCC | |
| -- | 0 | $212 | $96 | $885 | $1,097 | -- |
| 1 | 1 | $212 | $67 | $621 | $833 | 0.0 |
| 2 | 2 | $215 | $62 | $570 | $784 | 0.1 |
| 3 | 3 | $219 | $57 | $526 | $745 | 0.2 |
| 4 | 4 | $242 | $47 | $436 | $678 | 0.6 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.12 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Portable Dehumidifiers 30.01–45.00 Pints/Day**

| TSL | Efficiency Level | Average Costs 2013$ | | | | Simple Payback years |
|---|---|---|---|---|---|---|
| | | Installed Cost | First Year's Operating Cost | Lifetime Operating Cost | LCC | |
| -- | 0 | $256 | $137 | $1,266 | $1,522 | -- |
| 1 | 1 | $256 | $107 | $993 | $1,249 | 0.0 |
| 2 | 2 | $260 | $92 | $851 | $1,111 | 0.1 |
| 3 | 3 | $269 | $81 | $746 | $1,014 | 0.2 |
| 4 | 4 | $290 | $72 | $663 | $954 | 0.5 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.13 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Portable Dehumidifiers >45.00 Pints/Day**

| TSL | Efficiency Level | Average Costs 2013$ | | | | Simple Payback years |
|---|---|---|---|---|---|---|
| | | Installed Cost | First Year's Operating Cost | Lifetime Operating Cost | LCC | |
| -- | 0 | $917 | $120 | $1,112 | $2,029 | -- |
| 1 | 1 | $992 | $104 | $959 | $1,951 | 4.5 |
| 2, 3 | 2 | $1,011 | $89 | $823 | $1,834 | 3.0 |
| 4 | 3 | $1,127 | $68 | $631 | $1,757 | 4.0 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.14 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Dehumidifiers ≤8.0 ft$^3$ Case Volume (Whole-Home):**

| TSL | Efficiency Level | Average Costs 2013$ | | | | Simple Payback years |
|---|---|---|---|---|---|---|
| | | Installed Cost | First Year's Operating Cost | Lifetime Operating Cost | LCC | |
| -- | 0 | $1,626 | $92 | $1,201 | $2,827 | -- |
| 1, 2, 3 | 1 | $1,653 | $78 | $1,021 | $2,673 | 1.9 |
| 4 | 2 | $1,851 | $65 | $847 | $2,698 | 8.3 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.15 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Dehumidifiers >8.0 ft$^3$ Case Volume (Whole-Home):**

| TSL | Efficiency Level | Average Costs 2013$ | | | | Simple Payback years |
|---|---|---|---|---|---|---|
| | | Installed Cost | First Year's Operating Cost | Lifetime Operating Cost | LCC | |
| -- | 0 | $2,102 | 110 | $1,434 | $3,536 | -- |
| 1 | 1 | $2,113 | 98 | $1,283 | $3,396 | 1.0 |
| 2, 3 | 2 | $2,171 | 76 | $989 | $3,161 | 2.0 |
| 4 | 3 | $2,403 | 60 | $779 | $3,182 | 6.0 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.16 Low Income Households: Summary of Life-Cycle Cost Savings Relative to the Base Case Efficiency Distribution for Portable Dehumidifiers ≤30.00 Pints/Day**

| TSL | Efficiency Level | Life-Cycle Cost Savings | |
|---|---|---|---|
| | | % of Consumers that Experience Net Cost | Average Savings 2013$ |
| 1 | 1 | 0 | 28 |
| 2 | 3 | 0 | 45 |
| 3 | 3 | 0 | 58 |
| 4 | 4 | 13.9 | 125 |

Note: The LCC savings for each TSL are calculated relative to the base case efficiency distribution. The calculation includes households with zero LCC savings (no impact).

**Table 11.4.17 Low Income Households: Summary of Life-Cycle Cost Savings Relative to the Base Case Efficiency Distribution for Portable Dehumidifiers 30.01–45.00 Pints/Day**

| TSL | Efficiency Level | Life-Cycle Cost Savings | |
|---|---|---|---|
| | | % of Consumers that Experience Net Cost | Average Savings 2013$ |
| 1 | 1 | 0 | 0 |
| 2 | 3 | 0 | 0 |
| 3 | 3 | 1.2 | 92 |
| 4 | 4 | 7.8 | 150 |

Note: The LCC savings for each TSL are calculated relative to the base case efficiency distribution. The calculation includes households with zero LCC savings (no impact).

**Table 11.4.18 Low Income Households: Summary of Life-Cycle Cost Savings Relative to the Base Case Efficiency Distribution for Portable Dehumidifiers >45.00 Pints/Day**

| TSL | Efficiency Level | Life-Cycle Cost Savings | |
|---|---|---|---|
| | | % of Consumers that Experience Net Cost | Average Savings 2013$ |
| 1 | 1 | 21.9 | 43 |
| 2, 3 | 2 | 15.2 | 133 |
| 4 | 3 | 37.1 | 209 |

Note: The LCC savings for each TSL are calculated relative to the base case efficiency distribution. The calculation includes households with zero LCC savings (no impact).

**Table 11.4.19 Low Income Households: Summary of LCC and PBP Results by Efficiency Level for Dehumidifiers ≤8.0 $ft^3$ Case Volume (Whole-Home):**

| TSL | Efficiency Level | Life-Cycle Cost Savings: % of Consumers that Experience Net Cost | Life-Cycle Cost Savings: Average Savings 2013$ |
|---|---|---|---|
| 1, 2, 3 | 1 | 9.4 | 113 |
| 4 | 2 | 53.9 | 89 |

Note: The average LCC, LCC savings, and simple payback for each TSL are calculated assuming that all consumers use products with that EL. This allows the results for each TSL to be compared under the same conditions.

**Table 11.4.20 Low Income Households: Summary of Life-Cycle Cost Savings Relative to the Base Case Efficiency Distribution for Dehumidifiers >8.0 ft3 Case Volume (Whole-Home)**

| TSL | Efficiency Level | Life-Cycle Cost Savings: % of Consumers that Experience Net Cost | Life-Cycle Cost Savings: Average Savings 2013$ |
|---|---|---|---|
| 1 | 1 | 1.5 | 43 |
| 2, 3 | 2 | 12.2 | 224 |
| 4 | 3 | 48.3 | 204 |

Note: The LCC savings for each TSL are calculated relative to the base case efficiency distribution. The calculation includes households with zero LCC savings (no impact).

## REFERENCES


1 U.S. Department of Energy–Energy Information Administration. *Residential Energy Consumption Survey, 2009 Public Use Data Files*. 2013. Washington, D.C. (Last accessed March 25, 2013.) <http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=characteristics>

# CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

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# CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

## 12.1 INTRODUCTION

In determining whether a standard is economically justified, the 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 statute 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 dehumidifiers, and assess 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 to the product classes covered by 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), which is the sum of discounted industry annual cash-flows over the analysis period. The model estimates the financial impact of more stringent energy conservation standards by comparing changes in INPV between a base case and the various 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 dehumidifier manufacturing 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 Model and Interview Guide," DOE created a framework GRIM to analyze the economic impact of amended energy conservation standards on the residential dehumidifier manufacturing industry as a whole. The DOE also developed a manufacturer interview guide to gather additional information on the potential impacts on manufacturers in Phase III.

In Phase III, "Subgroup Impact Analysis," DOE interviewed manufacturers representing an estimated 70 percent of the residential dehumidifier market. Interviewees included manufacturers with various market shares and product focus, providing a representative cross-section of the industry. During interviews, DOE discussed financial topics specific to each manufacturer and obtained each manufacturer's view of the 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 dehumidifier industry that built upon the market and technology assessment prepared for this rulemaking. (See chapter 3 of this NOPR 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 SEC 10–K filings,[a] Standard & Poor's (S&P) 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 Model and Interview Guide

Phase II focused on the financial impacts of amended energy conservation standards on the residential dehumidifier manufacturing 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 created a framework GRIM to analyze the economic impact of amended energy conservation standards on the residential dehumidifier manufacturing industry as a whole. In preparing the GRIM, DOE used the financial values derived during Phase I and the shipment assumptions from the NIA. Additionally, DOE prepared a written guide for manufacturer interviews to collect additional data critical to developing other inputs for the GRIM.

#### 12.2.2.1 Industry Cash-Flow Analysis

The GRIM uses several factors to determine a series of annual cash flows over a period from the announcement year of the amended energy conservation standards until 30 years after the standards' compliance date. INPV is the sum of these annual cash flows discounted by the industry weighted average cost of capital. Inputs to the GRIM include the manufacturing costs, markups, and shipment forecasts developed in other analyses as well as the industry weighted average financial parameters developed in Phase I. DOE derived the manufacturing costs from the engineering analysis as presented in chapter 5 of this NOPR TSD, information provided by the industry, publicly available financial reports, and interviews with manufacturers. To examine the range of possible impacts, DOE developed alternative markup scenarios based on discussions

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[a] Available online at *www.sec.gov*.
[b] Available online at *www2.standardandpoors.com*.

with manufacturers. DOE's shipments analysis, presented in chapter 9 of the NOPR TSD, provided the basis for the shipment projections. DOE derived the financial parameters using publicly available reports and revised them using information received during confidential manufacturer interviews. DOE used the GRIM to compare 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 Guide

During Phase III of the MIA, DOE interviewed manufacturers of residential dehumidifiers 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 an interview guide to representatives of each participating manufacturer. The interview guide 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. The information DOE received from these meetings is protected by non-disclosure agreements and resides with DOE's contractors. The topics covered as part of these interviews include (1) key issues related to this rulemaking; (2) engineering and life cycle cost; (3) manufacturer markups and profitability; (4) financial parameters; and (5) conversion costs. The interview guide is presented in appendix 12A of this NOPR TSD.

### 12.2.3 Phase III: Subgroup Analysis

While conducting the MIA, DOE interviewed a representative cross-section of residential dehumidifier manufacturers. The MIA interviews broadened the discussion to include business-related topics. DOE sought to isolate key issues and concerns, to obtain feedback from industry on the approaches used in the GRIM, and to identify key manufacturer subgroups for 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 the GRIM to reflect the unique financial characteristics of the residential dehumidifier manufacturing industry. 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, as they help to 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 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 model 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 is not adequate for assessing differential impacts among subgroups of manufacturers. Small, low-volume manufacturers, or manufacturers exhibiting a cost structure that differs significantly from the industry average could be more negatively affected. Ideally, DOE would consider the impact on every manufacturer individually; however, it typically uses the results of the industry characterization to group manufacturers exhibiting similar characteristics. During the interview process, DOE discussed the potential subgroups and subgroup members that have been identified for the analysis. DOE looked to the manufacturers and other stakeholders to suggest what subgroups or characteristics are the most appropriate for the analysis.

***Small-Business Manufacturers***

DOE used the SBA small business size standards as amended by the Office of Management and Budget on January 1, 2012, and effective January 7, 2013, and the 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 including the total employee count of a parent company and its subsidiaries. An aggregated business entity with fewer employees than the listed limit is considered a small business.

As there is currently an energy conservation standard for residential dehumidifiers, DOE used its own publically available CCMS database[1] as a starting point to identify manufacturers of residential dehumidifiers. Additionally, DOE used public certification databases provided by the CEC[2] and ENERGY STAR[3] to identify residential dehumidifier manufacturers. DOE then checked this list of residential dehumidifier manufacturers against the employee limit for small businesses using reports from vendors such as Dun & Bradstreet. DOE also consulted publicly available data from the 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.

Based on the size standards published by the SBA (65 FR 30840 (May 15, 2000), as amended at 67 FR 52602 (Aug. 13, 2002); 74 FR 46313 (Sep. 9, 2009)), to be categorized as a small business manufacturer of residential dehumidifiers under NAICS codes 333415 ("Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing") or 335210 ("Small Electrical Appliance Manufacturing"), a

[c] The size standards are available on the SBA's website at www.sba.gov/content/table-small-business-size-standards.

dehumidifier manufacturer and its affiliates may employ a maximum of 750 employees. The 750-employee threshold includes all employees in a business' parent company and any other subsidiaries. Using this classification in conjunction with a search of industry databases and the SBA member directory, DOE identified five manufacturers of residential dehumidifiers that qualify as small businesses, all of which are manufacturers of whole-home and high-capacity portable dehumidifiers.

**Table 12.2.1 SBA and NAICS Classification of Small Businesses Potentially Affected by This Rulemaking**

| Industry Description | Revenue Limit | Employee Limit | NAICS |
|---|---|---|---|
| Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing | N/A | 750 | 333415 |
| Small Electrical Appliance Manufacturing | N/A | 750 | 335210 |

The analysis of impacts on the small business manufacturer subgroup is found in section 12.6.

#### 12.2.3.4 Manufacturing Capacity Impact

One possible outcome of amended energy conservation standards is the obsolescence of existing manufacturing assets, including tooling and production equipment. The manufacturer interview guide contains 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 annual cash flow projections in the GRIM. 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.

#### 12.2.3.5 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 dehumidifier 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.

#### 12.2.3.6 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects of regulation on manufacturers of residential dehumidifiers. These effects may be the result of other regulatory actions affecting residential dehumidifiers, or of amended energy conservation standards for other products and equipment made by the same manufacturers. DOE identified regulations relevant to residential dehumidifier manufacturers using its own research and discussions with manufacturers. A discussion of the cumulative regulatory burden of energy conservation standards and the impact on manufacturers of multiple, product-specific regulatory actions 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 this energy conservation standards 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 cited for all product classes under review.

### 12.3.1 Consumer Confusion

The majority of manufacturers interviewed emphasized concerns over the impact of new test conditions in the DOE dehumidifier test procedure on the rated capacity of their products. One manufacturer noted that lower ambient testing conditions would lead to a 60-percent to 70-percent decrease in capacity and efficiency. Some manufacturers fear that a shift in rated capacity resulting from a change in test procedure will lead to confusion in the market, as consumers find it important to have the same apparent capacity in a replacement residential dehumidifier, even if it is simply a larger unit at a lower rating condition. Also, dehumidifiers with smaller capacities cannot reach the same efficiency as higher-capacity units due to limitations of the vapor-compression cycle, because the parasitic losses make it harder to maintain efficiency with smaller compressors. One manufacturer estimated that a multi-million dollar investment would be necessary to redesign products that would maintain customer perception of rated capacities. That manufacturer went on to note that if it is unable to produce comparable products at the same effective capacity, it would consider exiting the market.

Other manufacturers indicated that as product ratings are modified to reflect the test results at the lower ambient temperature, the whole product classification system will need to be revisited, which will require a substantial investment in consumer education.

### 12.3.2 Consumer Utility

Multiple manufacturers interviewed expressed concerns that an amended energy conservation standard for residential dehumidifiers would have an adverse impact on price, noise level, and size, and would thus compromise consumer utility. Manufacturers are concerned that residential dehumidifiers would need to become physically larger to deliver the same moisture removal capacity to comply with new amended testing and energy conservation standards. For customers with space constraints, finding a product that best fits their needs may be more difficult under an amended standard. For example, some whole-home dehumidifiers must fit into a small attic or crawl space. If amended energy conservation standards for whole-home products cannot be met within the size constraints associated with this type of installation, part of the whole-home market segment may move to portable products, reducing consumer utility by forcing the unit into the living space. Additionally, larger portable dehumidifiers are already cumbersome to move around, making them close to the limit of what is considered portable. As such, consumers may be forced to purchase a lower-capacity dehumidifier or alternative product.

### 12.3.3 Impacts on Profitability

During interviews, many manufacturers stated that an industry-wide price increase of 25 percent would have major negative impacts on the portable dehumidifier market. Manufacturers went on to note that a price increase of 50 percent or more would cause the market to collapse entirely. A whole-home dehumidifier manufacturer stated that a 10-percent cost increase would have a significant impact on the whole-home market because any increases in manufacturer production costs are magnified due to the two-tiered distribution channel that is characteristic of the whole-home market. Among manufacturers, it was agreed that consumers find a product's price to be the most important aspect when considering dehumidifier purchases. Relatedly, one manufacturer suggested that as prices increase, consumers may opt to rent units as needed, instead of buying one. Accordingly, manufacturers expect a negative impact on profitability as revenues decline following any amended energy conservation standard which would raise prices for residential dehumidifiers. Similar impacts on profitability are expected if manufacturers maintain current prices while absorbing the higher costs associated with the design and manufacture of higher efficiency products.

### 12.3.4 Impacts on Small Businesses

One small manufacturer noted that it and its competitors in the whole-home segment would be disproportionately impacted by an amended energy conservation standard. Small business manufacturers have fewer human and capital resources than larger, more diversified portable unit manufacturers. Additionally, due the low-volume nature of the residential whole-home dehumidifier market, small business manufacturers of whole-home products are disadvantaged in achieving the scale needed to exert purchasing power in sourcing components from vendors. One small business manufacturer noted that its lack of influence on suppliers ultimately impacts its ability to compete with larger manufacturers.

## 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, the need for additional investments, and changes in associated margins. The GRIM spreadsheet uses a number of inputs to arrive at a series of annual cash flows, beginning with the base year, 2015, and continuing to 2048, 30 years after the compliance year of the rulemaking. The model calculates the INPV by summing the stream of annual discounted cash flows during this period.[4]

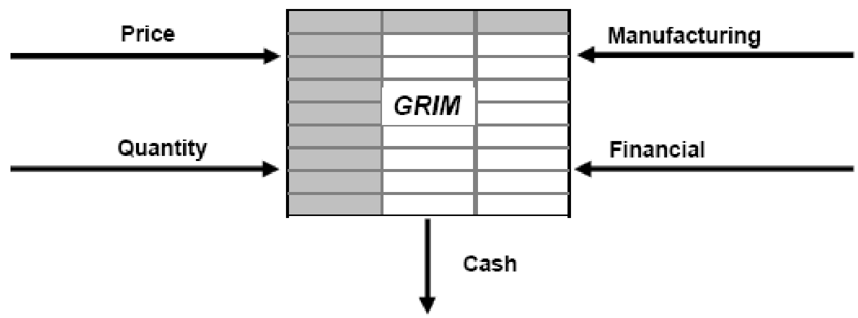


**Figure 12.4.1 Using the GRIM to Calculate Cash Flow**

The GRIM projects cash flows using standard accounting principles and compares INPV between the base-case and the standard-case scenarios. The difference in INPV between the base case and the standard case(s) represents the estimated financial impact of the amended energy conservation standards on manufacturers. Appendix 12B provides more technical details and user information for the GRIM.

### 12.4.2 Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, 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 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 whose combined product range includes residential dehumidifiers. As these companies do not provide detailed information about their individual product lines, DOE used the aggregate financial information at the corporate level in developing its initial estimates of the financial parameters to be used in the GRIM. In doing so, DOE assumes that the industry-average figures calculated for these companies were representative of manufacturing for residential dehumidifiers. These figures were later revised using feedback from interviews to be representative of the residential dehumidifier manufacturing industry. 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; and
- Net PPE.

#### 12.4.2.2 Standard and Poor's Credit Ratings

S&P provides independent credit ratings, research, and financial information. DOE relied on S&P reports to determine the industry's average cost of debt when calculating the weighted average cost of capital.

#### 12.4.2.3 Shipment Model

The GRIM used shipment projections derived from DOE's shipments model in the NIA. The model relied on historical shipments data for residential dehumidifiers. Chapter 10 of the NOPR TSD describes the methodology and analytical model DOE used to forecast shipments.

#### 12.4.2.4 Engineering Analysis

DOE conducted the engineering analysis for this rulemaking using the efficiency-level approach, combined with the cost-assessment approach, to develop a cost for each efficiency level for residential dehumidifiers. During this analysis, DOE used a manufacturing cost model to develop MPC estimates for residential dehumidifiers. 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 MSP for each product at every efficiency level. Chapter 5 of the NOPR TSD describes the engineering analysis in detail.

#### 12.4.2.5 Manufacturer Interviews

As part of the MIA, DOE conducted interviews with a representative cross-section of manufacturers. Through these discussions, DOE obtained information to determine and verify GRIM input assumptions. Key topics discussed during the interviews and reflected in the GRIM include:

- Capital conversion costs (one-time investments in PPE);
- Product conversion costs (one-time investments in research, product development, testing, and marketing);
- Product cost structure, 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 2006 to 2012 for four publicly held manufacturers of residential dehumidifiers as a starting point for determining the residential dehumidifier industry financial parameters. The industry financial parameters were determined by weighting each manufacturer's individual financial parameters by their respective estimated market share, and correcting for the fraction of the market that was not represented. Table 12.4.1 below shows the data used to determine the initial financial parameter estimates.

**Table 12.4.1 Financial Parameters based on 2006–2012 Weighted Company Financial Data**

| Parameter | Industry Weighted Average | Manufacturer A | Manufacturer B | Manufacturer C | Manufacturer D |
|---|---|---|---|---|---|
| Tax Rate *(% of Taxable Income)* | 31.1 | 38.1 | 33.7 | 19.2 | 29.0 |
| Working Capital *(% of Revenue)* | 11.3 | 44.5 | 19.8 | 5.9 | -4.5 |
| SG&A *(% of Revenue)* | 20.9 | 30.3 | 26.6 | 19.6 | 16.0 |
| R&D *(% of Revenue)* | 1.3 | 0.0 | 2.2 | 0.7 | 1.8 |
| Depreciation *(% of Revenue)* | 2.5 | 2.0 | 2.8 | 0.7 | 2.9 |
| Capital Expenditures *(% of Revenue)* | 2.7 | 2.5 | 2.4 | 0.3 | 3.2 |
| Net Property, Plant, and Equipment *(% of Revenues)* | 13.4 | 13.6 | 12.9 | 5.8 | 14.7 |

During interviews, manufacturers were asked to provide their own figures for the parameters listed in Table 12.4.1. Where applicable, DOE adjusted the financial parameters according to the manufacturers' feedback.

### 12.4.4 Corporate Discount Rate

A company's assets are financed by a combination of debt and equity, and the weighted average cost of capital (WACC) represents the minimum rate of return necessary to cover the debt and equity obligations manufacturers use to finance operations. The WACC is the total cost of debt and equity weighted by their respective proportions in the capital structure of the company.

DOE estimated the WACC for the residential dehumidifier manufacturing industry based on three representative companies, using the following formula:

WACC = After-Tax Cost of Debt × (Debt Ratio) + Cost of Equity × (Equity Ratio)

The cost of equity is the rate of return that equity investors (including, potentially, the company) expect to earn on a company's stock. These expectations are reflected in the market price of the company's stock. The capital asset pricing model (CAPM) provides one widely used means to estimate the cost of equity. According to the CAPM, the cost of equity (expected return) is:

Cost of Equity = Risk-free Rate of Return + β x Risk Premium

where:

*Risk-free rate of return* is the rate of return on a "safe" benchmark investment, typically considered the short-term Treasury Bill (T-Bill) yield. In practice, investors use a variety of different maturity T-Bills to estimate the risk-free rate. DOE used the 10-year T-Bill return because it captures long-term inflation expectations and is less volatile than short-term rates. The risk-free rate is estimated to be approximately 5.2 percent, which is the average 10-year T-Bill return between 1928 and 2012.

*Risk premium* is the difference between the expected return on stocks and the risk-free rate of return. DOE used the average annual return on the S&P 500 between 1928 and 2012 as the expected return on stocks to arrive at an estimated market risk premium of 6.1 percent.

*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. Values for Beta are only available for publicly traded companies.

DOE used the capital asset pricing model to calculate the cost of equity for four publicly-held residential dehumidifier manufacturers. DOE determined that the industry-average cost of equity for the residential dehumidifier industry is 13.5 percent (see Table 12.4.2).

**Table 12.4.2 Cost of Equity Calculation**

| Parameter | Industry Weighted Average | Manufacturer A | Manufacturer B | Manufacturer C | Manufacturer D |
|---|---|---|---|---|---|
| **(a) Average Beta** | 1.37 | 0.91 | 1.08 | 1.38 | 1.62 |
| **(b) Yield on 10 Year T-Bill (1928–2012) (%)** | 5.16 | | | | |
| **(c) Market Risk Premium (1928–2012) (%)** | 6.10 | | | | |
| **Cost of Equity (b) + [(a)*(c)] (%)** | 13.51 | | | | |
| **Equity/Total Capital (%)** | 78.20 | 86.97 | 72.73 | 86.47 | 73.33 |

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 four manufacturers by using S&P and other estimates of corporate credit ratings and adding the relevant spread to the risk-free rate.

Because 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. DOE determined that the after-tax industry-average cost of debt for the residential dehumidifier industry is 4.4 percent. 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 | Manufacturer B | Manufacturer C | |
|---|---|---|---|---|---|
| **S&P Bond Rating** | | AA | AA | AAA | BBB |
| **(a) Yield on 10 year T-Bill (1927–2011) (%)** | 5.16 | | | | |
| **(b) Gross Cost of Debt (%)** | 6.33 | 5.81 | 5.81 | 5.66 | 6.76 |
| **(c) Tax Rate (%)** | 31.09 | 38.05 | 33.70 | 22.38 | 29.01 |
| **Net Cost of Debt (b) x[1-(c)] (%)** | 4.36 | | | | |
| **Debt/Total Capital (%)** | 21.80 | 13.03 | 27.27 | 13.53 | 26.67 |

Correcting for an inflation rate of 3.1 percent over the analysis period, DOE's calculated value for the residential dehumidifier industry's inflation-adjusted WACC and the initial estimate of the discount rate is 8.4 percent. During interviews, DOE did not receive any feedback from manufacturers regarding this estimate of the discount rate.

### 12.4.5 Trial Standard Levels

DOE developed TSLs to analyze the impact on manufacturers of amended energy efficiency standards for the five product classes of residential dehumidifiers. Table 12.4.4 presents the TSLs and the corresponding product class efficiency levels based on IEF. See chapter 5 of this NOPR TSD for a discussion of product classes and IEF.

TSL 4 is comprised of the max-tech efficiency levels for all product classes. TSL 3 is comprised of the efficiency level corresponding to one below the max-tech level for all product classes. TSL 2 is comprised of Efficiency Level 2 for all product classes, except where Efficiency Level 2 is also the max-tech level (*i.e.* for product class 4—with only two efficiency levels—TSL 2 corresponds to Efficiency Level 1). TSL 1 is comprised of Efficiency Level 1 for each product class.

**Table 12.4.4 Trial Standard Levels for Residential Dehumidifiers**

| Product class | | Base Case | TSL 1 | TSL 2 | TSL 3 | TSL 4 |
|---|---|---|---|---|---|---|
| **Portable ≤ 30.00 pints/day** | Efficiency Level | Baseline | EL 1 | EL 2 | EL 3 | EL 4 |
| | IEF at 65 °F | 0.77 | 1.10 | 1.20 | 1.30 | 1.57 |
| **Portable 30.01–45.00 pints/day** | Efficiency Level | Baseline | EL 1 | EL 2 | EL 3 | EL 4 |
| | IEF at 65 °F | 0.94 | 1.20 | 1.40 | 1.60 | 1.80 |
| **Portable > 45.00 pints/day** | Efficiency Level | Baseline | EL 1 | EL 2 | EL 2 | EL 3 |
| | IEF at 65 °F | 2.07 | 2.40 | 2.80 | 2.80 | 3.66 |
| **Whole-Home ≤ 8.0 $ft^3$** | Efficiency Level | Baseline | EL 1 | EL 1 | EL 1 | EL 2 |
| | IEF at 73 °F | 1.77 | 2.09 | 2.09 | 2.09 | 2.53 |
| **Whole-Home > 8.0 $ft^3$** | Efficiency Level | Baseline | EL 1 | EL 2 | EL 2 | EL 3 |
| | IEF at 73 °F | 2.41 | 2.70 | 3.52 | 3.52 | 4.50 |

### 12.4.6 NIA Shipment Forecast

The GRIM estimates manufacturer revenues based on total-unit-shipment 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 residential dehumidifier shipment data from the NIA. Chapter 9 of the NOPR TSD explains DOE's calculations of total shipments in detail.

Table 12.4.5 shows total shipments forecasts for each product class of residential dehumidifiers in 2019, the year new standards for residential dehumidifiers would take effect.

**Table 12.4.5 Total Base-Case 2019 NIA Shipments**

| Product class | Total Industry Shipments |
|---|---|
| **Portable ≤ 30.00 pints/day** | 1,052,023 |
| **Portable 30.01–45.00 pints/day** | 857,947 |
| **Portable > 45.01 pints/day** | 69,664 |
| **Whole-Home ≤ 8.0 $ft^3$** | 13,361 |
| **Whole-Home > 8.0 $ft^3$** | 5,727 |

### 12.4.6.1 Base-Case Shipments Forecast

As part of the shipment analysis, DOE estimated the distribution of shipments by efficiency level for each product class of residential dehumidifiers. DOE held the base-case energy efficiency distribution constant throughout the forecast period. Table 12.4.6 through Table 12.4.10 show the base-case distributions of shipments by efficiency level estimated in the NIA for the residential dehumidifier product classes.

**Table 12.4.6 Base-Case Distribution of Efficiencies for Portable Dehumidifiers, ≤ 30.00 pints/day, in 2019**

| Efficiency Level | Baseline | EL 1 | EL 2 | EL 3 | EL 4 |
|---|---|---|---|---|---|
| **IEF** | 0.77 | 1.10 | 1.20 | 1.30 | 1.57 |
| **% of Shipments** | 10.7% | 22.9% | 0.0% | 66.4% | 0.0% |

**Table 12.4.7 Base-Case Distribution of Efficiencies for Portable Dehumidifiers, 30.01 to 45.00 pints/day, in 2019**

| Efficiency Level | Baseline | EL 1 | EL 2 | EL 3 | EL 4 |
|---|---|---|---|---|---|
| **IEF** | 0.94 | 1.20 | 1.40 | 1.60 | 1.80 |
| **% of Shipments** | 0.0% | 0.0% | 94.3% | 2.0% | 3.7% |

**Table 12.4.8 Base-Case Distribution of Efficiencies for Portable Dehumidifiers, > 45.00 pints/day, in 2019**

| Efficiency Level | Baseline | EL 1 | EL 2 | EL 3 |
|---|---|---|---|---|
| **IEF** | 2.07 | 2.40 | 2.80 | 3.66 |
| **% of Shipments** | 57.1% | 20.1% | 22.9% | 0.0% |

**Table 12.4.9 Base-Case Distribution of Efficiencies for Whole-Home Dehumidifiers ≤ 8.0 $ft^3$, in 2019**

| Efficiency Level | Baseline | EL 1 | EL 2 |
|---|---|---|---|
| IEF | 1.77 | 2.09 | 2.53 |
| % of Shipments | 74.9% | 25.1% | 0.0% |

**Table 12.4.10 Base-Case Distribution of Efficiencies for Whole-Home Dehumidifiers > 8.0 $ft^3$, in 2019**

| Efficiency Level | Baseline | EL 1 | EL 2 | EL 3 |
|---|---|---|---|---|
| IEF | 2.41 | 2.70 | 3.52 | 4.50 |
| % of Shipments | 30.9% | 46.3% | 22.9% | 0.0% |

#### 12.4.6.2 Standards-Case Shipments Forecast

To examine the impact of amended energy conservation standards on shipments, which in turn affects the INPV, DOE used the base-case shipments described in the previous section as a point of comparison for shipments forecast in the standards case. For each TSL described in the standards case, DOE used the shipments forecasts developed in the NIA for residential dehumidifiers. The portion of shipments for products that fall below the amended energy conservation standards are assumed to "roll-up" to the new standards efficiency level for a given product class on the compliance date[d] and thereafter.

As in the shipments analysis, DOE assumed no relative price elasticity in the residential dehumidifier market, meaning that amended energy conservation standards that increase the first cost of residential dehumidifiers would lead to no change the number of total shipments.

### 12.4.7 Production Costs

Changes in the MPCs of residential dehumidifiers can affect revenues, gross margins, and cash flow of the industry, making product cost data key GRIM inputs for DOE's analysis. In the engineering analysis, DOE created separate cost curves for the five residential dehumidifier product classes using data from tear-downs to develop both the baseline MPCs and the incremental costs that correspond to the proposed design options. Generally, manufacturing higher efficiency products is more costly than manufacturing baseline products due to the use of more complex components.

The cost model disaggregated the MPCs at each efficiency level into material, labor, overhead, and depreciation. For materials, DOE used the incremental component and raw material costs that correspond to the proposed design options at each efficiency level. For labor, DOE estimated the labor contribution at each efficiency level by examining how the proposed design options may influence manufacturing and assembly practices. For depreciation, DOE used a depreciation value that is consistent with historical information in SEC 10-Ks. The

[d] The estimated compliance date for the residential dehumidifier energy conservation standard is 2019.

remainder of total overhead was allocated to factory overhead.

Later, manufacturers validated these estimates and assumptions during interviews. DOE used the resulting MPCs and cost breakdowns as described in section 12.4.2.4 above, and further detailed in chapter 5 of the NOPR TSD, for each efficiency level analyzed in the GRIM.

The MSP is comprised of production costs (the direct manufacturing costs or MPCs), non-production costs (indirect costs including SG&A), and profit. DOE calculated the MSPs for residential dehumidifiers by multiplying the MPCs by the appropriate manufacturer markup for that product. Table 12.4.11 through Table 12.4.15 show the production cost estimates used in the GRIM for the representative product classes for residential dehumidifiers.

**Table 12.4.11 MPC Breakdown for Product Class 1 – Portable Dehumidifiers, ≤ 30.00 pints/day**

| EL | IEF | Materials | Labor | Depreciation | Overhead | MPC | Mfr. Markup | MSP |
|---|---|---|---|---|---|---|---|---|
| EL1 | 1.10 | $98.12 | $3.75 | $4.05 | $7.49 | $113.41 | 1.45 | $164.44 |
| EL2 | 1.20 | $99.81 | $3.75 | $4.11 | $7.43 | $115.09 | 1.45 | $166.88 |
| EL3 | 1.30 | $102.37 | $3.76 | $4.20 | $7.34 | $117.66 | 1.45 | $170.61 |
| EL4 | 1.57 | $117.54 | $3.73 | $4.74 | $6.78 | $132.79 | 1.45 | $192.54 |

**Table 12.4.12 MPC Breakdown for Product Class 2 - Portable Dehumidifiers, 30.01 to 45.00 pints/day**

| EL | IEF | Materials | Labor | Depreciation | Overhead | MPC | Mfr. Markup | MSP |
|---|---|---|---|---|---|---|---|---|
| EL1 | 1.20 | $117.89 | $4.26 | $4.86 | $9.38 | $136.39 | 1.45 | $197.76 |
| EL2 | 1.40 | $120.30 | $4.25 | $4.95 | $9.27 | $138.77 | 1.45 | $201.22 |
| EL3 | 1.60 | $126.00 | $4.25 | $5.15 | $9.07 | $144.47 | 1.45 | $209.48 |
| EL4 | 1.80 | $140.26 | $4.31 | $5.66 | $8.57 | $158.81 | 1.45 | $230.27 |

**Table 12.4.13 MPC Breakdown for Product Class 3 - Portable Dehumidifiers, > 45.00 pints/day**

| EL | IEF | Materials | Labor | Depreciation | Overhead | MPC | Mfr. Markup | MSP |
|---|---|---|---|---|---|---|---|---|
| EL1 | 2.40 | $312.20 | $88.75 | $16.83 | $53.94 | $471.71 | 1.45 | $683.98 |
| EL2 | 2.80 | $321.63 | $90.03 | $17.21 | $53.68 | $482.55 | 1.45 | $699.69 |
| EL3 | 3.66 | $357.42 | $108.12 | $19.59 | $64.11 | $549.24 | 1.45 | $796.39 |

**Table 12.4.14 MPC Breakdown for Product Class 4 - Whole-Home Dehumidifiers ≤ 8.0 $ft^3$**

| EL | IEF | Materials | Labor | Depreciation | Overhead | MPC | Mfr. Markup | MSP |
|---|---|---|---|---|---|---|---|---|
| EL1 | 2.09 | $267.49 | $80.03 | $14.73 | $50.79 | $413.04 | 1.45 | $598.91 |
| EL2 | 2.53 | $369.34 | $84.39 | $18.80 | $54.44 | $526.96 | 1.45 | $764.09 |

**Table 12.4.15 MPC Breakdown for Product Class 5 - Whole-Home Dehumidifiers > 8.0 $ft^3$**

| EL | IEF | Materials | Labor | Depreciation | Overhead | MPC | Mfr. Markup | MSP |
|---|---|---|---|---|---|---|---|---|
| EL1 | 2.70 | $364.53 | $103.21 | $19.41 | $57.01 | $544.16 | 1.45 | $789.03 |
| EL2 | 3.52 | $390.63 | $107.70 | $20.52 | $56.31 | $575.16 | 1.45 | $833.98 |
| EL3 | 4.50 | $496.10 | $120.03 | $24.95 | $58.28 | $699.35 | 1.45 | $1,014.06 |

### 12.4.8 Conversion Costs and Stranded Assets

Amended energy conservation standards typically cause manufacturers to incur one-time conversion costs to bring their production facilities and equipment designs into compliance with new regulations. For the MIA, DOE classified these one-time conversion costs into two major groups: product conversion costs and capital conversion costs. Product conversion costs are investments in research, development, testing, marketing, and other non-capitalized costs focused on making equipment designs that comply with the amended energy conservation standard. Capital conversion costs are investments in property, plant, and equipment needed to adapt or change existing production facilities so that new equipment designs can be fabricated and assembled. In the instance where changes to energy conservation standards result in the obsolescence of manufacturing capital, the un-depreciated value of any obsolete equipment is considered a stranded asset. In addition to product and capital conversion costs, stranded assets also factor into the GRIM's calculation of annual cash flows. The following sections describe the inputs DOE used in the GRIM in greater detail.

#### 12.4.8.1 Residential Dehumidifier Conversion Costs

DOE based its estimates of the conversion costs required to meet each TSL on confidential information received during manufacturer interviews. DOE asked manufacturers to estimate their investments in product development and new manufacturing capital and their anticipated stranded capital assets at various efficiency levels. DOE then reviewed public information in the DOE CCMS, CEC, and ENERGY STAR product databases, as well as manufacturer websites to understand which products manufacturers would need to upgrade at each efficiency level. DOE mapped manufacturers' estimates of investments and stranded assets to a composite database of products to disaggregate their reporting and allocate the estimated costs across the various product classes and efficiency levels that each representative company manufactures. From this, DOE also developed an average cost estimate to bring non-compliant products in each product class into compliance at each efficiency level. DOE applied these average cost estimates to the remaining products in the database to arrive the compliance costs required by the remainder of industry. These figures were then added to the disaggregated estimates of individual manufacturer conversion costs to arrive at a total industry estimate of product and capital conversion costs and stranded assets for each efficiency level of each product class.

Table 12.4.16 through Table 12.4.25 show DOE's estimates of the product and capital conversion costs necessary for each residential dehumidifier product class at each efficiency level identified. None of the manufacturers interviewed provided comment regarding potential stranded assets.

**Table 12.4.16 Product Conversion Costs for Product Class 1 – Portable Dehumidifiers, ≤ 30.00 pints/day by EL**

| **EL (IEF)** | **Product Conversion Costs** *(Millions 2013$)* |
|---|---|
| EL1 (1.10) | $0.02 |
| EL2 (1.20) | $0.02 |
| EL3 (1.30) | $9.20 |
| EL4 (1.57) | $15.20 |

**Table 12.4.17 Product Conversion Costs for Product Class 2 - Portable Dehumidifiers, 30.01 to 45.00 pints/day by EL**

| **EL (IEF)** | **Product Conversion Costs** *(Millions 2013$)* |
|---|---|
| EL1 (1.20) | $0.03 |
| EL2 (1.40) | $0.03 |
| EL3 (1.60) | $16.00 |
| EL4 (1.80) | $26.30 |

**Table 12.4.18 Product Conversion Costs for Product Class 3 - Portable Dehumidifiers, > 45.00 pints/day by EL**

| **EL (IEF)** | **Product Conversion Costs** *(Millions 2013$)* |
|---|---|
| EL1 (2.4) | $1.43 |
| EL2 (2.8) | $2.29 |
| EL3 (3.66) | $2.33 |

**Table 12.4.19 Product Conversion Costs for Product Class 4 - Whole-Home Dehumidifiers ≤ 8.0 $ft^3$ by EL**

| **EL (IEF)** | **Product Conversion Costs** *(Millions 2013$)* |
|---|---|
| EL1 (2.09) | $0.56 |
| EL2 (2.53) | $1.97 |

**Table 12.4.20 Product Conversion Costs for Product Class 5 - Whole-Home Dehumidifiers > 8.0 ft$^3$ by EL**

| EL (IEF) | **Product Conversion Costs** *(Millions 2013$)* |
|---|---|
| EL1 (2.70) | $1.88 |
| EL2 (3.52) | $2.16 |
| EL3 (4.50) | $2.34 |

**Table 12.4.21 Capital Conversion Costs for Product Class 1 – Portable Dehumidifiers, ≤ 30.00 pints/day by EL**

| EL (IEF) | **Capital Conversion Costs** *(Millions 2013$)* |
|---|---|
| EL1 (1.10) | $0.00 |
| EL2 (1.20) | $0.00 |
| EL3 (1.30) | $6.90 |
| EL4 (1.57) | $11.30 |

**Table 12.4.22 Capital Conversion Costs for Product Class 2 - Portable Dehumidifiers, 30.01 to 45.00 pints/day by EL**

| EL (IEF) | **Capital Conversion Costs** *(Millions 2013$)* |
|---|---|
| EL1 (1.20) | $0.00 |
| EL2 (1.40) | $0.00 |
| EL3 (1.60) | $11.90 |
| EL4 (1.80) | $19.60 |

**Table 12.4.23 Capital Conversion Costs for Product Class 3 - Portable Dehumidifiers, > 45.00 pints/day by EL**

| EL (IEF) | **Capital Conversion Costs** *(Millions 2013$)* |
|---|---|
| EL1 (2.4) | $0.48 |
| EL2 (2.8) | $0.76 |
| EL3 (3.66) | $0.78 |

**Table 12.4.24 Capital Conversion Costs for Product Class 4 - Whole-Home Dehumidifiers ≤ 8.0 ft$^3$ by EL**

| EL (IEF) | **Capital Conversion Costs** *(Millions 2013$)* |
|---|---|
| EL1 (2.09) | $0.19 |
| EL2 (2.53) | $0.66 |

**Table 12.4.25 Capital Conversion Costs for Product Class 5 - Whole-Home Dehumidifiers > 8.0 $ft^3$ by EL**

| EL (IEF) | Capital Conversion Costs *(Millions 2013$)* |
|---|---|
| EL1 (2.70) | $0.63 |
| EL2 (3.52) | $0.72 |
| EL3 (4.50) | $0.78 |

### 12.4.9 Markup Scenarios

MSPs include direct manufacturing production costs (*i.e.*, labor, material, overhead, and depreciation estimated in DOE's MPCs) and all non-production costs (*i.e.*, SG&A, R&D, and interest), along with profit. To calculate the MSPs in the GRIM, DOE applied manufacturer markups to the MPCs estimated in the engineering analysis. Based on publicly available financial information for manufacturers of residential dehumidifiers and comments from manufacturer interviews, DOE assumed the industry average base-case markup on production costs to be 1.45. This markup takes into account the two-tiered sourcing structure of the small portable dehumidifier segment, in addition to the traditional one-tiered structure of the high-capacity portable and whole-home dehumidifier segment. The majority of the market for the lower-capacity portable product classes (product classes 1 and 2) are manufactured under contract by overseas OEMs. The engineering analysis, as detailed in chapter 5 of the NOPR TSD, estimates the cost of manufacturing at the OEM level. These production costs are marked up once by the OEM to the company contracting its manufacture and again by the contracting company who imports the product, and sells it to "big box" stores or other retailers. For the small portable dehumidifier segment, the industry average baseline markup breaks down as follows:

**Table 12.4.26 Industry Average Baseline Markups**

| | |
|---|---|
| OEM to Contracting Company Markup | 1.20 |
| Contracting Company to First Customer Markup | 1.21 |
| Overall OEM to First Customer Markup | 1.45 |

In the standards case, DOE modeled two markup scenarios to represent the uncertainty about the potential impacts on prices and profitability following the implementation of amended energy conservation standards: (1) a preservation of gross margin percentage markup scenario, and (2) a preservation of per-unit operating profit markup scenario. Modifying these markups from the base case to the standards cases yields different sets of impacts on manufacturers by changing industry revenue and cash flow.

#### 12.4.9.1 Preservation of Gross Margin Percentage Markup Scenario

The preservation of gross margin percentage markup scenario assumes that the baseline markup of 1.45 is maintained for all products in the standards case. As production costs increase with efficiency, this scenario implies that the absolute dollar markup will increase as well. This scenario represents the upper bound of industry profitability as manufacturers are able to fully mark up and pass through higher production costs to their customers.

#### 12.4.9.2 Preservation of Per-Unit Operating Profit Markup Scenario

DOE also modeled the preservation of per-unit operating profit markup scenario to estimate a lower bound of profitability for the industry. This is similar to the preservation of gross margin percentage markup scenario with the exception that in the standards case, minimally compliant products lose a fraction of the baseline markup. The lower markup for minimally compliant products is derived by calibrating the markup for minimally compliant products such that industry-wide per-unit operating profit in the year after standards go into effect matches per-unit operating profit of the same year in the base case. This scenario represents a more substantial impact to the residential dehumidifier industry in the form of reduced gross margin percentage as manufacturers vie to maintain the lowest possible prices for marginally compliant products while securing the same level of per-unit operating profit they saw prior to new and amended standards.

While all compliant products receive the 1.45 markup in the preservation of gross margin percentage markup scenario, Table 12.4.27 through Table 12.4.31 list the calibrated markups used in the preservation of per-unit operating profit markup scenario.

**Table 12.4.27 Preservation of Per-Unit Operating Profit Markups for Product Class 1: Portable Dehumidifiers, ≤ 30.00 pints/day**

| EL | IEF | Minimally Compliant EL | | | |
|---|---|---|---|---|---|
| | | EL 1 | EL 2 | EL 3 | EL4 |
| EL 1 | 1.10 | 1.449 | | | |
| EL 2 | 1.20 | 1.450 | 1.448 | | |
| EL 3 | 1.30 | 1.450 | 1.450 | 1.449 | |
| EL 4 | 1.57 | 1.450 | 1.450 | 1.450 | 1.436 |

**Table 12.4.28 Preservation of Per-Unit Operating Profit Markups for Product Class 2: Portable Dehumidifiers, 30.01 to 45.00 pints/day Residential Dehumidifiers**

| EL | IEF | Minimally Compliant EL | | | |
|---|---|---|---|---|---|
| | | EL 1 | EL 2 | EL 3 | EL4 |
| EL 1 | 1.20 | 1.450 | | | |
| EL 2 | 1.40 | 1.450 | 1.450 | | |
| EL 3 | 1.60 | 1.450 | 1.450 | 1.446 | |
| EL 4 | 1.80 | 1.450 | 1.450 | 1.450 | 1.436 |

**Table 12.4.29 Preservation of Per-Unit Operating Profit Markups for Product Class 3: Portable Dehumidifiers, > 45.00 pints/day**

| EL | IEF | Minimally Compliant EL | | | |
|---|---|---|---|---|---|
| | | EL 1 | EL 2 | EL 3 | EL4 |
| EL 1 | 2.40 | 1.442 | | | |
| EL 2 | 2.80 | 1.450 | 1.442 | | |
| EL 3 | 3.66 | 1.450 | 1.450 | 1.429 | |

**Table 12.4.30 Preservation of Per-Unit Operating Profit Markups for Product Class 4: Whole-Home Dehumidifiers ≤ 8.0 $ft^3$**

| EL | IEF | Minimally Compliant EL | | | |
|---|---|---|---|---|---|
| | | EL 1 | EL 2 | EL 3 | EL4 |
| EL 1 | 2.09 | 1.447 | | | |
| EL 2 | 2.53 | 1.450 | 1.423 | | |

**Table 12.4.31 Preservation of Per-Unit Operating Profit Markups for Product Class 5: Whole-Home Dehumidifiers > 8.0 $ft^3$**

| EL | IEF | Minimally Compliant EL | | | |
|---|---|---|---|---|---|
| | | EL 1 | EL 2 | EL 3 | EL4 |
| EL 1 | 2.70 | 1.450 | | | |
| EL 2 | 3.52 | 1.450 | 1.445 | | |
| EL 3 | 4.50 | 1.450 | 1.450 | 1.425 | |

## 12.5 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, DOE used the GRIM to estimate the financial impacts on the residential dehumidifier industry. The MIA uses two key financial metrics: INPV and annual cash flows. The main results of the MIA are reported in this section.

### 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 at large. The INPV is specific to the residential dehumidifier manufacturing industry, and is the sum of all annual net cash flows discounted at the industry's WACC. The GRIM for the residential dehumidifier industry models cash flows from 2015 to 2048. This timeframe models both the short-term impacts on the industry from the announcement of the standard until the compliance date in 2019, and a long-term assessment over the 30-year analysis period immediately thereafter.

In the MIA, DOE compares the INPV at the base case (no amended energy conservation standards) to that at 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 dehumidifier industry, DOE examined the two markup scenarios described above: the preservation of gross margin percentage markup scenario and the preservation of per-unit operating profit markup scenario. DOE's estimates of INPV for the full analysis period (2015–2048) for the base case and at each TSL in the standards case are presented in Table 12.5.1 and Table 12.5.2 below. 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 capital reserves and cash flow. Consequently, the sharp drop in financial performance could cause investors to flee, even if recovery is 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 and Figure 12.5.2 below present the annual net or free cash flows from 2015 through 2048 for the base case and each TSL in the standards case.

Annual cash flows are discounted to the base year, 2015. Between 2015 and the 2019 compliance date, cash flows are driven by the level of conversion costs and the portion of these investments made each 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 flows from operations and capital conversion costs increase outlays of cash 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.*, the residual un-depreciated value of 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, the value of which is affected by the amended energy conservation standards. This one time write down acts as a tax shield that mitigates 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 can be attributed 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. Under the preservation of gross margin percentage markup scenario, more stringent TSLs typically have a positive impact on cash flows relative to the base case because in marking up more costly equipment, manufacturers are able to earner higher operating profit, which increases cash flow from operations. There is very little impact on cash flow from operations under the preservation of per-unit operating profit scenario because this scenario is calibrated to have the same earnings before interest and taxes in the standards case at each TSL as the base case as in the year after the standard takes effect. In this scenario production costs increase, but per-unit operating profit remains approximately equal to the base case, effectively decreasing profit margins as a percentage of revenue.

### 12.5.2 Residential Dehumidifier Industry Financial Impacts

Table 12.5.1 and Table 12.5.2 provide the INPV estimates for the residential dehumidifier manufacturing industry. Figure 12.5.1 and Figure 12.5.2 present the annual net cash flows for the residential dehumidifier manufacturing industry for each of the markup scenarios.

**Table 12.5.1 Manufacturer Impact Analysis for Residential Dehumidifiers – Preservation of Gross Margin Percentage Markup Scenario**

| | | Base Case | Trial Standard Level | | | |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| **INPV** | *(2013$ millions)* | 186.5 | 184.0 | 183.4 | 155.2 | 146.3 |
| **Change in INPV** | *(2013$ millions)* | - | (2.5) | (3.1) | (31.3) | (40.2) |
| | *(%)* | - | (1.4%) | (1.6%) | (16.8%) | (21.6%) |

*For tables in section 12.5, values in parenthesis indicate negative numbers

**Table 12.5.2 Manufacturer Impact Analysis for Residential Dehumidifiers – Preservation of Per-Unit Operating Profit Markup Scenario**

| | | Base Case | Trial Standard Level | | | |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| **INPV** | *(2013$ millions)* | 186.5 | 183.5 | 182.1 | 151.6 | 126.8 |
| **Change in INPV** | *(2013$ millions)* | - | $ (3.0) | $ (4.4) | $ (34.9) | $ (59.7) |
| | *(%)* | - | (1.6%) | (2.4%) | (18.7%) | (32.0%) |

*For tables in section 12.5, values in parenthesis indicate negative numbers

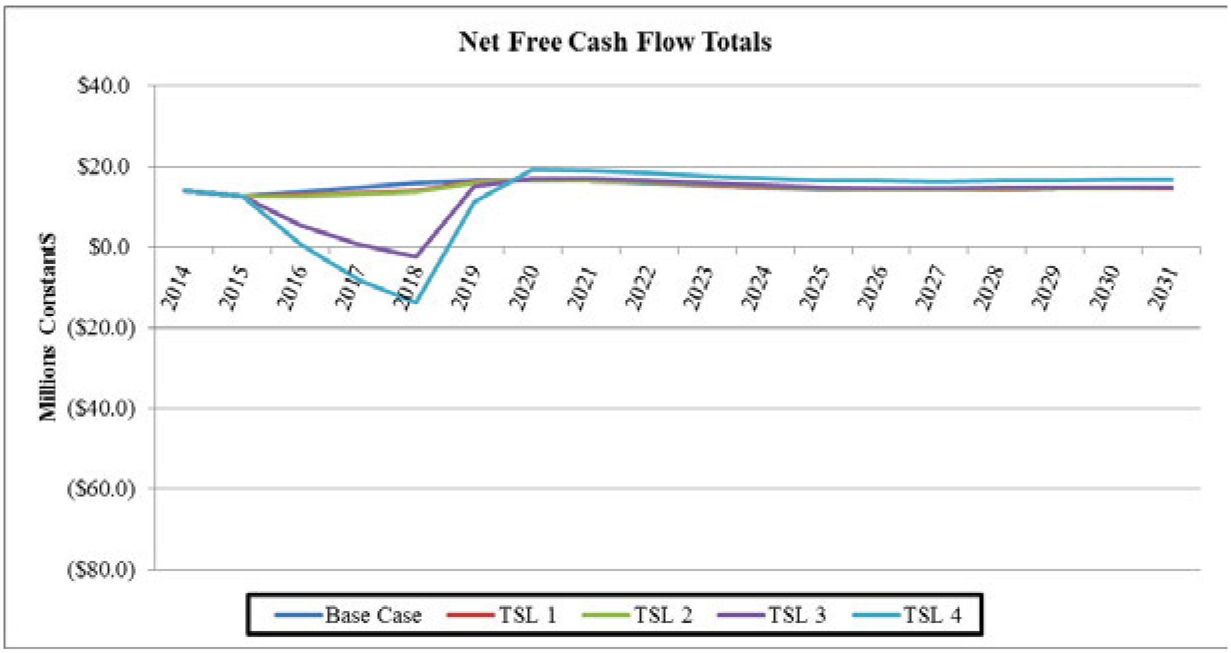


**Figure 12.5.1 Annual Industry Net Cash Flows for Residential Dehumidifiers (Preservation of Gross Margin Markup Scenario)**

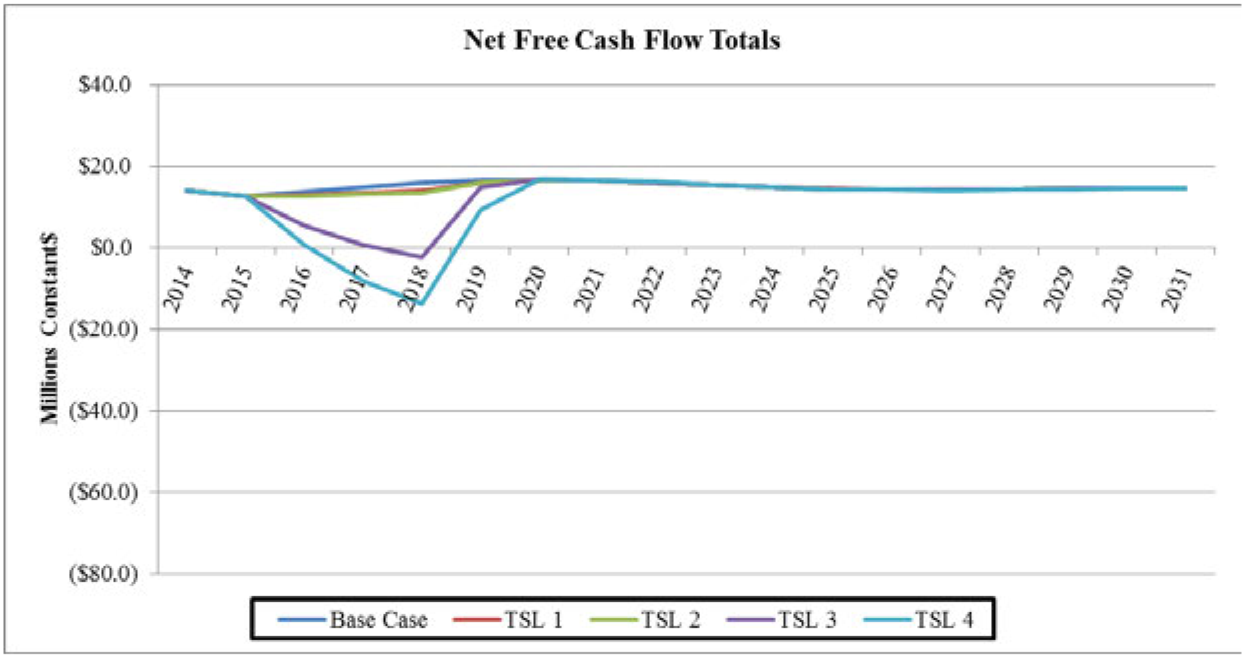


**Figure 12.5.2 Annual Industry Net Cash Flows for Residential Dehumidifiers (Preservation of Per-Unit Operating Profit Markup Scenario)**

## 12.6 IMPACTS ON SMALL BUSINESS RESIDENTIAL DEHUMIDIFIER MANUFACTURERS

As discussed in section 12.2.3.3, DOE identified five domestic small business manufacturers that may be disproportionately affected by any energy efficiency regulation in the residential dehumidifier industry. These manufacturers are focused on one specific market segment (high-capacity portable and whole-home dehumidifiers) and are at least one order of magnitude smaller than their diversified competitors. Due to this combination of market concentration and size, these small businesses are at risk of high disproportionate impacts, depending on the TSL chosen.

DOE received feedback from small business manufacturers and OEM contractors through public comments and confidential interviews (see section IV.J.3 of the NOPR notice for a discussion of public comments and feedback received from dehumidifier manufacturers during the NOPR phase). These manufacturers expressed a high degree of concern relating to the magnitude of burdens and the disproportionate impacts that they believe will result from amended energy conservation standards for residential dehumidifiers.

Today's proposed standards for residential dehumidifiers could cause small manufacturers to be at a disadvantage relative to large manufacturers. One way in which small manufacturers could be at a disadvantage is that they may be disproportionately affected by product and capital conversion costs. Product redesign, testing, and certification costs tend to be fixed per basic model and do not scale with sales volume. For each model, small businesses must make investments in research and development to redesign their products, but because they have lower sales volumes, they must spread these costs across fewer units. In addition, because small manufacturers have fewer engineers than large manufacturers, they would need to allocate a greater portion of their available resources to meet a standard. Because engineers may need to spend more time redesigning and testing existing models as a result of the new standard, they may have less time to develop new products. Similarly, upfront capital investments in new manufacturing capital for platform redesigns, as well as depreciated manufacturing capital, can only be spread across a disproportionately lower volume of shipments.

Furthermore, smaller manufacturers may lack the purchasing power of larger manufacturers. For example, since fan-motor suppliers give discounts to manufacturers based on the number of motors they purchase, larger manufacturers may have a pricing advantage because they have higher-volume purchases. This purchasing power differential between high-volume and low-volume orders applies to other residential dehumidifier components as well, including compressors and heat exchangers. Some larger manufacturers of lower-capacity portable dehumidifiers may even manufacture heat exchangers in-house. Additionally, because small business manufacturers produce larger units, they require larger/custom components (*e.g.* larger compressors) than do the large manufacturers who produce lower-capacity portable products and who account for the majority of the dehumidifier market. Because of the low-volume nature of the high-capacity portable and whole-home dehumidifier market, certain technological improvements to components may only be developed for small portable products, or with significant lag time for large dehumidifier products.

To access to the capital required to cover the conversion costs associated with reaching the proposed standards, small business manufacturers would likely be forced to take on additional debt, whereas larger manufacturers of small portable products would be better equipped to fund purchases with existing cash flow from operations.

In terms of impacts to small business manufacturers associated with the specific TSLs outline in this notice, disproportionate impacts will be greatest at TSL 1 and TSL 2, where relatively more high-capacity portable and whole-home dehumidifiers are at or below the baseline than is the case for the lower-capacity portable products. Additionally, it is assumed that small business manufacturers will be required to outsource the testing of their products to third-party testing facilities. In contrast, the large manufacturers of small portable dehumidifiers are assumed to have in-house testing capabilities, which significantly reduce the cost of testing. While the magnitude of conversion cost burden increases slightly for small business manufacturers at TSL 3 and TSL 4, relative to lower TSLs, disproportionate impacts decrease substantially, as relatively more lower-capacity portable product platforms will require substantial redesign. Between TSL 3 and TSL 4, TSL 3 minimizes standards compliance burdens for small business manufacturers relative to the burdens of high-volume portable dehumidifier manufacturers.

Further detail on small business high-capacity portable and whole-home dehumidifier manufacturers is found in section VI.B, “Review under the Regulatory Flexibility Act,” of the NOPR notice.

## 12.7 OTHER IMPACTS

### 12.7.1 Employment

For residential dehumidifiers, 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 2015 to 2048. DOE used statistical data from the most recent U.S Census Bureau's *ASM*, the results of the engineering analysis, and interviews with manufacturers to determine the inputs necessary to calculate industry-wide labor expenditures and domestic employment levels. Labor expenditures 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 dehumidifier industry. DOE used census data and interviews with manufacturers to estimate the portion of the total labor expenditures that is attributable to domestic labor.

The production worker estimates in this section only cover workers up to the line-supervisor level who are directly involved in fabricating and assembling a product within an OEM facility. Workers performing services that are closely associated with production operations, such as material handling with a forklift, are also included as production labor. DOE's estimates account only 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 total potential increase in the number of production workers after amended energy conservation standards. To calculate the total potential increase, DOE assumed that manufacturers continue to produce the same scope of covered products in domestic production facilities and domestic production is not shifted to lower-labor-cost countries. Because there is a 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 evaluation of the likelihood of negative domestic production employment impacts at the various TSLs.

Using the GRIM, DOE forecasts the domestic labor expenditure for residential dehumidifier production labor in 2019 will fall approximately within the range of $7.9 to $9.4 million, depending on the TSL chosen. Using the $18.32 hourly wage rate including fringe benefits and 1,955 production hours per year per employee found in the 2011 *ASM*, DOE estimates there will be 219 to 261 domestic production workers involved in the manufacturing of residential dehumidifiers in 2019, the year in which amended standards would go into effect, for TSL 1 through TSL 4. In addition, DOE estimates that 78 to 93 non-production employees in the

United States will support residential dehumidifier production.[e] Approximately 3 percent of residential dehumidifiers sold in the United States are manufactured domestically. The employment tab of the residential dehumidifier GRIM contains more detailed information on the annual domestic employment impacts.

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 dehumidifier market.

**Table 12.7.1 Potential Changes in the Total Number of Domestic Residential dehumidifier Production Workers in 2019**

| | Baseline | TSL 1 | TSL 2 | TSL 3 | TSL 4 |
|---|---|---|---|---|---|
| **Total Number of Domestic Production Workers in 2019 (without changes in production locations)** | 214 | 219 | 222 | 222 | 261 |
| **Potential Changes in Domestic Production Workers in 2019*** | - | 5 - (214) | 8 - (214) | 8 - (214) | 47 - (214) |

*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.

[e] As defined in the 2011 *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-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."

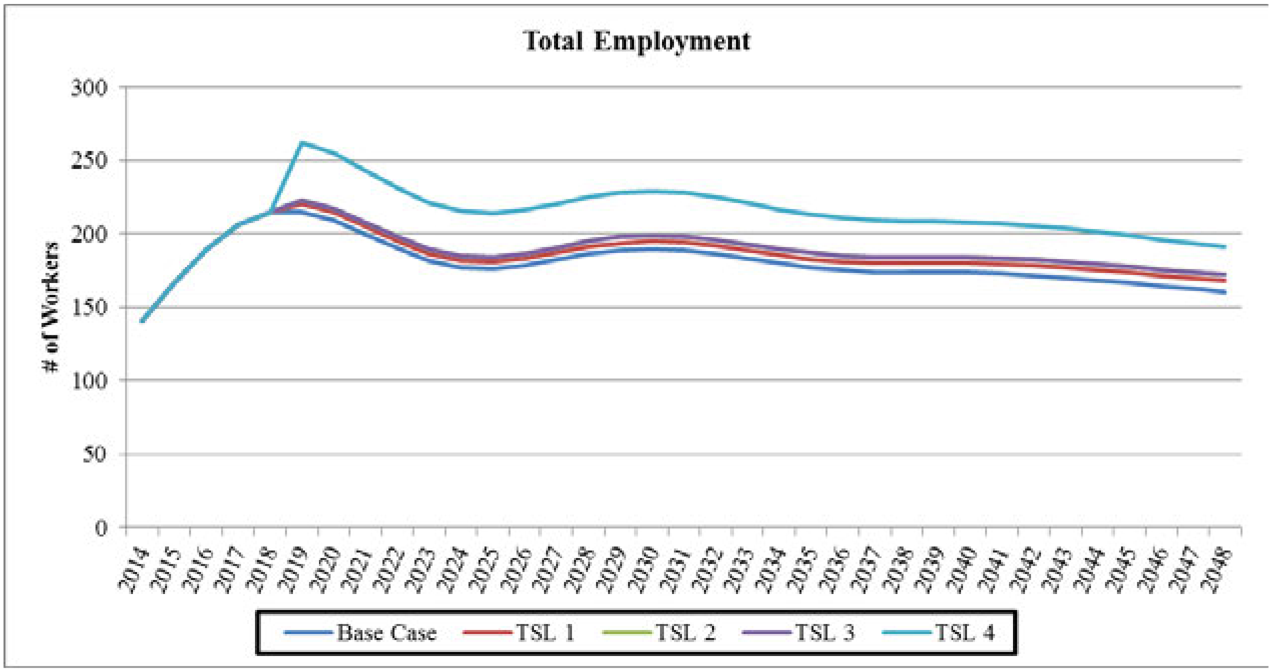


**Figure 12.7.1 Residential Dehumidifier Domestic Production Employment by Year**

Because production employment expenditures are assumed to be a fixed percentage of cost of goods sold and the MPCs typically increase with more efficient products, labor tracks the increased prices in the GRIM. As efficiency of dehumidifiers increases, so does the complexity of the products, generally requiring more labor to produce. However, because only 3 percent of residential dehumidifier manufacturing takes place domestically, employment impacts are expected to be minimal. DOE expects that there would be minimal employment impacts among domestic residential dehumidifier manufacturers for TSL 1 through TSL 3. For TSL 4, the GRIM predicts a 21.9-percent increase in total domestic production employment following amended standards based on the increase in complexity and relative price of the high-capacity portable and whole-home dehumidifier segment.

During manufacturer interviews, some small businesses stated that, contrary to the above findings, domestic production and non-production employment in the industry may decrease as a result of amended standards for residential dehumidifiers.

Similarly, the above analysis does not account for the possible relocation of domestic jobs to lower-labor-cost countries because the potential relocation of U.S. jobs is uncertain and highly speculative. As mentioned above, the vast majority of residential dehumidifiers sold in the United States are manufactured abroad. However, approximately 100 percent of high-capacity portable and whole-home dehumidifiers are manufactured domestically. Feedback from manufacturers during NOPR interviews reveals that some domestic small businesses in the residential dehumidifier industry may be forced to make employment cuts or to shift production to new locations, including locations outside of the United States, as a result of amended energy conservation standards.

### 12.7.2 Production Capacity

As noted previously, the majority of residential dehumidifiers sold in the United States are not produced domestically. However, feedback from domestic manufacturers of high-capacity portable products and whole-home dehumidifiers suggested that production of these products could shift abroad as a result of amended energy conservation standards. This could lead to a permanently lower production capacity within the residential dehumidifier industry.

### 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. Regulatory burdens can prompt companies to exit the market or reduce their equipment 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. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. A proposed standard is not economically justified if it contributes to an unacceptable level of cumulative regulatory burden.

For the cumulative regulatory burden analysis, DOE looks at other significant product-specific regulations that will take effect 3 years before or after the 2019 compliance date of any amended energy conservation standards for residential dehumidifiers. In addition to amended energy conservation regulations, several other Federal regulations apply to residential dehumidifiers. While this analysis focuses on the impacts on manufacturers born of other Federal requirements, DOE also has described some of other non-Federal regulations in section 12.7.3.2 because it recognizes that these regulations also impact the equipment covered by this rulemaking.

#### 12.7.3.1 DOE Regulations for Other Products Produced by Residential Dehumidifier Manufacturers

Companies that produce a wide range of regulated products and equipment may face more capital and product development expenditures than competitors with a narrower scope of products and equipment. The majority of residential dehumidifier manufacturers also produce other appliances and residential products. In addition to the amended energy conservation standards for residential dehumidifiers, these manufacturers contend with several other Federal regulations and pending regulations that apply to other products and equipment. 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 other DOE energy conservation standards that could also affect manufacturers of residential dehumidifiers in the 3 years leading up to and after the compliance date of any amended energy conservation standards for this product.

**Table 12.7.2 Other DOE and Federal Actions Affecting the Residential Dehumidifier Industry**

| Regulation | Approximate Compliance Date* | Number of Impacted Companies | Estimated Total Industry Conversion Costs |
|---|---|---|---|
| Microwave Ovens | 2016 | 4 | $43.1 M |
| Residential Clothes Washers | 2018 | 5 | $418.5 M |
| Commercial Clothes Washers | 2018 | 5 | $10.2 M |
| Dishwashers | 2019 | 5 | N/A† |
| Portable Air Conditioners | 2019 | 6 | N/A† |
| Miscellaneous Refrigeration | 2019 | 3 | N/A† |
| Packaged Terminal Air Conditioners | 2019 | 3 | N/A† |
| Room Air Conditioners | 2022 | 2 | N/A† |
| Clothes Dryers | 2022 | 2 | N/A† |

*The dates listed are an approximation. The exact dates are pending final DOE action.
† For energy conservation standards for rulemakings awaiting DOE final action, DOE does not have a finalized estimated total industry conversion cost.

#### 12.7.3.2 Other Regulations That Could Impact Residential Dehumidifiers

*Independent Testing and Certification*

Several manufacturers were concerned that changes in the DOE energy conservation standards, and the resulting re-design of their equipment, would require them to re-certify all of their equipment with other organizations aside from DOE. This would include re-testing and certification by Underwriters Laboratories (UL).

Additionally, one manufacturer cited increasing requirements of "big box" retailers—which are a crucial component in the portable dehumidifier distribution channel—as a cumulative burden. Retailers such as Walmart and Home Depot have adopted their own certification systems for suppliers in efforts relating to quality assurance and the fulfillment of "ethical sourcing" commitments.[f,g]

[f] https://homedepotlink.homedepot.com/en-us/Related%20Documents/Import%20Supplier%20Handbook%20092811.pdf
[g] http://cdn.corporate.walmart.com/0e/ca/52eda3d84f828f82da0e9a02f021/standards-for-suppliers-manual_129833075555266802.pdf

## 12.8 CONCLUSION

The following section summarizes the scenarios DOE believes are most likely to capture the range of impacts on residential dehumidifier 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.

At TSL 1, DOE estimates the impact on INPV for manufacturers of residential dehumidifiers to range from -$2.5 million to -$3.0 million, or a change in INPV of -1.4 percent to -1.6 percent under the preservation of gross margin percentage markup scenario and the preservation of per-unit operating profit markup scenario, respectively. At this TSL, industry free cash flow is estimated to decrease by approximately 11.2 percent to $14.1 million, compared to the base-case value of $15.8 million in the year before the compliance date (2018).

At TSL 1, the industry as a whole is expected to incur $3.9 million in product conversion costs attributed to upfront research, development, testing, and certification; as well as $1.3 million in one-time investments in property, plant and equipment (PP&E) necessary to manufacture redesigned platforms. The majority of industry conversion cost burden at TSL 1 will be felt by manufacturers of high-capacity portable and whole-home dehumidifiers, as relatively more of these products are currently at the baseline than is the case for the lower-capacity portable products. These baseline products may necessitate complete platform redesigns, which involve moving to a new case size to accommodate larger heat exchangers. These changes require upfront capital investments for new tooling among other changes to manufacturing production lines. Additionally, it is assumed that manufacturers of high-capacity portable and whole-home dehumidifiers, the majority of which are small business manufacturers, will be required to outsource testing of their products to third-party testing facilities, contributing to greater product conversion costs. In contrast, the large manufacturers of small portable dehumidifiers are assumed to have in-house testing capabilities which significantly reduce the cost of testing. DOE's assumptions regarding testing burdens were confirmed during manufacturer interviews.

At TSL 2, DOE estimates the impact on INPV for manufacturers of residential dehumidifiers to range from -$3.1 million to -$4.4 million, or a change in INPV of -1.6 percent to -2.4 percent under the preservation of gross margin percentage markup scenario and the preservation of per-unit operating profit markup scenario, respectively. At this TSL, industry free cash flow is estimated to decrease by approximately 14.4 percent to $13.6 million, compared to the base-case value of $15.8 million in the year before the compliance date (2018).

At TSL 2, the industry as a whole is expected to incur $5.1 million in product conversion costs associated with the upfront research, development, testing, and certification; as well as $1.7 million in one-time investments in PP&E to manufacture products requiring platform redesigns. Similar to TSL 1, the majority of industry conversion cost burden at TSL 2 will be felt by manufacturers of high-capacity portable and whole-home dehumidifiers, as relatively more products of these types are at the baseline than are the lower-capacity portable products, and will require complete platform redesigns. Platform redesigns at TSL 2 will require moving to a new case size to accommodate larger heat exchangers, and will necessitate upfront capital investments for new tooling. As at TSL 1, because manufacturers of high-capacity portable and whole-home dehumidifiers are largely small businesses, it is assumed that these manufacturers will be required to outsource testing of their products to third-party testing facilities. In contrast, the large manufacturers of small portable dehumidifiers are assumed to have in-house testing capabilities, which significantly reduce the cost of testing. DOE's assumptions regarding testing burdens were confirmed during manufacturer interviews.

At TSL 3, DOE estimates the impact on INPV for manufacturers of residential dehumidifiers to range from -$31.3 million to -$34.9 million, or a change in INPV of -16.8 percent to -18.7 percent under the preservation of gross margin percentage markup scenario and the preservation of per-unit operating profit markup scenario, respectively. At this TSL, industry free cash flow is estimated to decrease by approximately 116.1 percent to -$2.5 million, compared to the base-case value of $15.8 million in the year before the compliance date (2018).

At TSL 3, the industry as a whole is expected to spend $30.2 million in product conversion costs associated with the research and development and testing and certification, as well as $20.5 million in one-time investments in PP&E to manufacture redesigned platforms. While conversion costs remain relatively constant for manufacturers of high-capacity portable and whole-home dehumidifiers for TSL 1 through TSL 3, the conversion costs for manufacturers of lower-capacity portable products increase substantially at TSL 3, as a greater portion of these products will require total platform redesigns. As with the high-capacity portable and whole-home dehumidifier market segment, platform redesigns for lower-capacity portable units will consist of moving products to a new case size to accommodate larger heat exchangers, and in turn requires capital investments in new tooling for larger cases. This upfront investment is in addition to additional R&D and testing expenditures. Because lower-capacity portable units represent approximately 97 percent of the market, conversion costs associated with this segment have a significant impact on total industry conversion costs.

At TSL 4, DOE estimates the impact on INPV for manufacturers of residential dehumidifiers to range from -$40.2 million to -$59.7 million, or a change in INPV of -21.6 percent to -32.0 percent under the preservation of gross margin percentage markup scenario and the preservation of per-unit operating profit markup scenario, respectively. At this TSL, industry free cash flow is estimated to decrease by approximately 186.4 percent to -$13.7 million, compared to the base-case value of $15.8 million in the year before the compliance date (2018).

At TSL 4, the industry as a whole is expected to spend $48.1 million in product conversion costs associated with the research and development and testing and certification, as well as $33.1 million in one-time investments in PP&E for platform redesigns. Again, conversion costs remain relatively constant for manufacturers of high-capacity portable and whole-home dehumidifiers from TSL 1 through TSL 4. In contrast, the conversion cost burden for manufacturers of lower-capacity portable products increases substantially at TSL 4, as an increasingly larger portion of smaller portable products will require platform redesigns. Again, since lower-capacity portable units represent approximately 97 percent of the market, conversion costs associated with this segment have a significant impact on total industry conversion costs.

Beyond the direct financial impact on manufacturers, TSL 4 may also contribute to the potential unavailability of products at certain capacities across the five product classes. The efficiencies at TSL 4 are theoretical levels that DOE determined dehumidifiers could achieve by incorporating the most efficient type of each component. DOE is not aware of any dehumidifiers currently available on the market that achieve the TSL 4 efficiencies. To meet TSL 4, all products would be required to incorporate the highest efficiency compressors; however, manufacturers indicated that few such compressors are available in the range of compressor capacities suitable for residential dehumidifiers, and it is unlikely that substantially more would become available if standards at TSL 4 were adopted. In addition, the specific compressor capacities available at any given time are driven largely by the markets for other products with higher shipments (for example, room air conditioners), and thus dehumidifier manufacturers may be constrained in their design choices. Because DOE assumed manufacturers would optimize all components at TSL 4, including the use of larger heat exchangers and permanent-magnet blower motors, manufacturers would not have alternative design pathways to achieve the max-tech efficiency level in the absence of high efficiency compressors. Therefore, DOE expects that those dehumidifier platforms for which a suitable high efficiency compressor is not available would be unable to meet the max-tech efficiency level associated with TSL 4. While this would likely not eliminate entire product classes from the market, it has the potential to eliminate dehumidifiers of certain capacities within a given product class. The potential for this impact on manufacturers of high-capacity portable and whole-home dehumidifiers is exacerbated by this segment's low production volumes, which encumbers manufacturers' ability to influence the availability of higher efficiency components from their vendors.

## REFERENCES


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# CHAPTER 13. EMISSIONS ANALYSIS

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# CHAPTER 13. EMISSIONS ANALYSIS

## 13.1 INTRODUCTION

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site combustion emissions of carbon dioxide ($CO_2$), nitrogen oxides ($NO_X$), sulfur dioxide ($SO_2$) and mercury (Hg). The second component estimates the impacts of a potential standard on emissions of two additional greenhouse gases, methane ($CH_4$) and nitrous oxide ($N_2O$), as well as the reductions to emissions of all species due to "upstream" activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Together, these emissions account for the FFC, in accordance with DOE's FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011).

The analysis of power sector emissions uses marginal emissions intensity factors calculated by DOE. As of 2014, DOE is using a new methodology based on results published for the *AEO 2014* reference case and a set of side cases that implement a variety of efficiency-related policies.[1] The new methodology is described in chapter 15 and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014).[2] Site emissions of $CO_2$ and $NO_X$ are estimated using emissions intensity factors from a publication of the EPA.[3]

Combustion emissions of $CH_4$ and $N_2O$ are estimated using emissions intensity factors published by the EPA, GHG Emissions Factors Hub.[a] The FFC upstream emissions are estimated based on the methodology developed by Coughlin (2013).[4] The upstream emissions include both emissions from fuel combustion during extraction, processing and transportation of fuel, and "fugitive" emissions (direct leakage to the atmosphere) of $CH_4$ and $CO_2$.

The emissions intensity factors are expressed in terms of physical units per MWh or MMBtu of site energy savings. Total emissions reductions are estimated using the energy savings calculated in the national impact analysis (chapter 10).

For $CH_4$ and $N_2O$, DOE also presents results in terms of units of carbon dioxide equivalent ($CO_2e$). Gases are converted to $CO_2e$ by multiplying the physical units by the gas global warming potential (GWP) over a 100 year time horizon. Based on the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,[5] DOE used GWP values of 28 for $CH_4$ and 265 for $N_2O$.[b]

## 13.2 AIR QUALITY REGULATIONS AND EMISSIONS IMPACTS

Each annual version of the AEO incorporates the projected impacts of existing air quality regulations on emissions. *AEO 2014* generally represents current Federal and State legislation and final implementation regulations in place as of the end of October 2013.

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

[b] The values are without inclusion of climate-carbon feedbacks in response to emissions of the indicated non-$CO_2$ gases.

$SO_2$ emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap and trading programs. Title IV of the Clean Air Act sets an annual emissions cap on $SO_2$ for affected EGUs in the 48 contiguous states and the District of Columbia (D.C.). $SO_2$ emissions from 28 eastern states and D.C. were also limited under the Clean Air Interstate Rule (CAIR), which created an allowance-based trading program that that operates along with the Title IV program in those States and D.C. 70 FR 25162 (May 12, 2005). CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) but parts of it remained in effect. On July 6, 2011 EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule (CSAPR). 76 FR 48208 (August 8, 2011). On August 21, 2012, the D.C. Circuit issued a decision to vacate CSAPR. See *EME Homer City Generation, LP v. EPA*, 696 F.3d 7, 38 (D.C. Cir. 2012). The court ordered EPA to continue administering CAIR. The *AEO 2014* emissions factors used for the present analysis assume that CAIR remains a binding regulation through 2040. [c]

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

Beginning in 2016, however, $SO_2$ emissions will fall as a result of the MATS for power plants. 77 FR 9304 (Feb. 16, 2012). In the final MATS rule, EPA established a standard for hydrogen chloride as a surrogate for acid gas HAP, and also established a standard for $SO_2$ (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, $SO_2$ emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO 2014* assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2016. Both technologies, which are used to reduce acid gas emissions, also reduce $SO_2$ emissions. Under the MATS, emissions will be far below the cap established by CAIR, so it is unlikely that excess $SO_2$ emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in $SO_2$ emissions by any regulated EGU. Therefore, DOE believes that efficiency standards will reduce $SO_2$ emissions in 2016 and beyond.

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

CAIR established a cap on $NO_x$ emissions in 28 eastern States and the District of Columbia. Energy conservation standards are expected to have little effect on $NO_x$ emissions in those States covered by CSAPR because excess $NO_x$ emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in $NO_x$ emissions. However, standards would be expected to reduce $NO_x$ emissions in the States not affected by CAIR, so DOE estimated NOx emissions reductions from potential standards for those States.

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

## 13.3 POWER SECTOR AND SITE EMISSIONS FACTORS

The analysis of power sector emissions uses marginal emissions intensity factors derived from analysis of the *AEO 2014* reference and a number of side cases incorporating enhanced equipment efficiencies. To model the impact of a standard, DOE calculates factors that relate a unit reduction to annual site electricity demand for a given end use to corresponding reductions to installed capacity by fuel type, fuel use for generation, and power sector emissions. Details on the approach used may be found in Coughlin (2014).

Table 13.3.1 presents the average power plant emissions factors for selected years. These power plant emissions factors are derived from the emissions factors of the plant types used to supply electricity for homes. The average factors for each year take into account the projected shares of each of the sources in total electricity generation.

**Table 13.3.1 Power Plant Emissions Factors**

| | Unit* | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/MWh | 723 | 642 | 579 | 529 | 483 |
| $SO_2$ | g/MWh | 718 | 560 | 471 | 395 | 353 |
| NOx | g/MWh | 574 | 479 | 419 | 369 | 334 |
| Hg | g/MWh | 0.00222 | 0.00173 | 0.00145 | 0.00122 | 0.00109 |
| $N_2O$ | g/MWh | 7.2 | 7.1 | 6.9 | 6.6 | 6.4 |
| $CH_4$ | g/MWh | 50.2 | 49.4 | 47.9 | 46.4 | 44.8 |

* Refers to site electricity savings.

## 13.4 UPSTREAM FACTORS

The upstream emissions accounting uses the same approach as the upstream energy accounting described in appendix 10B. See also Coughlin (2013) and Coughlin (2014). When demand for a particular fuel is reduced, there is a corresponding reduction in the emissions from combustion of that fuel at either the building site or the power plant. The associated reduction in energy use for upstream activities leads to further reductions in emissions. These upstream emissions are defined to include the combustion emissions from the fuel used upstream, the fugitive emissions associated with the fuel used upstream, and the fugitive emissions associated with the fuel used on site.

Fugitive emissions of $CO_2$ occur during oil and gas production, but are small relative to combustion emissions. They comprise about 2.5 percent of total $CO_2$ emissions for natural gas and 1.7 percent for petroleum fuels. Fugitive emissions of methane occur during oil, gas and coal production. Combustion emissions of $CH_4$ are very small, while fugitive emissions (particularly for gas production) may be relatively large. Hence, fugitive emissions make up over 99 percent of total methane emissions for natural gas, about 95 percent for coal, and 93 percent for petroleum fuels.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. Fugitive emissions factors for methane from coal mining and natural gas production were estimated based on a review of recent studies compiled by Burnham (2011).[6] This review includes estimates of the difference between fugitive emissions factors for conventional production of natural vs. unconventional (shale or tight gas). These estimates rely in turn on data gathered by EPA under new GHG reporting requirements for the petroleum and natural gas industries.[7, 8] As more data are made available, DOE will continue to update these estimated emissions factors.

For ease of application in its analysis, DOE developed all of the emissions factors using site (point of use) energy savings in the denominator. Table 13.4.1 presents the electricity upstream emissions factors for selected years. These were used to estimate the emissions associated with the decreased electricity use. The caps that apply to power sector $NO_X$ emissions do not apply to upstream combustion sources.

**Table 13.4.1 Electricity Upstream Emissions Factors**

| | Unit | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/MWh | 29.1 | 29.4 | 29.7 | 29.9 | 29.8 |
| $SO_2$ | g/MWh | 5.0 | 5.1 | 4.9 | 4.7 | 4.6 |
| NOx | g/MWh | 368 | 375 | 382 | 387 | 387 |
| Hg | g/MWh | 0.000012 | 0.000011 | 0.000011 | 0.000010 | 0.000010 |
| $N_2O$ | g/MWh | 0.252 | 0.247 | 0.241 | 0.234 | 0.228 |
| $CH_4$ | g/MWh | 2149 | 2195 | 2216 | 2248 | 2255 |

* Refers to site electricity savings.

## 13.5 EMISSIONS IMPACT RESULTS

Table 13.5.1 presents the estimated cumulative emissions reductions for the lifetime of products sold in 2019-2048 for each TSL. Negative values indicate that emissions increase.

**Table 13.5.1 Cumulative Emissions Reduction for Potential Standard for Dehumidifiers**

| | TSL 1 | TSL 2 | TSL 3 | TSL 4 |
|---|---|---|---|---|
| **Power Sector and Site Emissions** | | | | |
| $CO_2$ (million metric tons) | 4.05 | 6.40 | 18.3 | 44.6 |
| $SO_2$ (thousand tons) | 3.52 | 5.55 | 15.8 | 38.2 |
| $NO_X$ (thousand tons) | 3.18 | 5.03 | 14.3 | 34.8 |
| Hg (tons) | 0.011 | 0.017 | 0.049 | 0.118 |
| $CH_4$ (thousand tons) | 0.382 | 0.607 | 1.75 | 4.28 |
| $N_2O$ (thousand tons) | 0.055 | 0.087 | 0.250 | 0.613 |
| **Upstream Emissions** | | | | |
| $CO_2$ (million metric tons) | 0.221 | 0.352 | 1.01 | 2.50 |
| $SO_2$ (thousand tons) | 0.039 | 0.062 | 0.179 | 0.440 |
| $NO_X$ (thousand tons) | 3.14 | 5.00 | 14.4 | 35.6 |
| Hg (tons) | 0.000 | 0.000 | 0.000 | 0.001 |
| $CH_4$ (thousand tons) | 18.3 | 29.1 | 84.1 | 207 |
| $N_2O$ (thousand tons) | 0.002 | 0.003 | 0.009 | 0.022 |
| **Total Emissions** | | | | |
| $CO_2$ (million metric tons) | 4.27 | 6.75 | 19.3 | 47.1 |
| $SO_2$ (thousand tons) | 3.56 | 5.61 | 16.0 | 38.6 |
| $NO_X$ (thousand tons) | 6.33 | 10.0 | 28.8 | 70.4 |
| Hg (tons) | 0.011 | 0.017 | 0.049 | 0.119 |
| $CH_4$ (thousand tons) | 18.7 | 29.8 | 85.9 | 211 |
| $N_2O$ (thousand tons) | 0.057 | 0.090 | 0.259 | 0.634 |

Figure 13.5.1 through Figure 13.5.6 show the annual reductions for total emissions for each type of emission from each TSL. The reductions reflect the lifetime impacts of products sold in 2019-2048.

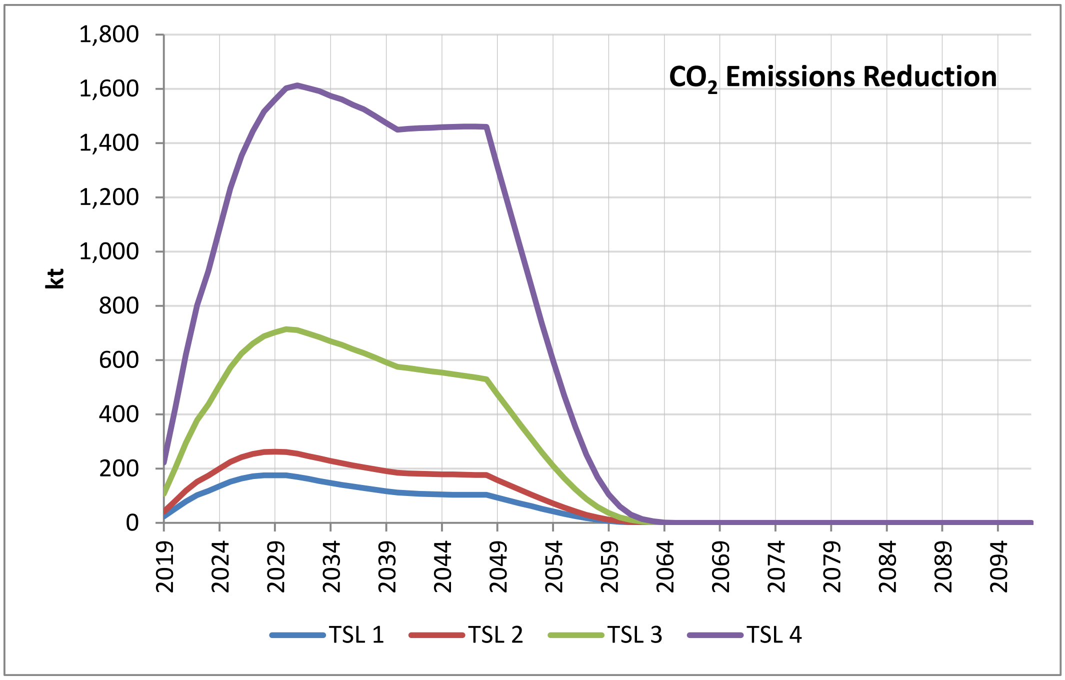


**Figure 13.5.1 $CO_2$ Total Emissions Reduction**

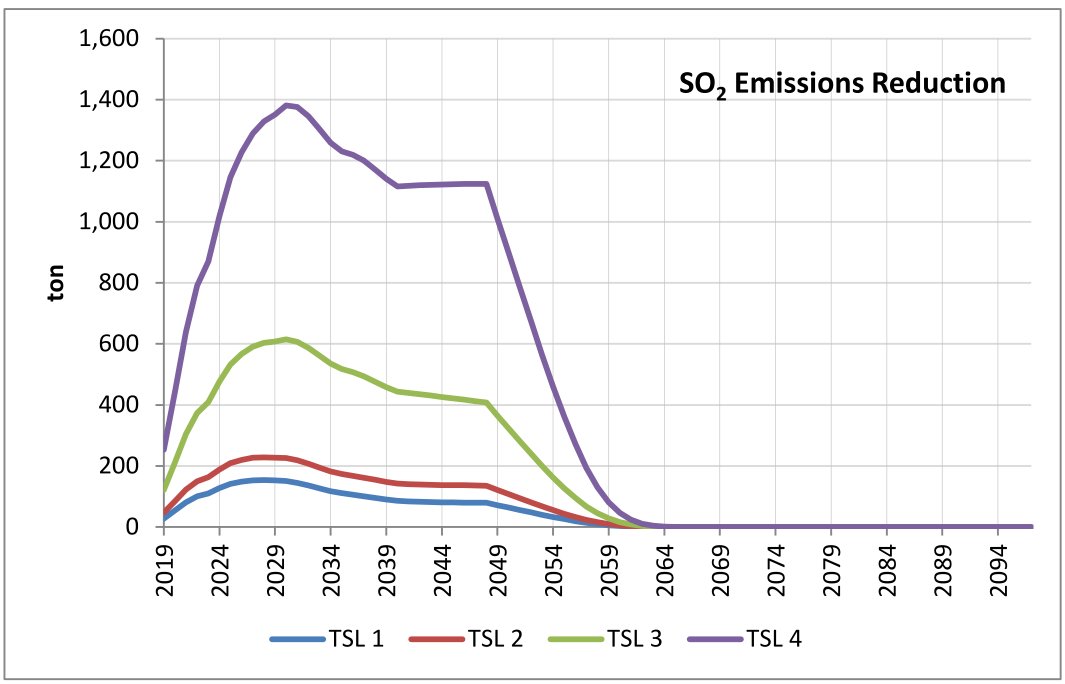


**Figure 13.5.2 $SO_2$ Total Emissions Reduction**

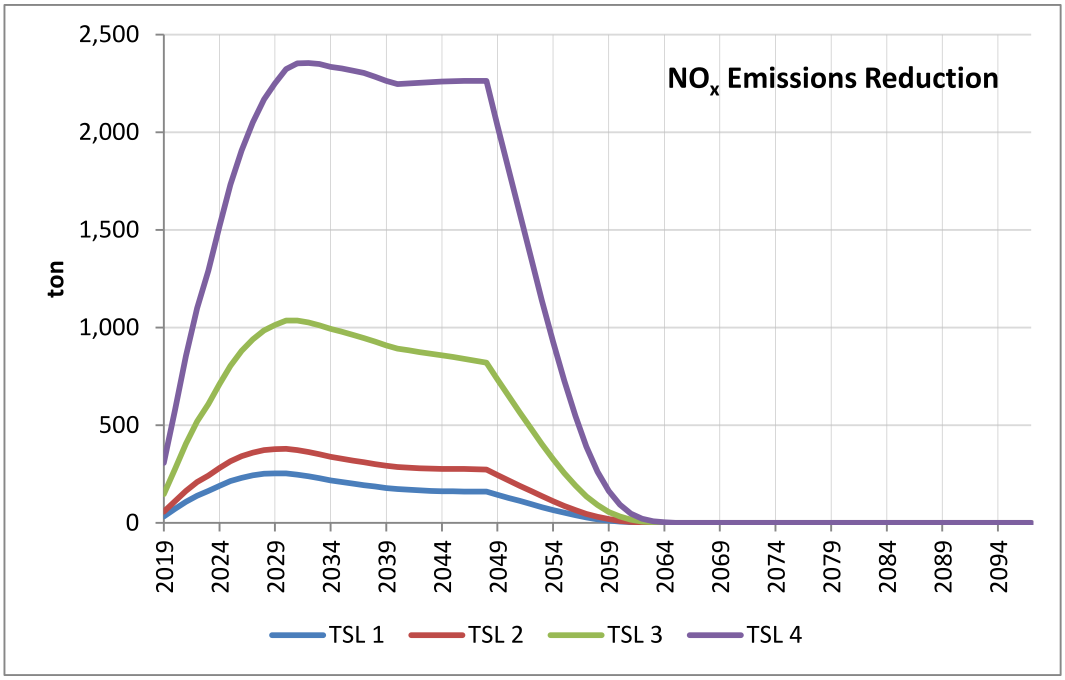


**Figure 13.5.3 NO$_x$ Total Emissions Reduction**

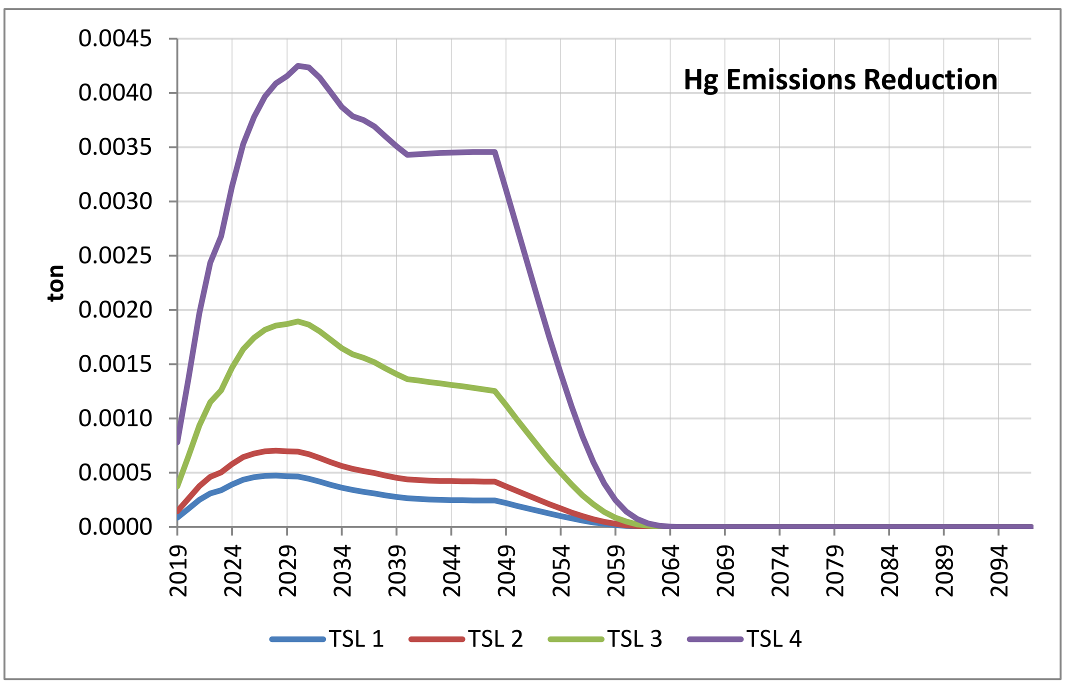


**Figure 13.5.4 Hg Total Emissions Reduction**

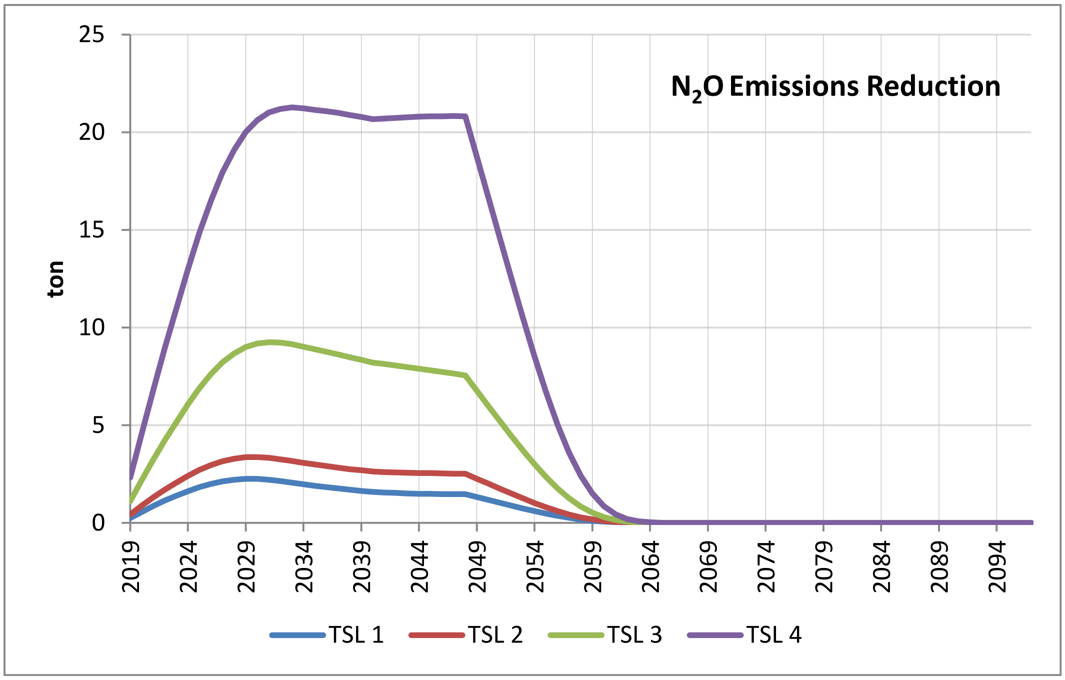


**Figure 13.5.5 $N_2O$ Total Emissions Reduction**

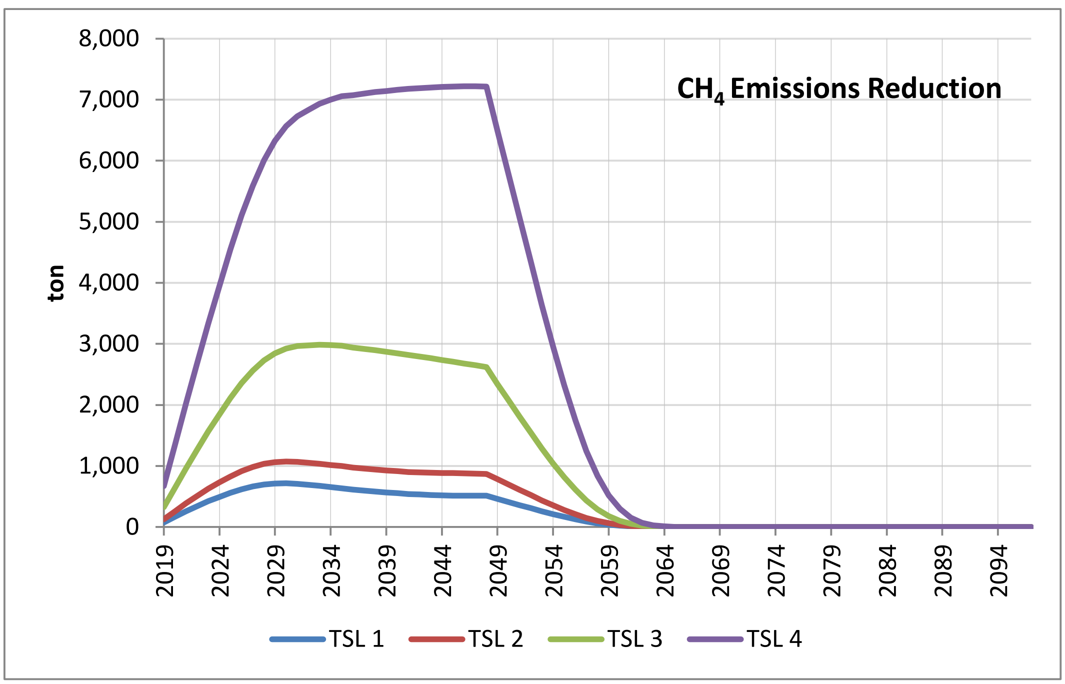


**Figure 13.5.6 $CH_4$ Total Emissions Reduction**

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# CHAPTER 14. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

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# CHAPTER 14. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

## 14.1 INTRODUCTION

As part of its assessment of the effects of potential energy conservation standards for dehumidifiers, the DOE estimated the monetary benefits of the reduced emissions of $CO_2$ and $NO_X$ that would be expected to result from each TSL considered for this rulemaking. This chapter summarizes the basis for the monetary values assigned to emissions and presents the modeled benefits of estimated reductions.

## 14.2 MONETIZING CARBON DIOXIDE EMISSIONS

One challenge for anyone attempting to calculate the monetary benefits of reduced emissions of $CO_2$ is what value to assign to each unit eliminated. The value must encompass a broad range of physical, economic, social, and political effects. Analysts developed the concept of the SCC to represent the broad cost or value associated with producing—or reducing—a quantifiable amount of $CO_2$ emissions.

### 14.2.1 Social Cost of Carbon

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. The SCC is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. SCC estimates are provided in dollars per metric ton of carbon dioxide. A value for the domestic SCC is meant to represent the damages in the United States resulting from a unit change in carbon dioxide emissions, whereas a global SCC is meant to reflect the value of damages worldwide.

Under section 1(b)(6) of Executive Order 12866,[1] agencies must, to the extent permitted by law, "assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the SCC estimates required by the Executive Order is to enable agencies to incorporate the monetized social benefits of reducing $CO_2$ emissions into cost-benefit analyses of regulatory actions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they will need updating in response to increasing knowledge of the science and economics of climate impacts.

As part of the interagency process that developed the SCC estimates, technical experts from numerous agencies met regularly to explore the technical literature in relevant fields, discuss key model inputs and assumptions, and consider public comments. The primary objective of the process was to develop a range of SCC values using a defensible set of assumptions regarding model inputs that was grounded in the scientific and economic literature. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates developed for use in the rulemaking process.

### 14.2.2 Monetizing Carbon Dioxide Emissions

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces several serious challenges. A report from the National Research Council[2] points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the effects of changes in climate on the physical and biological environment, and (4) the translation of those environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change raises serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing $CO_2$ emissions. An agency can estimate the benefits from reduced (or costs from increased) emissions in any future year by multiplying the change in emissions in that year by the SCC values appropriate for that year. Then the net present value of the benefits can be calculated by multiplying each of the future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions.

## 14.3 DEVELOPMENT OF SOCIAL COST OF CARBON VALUES

In 2009, an interagency process was initiated to develop a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To provide consistency in how benefits are evaluated across Federal agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced $CO_2$ emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the literature to use as interim values until a more comprehensive analysis could be conducted. The outcome of the preliminary assessment was a set of five interim values: global SCC estimates for 2007 (in 2006$) of $55, $33, $19, $10, and $5 per ton of $CO_2$.[3] Those interim values represented the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of that preliminary effort were presented in several proposed and final rules.

### 14.3.1 Current Approach and Key Assumptions

After the release of the interim values, the interagency group reconvened regularly to improve the SCC estimates. Specifically, the group considered public comments and further explored the technical literature in relevant fields. The interagency group relied on three integrated assessment models commonly used to estimate the SCC. The models are known by their acronyms of FUND, DICE, and PAGE. Those three models frequently are cited in the peer-reviewed literature and were used in the most recent assessment of the Intergovernmental Panel on Climate Change. Each model was given equal weight in developing SCC values.

Each model takes a slightly different approach to calculating how increases in emissions produce economic damages. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches taken by the key modelers in the field. An extensive review of the literature identified three sets of input parameters for the models: climate sensitivity; socioeconomic and emissions trajectories; and discount rates. A probability distribution for climate sensitivity was specified as an input to all three models. In addition, the interagency group used a range of scenarios for the socioeconomic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from the three integrated assessment models, at discount rates of 2.5 percent, 3 percent, and 5 percent. The fourth value, which represents the 95$^{th}$ percentile of the SCC estimate across all three models at a 3-percent discount rate, is included to represent larger-than-expected effects from temperature changes farther out in the tails of the SCC distribution. The values increase in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although preference is given to consideration of the global benefits of reducing $CO_2$ emissions. Table 14.3.1 presents the values in the 2010 interagency group report.[4]

**Table 14.3.1 Annual SCC Values for 2010-2050 from 2010 Interagency Report (in 2007$ per Metric Ton)**

| Year | Discount Rate (%) | | | |
|---|---|---|---|---|
| | 5 | 3 | 2.5 | 3 |
| | Average | Average | Average | 95$^{th}$ Percentile |
| 2010 | 4.7 | 21.4 | 35.1 | 64.9 |
| 2015 | 5.7 | 23.8 | 38.4 | 72.8 |
| 2020 | 6.8 | 26.3 | 41.7 | 80.7 |
| 2025 | 8.2 | 29.6 | 45.9 | 90.4 |
| 2030 | 9.7 | 32.8 | 50.0 | 100.0 |
| 2035 | 11.2 | 36.0 | 54.2 | 109.7 |
| 2040 | 12.7 | 39.2 | 58.4 | 119.3 |
| 2045 | 14.2 | 42.1 | 61.7 | 127.8 |
| 2050 | 15.7 | 44.9 | 65.0 | 136.2 |

The SCC values used for the analysis of the effects of potential standards for dehumidifiers were generated using the most recent versions of the three integrated assessment models that have been published in the peer-reviewed literature, as described in the 2013 update from the interagency working group (revised November 2013). Table 14.3.2 shows the updated sets of SCC estimates in 5-year increments from 2010 to 2050. The full set of annual SCC estimates for 2010–2050 is presented in appendix 14B of this TSD. The central value that emerges is the average SCC across models at a 3-percent discount rate. To capture the uncertainties involved in regulatory impact analysis, however, the interagency group emphasizes the importance of including all four sets of SCC values.

**Table 14.3.2 Annual SCC Values for 2010–2050 from 2013 Interagency Update (in 2007$ per Metric Ton of $CO_2$)**

| Year | Discount Rate (%) | | | |
|---|---|---|---|---|
| | 5 | 3 | 2.5 | 3 |
| | Average | Average | Average | 95th Percentile |
| 2010 | 11 | 32 | 51 | 89 |
| 2015 | 11 | 37 | 57 | 109 |
| 2020 | 12 | 43 | 64 | 128 |
| 2025 | 14 | 47 | 69 | 143 |
| 2030 | 16 | 52 | 75 | 159 |
| 2035 | 19 | 56 | 80 | 175 |
| 2040 | 21 | 61 | 86 | 191 |
| 2045 | 24 | 66 | 92 | 206 |
| 2050 | 26 | 71 | 97 | 220 |

### 14.3.2 Limitations of Current Estimates

The interagency group recognizes that current models are imperfect and incomplete. Because key uncertainties remain, current SCC estimates should be treated as provisional and revisable. Estimates doubtless will evolve in response to improved scientific and economic understanding. The 2009 National Research Council report points out the tension between producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of current modeling efforts. Several analytic challenges are being addressed by the research community, some by research programs housed in many of the Federal agencies participating in the interagency process. The interagency group intends to review and reconsider SCC estimates periodically to incorporate expanding knowledge of the science and economics of climate impacts, as well as improvements in modeling.

In summary, in considering the potential global benefits resulting from reduced $CO_2$ emissions, DOE used the values from the 2013 interagency report, applying the GDP price deflator to adjust the values to 2013$. For the four SCC values, the values of emissions in 2015 were $12.0, $40.5, $62.4, and $119 per metric ton avoided (values expressed in 2013$). DOE derived values after 2050 using the relevant growth rates for 2040–2050 in the interagency update.

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

## 14.4 VALUATION OF OTHER EMISSIONS REDUCTIONS

DOE considered the potential monetary benefits of reduced $NO_X$ emissions attributable to the TSLs considered for dehumidifiers. As noted in chapter 13, new or amended energy conservation standards would reduce $NO_X$ emissions in those States that are not affected by emissions caps. DOE estimated the monetized value of $NO_X$ emissions reductions resulting from each TSL based on estimates of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ precursor reduced by electricity generating units. The estimates were developed by Krewski et al. (2009) and are reported in EPA's Office of Air Quality Planning and Standards report "Technical Support Document: Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors."[5] Table 14.4.1 summarizes the monetized values estimated in 2010$ for $NO_X$ emission reductions in 2016, 2020, 2025 and 2030, at discount rates of 3 percent and 7 percent. DOE applied the GDP price deflator to adjust the values to 2013$. For the two $NO_X$ values, the values of emissions in 2016 were $5483 and $4850 per ton avoided (values expressed in 2013$). DOE further interpolated the values between the intervals, and extrapolated the values after 2030 using the relevant growth rates for 2016–2030. DOE then multiplied the $NO_X$ emissions reduction estimated for each year by the $NO_X$ value for that year under each discount rate. To calculate a present value of the stream of monetary values, DOE discounted the values calculated under each discount rate using the same discount rate that had been used to obtain the $NO_X$ values.

**Table 14.4.1 Summary of the total dollar value (mortality and morbidity) per ton of directly emitted $PM_{2.5}$ precursor reduced by Electricity Generating Units (2010$)**

| Year | Discount Rate (%) | |
|---|---|---|
| | 3 | 7 |
| 2016 | 5200 | 4600 |
| 2020 | 5400 | 4900 |
| 2025 | 5800 | 5200 |
| 2030 | 6200 | 5600 |

DOE continues to evaluate appropriate values for monetizing avoided $SO_2$ and Hg emissions. DOE did not monetize those emissions for this analysis.

## 14.5 RESULTS

Table 14.5.1 presents the global values of $CO_2$ emissions reductions for each considered TSL.

**Table 14.5.1 Estimates of Global Present Value of $CO_2$ Emissions Reduction under TSLs for Dehumidifiers**

| TSL | SCC Case* | | | |
|---|---|---|---|---|
| | 5% discount rate, average* | 3% discount rate, average* | 2.5% discount rate, average* | 3% discount rate, 95th percentile* |
| | Million 2013$ | | | |
| Primary Energy Emissions | | | | |
| 1 | 29.5 | 133 | 210 | 410 |
| 2 | 46.2 | 209 | 330 | 644 |
| 3 | 130 | 593 | 939 | 1,831 |
| 4 | 311 | 1,427 | 2,264 | 4,411 |
| Upstream Emissions | | | | |
| 1 | 1.57 | 7.16 | 11.3 | 22.1 |
| 2 | 2.48 | 11.3 | 18.0 | 35.0 |
| 3 | 7.06 | 32.4 | 51.5 | 100 |
| 4 | 17 | 79 | 126 | 244 |
| Full-Fuel-Cycle Emissions | | | | |
| 1 | 31.1 | 140 | 221 | 432 |
| 2 | 48.6 | 220 | 348 | 679 |
| 3 | 137 | 625 | 990 | 1,931 |
| 4 | 328 | 1,506 | 2,390 | 4,656 |

* For each of the four cases, the corresponding global SCC value for emissions in 2015 is $12.0, $40.5, $62.4, and $119 per metric ton (2013$).

After calculating global values of $CO_2$ emissions reductions for each considered TSL, DOE calculated domestic values as a range of from 7 percent to 23 percent of the global values. Results for domestic values are presented in Table 14.5.2.

**Table 14.5.2 Estimates of Domestic Present Value of $CO_2$ Emissions Reduction under TSLs for Dehumidifiers**

| TSL | SCC Case* | | | |
|---|---|---|---|---|
| | 5% discount rate, average* | 3% discount rate, average* | 2.5% discount rate, average* | 3% discount rate, 95$^{th}$ percentile* |
| | Million 2013$ | | | |
| Primary Energy Emissions | | | | |
| 1 | 2.1 to 6.8 | 9.3 to 30.6 | 14.7 to 48.3 | 28.7 to 94.3 |
| 2 | 3.2 to 10.6 | 14.6 to 48.0 | 23.1 to 76.0 | 45.1 to 148.2 |
| 3 | 9.1 to 30.0 | 41.5 to 136.3 | 65.7 to 216.0 | 128.2 to 421.1 |
| 4 | 21.8 to 71.5 | 99.9 to 328.1 | 158.5 to 520.8 | 308.8 to 1014.6 |
| Upstream Emissions | | | | |
| 1 | 0.1 to 0.4 | 0.5 to 1.6 | 0.8 to 2.6 | 1.5 to 5.1 |
| 2 | 0.2 to 0.6 | 0.8 to 2.6 | 1.3 to 4.1 | 2.4 to 8.0 |
| 3 | 0.5 to 1.6 | 2.3 to 7.5 | 3.6 to 11.8 | 7.0 to 23.1 |
| 4 | 1.2 to 3.9 | 5.5 to 18.2 | 8.8 to 28.9 | 17.1 to 56.2 |
| Full-Fuel-Cycle Emissions | | | | |
| 1 | 2.2 to 7.2 | 9.8 to 32.2 | 15.5 to 50.9 | 30.2 to 99.4 |
| 2 | 3.4 to 11.2 | 15.4 to 50.6 | 24.4 to 80.1 | 47.6 to 156.3 |
| 3 | 9.6 to 31.6 | 43.8 to 143.8 | 69.3 to 227.8 | 135.2 to 444.2 |
| 4 | 22.9 to 75.4 | 105.4 to 346.3 | 167.3 to 549.7 | 325.9 to 1070.8 |

* For each of the four cases, the corresponding global SCC value for emissions in 2015 is $12.0, $40.5, $62.4, and $119 per metric ton (2013$).

Table 14.5.3 presents the present value of cumulative $NO_X$ emissions reductions for each TSL. Monetary values are calculated using the average dollar-per-ton values assigned to $NO_X$ emissions at 7-percent and 3-percent discount rates.

**Table 14.5.3 Estimates of Present Value of $NO_X$ Emissions Reduction under TSLs for Dehumidifiers**

| TSL | 3% discount rate | 7% discount rate |
|---|---|---|
| | Million 2013$ | |
| Primary Energy Emissions | | |
| 1 | 11.9 | 5.36 |
| 2 | 18.6 | 8.27 |
| 3 | 52.4 | 22.8 |
| 4 | 125 | 52.9 |
| Upstream Emissions | | |
| 1 | 11.4 | 4.88 |
| 2 | 18.0 | 7.58 |
| 3 | 51.4 | 21.2 |
| 4 | 125 | 49.9 |
| Full-Fuel-Cycle Emissions | | |
| 1 | 23.3 | 10.2 |
| 2 | 36.5 | 15.9 |
| 3 | 104 | 44.0 |
| 4 | 250 | 103 |

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# CHAPTER 15. UTILITY IMPACT ANALYSIS

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# CHAPTER 15. UTILITY IMPACT ANALYSIS

## 15.1 INTRODUCTION

In the utility impact analysis, the DOE analyzes the changes in electric installed capacity and power generation that result for each TSL.

The utility impact analysis is based on output of the DOE/ EIA's NEMS.[a] NEMS is a public domain, multi-sectored, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce an energy forecast for the United States, the Annual Energy Outlook (AEO). The EIA publishes a reference case, which incorporates all existing energy-related policies at the time of publication, and a variety of side cases which analyze the impact of different policies, energy price and market trends. As of 2014, DOE is using a new methodology based on results published for the *AEO 2014* Reference case and a set of side cases that implement a variety of efficiency-related policies.[2]

The new approach retains key aspects of DOE's previous methodology, and provides some improvements:

- The assumptions used in the AEO reference case and side cases are fully documented and receive detailed public scrutiny.
- NEMS is updated each year, with each edition of the AEO, to reflect changes in energy prices, supply trends, regulations, *etc.*
- The comprehensiveness of NEMS permits the modeling of interactions among the various energy supply and demand sectors.
- Using EIA published side cases to estimate the utility impacts enhances the transparency of DOE's analysis.
- The variability in impacts estimates from one edition of AEO to the next will be reduced under the new approach.

On the average, however, over the full analysis period, the results from the new approach are comparable to results from the old approach.

## 15.2 METHODOLOGY

DOE estimates the marginal impacts of reduction in energy demand on the energy supply sector. In principle, marginal values should provide a better estimate of the actual impact of energy conservation standards.

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[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview*.[1]

NEMS uses predicted growth in demand for each end use to build up a projection of the total electric system load growth. The system load shapes are converted internally to load duration curves, which are then used to estimate the most cost-effective additions to capacity. When electricity demand deviates from the AEO reference case, in general there are three inter-related effects: the annual generation (TWh) from the stock of electric generating capacity changes, the total generation capacity itself (GW) may change, and the mix of capacity by fuel type may change. Each of these effects can vary for different types of end use. The change in total generating capacity is sensitive to the degree to which the end-use is peak coincident, while the capacity mix is sensitive to the hourly load shape associated with the end use. Changes in generation by fuel type lead in turn to changes in total power sector emissions of $SO_2$, $NO_x$, Hg and $CO_2$.

DOE's new approach examines a series of AEO side cases to estimate the relationship between demand reductions and the marginal energy, emissions and capacity changes. The assumptions for each side case are documented in Appendix E of the AEO. The side cases, or scenarios, that incorporate significant changes to equipment efficiencies relative to the Reference case are:

- 2013 Technology (leaves all technologies at 2013 efficiencies);
- Best Available Technology (highest efficiency irrespective of cost);
- High Technology (higher penetration rates for efficiency and demand management);
- Extended Policies (includes efficiency standards that are not in the reference).

Scenarios that incorporate policies that directly affect the power sector without changes in energy demand (for example, subsidies for renewables, or high fuel price assumptions) are not appropriate for this analysis. The methodology proceeds in seven steps:

1. Supply-side data on generation, capacity and emissions, and demand-side data on electricity use by sector and end-use, are extracted from each side case. The data are converted to differences relative to the AEO Reference case.

2. The changes in electricity use on the demand-side data are allocated to one of three categories: on-peak, shoulder, and off-peak. These categories are used in the utility sector to correlate end-use consumption with supply types. For each of the end-uses that are modeled explicitly in NEMS, load shape information is used to identify the fraction of annual electricity use assigned to each category. On-peak hours are defined as noon-5pm, June through September. Off-peak hours are nights and Sundays. All other hours are assigned to the shoulder period.

3. For each year and each side case, the demand-side reductions to on-peak, off-peak and shoulder-period electricity use are matched on the supply-side to reductions in generation by fuel type. The fuel types are petroleum fuels, natural gas, renewables, nuclear and coal. The allocation is based on the following rules:

   3.1. All Petroleum-Based Generation Is Allocated To Peak Periods;

3.2. Natural Gas Generation Is Allocated To Any Remaining Peak Reduction; This Is Consistent With The Fact That Oil And Gas Steam Units Are Used In Nems To Meet Peak Demand;

3.3. Base-Load Generation (Nuclear And Coal) Is Allocated Proportionally To All Periods;

3.4. The Remaining Generation Of All Types Is Allocated To The Remaining Off-Peak And Shoulder Reductions Proportionally.

4. The output of step 3 defines fuel-share weights giving the fraction of energy demand in each load category that is met by each fuel type as a function of time. These are combined with the weights that define the load category shares by end-use to produce coefficients that allocate a marginal reduction in end-use electricity demand to each of the five fuel types.

5. A regression model is used to relate reductions in generation by fuel type to reductions in emissions of power sector pollutants. The model produces coefficients that define the change in total annual emissions of a given pollutant resulting from a unit change in total annual generation for each fuel type, as a function of time. These coefficients are combined with the weights calculated in step 4 to produce coefficients that relate emissions changes to changes in end-use demand.

6. A regression model is used to relate reductions in generation by fuel type to reductions in installed capacity. The categories used for installed capacity are the same as for generation except for peak: NEMS uses two peak capacity types (combustion turbine/diesel and oil and gas steam) which are combined here into a single "peak" category. The model produces coefficients that define the change in total installed capacity of a given type resulting from a unit change in total annual generation for the corresponding fuel type. These coefficients are combined with the weights calculated in step 4 to produce coefficients that relate installed capacity changes to changes in end-use demand, as a function of time.

7. The coefficient time-series for fuel share, pollutant emissions and capacity for the appropriate end use are multiplied by the stream of energy savings calculated in the NIA to produce estimates of the utility impacts.

This analysis ignores pumped storage, fuel cells and distributed generation, as these generation types are not affected by the policy changes modeled in the EIA side cases. The methodology is described in more detail in K. Coughlin, "Utility Sector Impacts of Electricity Demand Reductions".[3]

## 15.3 UTILITY IMPACT RESULTS

This section presents results of the analysis for all of the capacity types used to supply electricity for homes.

### 15.3.1 Installed Capacity

The figures in this section show the changes in U.S. electricity installed capacity that result for each TSL by major plant type for selected years. Note that a negative number means an increase in capacity under a TSL.

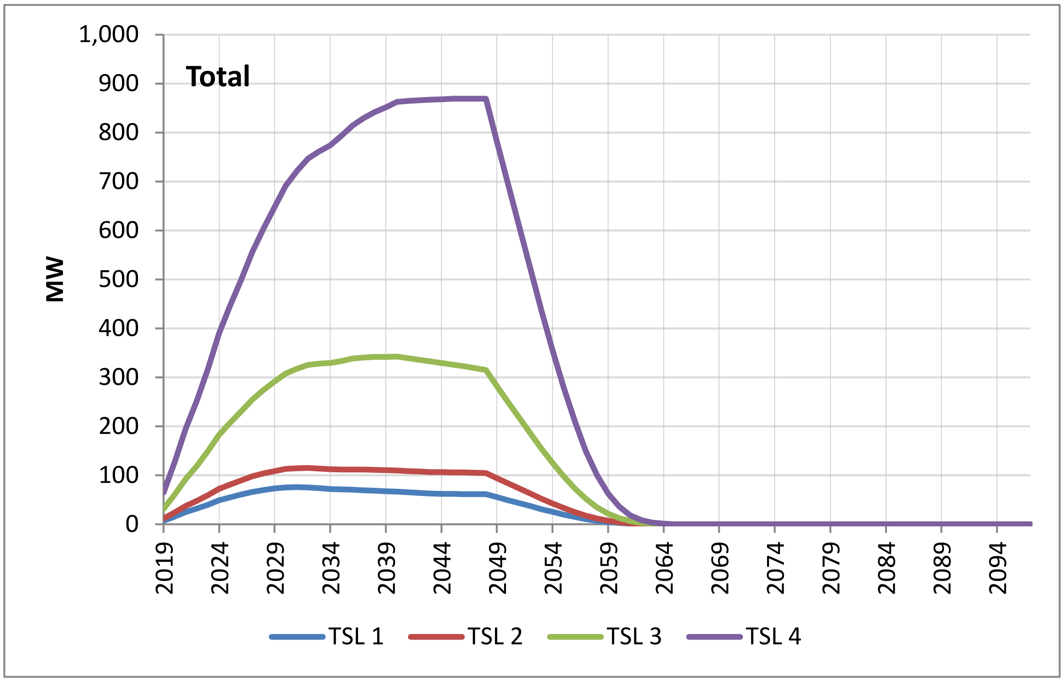


**Figure 15.7.1 Total Electric Capacity Reduction**

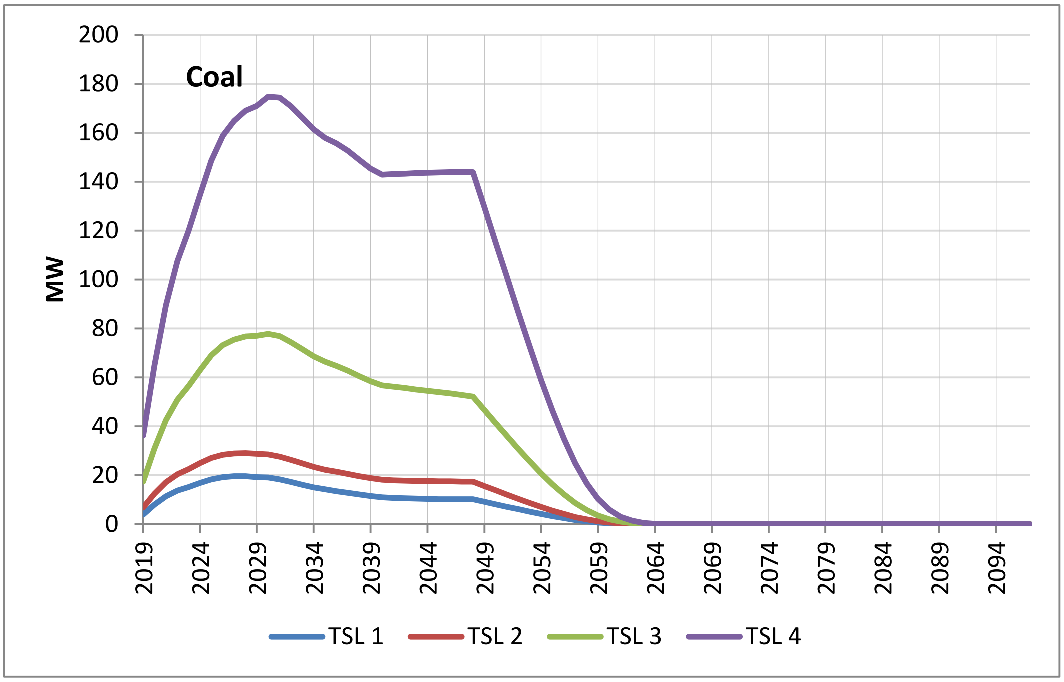


**Figure 15.7.2 Coal Capacity Reduction**

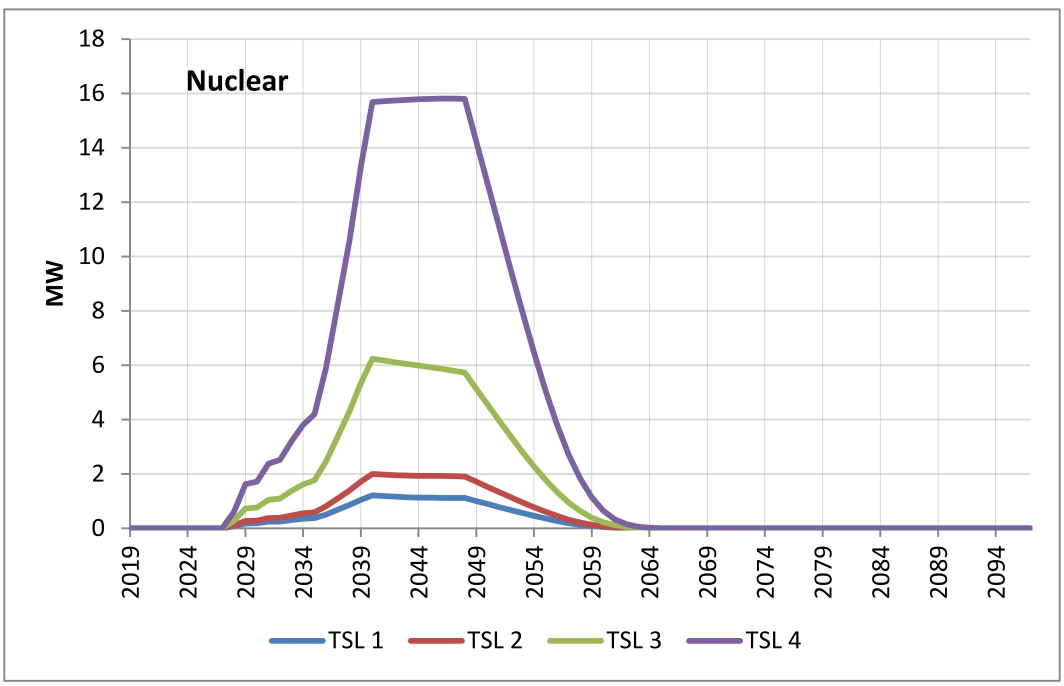


**Figure 15.7.3 Nuclear Capacity Reduction**

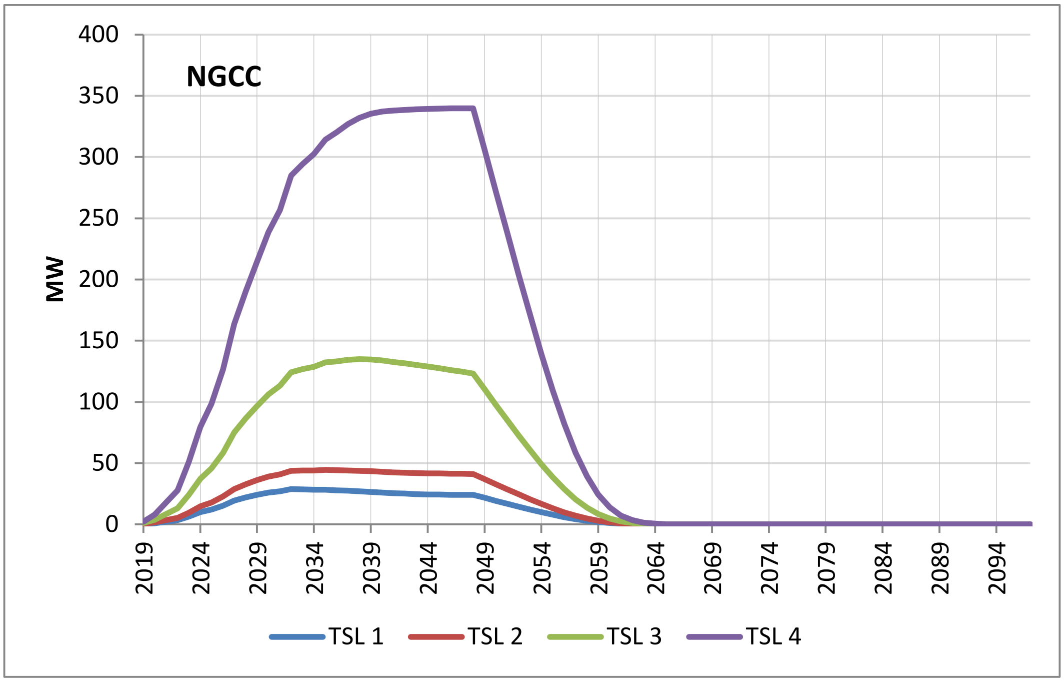


**Figure 15.7.4 Gas Combined Cycle Capacity Reduction**

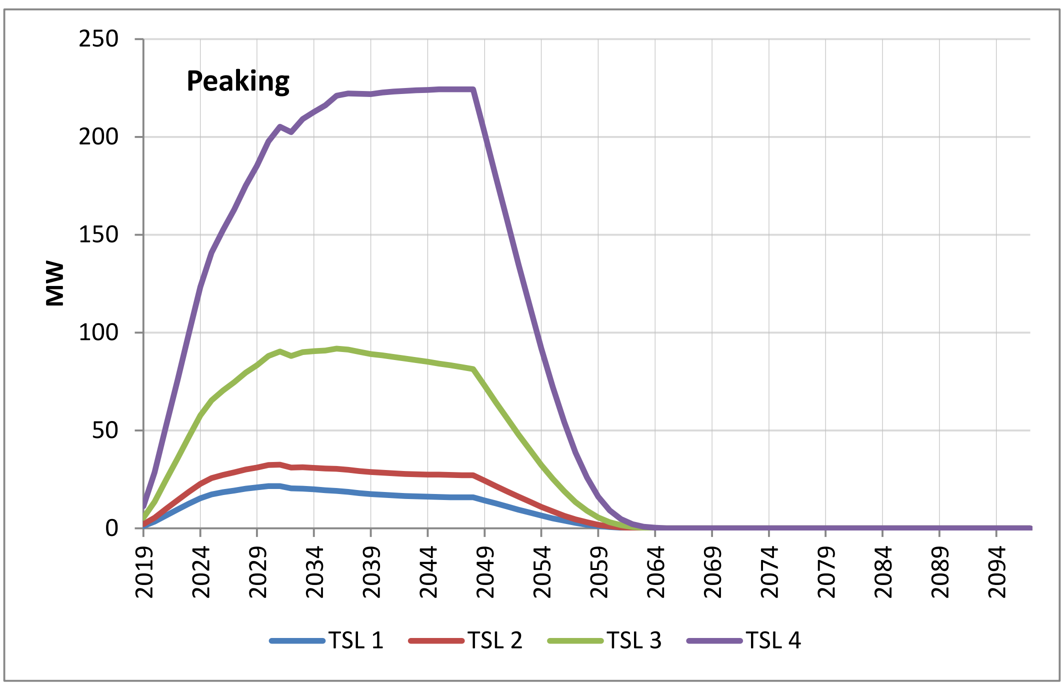


**Figure 15.7.5 Peaking Capacity Reduction**

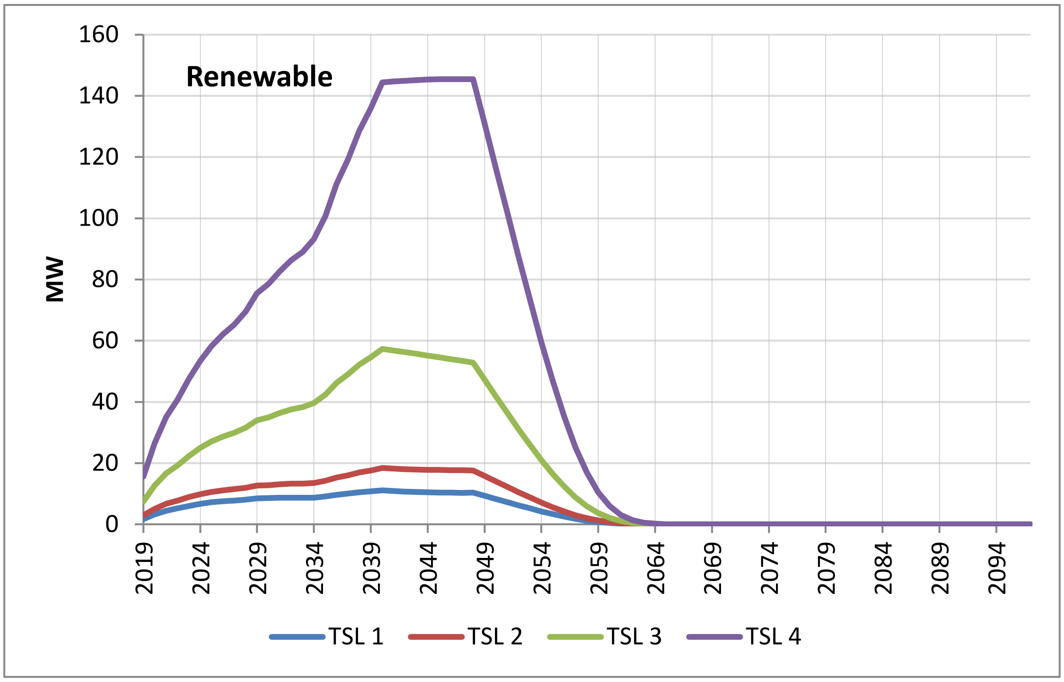


**Figure 15.7.6 Renewables Capacity Reduction**

### 15.3.2 Electricity Generation

The figures in this section show the annual change in electricity generation that result for each TSL by fuel type. Note that a negative number means an increase in generation under a TSL.

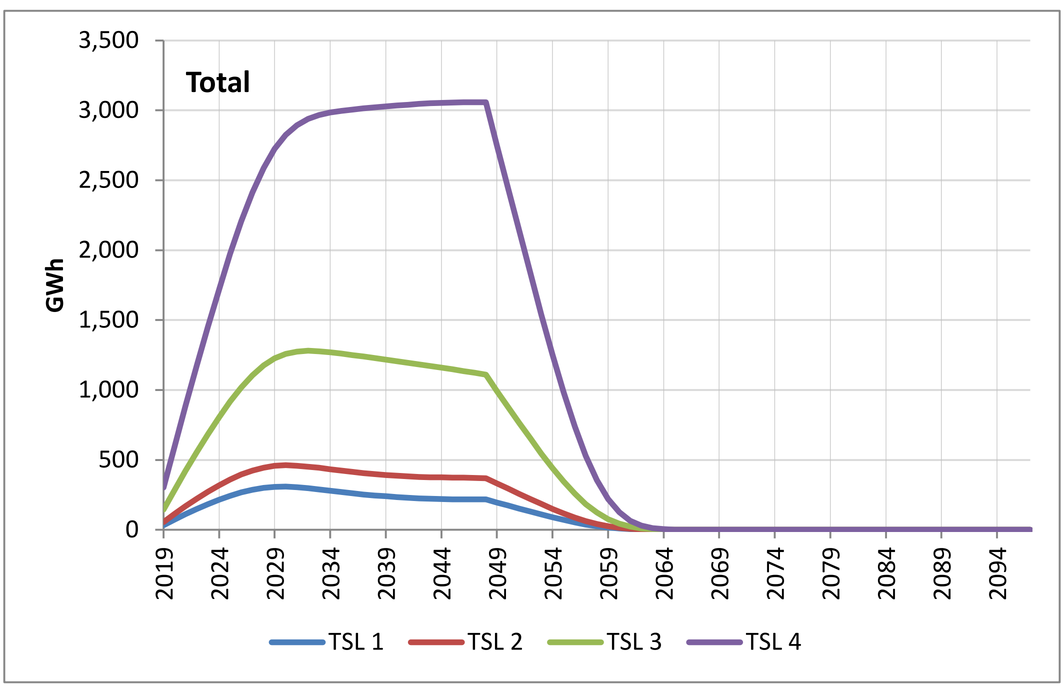


**Figure 15.7.7 Total Generation Reduction**

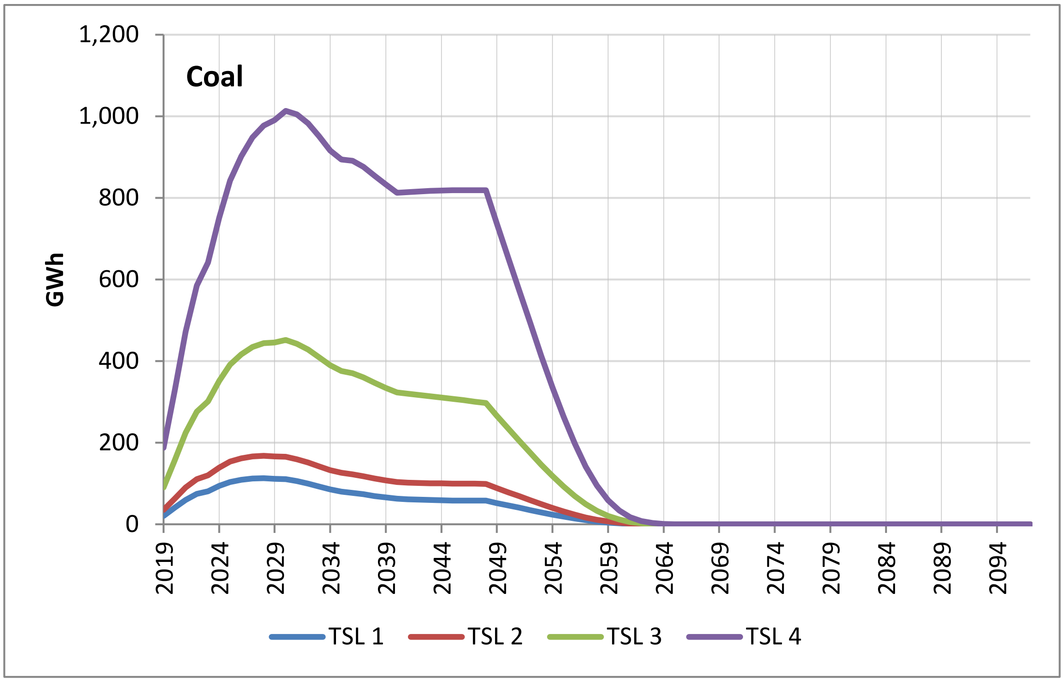


**Figure 15.7.8 Coal Generation Reduction**

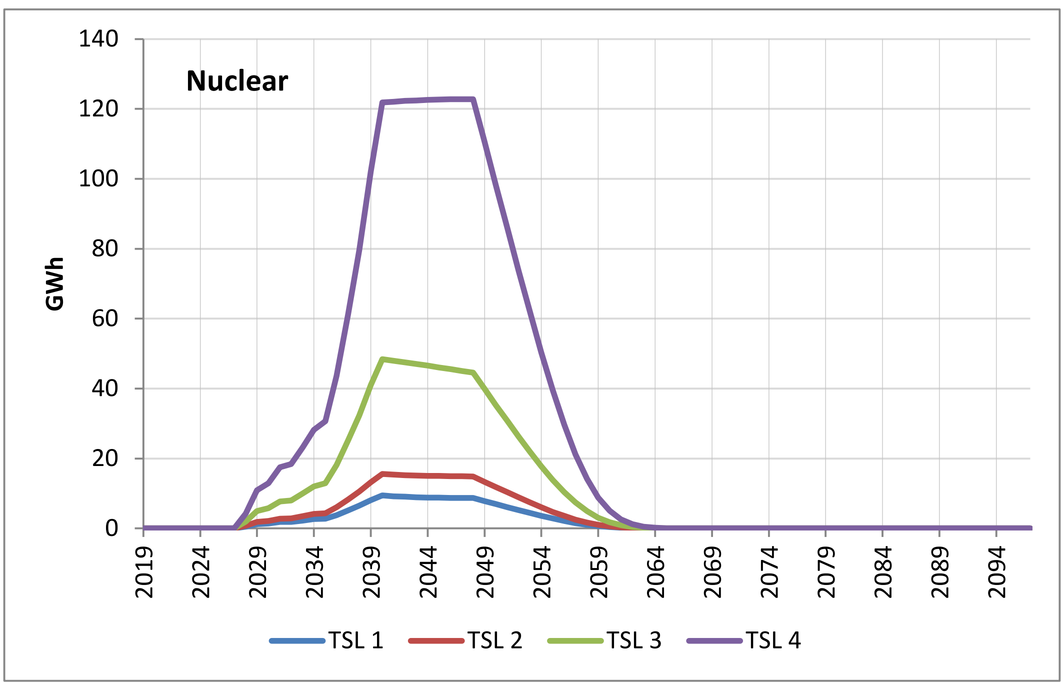


**Figure 15.7.9 Nuclear Generation Reduction**

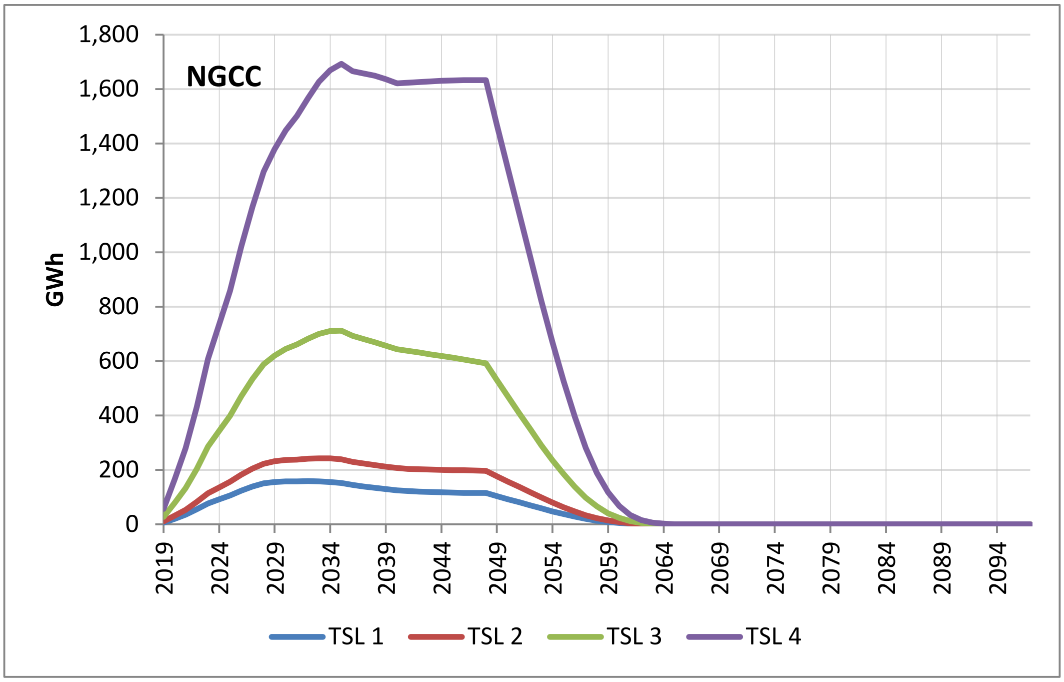


**Figure 15.7.10 Natural Gas Combined Cycle Generation Reduction**

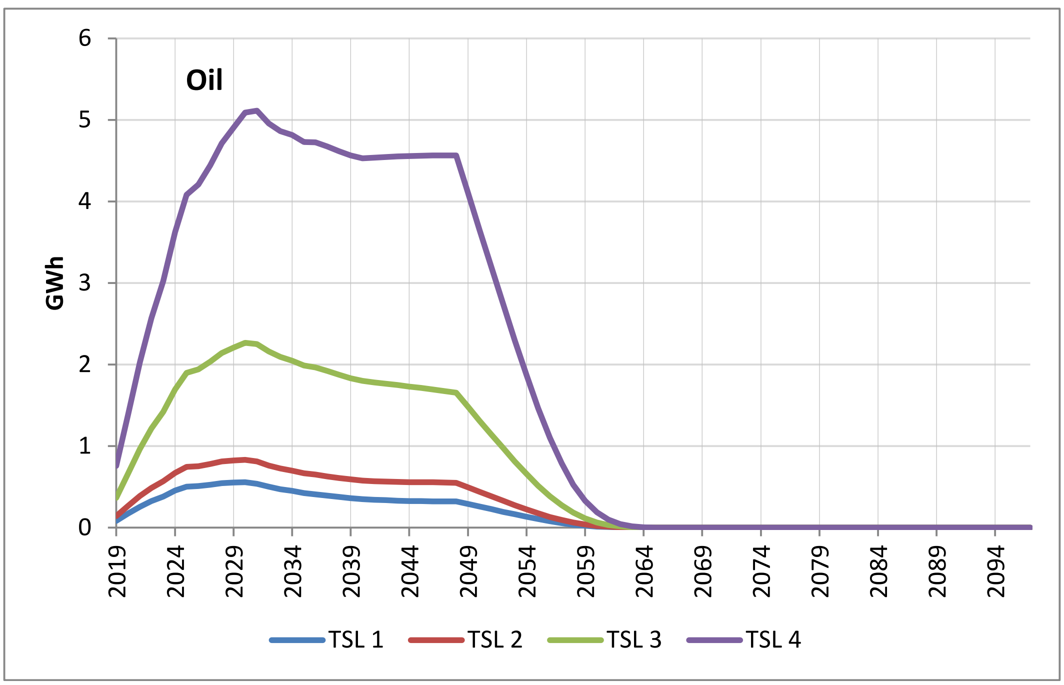


**Figure 15.7.11 Oil Generation Reduction**

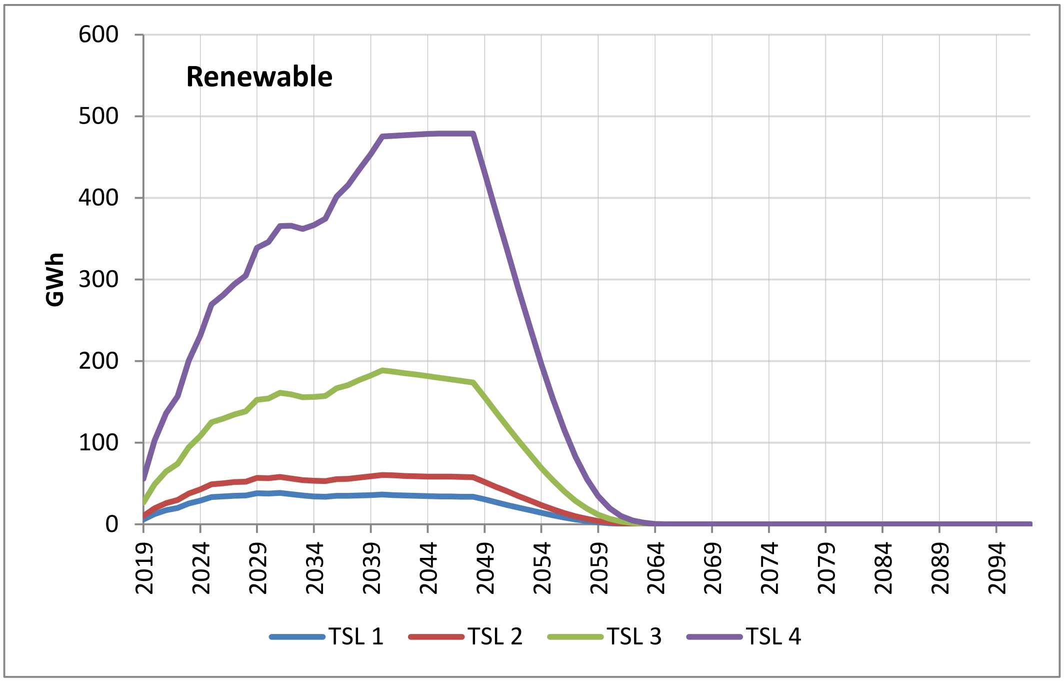


**Figure 15.7.12 Renewables Generation Reduction**

### 15.3.3 Results Summary

Table 15.7.1 presents a summary of the utility impact results for dehumidifiers.

**Table 15.7.1 Summary of Utility Impact Results**

| | TSL 1 | TSL 2 | TSL 3 | TSL 4 |
|---|---|---|---|---|
| Installed Capacity Reduction (MW) | | | | |
| 2020 | 15.8 | 24.5 | 61.0 | 128 |
| 2025 | 55.1 | 81.3 | 207 | 446 |
| 2030 | 75.5 | 113 | 308 | 691 |
| 2035 | 71.4 | 112 | 334 | 793 |
| 2040 | 66.6 | 110 | 343 | 863 |
| Electricity Generation Reduction (GWh) | | | | |
| 2020 | 74.1 | 115 | 286 | 599 |
| 2025 | 244 | 360 | 917 | 1,974 |
| 2030 | 309 | 462 | 1,258 | 2,825 |
| 2035 | 270 | 423 | 1,260 | 2,997 |
| 2040 | 234 | 387 | 1,205 | 3,035 |

## REFERENCES


1 U.S. Department of Energy-Energy Information Administration, *National Energy Modeling System: An Overview*, 2009. Report No. DOE/EIA-0581(2009). <http://www.eia.gov/oiaf/aeo/overview/>

2 U.S. Department of Energy-Energy Information Administration, *Annual Energy Outlook 2014 with Projections to 2040*, 2014. Washington, DC. <http://www.eia.gov/forecasts/aeo/>

3 Coughlin, K., *Utility Sector Impacts of Reduced Electricity Demand*, 2014. Lawrence Berkeley National Laboratory. Report No. LBNL-Pending.

# CHAPTER 16. EMPLOYMENT IMPACT ANALYSIS

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# CHAPTER 16. EMPLOYMENT IMPACT ANALYSIS

## 16.1 INTRODUCTION

DOE's employment impact analysis is designed to estimate indirect national job creation or elimination resulting from possible standards, due to reallocation of the associated expenditures for purchasing and operating dehumidifiers. Job increases or decreases reported in this chapter are separate from the direct dehumidifier production sector employment impacts reported in the manufacturer impact analysis (Chapter 12), and reflect the employment impact of efficiency standards on all other sectors of the economy.

## 16.2 ASSUMPTIONS

DOE expects energy conservation standards to decrease energy consumption, and therefore to reduce energy expenditures. The savings in energy expenditures may be spent on new investment or not at all (i.e., they may remain "saved"). The standards may increase the purchase price of products, including the retail price plus sales tax, and increase installation costs.

The ImSET input/output econometric model of the U.S. economy, this analysis estimated the short-term effect of these expenditure impacts on net economic output and employment. DOE intends this analysis to quantify the indirect employment impacts of these expenditure changes. It evaluated direct employment impacts at manufacturers' facilities in the manufacturer impact analysis (see Chapter 12).

DOE notes that ImSET is not a general equilibrium forecasting model, and understands the uncertainties involved in projecting employment impacts, especially changes in the later years of the analysis.[1] Because ImSET does not incorporate price changes, the employment effects predicted by ImSET would over-estimate the magnitude of actual job impacts over the long run for this rule. Since input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. DOE therefore includes a qualitative discussion of how labor markets are likely to respond in the longer term. In future rulemakings, DOE may consider the use of other modeling approaches for examining long run employment impacts.

## 16.3 METHODOLOGY

The Department based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 3.1.1[2] (Impact of Sector Energy Technologies) as a successor to ImBuild[3], a special-purpose version of the IMPLAN[4] national input/output model. ImSET estimates the employment and income effects of building energy technologies. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy-efficiency investments in buildings.

In an input/output model, the level of employment in an economy is determined by the relationship of different sectors of the economy and the spending flows among them. Different sectors have different levels of labor intensity and so changes in the level of spending (*e.g.,* due to the effects of an efficiency standard) in one sector of the economy will affect flows in other sectors, which affects the overall level of employment.

ImSET uses a 187-sector model of the national economy to predict the economic effects of residential and commercial buildings technologies. ImSET collects estimates of initial investments, energy savings, and economic activity associated with spending the savings resulting from standards (e.g., changes in final demand in personal consumption, business investment and spending, and government spending). It provides overall estimates of the change in national output for each input-output sector. The model applies estimates of employment and wage income per dollar of economic output for each sector and calculates impacts on national employment and wage income.

Energy-efficiency technology primarily affects the U.S. economy along three spending pathways. First, general investment funds are diverted to sectors that manufacture, install, and maintain energy-efficient products. The increased cost of products leads to higher employment in the product manufacturing sectors and lower employment in other economic sectors. Second, commercial firm and residential spending are redirected from utilities toward firms that supply production inputs. Third, 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 dehumidifier manufacturing sector estimated in Chapter 12 using the GRIM. The methodologies used and the sectors analyzed in the ImSET and GRIM models are different.

## 16.4 SHORT-TERM RESULTS

The results in this section refer to impacts dehumidifier standards relative to the base case. DOE disaggregated the impact of standards on employment into three component effects: increased capital investment costs, decreased energy costs, and changes in operations and maintenance costs. DOE presents the summary impact.

Conceptually, one can consider the impact of the rule in its first year on three aggregate sectors, the dehumidifier production sector, the energy generation sector, and the general consumer goods sector (as mentioned above ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the rule generally increases the purchase price of dehumidifiers; this increase in expenditures causes an increase in employment in this sector. At the same time, the improvements in energy efficiency reduce consumer expenditures on energy, freeing up this money to be spent in other sectors. The reduction in energy demand causes a reduction in employment in the energy production sector. Finally, based on the net impact of increased expenditures on dehumidifiers and reduced expenditures on energy, consumer expenditures on everything else are either positively or negatively affected, increasing or reducing jobs in that sector accordingly. The model also captures any indirect jobs created or lost by changes in consumption due to changes in employment (*e.g.* as more workers are hired they consume more goods, which generates more employment; the converse is true for workers laid off).

Table 16.4.1 present the modeled net employment impact from the rule in 2019, rounded to the nearest ten jobs. Approximately 97 percent of dehumidifiers are imported and 3 percent are produced domestically. The net employment impact estimate is sensitive to assumptions regarding the return to the U.S. economy of money spent on imported dehumidifiers. The two scenarios bounding the ranges presented in Table 16.4.1 represent situations in which none of the money spent on imported dehumidifiers returns to the U.S. economy and all of the money spent on imported dehumidifiers returns to the U.S. economy. The U.S. trade deficit in recent years suggests that between 50 percent and 75 percent of the money spent on imported dehumidifiers is likely to return, with employment impacts falling within the ranges presented below.

**Table 16.4.1 Dehumidifier Net National Short-term Change in Employment (Number of Jobs)**

| Trial Standard Level | 2019 | 2024 |
|---|---|---|
| TSL 1 | 20 to 60 | 150 to 190 |
| TSL 2 | 40 to 100 | 210 to 280 |
| TSL 3 | 100 to 260 | 570 to 720 |
| TSL 4 | 200 to 980 | 1,230 to 1,920 |

For context, the OMB currently assumes that the unemployment rate may decline to 5.3 percent in 2017.[5] The unemployment rate in 2019 is projected to remain close to "full employment." When an economy is at full employment any effects on net employment are likely to be transitory as workers change jobs, rather than enter or exit longer-term employment.

## 16.5 LONG-TERM RESULTS

Over the long term DOE expects the energy savings to consumers to increasingly dominate the increase in product costs, resulting in increased aggregate savings to consumers. As a result, DOE expects demand for energy to decline over time and demand for other goods to increase. Since the electricity generation and natural gas sectors are relatively capital intensive compared to the consumer goods sector, the net effect will be an increase in labor demand. In equilibrium, this should lead to upward pressure on wages and a shift in employment away from electricity generation towards consumer goods. Note that in long-run equilibrium there is no net effect on total employment since wages adjust to bring the labor market into equilibrium. Nonetheless, even to the extent that markets are slow to adjust, DOE anticipates that net labor market impacts will in general be negligible over time due to the small magnitude of the short-term effects presented in Table 16.4.1. The ImSET model projections, assuming no price or wage effects until 2024, are included in the second column of Table 16.4.1.

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1. Scott, M., JM Roop, RW Schultz, DM Anderson, KA Cort, The Impact of DOE Building Technology Energy Efficiency Programs on U.S. Employment, Income, and Investment. *Energy Economics*, 2008. 30(5): pp. 2283-2301

2. Roop, J. M., M. J. Scott, and R. W. Schultz, *ImSET: Impact of Sector Energy Technologies*, 2005. Pacific Northwest National Laboratory. Richland, WA. Report No. PNNL- 15273.

3. Scott, M. J., D. J. Hostick, and D. B. Belzer, *ImBuild: Impact of Building Energy Efficiency Programs,* April, 1998. Pacific Northwest National Laboratory. Richland, WA. Report No. PNNL-11884. Prepared for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

4. Minnesota IMPLAN Group Inc., *IMPLAN Professional: User's Guide, Analysis Guide, Data Guide*, 1997. Stillwater, MN.

5. Office of Management and Budget, *Fiscal Year 2012 Mid-Session Review: Budget of the U.S. Government,* Washington, DC. <http://www.whitehouse.gov/sites/default/files/omb/budget/fy2012/assets/12msr.pdf>

# CHAPTER 17. REGULATORY IMPACT ANALYSIS

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# CHAPTER 17. REGULATORY IMPACT ANALYSIS

## 17.1 INTRODUCTION

The DOE has determined that the regulatory action described in the Federal Register notice associated with this TSD constitutes an "economically significant regulatory action" under Executive Order (E.O.) 12866, Regulatory Planning and Review. 58 FR 51735 (October 4, 1993). For such actions, E.O. 12866 requires Federal agencies to provide "an assessment, including the underlying analysis, of costs and benefits of potentially effective and reasonably feasible alternatives to the planned regulation, identified by the agencies or the public (including improving the current regulation and reasonably viable non-regulatory actions), and an explanation why the planned regulatory action is preferable to the identified potential alternatives." 58 FR 51735, 51741.

To conduct this analysis, DOE used an integrated NIA and RIA model. The NIA-RIA was built on the NIA model as discussed in Chapter 10. DOE identified five non-regulatory policy alternatives that possibly could provide incentives for the same energy efficiency levels as the ones in the proposed trial standard levels for the dehumidifiers that are the subject of this rulemaking. The non-regulatory policy alternatives are listed in Table 17.1.1, which also includes the "no new regulatory action" alternative. DOE evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each to the effectiveness of the proposed standards for the 5 product classes of dehumidifiers covered by this rulemaking.

**Table 17.1.1 Non-Regulatory Alternatives to National Standards**

| |
|---|
| No New Regulatory Action |
| Consumer Rebates |
| Consumer Tax Credits |
| Manufacturer Tax Credits |
| Voluntary Energy Efficiency Targets |
| Bulk Government Purchases |

Sections 17.2 and 17.3 discuss the analysis of five selected policies listed in Table 17.1.1 (excluding the alternative of "No New Regulatory Action"). Section 17.4 presents the results of the policy alternatives.

## 17.2 NON-REGULATORY POLICIES

This section describes the method DOE used to analyze the energy savings and cost effectiveness of the non-regulatory policy alternatives for dehumidifiers. This section also describes the assumptions underlying the analysis.

### 17.2.1 Methodology

DOE used its integrated NIA-RIA spreadsheet model to calculate the NES and NPV associated with each non-regulatory policy alternative. Chapter 10 of the TSD describes the NIA spreadsheet model. Appendix 17A discusses the NIA-RIA integrated model approach.

DOE quantified the effect of each alternative on the purchase of equipment that meets the efficiency levels corresponding to each TSL. After establishing the quantitative assumptions underlying each alternative, DOE appropriately revised inputs to the NIA-RIA spreadsheet model. The primary model inputs revised were market shares of equipment meeting the target efficiency levels set for each TSL. The shipments of equipment for any given year reflect a distribution of efficiency levels. DOE assumed, for each TSL, that new energy efficiency standards would affect 100 percent of the shipments of products that did not meet the TSL target levels in the base case,[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 dehumidifiers attributable to each policy alternative.

Increasing the efficiency of a product often increases its average installed cost. However, operating costs generally decrease because energy consumption declines. DOE, therefore, calculated an NPV for each non-regulatory alternative in the same way it did for the proposed standards. In some policy scenarios, increases in total installed cost are mitigated by government rebates or tax credits. Because DOE assumed that consumers would re-pay credits and rebates in some way (such as additional taxes), DOE did not include rebates or tax credits as a consumer benefit when calculating national NPV. DOE's analysis also excluded any administrative costs for the non-regulatory policies; including such costs would decrease the NPVs slightly.

The following are key measures for evaluating the impact of each alternative.

- National Energy Savings, given in quadrillion Btus (quads), describes the cumulative national energy saved over the lifetime of equipment purchased during the 30-year analysis period starting in the effective date of the policy (2019-2048).
- Net Present Value, represents the value of net monetary savings in 2014, expressed in 2013$, from equipment purchased during the 30-year analysis period starting in the effective date of the policy (2019-2048). DOE calculated the NPV as the difference between the present values of installed equipment cost and operating expenditures in the base case and the present values of those costs in each standards case. DOE calculated operating expenses (including energy costs) for the life of the product.

### 17.2.2 Assumptions Regarding Non-Regulatory Policies

The effects of non-regulatory policies are by nature uncertain because they depend on program implementation, marketing efforts, and on consumers' response to a program. Because the projected effects depend on assumptions regarding the rate of consumer participation, they

[a] The base case for the NIA is a market-weighted average energy efficiency calculated from units at several efficiency levels.

are subject to more uncertainty than are the impacts of mandatory standards, which DOE assumes will be met with full compliance. To increase the robustness of the analysis, DOE conducted a literature review regarding each non-regulatory policy and consulted with recognized experts to gather information on similar incentive programs that have been implemented in the United States. By studying experiences with the various types of programs, DOE sought to make credible assumptions regarding potential market impacts. Section 17.3 presents the sources DOE on which relied when developing assumptions about each alternative policy and reports DOE's conclusions as they affected the assumptions that underlie the modeling of each alternative policy.

Each non-regulatory policy that DOE considered would improve the average efficiency of new dehumidifiers relative to their base case efficiency scenario (which involves no new regulatory action). The analysis considered that each alternative policy would induce consumers to purchase units having the same technology as required by standards (the target level), according to the minimum energy efficiency set for each TSL. As opposed to the standards case, however, the policy cases may not lead to 100 percent market penetration of units that meet the target level.

Table 17.2.1 shows the energy efficiencies from the technologies stipulated for dehumidifiers for each TSL.

**Table 17.2.1 Energy Efficiency by TSL (IEF)**

| | TSL 1 | TSL 2 | TSL 3 | TSL 4 |
|---|---|---|---|---|
| Portable Dehumidifiers ≤30.00 Pints/Day | 1.10 | 1.20 | 1.30 | 1.57 |
| Portable Dehumidifiers 30.01–45.00 Pints/Day | 1.20 | 1.40 | 1.60 | 1.80 |
| Portable Dehumidifiers >45.00 Pints/Day | 2.40 | 2.80 | 2.80 | 3.66 |
| Whole-Home Dehumidifiers ≤8.0 $ft^3$ Case Volume | 2.09 | 2.09 | 2.09 | 2.53 |
| Whole-Home Dehumidifiers >8.0 $ft^3$ Case Volume | 2.70 | 3.52 | 3.52 | 4.50 |

DOE assumed that the effects of non-regulatory policies would last from the effective date of standards, 2019, through the end of the analysis period, 2048.

### 17.2.3 Policy Interactions

DOE calculated the effects of each non-regulatory policy separately from those of the other policies. In practice, some policies are most effective when implemented in combination, such as voluntary efficiency targets implemented with consumer rebates or tax credits. However, DOE made conservative assumptions to avoid double-counting policy impacts. The resulting policy impacts are, therefore, not additive, and the combined effect of several or all policies cannot be inferred from summing their results.

Section 17.4 presents graphs that show the market penetration estimated under each non-regulatory policy for dehumidifiers.

## 17.3 NON-REGULATORY POLICY ASSUMPTIONS

The following subsections describe DOE's analysis of the impacts of the five non-regulatory policy alternatives to the standards proposed for dehumidifiers. (Because the alternative of "No New Regulatory Action" has no energy or economic impacts, essentially representing the NIA base case, DOE did not perform any additional analysis for that alternative.) DOE developed estimates of the market penetration of more efficient products both with and without each of the non-regulatory policy alternatives.

### 17.3.1 No New Regulatory Action

The case in which no new regulatory action is taken with regard to the energy efficiency of dehumidifiers constitutes the base case, as described in chapter 10. The base case provides the basis of comparison for all other policies. By definition, no new regulatory action yields zero energy savings for an NES and zero dollars for an NPV.

### 17.3.2 Consumer Rebates

DOE considered the scenario in which the Federal government would provide financial incentives in the form of rebates to consumers for purchasing energy-efficient equipment. This policy provides a consumer rebate for purchasing dehumidifiers that operate at the same efficiency levels as stipulated in each TSL.

#### 17.3.2.1 Methodology

DOE based its evaluation methodology for consumer rebates on a comprehensive study of California's potential for achieving energy efficiency. The study, performed by XENERGY, Inc.,[b] summarized experiences with various utility rebate programs.[1] XENERGY's analytical method utilized graphs, or penetration curves, that estimate the market penetration of a technology based on its benefit/cost (B/C) ratio. DOE consulted with experts and reviewed other methods of estimating the effect of consumer rebate programs on the market penetration of efficient technologies. The other methods, developed after the referenced XENERGY report was published,[2, 3, 4, 5, 6, 7] used different approaches: other economic parameters (e.g., payback period), expert surveys, or model calibration based on specific utility program data rather than multi-utility data. Some models in use by energy efficiency program evaluation experts were so client-specific that generic relationships between economic parameters and consumer response could not be established.[5] DOE decided that the most appropriate available method for this RIA was the XENERGY approach of penetration curves based on B/C ratio, which incorporates lifetime operating cost savings.

XENERGY's model estimates market impacts induced by financial incentives based on the premise that two types of information diffusion drive the adoption of new technologies. *Internal sources* of information encourage consumers to purchase new equipment primarily through word-of-mouth from early adopters. *External sources* affect consumer purchase

[b] XENERGY is now owned by KEMA, Inc. (www.kema.com)

decisions through marketing efforts and information from outside the consumer group. Appendix 17A contains additional details on internal and external information diffusion.

XENERGY's model equation accounts for the influences of both internal and external sources of information by superimposing the two components. Combining the two mechanisms for information diffusion, XENERGY's model generates a set of penetration (or implementation) curves for a policy measure. XENERGY calibrated the curves based on participation data from utility rebate programs. The curves illustrate the increased penetration (i.e., increased market share) of efficient equipment driven by consumer response to changes in B/C ratio induced by rebate programs. The penetration curves depict various diffusion patterns based on perceived market barriers (from no-barriers to extremely-high-barriers) to consumer purchase of high-efficiency equipment. DOE adjusted the XENERGY former penetration curves based on expert advice founded on more recent utility program experience.[5, 8]

DOE modeled the effects of a consumer rebate policy for dehumidifiers by determining, for each TSL, the increase in market penetration of equipment meeting the target level relative to their market penetration in the base case. It used the interpolation method presented in Blum et al (2011)[9] to create customized penetration curves based on relationships between actual base case market penetrations and actual B/C ratios. To inform its estimate of B/C ratios provided by a rebate program DOE performed a thorough nationwide search for existing rebate programs for dehumidifiers. It gathered data on utility or agency rebates throughout the nation for this equipment, and used this data to calibrate the customized penetration curves it developed for each product class covered by this RIA so they can best reflect the market barrier levels that consumer rebates for dehumidifiers would face. Section 17.3.2.2 shows the resulting interpolated curves used in the analysis.

#### 17.3.2.2 Analysis

DOE estimated the effect of increasing the B/C ratio of dehumidifiers via a rebate that would pay – depending on the product class – part or all of the increased installed cost of units that meet the target efficiency levels compared to units meeting the baseline efficiency level.[c] To inform its estimate of an appropriate rebate amount, DOE performed a thorough nationwide search for existing rebate programs for dehumidifiers. It gathered data from a sample of utility and agency rebate programs that includes 34 rebates for dehumidifiers initiated by 29 utilities or agencies in various States. DOE then estimated a market representative rebate value for all product classes covered by this RIA which it applied in the calculation of the B/C ratio of dehumidifiers under the effect of consumer rebates. (Appendix 17A identifies the rebate programs and details the methodology DOE used to estimate a market representative rebate amount.) DOE assumed that rebates would remain in effect at the same level throughout the forecast period (2019-2048).

[c] The baseline technology is defined in the engineering analysis, Chapter 5, as the technology that represents the basic characteristics of dehumidifiers. A baseline unit typically is one that just meets current Federal energy conservation standards and provides basic consumer utility.

DOE first calculated the B/C ratio of a dehumidifier without a rebate using the difference in total installed costs (C) and lifetime operating cost savings[d] (B) between a unit meeting the target level and a baseline unit. It then calculated the B/C ratio given a rebate for the unit meeting the target efficiency level. Because the rebate reduced the incremental cost, the unit receiving the rebate had a larger B/C ratio. Table 17.3.1 shows the effect of consumer rebates for each TSL on the B/C ratio of dehumidifiers shipped in the first year of the analysis period.

**Table 17.3.1 Benefit/Cost Ratios Without and With Rebates**

| | TSL 1 | TSL 2 | **TSL 3** | TSL 4 |
|---|---|---|---|---|
| Portable Dehumidifiers ≤30.00 Pints/Day | | | | |
| B/C Ratio Without Rebate | 0.0 | 97.7 | **44.0** | 12.1 |
| Rebate Amount (2013$) | 24.05 | 24.05 | **24.05** | 24.05 |
| B/C Ratio With Rebate | 0.0 | infinite | **infinite** | 66.6 |
| Estimated Market Barriers | High | High | **Low-Mod** | High |
| Portable Dehumidifiers 30.01–45.00 Pints/Day | | | | |
| B/C Ratio Without Rebate | 0.0 | 90.7 | **33.7** | 14.1 |
| Rebate Amount (2013$) | 24.05 | 24.05 | **24.05** | 24.05 |
| B/C Ratio With Rebate | 0.0 | infinite | **infinite** | 48.0 |
| Estimated Market Barriers | High | No | **High** | High |
| Portable Dehumidifiers >45.00 Pints/Day | | | | |
| B/C Ratio Without Rebate | 1.6 | 2.5 | **2.5** | 1.8 |
| Rebate Amount (2013$) | 24.05 | 24.05 | **24.05** | 24.05 |
| B/C Ratio With Rebate | 2.4 | 3.3 | **3.3** | 2.1 |
| Estimated Market Barriers | Low-Mod | Low-Mod | **Low-Mod** | High |
| Whole-Home Dehumidifiers ≤8.0 $ft^3$ Case Volume | | | | |
| B/C Ratio Without Rebate | 5.2 | 5.2 | **5.2** | 1.2 |
| Rebate Amount (2013$) | 24.05 | 24.05 | **24.05** | 24.05 |
| B/C Ratio With Rebate | 47.7 | 47.7 | **47.7** | 1.3 |
| Estimated Market Barriers | Mod | Mod | **Mod** | High |
| Whole-Home Dehumidifiers >8.0 $ft^3$ Case Volume | | | | |
| B/C Ratio Without Rebate | 10.1 | 4.9 | **4.9** | 1.7 |
| Rebate Amount (2013$) | 24.05 | 24.05 | **24.05** | 24.05 |
| B/C Ratio With Rebate | infinite | 7.5 | **7.5** | 1.8 |
| Estimated Market Barriers | Low-Mod | Mod | **Mod** | High |

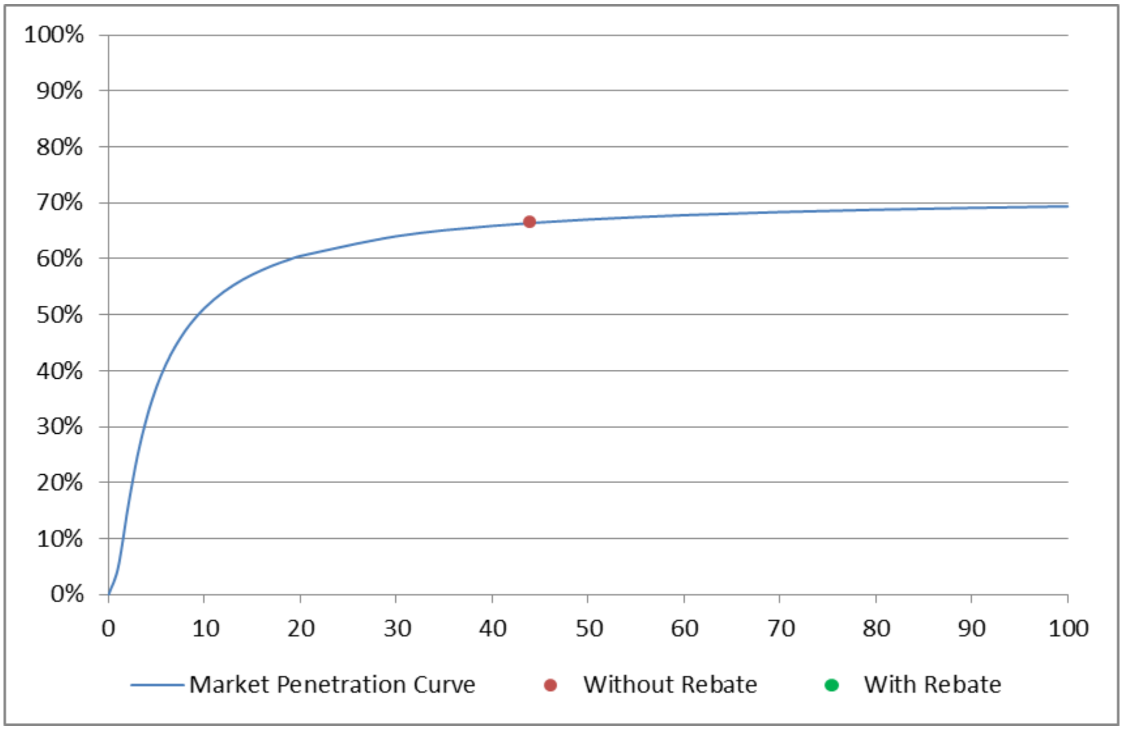
* Mod: Moderate market barriers; Low-Mod: Low-to-Moderate market barriers.

DOE used the B/C ratio along with the customized penetration curves shown in Figure 17.3.1 to estimate the percentage of consumers who would purchase dehumidifiers that meet the target levels both with and without a rebate incentive. The estimated levels of market barriers corresponding to the penetration curves DOE calculated to represent the market behavior for dehumidifiers at the proposed TSL are indicated (bolded) in Table 17.3.1. DOE assumed the estimated market barriers would remain the same over the whole analysis period.

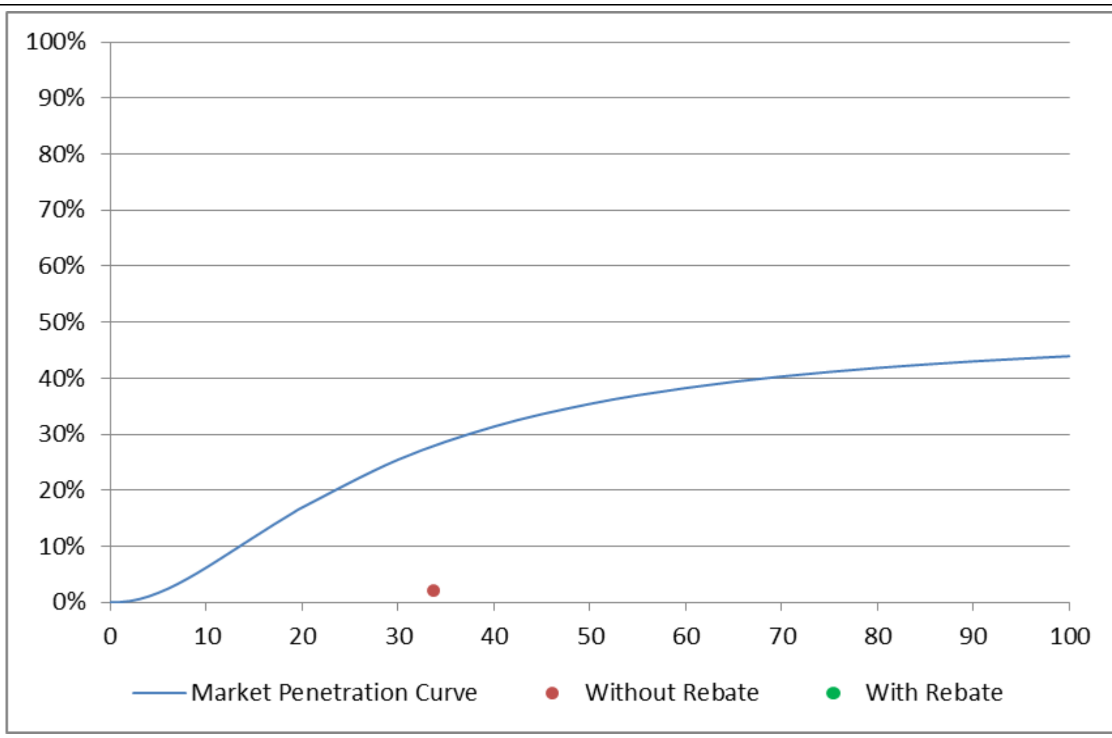
[d] The cash flow of the operating cost savings is discounted to the purchase year using a 7 percent discount rate.

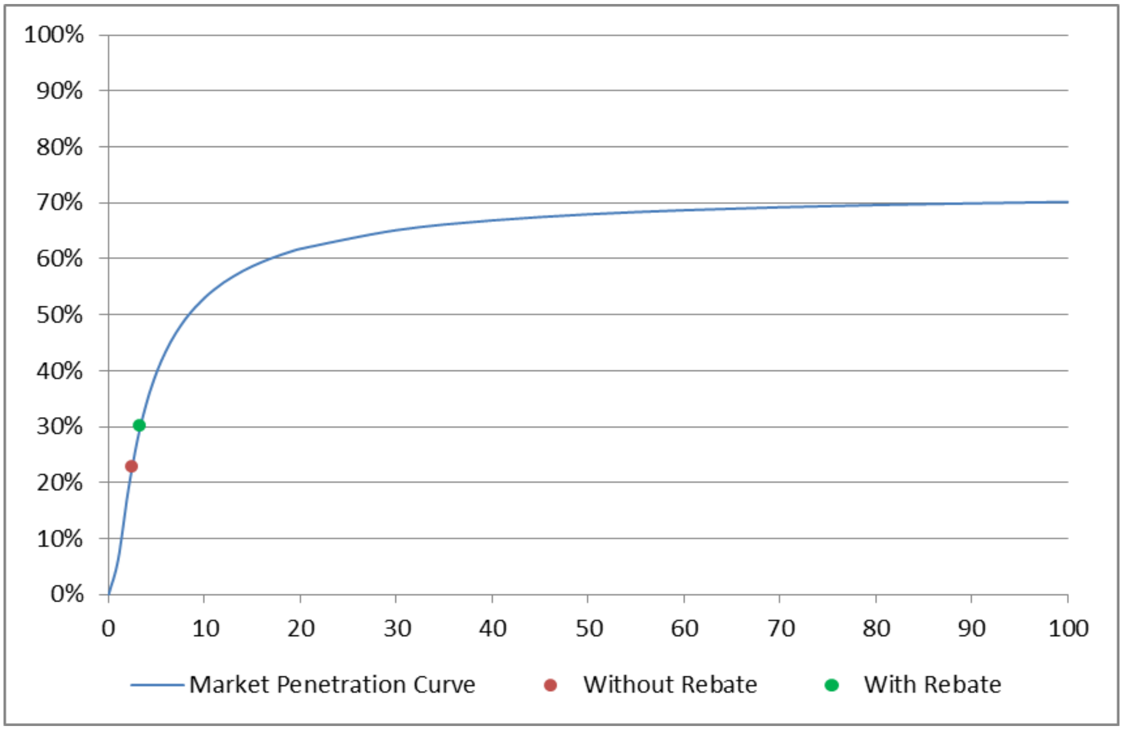
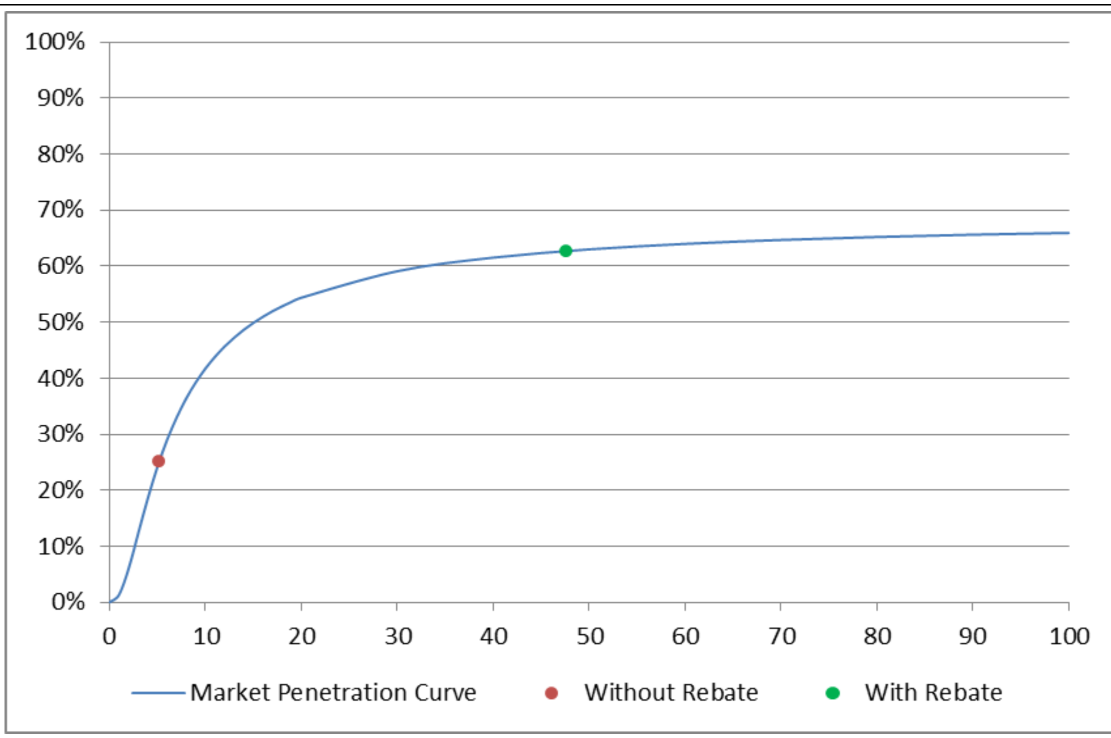
TSL 3

Portable Dehumidifiers ≤30.00 Pints/Day




Portable Dehumidifiers 30.01–45.00 Pints/Day



| | |
|---|---|
| Portable Dehumidifiers >45.00 Pints/Day |   |
| Whole-Home Dehumidifiers ≤8.0 ft$^3$ Case Volume |   |

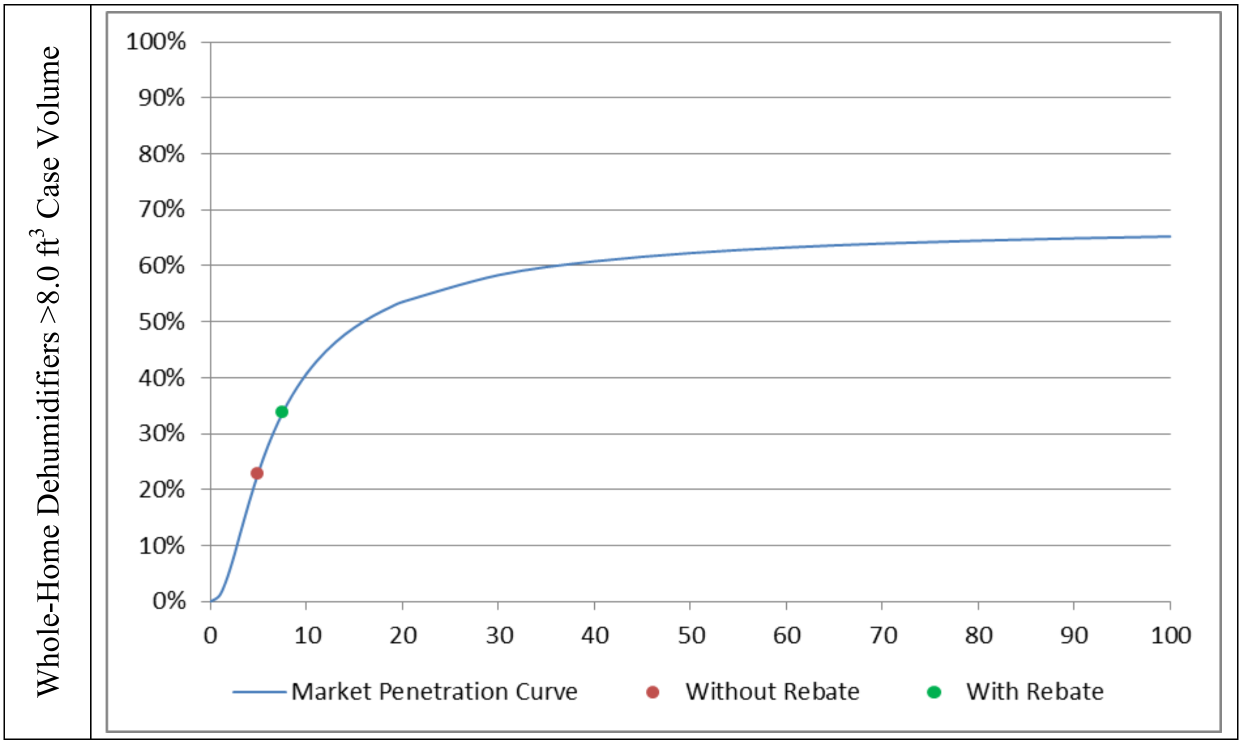



**Figure 17.3.1 Market Penetration Curves for Dehumidifiers**

DOE next estimated the percent increase represented by the change in penetration rate shown on the corresponding penetration curve. It then added this percent increase to the market share of units that meet the target level in the base case to obtain the market share of units that meet the target level in the rebate policy case.

Table 17.3.2 summarizes DOE's assumptions for dehumidifiers regarding the market penetration of products in 2019 that meet the target levels at each TSL given a consumer rebate.

**Table 17.3.2 Market Penetrations in 2019 Attributable to Consumer Rebates**

| | TSL 1 | TSL 2 | **TSL 3** | TSL 4 |
|---|---|---|---|---|
| Portable Dehumidifiers ≤30.00 Pints/Day | | | | |
| Base-Case Market Share | 22.9% | 0.0% | **66.4%** | 0.0% |
| Policy Case Market Share | 33.6% | 33.6% | **71.8%** | 39.7% |
| Increased Market Share | 10.7% | 33.6% | **5.4%** | 39.7% |
| Portable Dehumidifiers 30.01–45.00 Pints/Day | | | | |
| Base-Case Market Share | 0.0% | 94.3% | **2.0%** | 3.7% |
| Policy Case Market Share | 0.0% | 94.3% | **50.0%** | 34.7% |
| Increased Market Share | 0.0% | 0.0% | **48.0%** | 31.1% |
| Portable Dehumidifiers >45.00 Pints/Day | | | | |
| Base-Case Market Share | 20.1% | 22.9% | **22.9%** | 0.0% |
| Policy Case Market Share | 29.1% | 30.0% | **30.0%** | 0.2% |
| Increased Market Share | 9.0% | 7.2% | **7.2%** | 0.2% |
| Whole-Home Dehumidifiers ≤8.0 $ft^3$ Case Volume | | | | |
| Base-Case Market Share | 25.1% | 25.1% | **25.1%** | 0.0% |
| Policy Case Market Share | 62.7% | 62.7% | **62.7%** | 0.1% |
| Increased Market Share | 37.6% | 37.6% | **37.6%** | 0.1% |
| Whole-Home Dehumidifiers >8.0 $ft^3$ Case Volume | | | | |
| Base-Case Market Share | 46.3% | 22.9% | **22.9%** | 0.0% |
| Policy Case Market Share | 70.5% | 33.8% | **33.8%** | 0.2% |
| Increased Market Share | 24.2% | 10.9% | **10.9%** | 0.2% |

DOE used the resulting annual increases in market shares as inputs to represent the rebate policy case scenario in its NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of consumer rebates for dehumidifiers. Because energy prices increase over the analysis period and equipment prices are held constant, the B/C ratios increase over time. With increasing B/C ratios and constant market barriers, the increase in market penetration of more efficient technologies eventually increases over the analysis period.

### 17.3.3 Consumer Tax Credits

DOE estimated the effects of tax credits on consumer purchases based on its previous analysis of consumer participation in tax credits. DOE supported its approach using data from Oregon State's tax credit program for energy-efficient appliances. DOE also incorporated previous research that disaggregated the effect of rebates and tax credits into a *direct price effect*, which derives from the savings in purchase price, and an *announcement effect*, which is independent of the amount of the incentive.[10, 11] The announcement effect derives from the credibility that a technology receives from being included in an incentive program, as well as changes in product marketing and modifications in markup and pricing. DOE assumed that the rebate and consumer tax credit policies would encompass both direct price effects and announcement effects, and that half the increase in market penetration associated with either policy would be due to the direct price effect and half to the announcement effect.

In estimating the effects of a tax credit on purchases of consumer products that meet new efficiency standards, DOE assumed the amount of the tax credit would be the same as the corresponding rebate amount discussed above.

DOE estimated that fewer consumers would participate in a tax credit program than would take advantage of a rebate. Research has shown that the delay required for a consumer to receive a tax credit, plus the added time and cost in preparing the tax return, make a tax credit incentive less effective than a rebate received at the time of purchase. Based on previous analyses, DOE assumed that only 60 percent of the consumers who would take advantage of a rebate would take advantage of a tax credit.[12]

In preparing its assumptions to estimate the effects of tax credits on consumer purchases of dehumidifiers, DOE also reviewed other tax credit programs that have been offered at both the Federal and State levels for energy-efficient appliances.

The Energy Policy Act of 2005 (EPACT 2005) included Federal tax credits for consumers who purchase energy-efficient products.[13] Those tax credits were in effect in 2006 and 2007, expired in 2008, were reinstated for 2009–2010 by the American Recovery and Reinvestment Act of 2009 (ARRA), extended by Congress for 2011 with some modifications, and expired at the end of 2011.[14, 15] The American Taxpayer Relief Act of 2012 extended, with some modifications, residential tax credits for air conditioners, heat pumps, furnaces, and water heaters placed in service between January 1, 2012 and December 31, 2013.[16] DOE reviewed Internal Revenue Service data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. However, DOE did not find data specific enough to dehumidifiers to warrant adjusting its analysis method for the Consumer Tax Credits policy case. Appendix 17A contains more information on Federal consumer tax credits.

DOE also reviewed its previous analysis of Oregon's tax credits for clothes washers to provide support for its assumptions.[17] In that previous analysis, DOE compared the market shares of ultra-high efficiency (UHE) residential clothes washers in Oregon, which offered both State tax credits and utility rebates, with those in Washington State, which offered only utility rebates during the same period. Based on this analysis, DOE estimated that in Oregon the impact of tax credits was 62 percent of the impact of rebates for UHE clothes washers having equivalent efficiency. This finding supports its original assumption that participation in a tax credit program would be about 60 percent of participation in a rebate program. Additional discussion of State tax credits for Oregon and other states is in appendix 17A.

DOE applied the assumed 60 percent participation described above to the increase in penetration rates estimated for the rebate policy to estimate penetration rates attributable to consumer tax credits. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the customized penetration curves it developed for dehumidifiers (See Figure 17.3.1).

Table 17.3.3 summarizes DOE's assumptions for dehumidifiers regarding the market penetration of products in 2019 that meet the target levels at each TSL given a consumer tax credit.

**Table 17.3.3 Market Penetrations in 2019 Attributable to Consumer Tax Credits**

| | TSL 1 | TSL 2 | **TSL 3** | TSL 4 |
|---|---|---|---|---|
| Portable Dehumidifiers ≤30.00 Pints/Day | | | | |
| Base-Case Market Share | 22.9% | 0.0% | **66.4%** | 0.0% |
| Policy Case Market Share | 29.3% | 20.2% | **69.6%** | 23.8% |
| Increased Market Share | 6.4% | 20.2% | **3.2%** | 23.8% |
| Portable Dehumidifiers 30.01–45.00 Pints/Day | | | | |
| Base-Case Market Share | 0.0% | 94.3% | **2.0%** | 3.7% |
| Policy Case Market Share | 0.0% | 94.3% | **30.8%** | 22.3% |
| Increased Market Share | 0.0% | 0.0% | **28.8%** | 18.6% |
| Portable Dehumidifiers >45.00 Pints/Day | | | | |
| Base-Case Market Share | 20.1% | 22.9% | **22.9%** | 0.0% |
| Policy Case Market Share | 25.5% | 27.2% | **27.2%** | 0.1% |
| Increased Market Share | 5.4% | 4.3% | **4.3%** | 0.1% |
| Whole-Home Dehumidifiers ≤8.0 $ft^3$ Case Volume | | | | |
| Base-Case Market Share | 25.1% | 25.1% | **25.1%** | 0.0% |
| Policy Case Market Share | 47.7% | 47.7% | **47.7%** | 0.1% |
| Increased Market Share | 22.6% | 22.6% | **22.6%** | 0.1% |
| Whole-Home Dehumidifiers >8.0 $ft^3$ Case Volume | | | | |
| Base-Case Market Share | 46.3% | 22.9% | **22.9%** | 0.0% |
| Policy Case Market Share | 60.8% | 29.4% | **29.4%** | 0.1% |
| Increased Market Share | 14.5% | 6.6% | **6.6%** | 0.1% |

The increased market shares attributable to consumer tax credits shown in Table 17.3.3 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of consumer tax credits for dehumidifiers that meet the efficiency level for the proposed TSL. Because the increase in market penetration for consumer tax credits is proportional to the increase in market penetration DOE calculated for consumer rebates, the former follows a similar increasing trend over the analysis period as the latter.

### 17.3.4 Manufacturer Tax Credits

To analyze the potential effects of a policy that offers tax credits to manufacturers that produce dehumidifiers that meet the target efficiency levels at each TSL, DOE assumed that a manufacturer tax credit would lower the consumer's purchase cost by an amount equivalent to that provided by the consumer rebates or tax credits described above. DOE further assumed that manufacturers would pass on some of their reduced costs to consumers, causing a direct price effect. DOE assumed that no announcement effect would occur, because the program would not be visible to consumers.[e] Because the direct price effect is approximately equivalent to the

[e] Note that this is a conservative assumption, since it is possible that manufacturers or utility/agency efficiency programs might promote the models for which manufacturers increase production due to the tax credits, which in turn might induce some announcement effect. However, DOE found no data on such programs on which to base an estimate of the magnitude of this possible announcement effect on consumer behavior.

announcement effect,[10] DOE estimated that a manufacturer tax credit would induce half the number of consumers assumed to take advantage of a consumer tax credit to purchase more efficient products. Thus the assumed participation rate is equal to 30 percent of the number of consumers who would participate in a rebate program.

DOE attempted to investigate manufacturer response to the Energy Efficient Appliance Credits for manufacturers mandated by EPACT 2005.[18] Those manufacturer tax credits have been in effect for dishwashers, clothes washers and refrigerators produced beginning in 2009. DOE was unable to locate data from the Internal Revenue Service or other sources on manufacturer response to the Federal credits. Appendix 17A presents details on Federal manufacturer tax credits.

DOE applied the assumption of 30 percent participation to the increase in penetration rates predicted for the rebate policy to estimate the effects of a manufacturer tax credit policy. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the customized penetration curves it developed for dehumidifiers. (See Figure 17.3.1)

Table 17.3.4 summarizes DOE's assumptions for dehumidifiers regarding the market penetration of products in 2019 that meet the target levels at each TSL given a manufacturer tax credit.

**Table 17.3.4 Market Penetrations in 2019 Attributable to Manufacturer Tax Credits**

| | TSL 1 | TSL 2 | **TSL 3** | TSL 4 |
|---|---|---|---|---|
| Portable Dehumidifiers ≤30.00 Pints/Day | | | | |
| Base-Case Market Share | 22.9% | 0.0% | **66.4%** | 0.0% |
| Policy Case Market Share | 26.1% | 10.1% | **68.0%** | 11.9% |
| Increased Market Share | 3.2% | 10.1% | **1.6%** | 11.9% |
| Portable Dehumidifiers 30.01–45.00 Pints/Day | | | | |
| Base-Case Market Share | 0.0% | 94.3% | **2.0%** | 3.7% |
| Policy Case Market Share | 0.0% | 94.3% | **16.4%** | 13.0% |
| Increased Market Share | 0.0% | 0.0% | **14.4%** | 9.3% |
| Portable Dehumidifiers >45.00 Pints/Day | | | | |
| Base-Case Market Share | 20.1% | 22.9% | **22.9%** | 0.0% |
| Policy Case Market Share | 22.8% | 25.0% | **25.0%** | 0.1% |
| Increased Market Share | 2.7% | 2.2% | **2.2%** | 0.1% |
| Whole-Home Dehumidifiers ≤8.0 $ft^3$ Case Volume | | | | |
| Base-Case Market Share | 25.1% | 25.1% | **25.1%** | 0.0% |
| Policy Case Market Share | 36.4% | 36.4% | **36.4%** | 0.0% |
| Increased Market Share | 11.3% | 11.3% | **11.3%** | 0.0% |
| Whole-Home Dehumidifiers >8.0 $ft^3$ Case Volume | | | | |
| Base-Case Market Share | 46.3% | 22.9% | **22.9%** | 0.0% |
| Policy Case Market Share | 53.5% | 26.1% | **26.1%** | 0.1% |
| Increased Market Share | 7.3% | 3.3% | **3.3%** | 0.1% |

The increased market shares attributable to a manufacturer tax credit shown in Table 17.3.4 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of manufacturer tax credits for dehumidifiers. Because the increase in market penetration for manufacturer tax credits is proportional to the increase in market penetration DOE calculated for consumer rebates, the former follows a similar increasing trend over the analysis period as the latter.

### 17.3.5 Voluntary Energy Efficiency Targets

DOE assumed that voluntary energy efficiency targets would lead manufacturers of dehumidifiers to gradually stop producing units that operate below the efficiency levels set for each TSL. DOE assumed that the impetus for phasing out production of low-efficiency units would be a program with impacts similar to those of the ENERGY STAR labeling program conducted by the EPA and DOE in conjunction with industry partners. The ENERGY STAR program specifies the minimum energy efficiencies that various products must have to receive the ENERGY STAR label. ENERGY STAR encourages consumers to purchase efficient products via marketing that promotes consumer label recognition, various incentive programs that adopt the ENERGY STAR specifications, and manufacturers' promotion of their qualifying appliances. ENERGY STAR projects market penetration of compliant appliances and estimates the percentage of sales of compliant appliances that are attributable to the ENERGY STAR program.

Researchers have analyzed the ENERGY STAR program's effects on sales of several consumer products. Program efforts generally involve a combination of information dissemination and utility or agency rebates. The analyses have been based on State-specific data on percentages of shipments of various appliances that meet ENERGY STAR specifications. The analyses generally have concluded that the market penetration of ENERGY STAR-qualifying appliances is higher in regions or States where ancillary promotional programs have been active.[19, 20, 21]

DOE believes that informational incentive programs – like ENERGY STAR, or any other labeling program sponsored by industry or other organizations – are likely to reduce the market barriers to more efficient products over time. During the rebate analysis, when assessing the B/C ratio and market penetration in the base case for dehumidifiers, DOE observed that the level of market barriers for more efficient dehumidifiers are in the range of low-to-moderate barriers to a high level of market barriers. DOE estimates that voluntary energy efficiency targets could reduce these barriers to lower levels over 10 years. Table 17.3.5 presents the levels of market barriers DOE estimated for dehumidifiers in the base case and in the policy case of voluntary energy efficiency targets. DOE followed the methodology presented by Blum et al (2011)[22] to evaluate the effects that such a reduction in market barriers would have on the market penetration of efficient dehumidifiers.[f] The methodology relies on interpolated market penetration curves to calculate – given a B/C ratio – how the market penetration of more efficient units increases as the market barrier level to those units decreases.

[f] For the calculation of B/C ratios DOE discounted the cash flow of the operating cost savings to the purchase year using a 7 percent discount rate.

**Table 17.3.5 Market Barriers Changes Attributable to Voluntary Energy Efficiency Targets for TSL 3**

| | Base Case | Voluntary Energy Efficiency Targets |
|---|---|---|
| Portable Dehumidifiers ≤30.00 Pints/Day | Low-Moderate | Low |
| Portable Dehumidifiers 30.01–45.00 Pints/Day | High | Moderate-High |
| Portable Dehumidifiers >45.00 Pints/Day | Low-Moderate | Low |
| Whole-Home Dehumidifiers ≤8.0 $ft^3$ Case Volume | Moderate | Low |
| Whole-Home Dehumidifiers >8.0 $ft^3$ Case Volume | Moderate | Low |

Table 17.3.6 summarizes DOE's assumptions for dehumidifiers regarding the market penetration of products in 2019 that meet the target levels at each TSL given voluntary energy efficiency targets. Table 17.3.7 expands on Table 17.3.6 to include, for the proposed TSL, DOE's assumptions regarding the market penetration of units in selected years.

**Table 17.3.6 Market Penetrations in 2019 Attributable to Voluntary Energy Efficiency Targets**

| | TSL 1 | TSL 2 | **TSL 3** | TSL 4 |
|---|---|---|---|---|
| Portable Dehumidifiers ≤30.00 Pints/Day | | | | |
| Base-Case Market Share | 22.9% | 0.0% | **66.4%** | 0.0% |
| Policy Case Market Share | 33.6% | 33.6% | **67.5%** | 10.4% |
| Increased Market Share | 10.7% | 33.6% | **1.1%** | 10.4% |
| Portable Dehumidifiers 30.01–45.00 Pints/Day | | | | |
| Base-Case Market Share | 0.0% | 94.3% | **2.0%** | 3.7% |
| Policy Case Market Share | 0.0% | 94.3% | **31.0%** | 12.8% |
| Increased Market Share | 0.0% | 0.0% | **29.0%** | 9.2% |
| Portable Dehumidifiers >45.00 Pints/Day | | | | |
| Base-Case Market Share | 20.1% | 22.9% | **22.9%** | 0.0% |
| Policy Case Market Share | 21.5% | 25.6% | **25.6%** | 0.2% |
| Increased Market Share | 1.4% | 2.7% | **2.7%** | 0.2% |
| Whole-Home Dehumidifiers ≤8.0 $ft^3$ Case Volume | | | | |
| Base-Case Market Share | 25.1% | 25.1% | **25.1%** | 0.0% |
| Policy Case Market Share | 26.7% | 26.7% | **26.7%** | 0.1% |
| Increased Market Share | 1.6% | 1.6% | **1.6%** | 0.1% |
| Whole-Home Dehumidifiers >8.0 $ft^3$ Case Volume | | | | |
| Base-Case Market Share | 46.3% | 22.9% | **22.9%** | 0.0% |
| Policy Case Market Share | 50.1% | 24.6% | **24.6%** | 0.2% |
| Increased Market Share | 3.9% | 1.7% | **1.7%** | 0.2% |

**Table 17.3.7 Market Penetrations in Selected Years Attributable to Voluntary Energy Efficiency Targets for TSL 3**

| | 2019 | 2028 | 2048 |
|---|---|---|---|
| Portable Dehumidifiers ≤30.00 Pints/Day | | | |
| Base-Case Market Share | 66.4% | 66.4% | 87.4% |
| Policy Case Market Share | 67.5% | 77.2% | 87.4% |
| Increased Market Share | 1.1% | 10.8% | 0.0% |
| Portable Dehumidifiers 30.01–45.00 Pints/Day | | | |
| Base-Case Market Share | 2.0% | 18.1% | 55.3% |
| Policy Case Market Share | 31.0% | 50.4% | 55.3% |
| Increased Market Share | 29.0% | 32.3% | 0.0% |
| Portable Dehumidifiers >45.00 Pints/Day | | | |
| Base-Case Market Share | 22.9% | 22.9% | 22.9% |
| Policy Case Market Share | 25.6% | 46.4% | 56.8% |
| Increased Market Share | 2.7% | 23.5% | 34.0% |
| Whole-Home Dehumidifiers ≤8.0 $ft^3$ Case Volume | | | |
| Base-Case Market Share | 25.1% | 38.3% | 68.5% |
| Policy Case Market Share | 26.7% | 60.8% | 68.5% |
| Increased Market Share | 1.6% | 22.5% | 0.0% |
| Whole-Home Dehumidifiers >8.0 $ft^3$ Case Volume | | | |
| Base-Case Market Share | 22.9% | 22.9% | 37.6% |
| Policy Case Market Share | 24.6% | 60.0% | 67.8% |
| Increased Market Share | 1.7% | 37.2% | 30.2% |

The increased market shares attributable to voluntary energy efficiency targets shown in Table 17.3.6 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of voluntary energy efficiency targets for dehumidifiers that meet the efficiency level for the proposed TSL. Because of the decrease in the market barriers level over the first 10 years of the analysis period, the market penetration of more efficient dehumidifiers significantly increases over that period. For the remaining 20 years of the forecast period the increase in market penetration keeps growing because, even though the market barriers level remains constant (at 2028 level), the increase in energy prices leads to increasing B/C ratios and eventually to higher market penetrations.

### 17.3.6 Bulk Government Purchases

Bulk government purchases can lead to Federal, State, and local governments purchasing large quantities of products that meet a certain, target efficiency level. Combining the market demands of multiple public sectors can provide a market signal to manufacturers and vendors that some of their largest customers seek products that meet an efficiency target at favorable prices. Such a program also can induce "market pull," whereby manufacturers and vendors would achieve economies of scale for high efficiency products.

Most of the previous bulk government purchase (procurement) initiatives at the Federal, State, and municipal levels have not tracked data on numbers of purchases or degree of compliance with procurement specifications. In many cases, procurement programs are decentralized, being part of larger State or regional initiatives. DOE based its assumptions regarding the effects of this policy on studies the Federal Energy Management Program (FEMP) performed regarding the savings potential of its procurement specifications for appliances and other products. FEMP, however, does not track purchasing data, because of the complex range of purchasing systems, large number of vendors, and so on. States, counties, and municipalities have demonstrated increasing interest and activity in "green purchasing." Although many of the programs target office equipment, the growing infrastructure for developing and applying efficient purchasing specifications indicates that bulk government purchase programs are feasible.[23, 24]

DOE assumed that government agencies would administer bulk purchasing programs for dehumidifiers. At the federal level, this type of program could modify the current FEMP procurement guidelines for dehumidifiers, which refer to the ENERGY STAR requirements for dehumidifiers.[25] 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.[26] Based on this study, DOE estimated that a bulk government purchase program instituted within a 10-year period would result in at least 80 percent of government-purchased dehumidifiers meeting the target efficiency level.

DOE assumed that bulk government purchases would affect a subset of housing units for which government agencies purchased or influenced the purchase of dehumidifiers. This subset would consist primarily of public housing and housing on military bases. According to the RECS 2009, about 1.2 percent of all U.S. households with dehumidifiers are housing units in public housing authority.[27] DOE therefore estimated that 1.2 percent of the U.S. housing units with dehumidifiers constitutes the market to which this policy would apply.

DOE estimated that starting in 2019, each year of a bulk government purchase policy would result in an increasing percent of shipments of government-purchased units beyond the base case that would meet the target efficiency level. DOE estimated that within 10 years (by 2028) bulk government purchasing programs would result in 80 percent[g] of the market for dehumidifiers used in publicly owned houses meeting the target level. DOE modeled the bulk government purchase program assuming that the market share for dehumidifiers achieved in 2028 would be at least maintained throughout the rest of the forecast period.

Table 17.3.8 summarizes DOE's assumptions for dehumidifiers regarding the market penetration of products in 2019 that meet the target levels at each TSL given bulk government purchases.

[g] The 80 percent target to be achieved within 10 years may not be reached, as it is constrained by the market share below the target level in the base case scenario.

**Table 17.3.8 Market Penetrations in 2019 Attributable to Bulk Government Purchases**

| | TSL 1 | TSL 2 | **TSL 3** | TSL 4 |
|---|---|---|---|---|
| Portable Dehumidifiers ≤30.00 Pints/Day | | | | |
| Base-Case Market Share | 22.9% | 0.0% | **66.4%** | 0.0% |
| Policy Case Market Share | 22.9% | 0.0% | **66.4%** | 0.1% |
| Increased Market Share | 0.0% | 0.0% | **0.0%** | 0.1% |
| Portable Dehumidifiers 30.01–45.00 Pints/Day | | | | |
| Base-Case Market Share | 0.0% | 94.3% | **2.0%** | 3.7% |
| Policy Case Market Share | 0.0% | 94.3% | **2.1%** | 3.8% |
| Increased Market Share | 0.0% | 0.0% | **0.1%** | 0.1% |
| Portable Dehumidifiers >45.00 Pints/Day | | | | |
| Base-Case Market Share | 20.1% | 22.9% | **22.9%** | 0.0% |
| Policy Case Market Share | 20.2% | 22.9% | **22.9%** | 0.1% |
| Increased Market Share | 0.1% | 0.1% | **0.1%** | 0.1% |
| Whole-Home Dehumidifiers ≤8.0 $ft^3$ Case Volume | | | | |
| Base-Case Market Share | 25.1% | 25.1% | **25.1%** | 0.0% |
| Policy Case Market Share | 25.2% | 25.2% | **25.2%** | 0.1% |
| Increased Market Share | 0.1% | 0.1% | **0.1%** | 0.1% |
| Whole-Home Dehumidifiers >8.0 $ft^3$ Case Volume | | | | |
| Base-Case Market Share | 46.3% | 22.9% | **22.9%** | 0.0% |
| Policy Case Market Share | 46.3% | 22.9% | **22.9%** | 0.1% |
| Increased Market Share | 0.0% | 0.1% | **0.1%** | 0.1% |

The increased market shares attributable to bulk government purchases shown in Table 17.3.8 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of bulk government purchases for dehumidifiers. Market penetrations slightly increase over the first 10 years of the forecast period, steady for some years, and follow the base case market penetration trend for the rest of the analysis period.

## 17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

Figure 17.4.1 through Figure 17.4.5 show the effects of each non-regulatory policy alternative on the market penetration of more efficient dehumidifiers. Relative to the base case, the alternative policy cases increase the market shares that meet the target level. Recall the proposed standards (not shown in the figures) would result in a 100-percent market penetration of products that meet the more efficient technology.

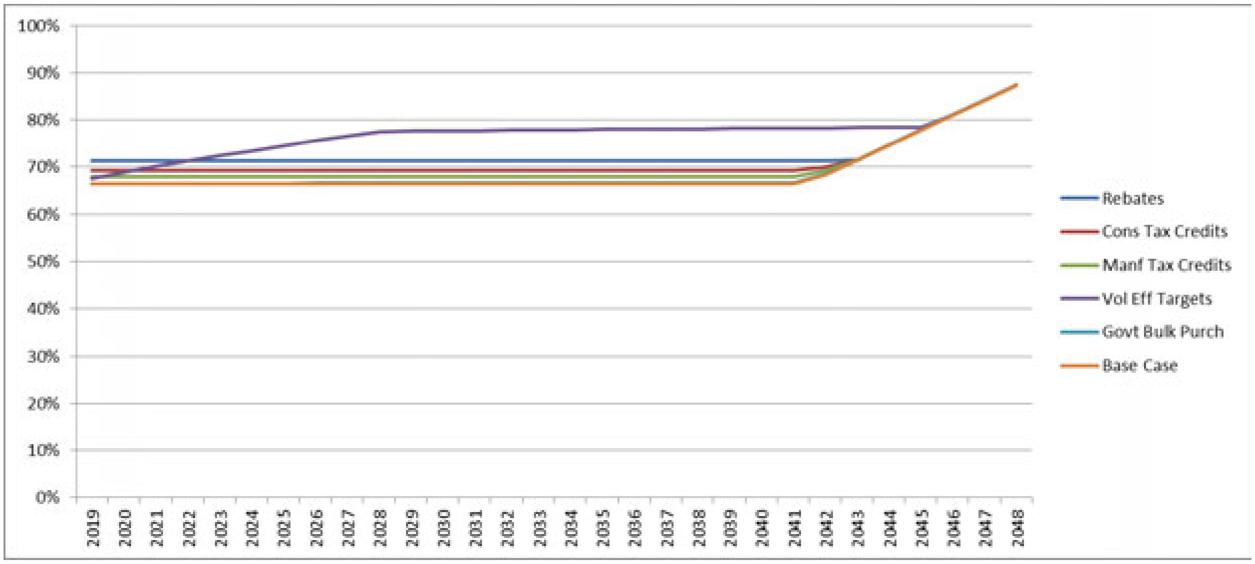



**Figure 17.4.1 Market Penetration of Efficient Portable Dehumidifiers ≤30.00 Pints/Day (TSL 3)**

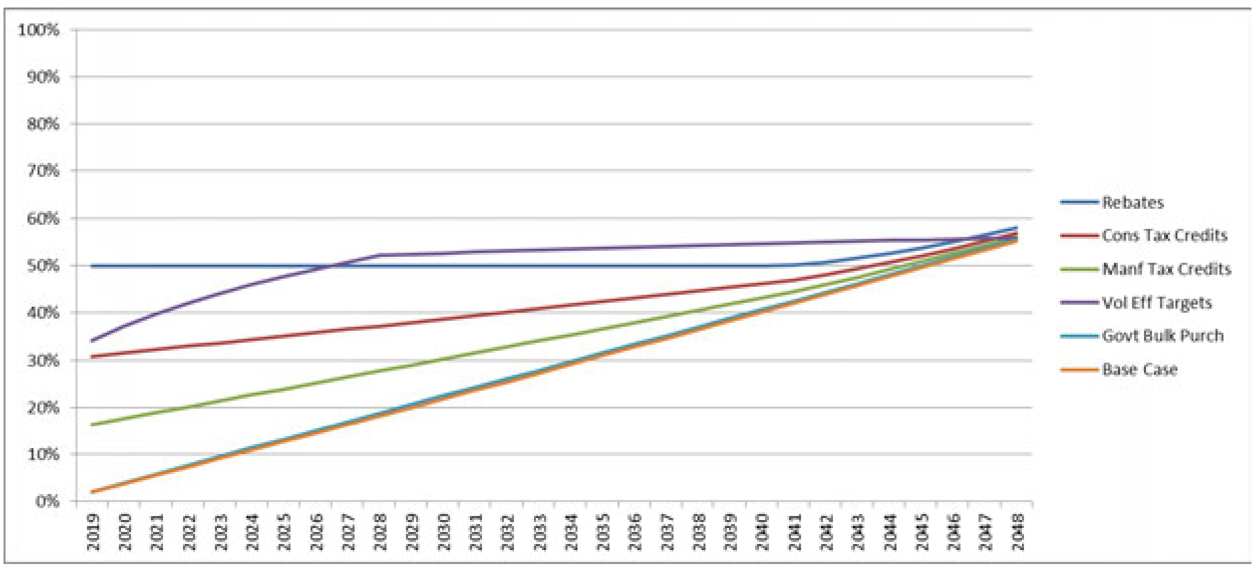



**Figure 17.4.2 Market Penetration of Efficient Portable Dehumidifiers 30.01–45.00 Pints/Day (TSL 3)**

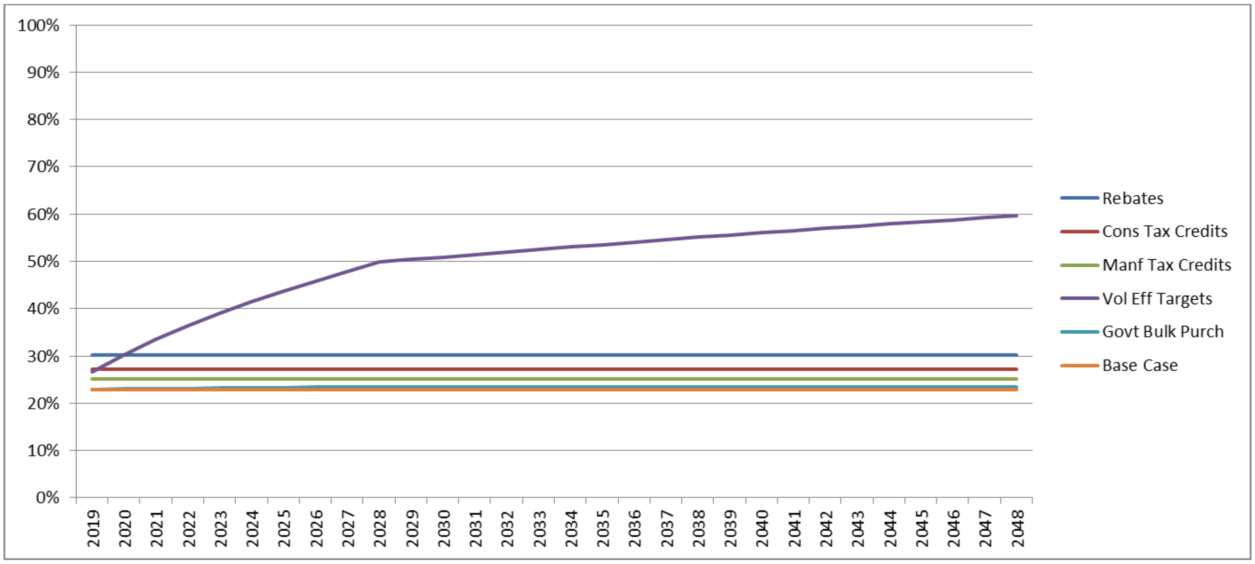



**Figure 17.4.3 Market Penetration of Efficient Portable Dehumidifiers >45.00 Pints/Day (TSL 3)**

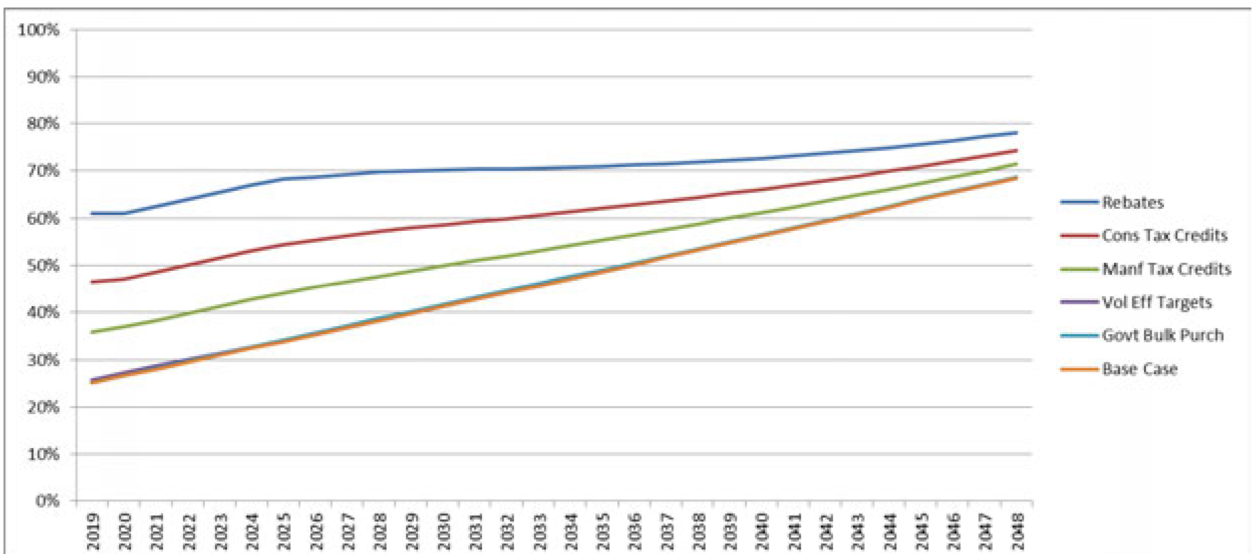



**Figure 17.4.4 Market Penetration of Efficient Whole-Home Dehumidifiers ≤8.0 ft$^3$ Case Volume (TSL 3)**

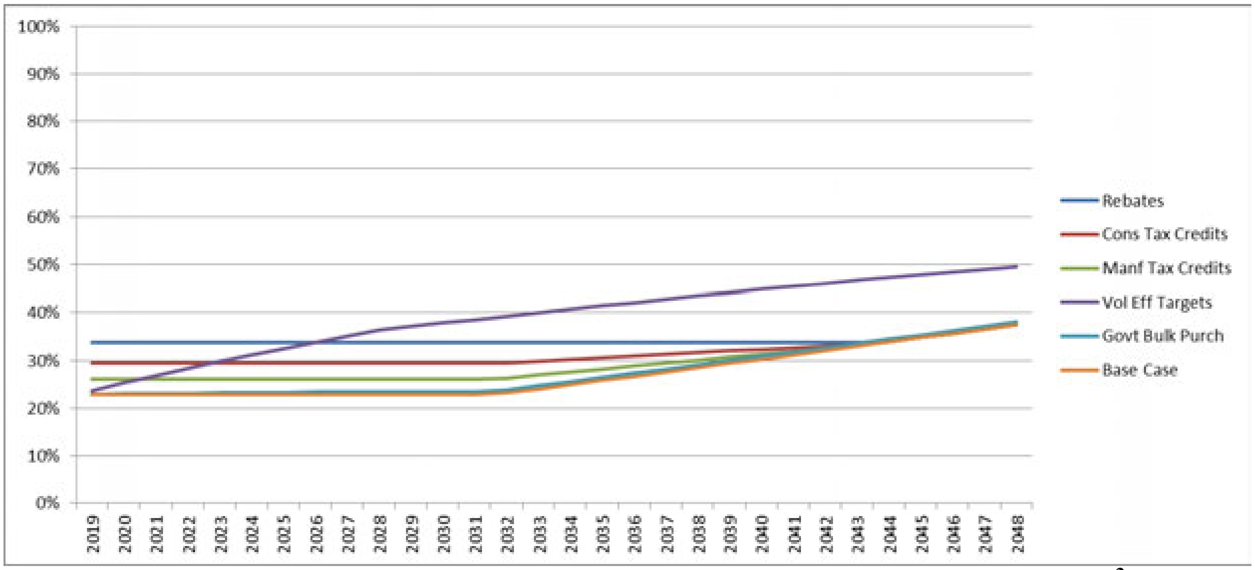



**Figure 17.4.5 Market Penetration of Efficient Whole-Home Dehumidifiers >8.0 ft$^3$ Case Volume (TSL 3)**

Table 17.4.1 shows the national energy savings and net present value for the five non-regulatory policy alternatives analyzed in detail for dehumidifiers. The target level for each policy corresponds to the same efficient technology proposed for standards in TSL 3. The case in which no regulatory action is taken with regard to dehumidifiers constitutes the base case (or "No New Regulatory Action" scenario), in which NES and NPV are zero by definition. For comparison, the tables include the impacts of the proposed standards. Energy savings are given in quadrillion British thermal units (quads).[h] The NPVs shown in Table 17.4.1 are based on two discount rates, 7 percent and 3 percent.

The policy with the highest projected cumulative energy savings is consumer rebates, followed by voluntary energy efficiency targets, consumer tax credits and manufacturer tax credits. Bulk government purchases lead to the lowest cumulative energy savings. Overall, the energy saving benefits from the alternative policies, range from 0.2 percent to 35 percent of the benefits from the proposed standards.

[h] For the alternative policies whose market penetration depends on B/C ratio, the energy savings in Table 17.4.1 correspond to the case where the cash flow of the operating cost savings was discounted to the purchase year using a 7 percent discount rate.

**Table 17.4.1 Impacts of Non-Regulatory Policy Alternatives for TSL 3**

| Policy Alternative | Energy Savings* *quads* | | Net Present Value* *million 2013$* | |
|---|---|---|---|---|
| | | | 7% Disc Rate | 3% Disc Rate |
| Consumer Rebates | 0.107 | (34.7%)** | 361.7 | 789.2 |
| Consumer Tax Credits | 0.064 | (20.8%) | 217.0 | 473.5 |
| Manufacturer Tax Credits | 0.032 | (10.4%) | 108.5 | 236.8 |
| Voluntary Energy Efficiency Targets | 0.077 | (25.2%) | 233.0 | 568.0 |
| Bulk Government Purchases | 0.001 | (0.2%) | 2.0 | 4.4 |
| Proposed Standards*** | 0.307 | (100.0%) | 1035.2 | 2267.3 |

* For products shipped 2019-2048.
**The percentages show how the energy savings from each policy alternative compare to the (primary) energy savings from the proposed standards (represented in the table as 100%).
*** Refers to primary energy savings.

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# APPENDIX 3A. AHAM DATA SUBMITTAL

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# APPENDIX 3A. AHAM DATA SUBMITTAL

## 3A.1 RESIDENTIAL DEHUMIDIFIERS

### ENGINEERING ANALYSIS DATA REQUEST SHEETS FOR RESIDENTIAL DEHUMIDIFIERS

Aggregated industry data is requested for Table A-1 through Table A-5.

**Table A-1 Residential Dehumidifier Shipments**

| | Shipments, Domestic + Imports *(Units)* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Portable | | | | | | | | | | |
| **Year** | **Under 15 pints/day** | **15 < 20 pints/day** | **20 < 25 pints/day** | **25 < 30 pints/day** | **30 < 35 pints/day** | **35 < 40 pints/day** | **40 < 45 pints/day** | **45 < 50 pints/day** | **50 < 60 pints/day** | **60 & Over pints/day** | **Whole Home** |
| 1995 | | | | | | | | | | | |
| 1996 | | | | | | | | | | | |
| 1997 | | | | | | | | | | | |
| 1998 | | | | | | | | | | | |
| 1999 | 0 | 6,825 | 275 | 222,856 | 63,754 | 41,961 | 307,165 | 0 | 307,324 | | |
| 2000 | 0 | 7,897 | 211 | 206,745 | 65,896 | * | 327,781 | * | 366,897 | + | |
| 2001 | 0 | 7,148 | 4 | 139,389 | 113,647 | * | 335,080 | * | 210,382 | + | |
| 2002 | 0 | 6,474 | 0 | 157,076 | 72,562 | * | 426,510 | * | 136,380 | + | |
| 2003 | 0 | * | * | 207,375 | 145,585 | * | 437,056 | 0 | 313,993 | 207,030 | |
| 2004 | 0 | * | 0 | 275,343 | 308,644 | * | 679,490 | 0 | 316,460 | 92,552 | |
| 2005 | 0 | * | * | 194,598 | 210,906 | * | 517,902 | * | 655,926 | 377,503 | |
| 2006 | 0 | * | * | 154,708 | 239,977 | * | 157,993 | 295,777 | 315,886 | 291,238 | |
| 2007 | 0 | * | * | 248,896 | 353,688 | * | 311,645 | 207,846 | 428,241 | 453,255 | |
| 2008 | 0 | * | * | 266,320 | 261,102 | * | 180,387 | * | 543,683 | 306,811 | |
| 2009 | * | * | * | 183,316 | 288,928 | * | 87,286 | * | 755,972 | 384,115 | |
| 2010 | * | * | * | * | 409,449 | 0 | * | 219,988 | * | 922,785 | |
| 2011 | * | * | * | 21,170 | 363,233 | 0 | * | 99,802 | 454,096 | 430,190 | |

**<u>NOTES:</u>**
* Combined with next larger range to avoid disclosure.
+ Combined with the next smaller range to avoid disclosure.
= AHAM does not have data for this category during the requested period.

Domestic shipments includes units imported into the US, but does not include exports.
Data represent estimates of total industry volume, based upon information submitted by the participants.

**Table A-2 Shipment-Weighted Average Efficiency Data**

| Year | Shipment-Weighted Average Efficiency *(EF, in liters/kWh)* | | | | | |
|---|---|---|---|---|---|---|
| | Portable | | | | | Whole Home |
| | 35.00 pints/day or less | 35.01 to 45.00 pints/day | 45.01 to 54.00 pints/day | 54.01 to 75.00 pints/day | Greater than 75.00 pints/day | |
| 1995 | | | | | | |
| 1996 | | | | | | |
| 1997 | | | | | | |
| 1998 | | | | | | |
| 1999 | | | | | | |
| 2000 | | | | | | |
| 2001 | | | | | | |
| 2002 | | | | | | |
| 2003 | | | | | | |
| 2004 | | | | | | |
| 2005 | | | | | | |
| 2006 | | | | | | |
| 2007 | | | | | | |
| 2008 | | | | | | |
| 2009 | | | | | | |
| 2010 | | | | | | |
| 2011 | | | | | | |

**NOTES:**

= AHAM does not have data for this category during the requested period.

**Table A-3 Market Share Efficiency Data: Portable Dehumidifiers with Capacity up to 54.00 pints/day**

| Portable, 35.00 pints/day or less | | Portable, 35.01 to 45.00 pints/day | | Portable, 45.01 to 54.00 pints/day | |
|---|---|---|---|---|---|
| Efficiency Bins *(EF)* | Market Share for 2010 or 2011* | Efficiency Bins *(EF)* | Market Share for 2010 or 2011* | Efficiency Bins *(EF)* | Market Share for 2010 or 2011* |
| 1.35 | | 1.50 | | 1.60 | |
| 1.45 | | 1.62 | | 1.70 | |
| 1.61 | | | | 1.80 | |

**Notes:**
* Total market share percentages should equal 100%.
= AHAM does not have data for this category during the requested period.

**Table A-4 Market Share Efficiency Data: Portable Dehumidifiers with Capacity Greater Than 54.00 pints/day and Whole-Home Dehumidifiers**

| Portable, 54.01 to 75.00 pints/day | | Portable, greater than 75.00 pints/day | | Whole-Home | |
|---|---|---|---|---|---|
| Efficiency Bins *(EF)* | Market Share for 2010 or 2011* | Efficiency Bins *(EF)* | Market Share for 2010 or 2011* | Efficiency Bins *(EF)* | Market Share for 2010 or 2011* |
| 1.70 | | 2.50 | | 2.50 | |
| 1.85 | | 2.80 | | 2.80 | |
| 2.10 | | 3.50 | | 3.50 | |
| 2.47 | | 4.17 | | 4.17 | |

**Notes:**
* Total market share percentages should equal 100%.
= AHAM does not have data for this category during the requested period.

## Table A-5 Manufacturer Cost Data: Portable Dehumidifiers

| Product Class ➔ | Portable, 35.01 to 45.00 pints/day | | Portable, 45.01 to 54.00 pints/day | | | Portable, 54.01 to 75.00 pints/day | | | |
|---|---|---|---|---|---|---|---|---|---|
| Efficiency Level | 1 | 2 | 1 | 2 | 3 | 1 | 2 | 3 | 4 |
| EF (*liters/kWh*) | 1.50 | 1.62 | 1.60 | 1.70 | 1.80 | 1.70 | 1.85 | 2.10 | 2.47 |
| **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 | | | | | | | | | |

**NOTES:**

= AHAM does not have data for this category during the requested period.

# 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 standards for residential dehumidifiers as of October 1, 2012.

**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 A-6 Manufacturer Cost Data: Whole-Home Dehumidifiers

| Product Class ➔ | Whole Home | | | |
|---|---|---|---|---|
| Efficiency Level | 1 | 2 | 3 | 4 |
| EF (*liters/kWh*) | 2.50 | 2.80 | 3.50 | 4.17 |
| **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 | | | | |

**NOTES:**
= AHAM does not have data for this category during the requested period.

# 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 whole-home dehumidifiers complies with the federal standards for residential dehumidifiers with greater than 75.00 pints/day capacity as of October 1, 2012.

**Other Information:**
2. 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)

# APPENDIX 5A. ENGINEERING ANALYSIS INTERVIEW GUIDE

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# APPENDIX 5A. ENGINEERING ANALYSIS INTERVIEW GUIDE

## 5A.1 RESIDENTIAL DEHUMIDIFIERS

# Residential Dehumidifier Rulemaking
# Engineering Analysis Interview Guide for
# Residential Dehumidifiers

August 6. 2014

The U.S. Department of Energy (DOE) conducts the manufacturer impact analysis (MIA) as part of the rulemaking process for amended energy conservation standards for residential portable and whole-home dehumidifiers. In this analysis, DOE uses publicly available information and information provided by manufacturers during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

DOE published a notice of public meeting and availability of the preliminary technical support document (TSD) regarding energy conservation standards for dehumidifiers on May 22, 2014. 79 FR 29380. Based on feedback received from stakeholders, DOE is revising the preliminary analyses in preparation for a notice of proposed rulemaking (NOPR). DOE requests manufacturer feedback on a number of issues covered in the sections below in support of updating its analyses.

# 1 PRODUCT CLASSES

As specified in the preliminary TSD, DOE conducted its analyses on the following product classes and efficiency levels for portable and whole-home dehumidifiers. The capacities and efficiency levels reflect results obtained using the test procedure proposed in the NOPR published in the Federal Register on May 21, 2014. 79 FR 29271.

**Table 1.1 Preliminary Analysis Portable Dehumidifier Efficiency Levels at 65 °F**

| Efficiency Level | Efficiency Level Source | Integrated Energy Factor Efficiency Levels (*L/kWh*) | | | | |
|---|---|---|---|---|---|---|
| | | 20.00 pints/day or less | 20.01–30.00 pints/day | 30.01–35.00 pints/day | 35.01–45.00 pints/day | 45.01 pints/day or more |
| Baseline | DOE Standard with Fan-only Mode | 0.77 | 0.80 | 0.94 | 1.00 | 2.07 |
| 1 | DOE Standard with no Fan-only Mode | 1.10 | 1.10 | 1.20 | 1.30 | 2.40 |
| 2 | Gap Fill 1* | 1.20 | 1.20 | 1.40 | 1.40 | 2.80 |
| 3 | Gap Fill 2 | 1.30 | 1.30 | 1.60 | 1.60 | 3.52 |
| 4 | Maximum Available | 1.42 | 1.52 | 1.75 | 1.75 | N/A |

1.1 Should DOE consider collapsing portable dehumidifiers into fewer product classes? If so, what capacity bins would be appropriate?

1.2 Is there any unique consumer utility associated with portable products in the different capacity bins that would warrant maintaining separate product classes?

**Table 1.2 Preliminary Analysis Whole-Home Dehumidifier Efficiency Levels 65 °F**

| Efficiency Level | Efficiency Level Source | Integrated Energy Factor Efficiency Levels *(L/kWh)* | |
|---|---|---|---|
| | | **Less than or equal to 8.0 $ft^3$ (Case Volume)** | **Greater than 8.0 $ft^3$ (Case Volume)** |
| Baseline | Minimum Available | 1.10 | 1.68 |
| 1 | Gap Fill 1 | 1.40 | 1.90 |
| 2 | Gap Fill 2/Maximum Available | 1.59 | 2.80 |
| 3 | Maximum Available | N/A | 3.41 |

1.3 Is case volume an appropriate differentiator between whole-home dehumidifier product classes? If so, is 8 $ft^3$ the appropriate cutoff point between the small and large product classes?

1.4 If case volume is not an appropriate metric for separating whole-home dehumidifier product classes, are multiple product classes necessary? If so, what would be the appropriate product classes and differentiators?

## 2 ENGINEERING

In the preliminary analysis, DOE developed cost estimates associated with improving product efficiencies beyond the baseline for the product classes listed in Table 1.1 and Table 1.2. Table 2.1 below lists the incremental manufacturing costs determined in the preliminary analysis.

**Table 2.3 Incremental Dehumidifier Manufacturing Costs at Higher Efficiencies**

| | **Portable Product Class Capacities** *(pints/day)* | | | | | **Whole-Home Product Class Case Volume** *($ft^3$)* | |
|---|---|---|---|---|---|---|---|
| **Efficiency Level** | **≤ 20** | **20.01-30** | **30.01-35** | **35.01-45** | **> 45** | **≤ 8.0** | **> 8.0** |
| **EL1** | $- | $- | $- | $- | $38.40 | $15.22 | $6.14 |
| **EL2** | $1.56 | $1.85 | $2.94 | $1.98 | $49.16 | $76.18 | $37.05 |
| **EL3** | $4.64 | $3.78 | $8.72 | $7.56 | $100.13 | | $112.01 |
| **EL4** | $7.77 | $10.82 | $13.40 | $11.24 | | | |

2.1 Are the costs presented in Table 2.1 appropriate for the corresponding efficiency improvements in each product class? DOE assumed in the preliminary analysis that manufacturers would primarily rely on increased compressor efficiencies and improvements to the heat exchangers to reach higher efficiency levels.

2.2 DOE assumed in its preliminary analysis that rotary R-410A compressor efficiencies may reach energy efficiency ratios (EERs) up to 10.5 British thermal units per hour per Watt (Btu/h/W). Is this maximum EER appropriate for the entire range of rotary R-410A compressor capacities (*i.e.*, <3,000 Btu/h up to roughly 15,000 Btu/h)? What price premium is associated with more efficient compressors?

2.3 DOE relied on information from the room air conditioners final rule published in 2011 in determining compressor pricing information (described in chapter 5 of the preliminary TSD). Are the costs shown on this curve appropriate for compressors included in dehumidifiers? What price-capacity trend should DOE use for low-capacity compressors (below 5,000 Btu/h) beyond the range of the room air conditioners pricing curve?

2.4 What efficiency gains would be associated with moving to more efficient blower motors (*i.e.*, permanent magnet motors)? What price premium would these motors have compared to the typical permanent-split capacitor motors used in most dehumidifiers?

2.5 In the preliminary analysis, DOE considered improvements to the evaporator and condenser by increasing the cross-sectional area of these heat exchangers. What factors limit the extent to which manufacturers may increase the heat exchanger sizes? Would manufacturers consider improvements to the heat exchangers other than increasing cross-sectional area (*e.g.*, increasing the number of tube passes in the direction of the air flow)?

2.6 For the portable product classes with capacities less than 45 pints/day, DOE assumed that manufacturers would improve efficiencies from the baseline to EL1 by eliminating fan-only mode. Would removing fan-only mode have any impact on consumer utility?

2.7 Testing

2.7.a What should the inlet air condition (dry-bulb temperature and relative humidity) be for testing whole-home dehumidifiers? How would an inlet air temperature of 73 °F affect measured efficiencies and capacities compared to the 65 °F used for the preliminary analysis?

2.7.b What should the test external static pressure be for whole-home dehumidifiers? How would an external static pressure of 0.25 inches of water affect measured efficiencies and capacities compared to 0.5 in. water as proposed in the preliminary analysis?

2.7.c Should the test procedure require an additional test duct for units with ventilation/fresh air collars or should these collars be capped closed for testing?

2.7.d Is 65 °F the most appropriate inlet temperature condition for portable dehumidifiers? If not, what should it be?

2.7.e The proposed test procedure does not account for dehumidifier performance under varying ambient conditions. Should DOE consider testing at multiple ambient conditions to assess potential efficiency improvements associated with certain design options (*e.g.*, variable speed compressors, flow control devices, improved defrost control)? If so, what ambient conditions should be tested?

2.7.f If multiple ambient conditions were assessed, how would the increased test burden associated with these additional test points impact profitability and overall manufacturing costs? Also, how much energy would a field unit with these design options save when compared with a unit without these design options.

# 3 KEY ISSUES

3.1 Since the preliminary interview, are there any **new** key issues for your company regarding amended energy conservation standards for residential dehumidifiers?

## 4 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

DOE is interested in understanding manufacturer impacts at the plant or profit center level directly pertinent to dehumidifier production. However, the context within which this profit center operates and the details of plant production are not always readily available from public sources. Understanding the organizational setting around the dehumidifier industry profit center will help DOE understand the probable future of the manufacturing activity with and without amended energy conservation standards.

4.1 What percentage of your dehumidifier manufacturing corresponds to each product class, in terms of both revenue and shipments within the U.S.? If known, please also indicate your company's approximate market share for each product class. Please also indicate whether you purchase your dehumidifiers from other manufacturers, and whether the factory that supplies the products is located in the United States.

**Table 4.4 Portable Dehumidifier U.S. Revenue and Shipment Volumes by Product Class**

| Product Class Number | Product Class | 2013 Revenue | 2013 Shipments | % Made | % Bought | % Made in U.S. | Market Share |
|---|---|---|---|---|---|---|---|
| 1 | 20.00 pints/day or less** | | | | | | |
| 2 | 20.01–30.00 pints/day | | | | | | |
| 3 | 30.01–35.00 pints/day | | | | | | |
| 4 | 35.01–45.00 pints/day | | | | | | |
| 5 | 45.01 pints/day or more | | | | | | |

**Table 4.2 Whole-Home Dehumidifier U.S. Revenue and Shipment Volumes by Product Class**

| Product Class Number | Product Class | 2013 Revenue | 2013 Shipments | % Made | % Bought | % Made in U.S. | Market Share |
|---|---|---|---|---|---|---|---|
| 1 | <= 8.0 $ft^3$ (Case Volume) | | | | | | |
| 2 | > 8.0 $ft^3$ (Case Volume) | | | | | | |

## 5 MARKUPS AND PROFITABILITY

One of the primary objectives of the MIA is to assess the impact of amended energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how amended energy conservation standards would impact your company's markup structure and profitability.

DOE will estimate the manufacturer production costs for each product classes of residential dehumidifiers. DOE defines manufacturer production cost as all direct costs associated with manufacturing a product: direct labor, direct materials, overhead, and 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 times 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.

**DOE estimated a baseline markup of 1.43 for residential dehumidifiers.**

5.1 Is the 1.43 baseline markup representative of an average industry markup?

5.2 Please comment on the baseline markups DOE calculated as compared to your company's baseline markups for the dehumidifier product classes. How would revised standards potentially impact your baseline markups and margins for each product class?

**Table 5.5 Portable Dehumidifier Baseline Manufacturer Markups by Product Class**

| Product Class | Product Type | Estimated Baseline Markup | Manufacturer Comments or Revised Estimates |
|---|---|---|---|
| 1 | 20.00 pints/day or less** | 1.43 | |
| 2 | 20.01–30.00 pints/day | 1.43 | |
| 3 | 30.01–35.00 pints/day | 1.43 | |
| 4 | 35.01–45.00 pints/day | 1.43 | |
| 5 | 45.01 pints/day or more | 1.43 | |

**Table 5.6 Whole-Home Dehumidifier Baseline Manufacturer Markups by Product Class**

| Product Class | Product Type | Estimated Baseline Markup | Manufacturer Comments or Revised Estimates |
|---|---|---|---|
| 1 | <= 8.0 $ft^3$ (Case Volume) | 1.43 | |
| 2 | > 8.0 $ft^3$ (Case Volume) | 1.43 | |

5.3 DOE is interested in understanding if efficiency is a feature that earns a premium or whether it would cut into profit margins (and reduce markups). Within each product class, would markups vary by efficiency level? If yes, please provide estimates for your markups by product class and efficiency level in Table 5.3 and Table 5.4.

**Table 5.7 Estimated Markups for Portable Dehumidifiers**

| Efficiency Level | Efficiency Level Source | Integrated Energy Factor Efficiency Levels (*L/kWh*) | | | | |
|---|---|---|---|---|---|---|
| | | 20.00 pints/day or less | 20.01–30.00 pints/day | 30.01–35.00 pints/day | 35.01–45.00 pints/day | 45.01 pints/day or more |
| 1 | DOE Standard with no Fan-only Mode | | | | | |
| 2 | Gap Fill 1 | | | | | |
| 3 | Gap Fill 2 | | | | | |
| 4 | Maximum Available | | | | | |

**Table 5.8 Estimated Markups for Whole-Home Dehumidifiers**

| Efficiency Level | Efficiency Level Source | Integrated Energy Factor Efficiency Levels *(L/kWh)* | |
|---|---|---|---|
| | | Less than or equal to 8.0 $ft^3$ (Case Volume) | Greater than 8.0 $ft^3$ (Case Volume) |
| 1 | Gap Fill 1 | | |
| 2 | Gap Fill 2/Maximum Available | | |
| 3 | Maximum Available | | |

5.4 What factors or product attributes besides efficiency affect the profitability of dehumidifiers within a product class?

5.5 Would you expect changes in your estimated profitability following an amended energy conservation standard? If so, please explain why.

## 6 FINANCIAL PARAMETERS

DOE's contractor has developed a draft model of the dehumidifier industry financial performance called the Government Regulatory Impact Model (GRIM), using publicly available data. However, this public information might not be reflective of manufacturing at the dehumidifier profit center. This section attempts to understand the financial parameters for dehumidifier manufacturing and how your company's financial situation could differ from the industry aggregate picture.

6.1 In order to accurately collect information about dehumidifier manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

**1.**

**Table 6.9 Financial Parameters for Residential Dehumidifier 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) | 31.1% | |
| Discount Rate | Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity) | 8.4% | |
| Working Capital | Current assets less current liabilities (percentage of revenues) | 20.1% | |
| Net PPE | Net plant property and equipment (percentage of revenues) | 13.4% | |
| SG&A | Selling, general, and administrative expenses (percentage of revenues) | 20.9% | |
| R&D | Research and development expenses (percentage of revenues) | 1.3% | |
| Depreciation | Amortization of fixed assets (percentage of revenues) | 2.5% | |
| 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) | 71.7% | |

6.2 Relative to the sale of dehumidifiers, do you typically pay for shipping costs? Does the customer reimburse you for some or all of the costs associated with the shipment of your dehumidifier products?

6.3 DOE accounts for one time product and capital conversion costs including research and development, as well as capital expenditures for facility changes and the depreciation of these fixed assets. Beyond these short term changes in cost structure, how would you expect an amended energy conservation standard to impact any of the financial parameters for the industry over time?

## 7 CONVERSION COSTS

Amended energy conservation standards may cause your company to incur capital and product conversion costs to redesign existing products and make changes to existing production lines to be compliant with the amended energy conservation standard. Depending on their magnitude, the conversion costs can have a substantial impact on the outputs used by DOE to evaluate the industry impacts. Understanding the nature and magnitude of the conversion costs is critical portion of the MIA. 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 and certification, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.

CAPITAL CONVERSION COSTS

7.1 Please provide estimates for your capital conversion costs by product class and efficiency level in Table 7.1 through Table 7.7. 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, etc. that would be required to implement the specified design changes.

For each of the product categories, please note which efficiency level changes could be made within existing platform designs and which would result in major product redesigns. Also note which design options would require only minor changes to production lines, and which would require major changes to production lines, substantial modifications to existing facilities, or the development of entirely new manufacturing facilities.

*Portable Dehumidifiers*

**Table 7.10 Expected Capital Conversion Costs for Portable Dehumidifiers – 20.00 pints/day of less**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.10 | | |
| 2 | 1.20 | | |
| 3 | 1.30 | | |
| 4 | 1.42 | | |

**Table 7.11 Expected Capital Conversion Costs for Portable Dehumidifiers – 20.01 to 30.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.10 | | |
| 2 | 1.20 | | |
| 3 | 1.30 | | |
| 4 | 1.52 | | |

**Table 7.12 Expected Capital Conversion Costs for Portable Dehumidifiers – 30.01 to 35.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.20 | | |
| 2 | 1.40 | | |
| 3 | 1.60 | | |
| 4 | 1.75 | | |

**Table 7.13 Expected Capital Conversion Costs for Portable Dehumidifiers – 35.01 to 45.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.30 | | |
| 2 | 1.40 | | |
| 3 | 1.60 | | |
| 4 | 1.75 | | |

**Table 7.14 Expected Capital Conversion Costs for Portable Dehumidifiers – 45.01 pints/day or more**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 2.40 | | |
| 2 | 2.80 | | |
| 3 | 3.52 | | |
| 4 | N/A | | |

*Whole-Home Dehumidifiers*

**Table 7.15 Expected Capital Conversion Costs for Whole-Home Dehumidifiers - Less than or equal to 8.0 $ft^3$**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.40 | | |
| 2 | 1.59 | | |
| 3 | N/A | | |

**Table 7.16 Expected Capital Conversion Costs for Whole-Home Dehumidifiers - 8.0 $ft^3$ or more**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.90 | | |
| 2 | 2.80 | | |
| 3 | 3.41 | | |

PRODUCT CONVERSION COSTS

7.2 What level of product conversion costs would you expect to incur at each of these efficiency levels for each product class? Please provide your estimates in Table 7.8 through Table 7.14 (where applicable) considering such expenses as product development expenses, prototyping, testing, certification, and marketing [if you have not previously certified your products with the DOE, please be sure to breakout an estimate of the costs associated with testing and certification, if possible]. In the description column, please describe the assumptions behind the estimates provided.

*Portable Dehumidifiers*

**Table 7.17 Expected Product Conversion Costs for Portable Dehumidifiers – 20.00 pints/day of less**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.10 | | |
| 2 | 1.20 | | |
| 3 | 1.30 | | |
| 4 | 1.42 | | |

**Table 7.18 Expected Product Conversion Costs for Portable Dehumidifiers – 20.01 to 30.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.10 | | |
| 2 | 1.20 | | |
| 3 | 1.30 | | |
| 4 | 1.52 | | |

**Table 7.19 Expected Product Conversion Costs for Portable Dehumidifiers – 30.01 to 35.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.20 | | |
| 2 | 1.40 | | |
| 3 | 1.60 | | |
| 4 | 1.75 | | |

**Table 7.20 Expected Product Conversion Costs for Portable Dehumidifiers – 35.01 to 45.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.30 | | |
| 2 | 1.40 | | |
| 3 | 1.60 | | |
| 4 | 1.75 | | |

**Table 7.21 Expected Product Conversion Costs for Portable Dehumidifiers – 45.01 pints/day or more**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 2.40 | | |
| 2 | 2.80 | | |
| 3 | 3.52 | | |
| 4 | N/A | | |

*Whole-Home Dehumidifiers*

**Table 7.22 Expected Product Conversion Costs for Whole-Home Dehumidifiers - Less than or equal to 8.0 $ft^3$**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.40 | | |
| 2 | 1.59 | | |
| 3 | N/A | | |

**Table 7.23 Expected Product Conversion Costs for Whole-Home Dehumidifiers - 8.0 $ft^3$ or more**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.90 | | |
| 2 | 2.80 | | |
| 3 | 3.41 | | |

# 8 DIRECT EMPLOYMENT IMPACT ASSESSMENT AND MANUFACTURING CAPACITY

8.1 Where are your dehumidifier manufacturing facilities that produce products for the United States located? What types of products are manufactured at each location? Please provide employment levels and annual shipment figures for your company's dehumidifier manufacturing at each location by product class.

**Table 8.24 Dehumidifiers Employment and Shipment Volumes by Product Class***

| Facility | Location | Product Types Manufactured | Employees | Annual Shipments |
|---|---|---|---|---|
| *Example* | *Sheboygan, WI* | *Portable dehumidifiers* | *200* | *100,000* |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

*For manufacturing facilities that produce products for the U.S.

8.2 Would your domestic employment levels be expected to change significantly under amended energy conservation standards? If so, please explain how they would change if higher efficiency levels are required.

8.3 How would amended energy conservation standards impact your company's manufacturing capacity? How much, if any, downtime would be required?

8.4 What percentage of your company's overall dehumidifier sales is made within the United States?

8.5 Would amended energy conservation standards impact your domestic vs. foreign manufacturing or sourcing decisions? Is there an efficiency level that would cause you to move domestic production facilities outside the U.S.?

# 9 IMPACTS ON SMALL BUSINESS

9.1 The Small Business Administration (SBA) denotes a small business in the dehumidifier manufacturing industry as having less than 750 total employees, including the parent company and all subsidiaries.[a] By this definition, is your company considered a small business?

9.2 Are there any reasons that a small business manufacturer might be at a disadvantage relative to a larger business under amended energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

9.3 To your knowledge, are there any small businesses, niche manufacturers or component manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, why?

[a] DOE uses the small business size standards published on January 1, 2012, as amended, by the SBA to determine whether a company is a small business. The products covered by this rulemaking are classified under NAICS codes 333415: Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing and 335210: Small Electrical Appliance Manufacturing. To be categorized as a small business, a manufacturer (and its affiliates) classified by one of these NAICS codes may employ a maximum of 750 employees. The 750 employee threshold includes all employees in a business's parent company and any other subsidiaries.

# APPENDIX 6A. DETAILED DATA FOR PRODUCT PRICE MARKUPS

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# APPENDIX 6A. DETAILED DATA FOR PRODUCT PRICE MARKUPS

## 6A.1 DETAILED WHOLESALER COST DATA

Based on data provided by the Heating Air-conditioning & Refrigeration Distributors International (HARDI) 2013 Profit Report, Table 6.5.1 of chapter 6 shows wholesaler revenues and costs in aggregated form. Table 6A-1 in this appendix provides the complete breakdown of costs and expenses. The column labeled "Scaling" in Table 6A.1.1 indicates which expenses the U.S. Department of Energy (DOE) assumed to scale with only the baseline markup and which with both the baseline and incremental markups. Only those expenses that scale with both baseline and incremental costs are marked up when there is an incremental change in equipment costs.

**Table 6A.1.1 Disaggregated Costs and Expenses for Wholesalers**

| Item | Percent of Revenue % | Scaling |
|---|---|---|
| **Cost of Goods Sold** | **73.9** | |
| **Gross Margin** | **26.1** | |
| **Payroll Expenses** | **15.1** | Baseline |
| Executive Salaries & Bonuses | 1.6 | |
| Branch Manager Salaries and Commissions | 1.3 | |
| Sales Executive Salaries & Commissions | 0.5 | |
| Outside Sales Salaries & Commissions | 2.3 | |
| Inside/Counter Sales/Wages | 2.6 | |
| Purchasing Salaries/Wages | 0.5 | |
| Credit Salaries/Wages | 0.2 | |
| IT Salaries/Wages | 0.2 | |
| Warehouse Salaries/Wages | 1.4 | |
| Accounting | 0.5 | |
| Delivery Salaries/Wages | 0.8 | |
| All Other Salaries/Wages & Bonuses | 0.8 | |
| Payroll Taxes | 1.0 | |
| Group Insurance | 1.0 | |
| Benefit Plans | 0.4 | |
| **Occupancy Expenses** | **3.5** | Baseline |
| Utilities: Heat, Light, Power, Water | 0.4 | |
| Telephone | 0.3 | |
| Building Repairs & Maintenance | 0.3 | |
| Rent or Ownership in Real Estate | 2.5 | |

| Item | Percent of Revenue % | Scaling |
|---|---|---|
| **Other Operating Expenses** | **5.2** | Baseline & Incremental |
| Sales Expenses (incl. advertising & promotion) | 0.9 | |
| Insurance (business liability & casualty) | 0.2 | |
| Depreciation | 0.4 | |
| Vehicle Expenses | 1.2 | |
| Personal Property Taxes/Licenses | 0.1 | |
| Collection Expenses | 0.3 | |
| Bad Debt Losses | 0.2 | |
| Data Processing | 0.3 | |
| All Other Operating Expenses | 1.6 | |
| **Total Operating Expenses** | **23.8** | |
| **Operating Profit** | **2.3** | Baseline & Incremental |
| Other Income | 0.4 | |
| Interest Expense | 0.4 | |
| Other Non-operating Expenses | 0.0 | |
| **Profit Before Taxes** | **2.3** | |

Source: Heating, Air-conditioning & Refrigeration Distributors International. 2013. 2013 Profit Report (2012 Data).
Note: The wholesaler costs and expenses are percentage values as opposed to the per-dollar of sales revenue values shown in Table 6.4.1.

## 6A.2 DETAILED MECHANICAL CONTRACTOR DATA

Tables 6.5.3 and Table 6.5.4 of chapter 6 provide mechanical contractor revenues and costs in aggregated form by 'Cost of Goods Sold' and 'Gross Margin.' The tables are based on data in the 2005 edition of *Financial Analysis for the HVACR Contracting Industry,* published by the Air Conditioning Contractors of America (ACCA). The ACCA report did not provide a more disaggregated tabulation of these costs and expenses. As in section 6A.1, the gross margin category was assumed to scale only with the baseline markup.

A further disaggregated breakdown of costs used to scale the incremental markup are shown in Table 6A.2.1 by both dollar value and percentage terms from the 2007 Census of Business. As the ACCA data were used to calculate the baseline markup, in Table 6A.2.1 only the categories in the 'Scaling' column that are scaled with both the baseline and incremental markups are marked when there is an incremental change in equipment costs.

**Table 6A.2.1 Mechanical Contractor Expenses and Markups Used To Scale the Incremental Markups**

| Item | Dollar Value $1,000 | Percentage % | Scaling |
|---|---|---|---|
| **Total Cost of Equipment Sales** | **107,144,428** | **67.80** | |
| Total payroll, construction workers wages | 31,373,558 | 19.85 | |
| Cost of materials, components, and supplies | 59,023,964 | 37.35 | |
| Cost of construction work subcontracted out to others | 13,646,192 | 8.63 | |
| Total cost of selected power, fuels, and lubricants | 3,100,714 | 1.96 | |
| **Gross Margin** | **50,895,129** | **32.20** | |
| **Payroll Expenses** | **28,065,632** | **17.76** | Baseline |
| Total payroll, other employee wages | 14,041,336 | 8.88 | |
| Total fringe benefits | 13,585,040 | 8.60 | |
| Temporary staff and leased employee expenses | 439,256 | 0.28 | |
| **Occupancy Expenses** | **3,436,208** | **2.17** | Baseline |
| Rental costs of machinery and equipment | 1,047,026 | 0.66 | |
| Rental costs of buildings | 1,231,263 | 0.78 | |
| Communication services | 640,851 | 0.41 | |
| Cost of repair to machinery and equipment | 517,068 | 0.33 | |
| **Other Operating Expenses** | **12,671,194** | **8.02** | Baseline & Incremental |
| Purchased professional and technical services | 843,641 | 0.53 | |
| Data processing and other purchased computer services | 98,016 | 0.06 | |
| Expensed computer hardware and other equipment | 255,474 | 0.16 | |
| Expensed purchases of software | 64,195 | 0.04 | |
| Advertising and promotion services | 1,018,265 | 0.64 | |
| All other expenses | 6,944,674 | 4.39 | |
| Refuse removal (including hazardous waste) services | 153,241 | 0.10 | |
| Taxes and license fees | 996,138 | 0.63 | |
| Total depreciation ($1,000) | 2,297,550 | 1.45 | |
| **Net Profit Before Income Taxes** | **6,722,095** | **4.25** | Baseline & Incremental |

Source: U.S. Census Bureau. 2007. Plumbing, Heating, and Air-Conditioning Contractors: 2007. Sector 23: 238220. Construction: Geographic Area Series. Detailed Statistics for Establishments: 2007.
Note: Mechanical contractor costs and expenses are first presented as *total dollar* values and then converted to *percentage* values. This is in contrast to the *cost per dollar of sales revenue* values shown in Table 6.5.2.

## 6A.3 DETAILED GENERAL CONTRACTOR COST DATA

Based on U.S. Department of Census data, Table 6.5.6 of chapter 6 shows residential building general contractor revenues and costs in aggregated form. Table 6A.3.1 shows the complete breakdown of costs and expenses of residential building contractor provided by the U.S. Department of Census. The column labeled "Scaling" indicates which expenses DOE assumed to scale with only the baseline markup and which are scaled with both the baseline and incremental markups. Only those expenses that scale with baseline and incremental costs are marked up when there is an incremental change in equipment costs.

**Table 6A.3.1 Residential General Contractor Expenses and Markups**

| Item | Dollar Value *$1,000* | Percentage *%* | Scaling |
|---|---|---|---|
| **Total Cost of Equipment Sales** | **238,431,389** | **67.55** | |
| Total payroll, construction workers wages | 16,629,321 | 4.71 | |
| Cost of materials, components, and supplies | 126,764,975 | 35.91 | |
| Cost of construction work subcontracted out to others | 90,956,668 | 25.77 | |
| Total cost of selected power, fuels, and lubricants | 4,080,425 | 1.16 | |
| **Gross Margin** | **114,558,247** | **32.45** | |
| **Payroll Expenses** | **28,806,792** | **8.16** | Baseline |
| Total payroll, other employee wages | 20,843,029 | 5.90 | |
| Total fringe benefits | 7,464,670 | 2.11 | |
| Temporary staff and leased employee expenses | 499,093 | 0.14 | |
| **Occupancy Expenses** | **3,558,796** | 1.01 | Baseline |
| Rental costs of machinery and equipment | 572,783 | 0.16 | |
| Rental costs of buildings | 1,532,841 | 0.43 | |
| Communication services | 810,436 | 0.23 | |
| Cost of repair to machinery and equipment | 642,736 | 0.18 | |
| **Other Operating Expenses** | **21,341,175** | **6.05** | Baseline & Incremental |
| Purchased professional and technical services | 1,834,816 | 0.52 | |
| Data processing and other purchased computer services | 141,344 | 0.04 | |
| Expensed computer hardware and other equipment | 261,701 | 0.07 | |
| Expensed purchases of software | 105,338 | 0.03 | |
| Advertising and promotion services | 2,544,687 | 0.72 | |
| All other expenses | 10,840,757 | 3.07 | |
| Refuse removal (including hazardous waste) services | 520,907 | 0.15 | |
| Taxes and license fees | 1,791,539 | 0.51 | |
| Total depreciation ($1,000) | 3,300,086 | 0.93 | |
| **Net Profit Before Income Taxes** | **60,851,484** | **17.24** | Baseline & Incremental |

Source: U.S. Census Bureau. 2007. Residential Building Construction. Sector 23, EC0723I1: 236115 through 236118. Construction, Industry Series, Preliminary Detailed Statistics for Establishments: 2007.
Note: General contractor costs and expenses are first presented as *total dollar* values and then converted to *percentage* values. This is in contrast to the *cost per dollar of sales revenue* values shown in Table 6.5.6.

## 6A.4 STATE SALES TAX RATES

**Table 6A.4.1 State Sales Tax Rates**

| State | Combined State and Local Tax Rate % | State | Combined State and Local Tax Rate % | State | Combined State and Local Tax Rate % |
|---|---|---|---|---|---|
| Alabama | 8.55 | Kentucky | 6.00 | North Dakota | 5.95 |
| Alaska | 1.30 | Louisiana | 8.80 | Ohio | 7.10 |
| Arizona | 7.15 | Maine | 5.50 | Oklahoma | 8.40 |
| Arkansas | 8.90 | Maryland | 6.00 | Oregon | -- |
| California | 8.40 | Massachusetts | 6.25 | Pennsylvania | 6.35 |
| Colorado | 6.10 | Michigan | 6.00 | Rhode Island | 7.00 |
| Connecticut | 6.35 | Minnesota | 7.20 | South Carolina | 7.00 |
| Delaware | -- | Mississippi | 7.05 | South Dakota | 5.45 |
| Dist. of Columbia | 5.75 | Missouri | 7.40 | Tennessee | 9.45 |
| Florida | 6.65 | Montana | -- | Texas | 7.95 |
| Georgia | 7.05 | Nebraska | 6.05 | Utah | 6.65 |
| Hawaii | 4.35 | Nevada | 7.95 | Vermont | 6.10 |
| Idaho | 6.05 | New Hampshire | -- | Virginia | 5.60 |
| Illinois | 8.00 | New Jersey | 6.95 | Washington | 8.90 |
| Indiana | 7.00 | New Mexico | 6.60 | West Virginia | 6.05 |
| Iowa | 6.80 | New York | 8.45 | Wisconsin | 5.45 |
| Kansas | 7.90 | North Carolina | 6.90 | Wyoming | 5.50 |

Source: The Sales Tax Clearinghouse at https://thestc.com/STRates.stm (Accessed on July 18, 2014).

# APPENDIX 7A. HOUSING VARIABLES

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# APPENDIX 7A. HOUSING VARIABLES

## 7A.1 INTRODUCTION

Using Microsoft ACCESS, DOE created a database containing a subset of the records and variables from DOE's Energy Information Administration (EIA)'s RECS 2009.[1] DOE used this RECS subset in the life-cycle cost (LCC) analysis of the Dehumidifier Rulemaking. This appendix explains the variable name abbreviations and provides definitions of the variable values. For the entire RECS 2009 dataset, refer to http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=microdata.

## 7A.2 RECS SAMPLE DETERMINATION

The RECS consists of three parts:

- Personal interviews with households for information about energy used, how it is used, energy-using appliances, structural features, energy efficiency measures, and demographic characteristics of the household.
- Telephone interviews with rental agents for households that have any of their energy use included in their rent.
- Mail questionnaires sent to energy suppliers (after obtaining permission from households) to collect the actual billing data on energy consumption and expenditures.

The subset of RECS 2009 records used to study dehumidifiers met all of the following criteria:

- used a dehumidifier;
- and for homes with a whole-home dehumidifier:
  - located in a mixed temperature and moist climate;
  - single-family attached or detached;
  - equipped with a central air conditioner;
  - equipped with duct work;

The RECS 2009 weighting indicates how commonly each household configuration occurs in the general population. Table 7A.2.1 shows the RECS sample weights and criteria for replacements.

Table 7A.2.1 lists the variables use in the analysis.

**Table 7A.2.1 List of RECS 2009 Variables Used for Dehumidifier LCC Analysis**

| Variable | Description |
|---|---|
| **Location Variables** | |
| REGIONC | Census Region |

| Variable | Description |
|---|---|
| DIVISION | Census Division |
| REPORTABLE_DOMAIN | Reportable states and groups of states |
| Climate_Region_Pub | Building America Climate Region |
| HDD65 | Heating degree days in 2009, base temperature 65F |
| HDD30YR | Heating degree days, 30-year average 1981-2010, base 65F |
| CDD65 | Heating degree days in 2009, base temperature 65F |
| CDD30YR | Cooling degree days, 30-year average 1981-2010, base 65F |
| StationID* | ID number of weather station identified with household (See Appendix 7-B) |
| **Housing Unit Characteristics Variables** | |
| NWEIGHT | Final sample weight |
| DOEID | Unique identifier for each respondent |
| TYPEHUQ | Type of housing unit |
| YEARMADE | Year housing unit was built |
| NOTMOIST | Use dehumidifier |
| USENOTMOIST | Number of months in 2009 use dehumidifier |
| COOLTYPE | Type of air conditioning equipment used |
| CENACHP | Central air conditioner is a heat pump |
| CELLAR | Basement in housing unit |
| BASEFIN | Finished basement |
| **Household Characteristics Variables** | |
| NHSLDMEM | Number of household members |
| Seniors* | Number of household members age 65 or older |
| POVERTY100 | Household income at or below 100% of poverty line |

* Not part of RECS 2009 variables.

## 7A.3 RECS 2009 DATABASE VARIABLE RESPONSE CODES

Table 7A.3.1 provides the response codes for all RECS 2009 variables used in the dehumidifier housing samples.

**Table 7A.3.1 Definitions of RECS 2009 Variables Used in Life-Cycle Cost Analysis**

| Variable | Response Codes |
|---|---|
| CDD65 | Cooling degree days in 2009, base temperature 65F |
| CELLAR | 0 No<br>1 Yes<br>-2 Not Applicable |
| CENACHP | 0 No<br>1 Yes<br>-2 Not Applicable |
| Climate_Region_Pub | 1 Very Cold/Cold<br>2 Hot-Dry/Mixed-Dry<br>3 Hot-Humid<br>4 Mixed-Humid<br>5 Marine |

| Variable | Response Codes | |
| --- | --- | --- |
| | 1 | Central system |
| | 2 | Window/wall units |
| | 3 | Both a central system and window/wall units |
| COOLTYPE | -2 | Not Applicable |
| | 1 | New England Census Division (CT, MA, ME, NH, RI, VT) |
| | 2 | Middle Atlantic Census Division (NJ, NY, PA) |
| | 3 | East North Central Census Division (IL, IN, MI, OH, WI) |
| | 4 | West North Central Census Division (IA, KS, MN, MO, ND, NE, SD) |
| | 5 | South Atlantic Census Division (DC, DE, FL, GA, MD, NC, SC, VA, WV) |
| | 6 | East South Central Census Division (AL, KY, MS, TN) |
| | 7 | West South Central Census Division (AR, LA, OK, TX) |
| | 8 | Mountain North Sub-Division (CO, ID, MT, UT, WY) |
| | 9 | Mountain South Sub-Division (AZ, NM, NV) |
| DIVISION | 10 | Pacific Census Division (AK, CA, HI, OR, WA) |
| DOEID | 00001 - 12083 | Unique identifier for each respondent |
| HDD65 | Heating degree days in 2009, base temperature 65F | |
| | 0 | No |
| NOTMOIST | 1 | Yes |
| NWEIGHT | Final sample weight | |
| | 0 | No |
| POVERTY100 | 1 | Yes |
| | 1 | Northeast Census Region |
| | 2 | Midwest Census Region |
| | 3 | South Census Region |
| REGIONC | 4 | West Census Region |
| | 1 | Connecticut, Maine, New Hampshire, Rhode Island, Vermont |
| | 2 | Massachusetts |
| | 3 | New York |
| | 4 | New Jersey |
| | 5 | Pennsylvania |
| | 6 | Illinois |
| | 7 | Indiana, Ohio |
| | 8 | Michigan |
| | 9 | Wisconsin |
| | 10 | Iowa, Minnesota, North Dakota, South Dakota |
| | 11 | Kansas, Nebraska |
| | 12 | Missouri |
| | 13 | Virginia |
| | 14 | Delaware, District of Columbia, Maryland, West Virginia |
| | 15 | Georgia |
| | 16 | North Carolina, South Carolina |
| | 17 | Florida |
| | 18 | Alabama, Kentucky, Mississippi |
| | 19 | Tennessee |
| REPORTABLE_DOMAIN | 20 | Arkansas, Louisiana, Oklahoma |

| Variable | Response Codes | |
|---|---|---|
| | 21 | Texas |
| | 22 | Colorado |
| | 23 | Idaho, Montana, Utah, Wyoming |
| | 24 | Arizona |
| | 25 | Nevada, New Mexico |
| | 26 | California |
| | 27 | Alaska, Hawaii, Oregon, Washington |
| | 0 | No |
| Seniors | 1 | Yes |
| | 1 | Mobile Home |
| | 2 | Single-Family Detached |
| | 3 | Single-Family Attached |
| | 4 | Apartment in Building with 2 - 4 Units |
| TYPEHUQ | 5 | Apartment in Building with 5+ Units |
| | 1 | 1 to 3 months |
| | 2 | 4 to 6 months |
| | 3 | 7 to 9 months |
| | 4 | 10 to 11 months |
| | 5 | Turned on all year |
| USENOTMOIST | -2 | Not applicable |
| YEARMADE | 1600 - 2009 | Year housing unit was built |

* Not part of RECS 2009 variables.

## REFERENCES


1 U.S. Department of Energy: Energy Information Administration, *Residential Energy Consumption Survey: 2009 RECS Survey Data,* 2013. (Last accessed March, 2013.) <http://www.eia.gov/consumption/residential/data/2009/>

2 U.S. Department of Energy: Energy Information Administration, *Commercial Buildings Energy Consumption Survey,* 2003. (Last accessed September, 2013.) <http://www.eia.doe.gov/emeu/cbecs/>

# APPENDIX 7B. WEATHER STATION DATA MAPPING TO RECS HOUSEHOLDS

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# APPENDIX 7B. WEATHER STATION DATA MAPPING TO RECS HOUSEHOLDS

## 7B.1 INTRODUCTION

Energy Information Administration's (EIA) 2009 Residential Energy Consumption Survey (RECS 2009)[1] provide data on annual heating and cooling degree-days but not on other weather parameters needed for the analysis such as average monthly outdoor absolute humidity (AH), monthly heating degree days (HDD) and cooling degree days (CDD), and average outdoor temperature.

## 7B.2 MAPPING METHODOLOGY

To derive the additional weather data that is needed for the analysis (e.g., AH), for each building in the sample, DOE developed an approach to assign a physical location to each RECS household. [a] The methodology consists of the following steps:

1. DOE assembled monthly weather data from 151 weather stations from the National Oceanic and Atmospheric Administration (NOAA)'s National Climatic Data Center (NCDC) that provide the heating and cooling degree-days at base temperature 65°F for year 2009 (for the RECS sample).[3] The 2009 heating and cooling degree days match the period used to determine the degree-days in RECS 2009.
2. RECS reports both annual HDD and CDD to base temperature 65°F for each building record. DOE assigned each building to one of the 151 weather stations by calculating which weather station (within the appropriate region) was the closest using the root mean square distance of the RECS annual degree days to the weather station annual degree days. The following equation calculates the root mean square distance in degree days between the U.S. weather data and the RECS/CBECS data:

$$"Distance" = \sqrt{(HDD_2 - HDD_1)^2 + (CDD_2 - CDD_1)^2}$$

Where:

| | |
|---|---|
| $HDD_1$ = | heating degree days from U.S. weather data, |
| $HDD_2$ = | heating degree days from RECS data, |
| $CDD_1$ = | cooling degree days from U.S. weather data, and |
| $CDD_2$ = | cooling degree days from RECS data. |

[a] For confidentiality, heating and cooling degree day values were altered slightly by EIA to mask the exact geographic location of the housing unit.

## 7B.3 MAPPING RESULTS

Table 7B.3.1 shows the imputation results for all RECS locations. Note that some U.S. weather station data match with several of the RECS weather data. The number of RECS buildings that were matched to the specified weather station is indicated in the column "Count". Table 7B.3.1 shows the data matches (151 weather stations) including the outdoor AH for the weather stations.

**Table 7B.3.1 Weather Station Data**

| WBAN | State | City | HDD | CDD | Vapor Density | Count |
|---|---|---|---|---|---|---|
| 03013 | CO | LAMAR | 5374 | 1003 | 0.0060160842 | 1 |
| 03031 | TX | ODESSA | 2355 | 2478 | 0.0076450452 | 4 |
| 03102 | CA | ONTARIO | 1315 | 1952 | 0.0080335282 | 10 |
| 03104 | CA | PALM SPRINGS | 1067 | 3943 | 0.0066554348 | 1 |
| 03178 | CA | SAN DIEGO | 1530 | 826 | 0.0093166774 | 1 |
| 03849 | KY | LONDON | 4287 | 1039 | 0.0093844476 | 8 |
| 03856 | AL | HUNTSVILLE | 2971 | 1847 | 0.0106559281 | 4 |
| 03882 | FL | PANAMA CITY | 1235 | 2952 | 0.0143677968 | 4 |
| 03894 | TN | CLARKSVILLE | 3927 | 1293 | 0.0100264573 | 10 |
| 03904 | TX | COLLEGE STATION | 1475 | 3421 | 0.0119196775 | 1 |
| 03919 | KS | SALINA | 5080 | 1307 | 0.008216447 | 1 |
| 03928 | KS | WICHITA | 4521 | 1495 | 0.0087987799 | 6 |
| 03947 | MO | KANSAS CITY | 5007 | 1083 | 0.0088161017 | 41 |
| 03953 | AR | JONESBORO | 3521 | 1684 | 0.010599441 | 4 |
| 03963 | MO | JEFFERSON CITY | 4507 | 1158 | 0.0089089311 | 6 |
| 04726 | PA | JOHNSTOWN | 6676 | 263 | 0.0069141535 | 2 |
| 04781 | NY | ISLIP | 5277 | 657 | 0.007716758 | 46 |
| 04841 | WI | SHEBOYGAN | 7720 | 258 | 0.0067380115 | 21 |
| 04845 | WI | KENOSHA | 7149 | 345 | 0.0070480555 | 21 |
| 04849 | OH | LORAIN/ELYRIA | 5667 | 733 | 0.0075507607 | 8 |
| 04852 | OH | NEW PHILADELPHIA | 5649 | 605 | 0.0075274837 | 3 |
| 04858 | OH | NEWARK | 5862 | 518 | 0.0080336913 | 20 |
| 12815 | FL | ORLANDO | 590 | 3599 | 0.0144723192 | 4 |
| 12838 | FL | MELBOURNE | 548 | 3590 | 0.0154710453 | 4 |
| 12839 | FL | MIAMI | 109 | 4905 | 0.0168885045 | 4 |
| 12842 | FL | TAMPA | 488 | 3866 | 0.0152015791 | 4 |
| 12843 | FL | VERO BEACH | 489 | 3547 | 0.0159311502 | 4 |
| 12844 | FL | WEST PALM BEACH | 239 | 4234 | 0.0155691407 | 4 |
| 12849 | FL | FORT LAUDERDALE | 120 | 4726 | 0.0165875652 | 4 |
| 12873 | FL | ST PETERSBURG/ CLEARWATER | 444 | 3963 | 0.0153142247 | 4 |
| 12947 | TX | COTULLA | 1089 | 4060 | 0.0122759646 | 1 |
| 12960 | TX | HOUSTON | 1255 | 3419 | 0.0138533393 | 5 |
| 13722 | NC | RALEIGH/DURHAM | 3126 | 1876 | 0.0099136985 | 4 |
| 13729 | WV | ELKINS | 5508 | 420 | 0.007951544 | 50 |
| 13733 | VA | LYNCHBURG | 4394 | 1025 | 0.0088138222 | 29 |
| 13739 | PA | PHILADELPHIA | 4498 | 1211 | 0.0085328605 | 5 |
| 13740 | VA | RICHMOND | 3742 | 1570 | 0.0094171582 | 14 |
| 13748 | NC | WILMINGTON | 2439 | 2053 | 0.0118205767 | 1 |

| WBAN | State | City | HDD | CDD | Vapor Density | Count |
|---|---|---|---|---|---|---|
| 13833 | MS | HATTIESBURG | 1878 | 2617 | 0.0126452945 | 3 |
| 13837 | GA | AUGUSTA | 2082 | 2444 | 0.0105780255 | 2 |
| 13841 | OH | WILMINGTON | 5373 | 702 | 0.008214416 | 8 |
| 13874 | GA | ATLANTA | 2803 | 1849 | 0.0107638781 | 6 |
| 13876 | AL | BIRMINGHAM | 2612 | 1950 | 0.0110090341 | 2 |
| 13877 | TN | BRISTOL/JHNSN CTY/KNGSPRT | 4244 | 941 | 0.0091840512 | 2 |
| 13881 | NC | CHARLOTTE | 3325 | 1623 | 0.0099698823 | 13 |
| 13882 | TN | CHATTANOOGA | 3141 | 1822 | 0.0103702599 | 2 |
| 13891 | TN | KNOXVILLE | 3593 | 1401 | 0.0099456766 | 3 |
| 13894 | AL | MOBILE | 1608 | 2680 | 0.0130542794 | 2 |
| 13897 | TN | NASHVILLE | 3589 | 1553 | 0.0098770797 | 3 |
| 13963 | AR | LITTLE ROCK | 2939 | 1940 | 0.011046741 | 1 |
| 13978 | MS | GREENWOOD | 2464 | 2237 | 0.0117848858 | 1 |
| 13987 | MO | JOPLIN | 4258 | 1349 | 0.0091626993 | 18 |
| 13989 | KS | EMPORIA | 4939 | 1130 | 0.0084067492 | 14 |
| 13993 | MO | ST JOSEPH | 5583 | 971 | 0.0081289433 | 29 |
| 13995 | MO | SPRINGFIELD | 4570 | 1110 | 0.0089819159 | 15 |
| 14605 | ME | AUGUSTA | 7465 | 275 | 0.0065529735 | 31 |
| 14710 | NH | MANCHESTER | 6366 | 553 | 0.0068233628 | 17 |
| 14732 | NY | NEW YORK | 4566 | 1049 | 0.0077815891 | 35 |
| 14735 | NY | ALBANY | 6506 | 450 | 0.0070472883 | 14 |
| 14736 | PA | ALTOONA | 6095 | 390 | 0.0073154231 | 8 |
| 14745 | NH | CONCORD | 7350 | 329 | 0.0067044268 | 12 |
| 14758 | CT | NEW HAVEN | 5339 | 706 | 0.0081707387 | 4 |
| 14764 | ME | PORTLAND | 7023 | 304 | 0.0070281667 | 27 |
| 14765 | RI | PROVIDENCE | 5610 | 591 | 0.0075202781 | 14 |
| 14768 | NY | ROCHESTER | 6689 | 325 | 0.0071111021 | 69 |
| 14770 | PA | SELINSGROVE | 5524 | 715 | 0.0077313171 | 4 |
| 14771 | NY | SYRACUSE | 6516 | 428 | 0.0069783428 | 13 |
| 14778 | PA | WILLIAMSPORT | 5584 | 659 | 0.0074689608 | 1 |
| 14794 | RI | WESTERLY | 5721 | 464 | 0.0083001294 | 3 |
| 14815 | MI | BATTLE CREEK | 6420 | 514 | 0.0072130328 | 19 |
| 14820 | OH | CLEVELAND | 5742 | 681 | 0.0076627958 | 21 |
| 14821 | OH | COLUMBUS | 5207 | 873 | 0.0077971836 | 9 |
| 14827 | IN | FORT WAYNE | 5939 | 616 | 0.00788948 | 15 |
| 14850 | MI | TRAVERSE CITY | 7517 | 247 | 0.0064113439 | 19 |
| 14853 | MI | DETROIT | 6659 | 449 | 0.0071093382 | 19 |
| 14914 | ND | FARGO | 9240 | 361 | 0.005866579 | 9 |
| 14916 | ND | GRAND FORKS | 9736 | 268 | 0.0059222236 | 19 |
| 14919 | ND | JAMESTOWN | 9644 | 258 | 0.0058707582 | 12 |
| 14920 | WI | LA CROSSE | 7210 | 520 | 0.0069321426 | 21 |
| 14921 | WI | LONE ROCK | 7130 | 378 | 0.0070061569 | 21 |
| 14925 | MN | ROCHESTER | 7658 | 319 | 0.0066144531 | 38 |
| 14939 | NE | LINCOLN | 6105 | 896 | 0.007342676 | 14 |
| 14950 | IA | OTTUMWA | 6277 | 573 | 0.0079394164 | 11 |
| 14991 | WI | EAU CLAIRE | 8026 | 329 | 0.0063139509 | 21 |
| 22010 | TX | DEL RIO | 1265 | 3806 | 0.0105411543 | 1 |
| 23042 | TX | LUBBOCK | 3151 | 1968 | 0.0071494326 | 1 |

| WBAN | State | City | HDD | CDD | Vapor Density | Count |
|---|---|---|---|---|---|---|
| 23065 | KS | GOODLAND | 5983 | 728 | 0.0063323031 | 1 |
| 23090 | NM | FARMINGTON | 5225 | 1003 | 0.0041742386 | 1 |
| 23129 | CA | LONG BEACH | 1125 | 1208 | 0.0098345389 | 4 |
| 23157 | CA | BISHOP | 4063 | 1140 | 0.0036467675 | 2 |
| 23174 | CA | LOS ANGELES | 1275 | 551 | 0.0096459357 | 2 |
| 23185 | NV | RENO | 4942 | 1069 | 0.0040345727 | 1 |
| 23213 | CA | SANTA ROSA | 3135 | 350 | 0.0081665898 | 2 |
| 23230 | CA | OAKLAND | 2827 | 174 | 0.0085942545 | 2 |
| 23232 | CA | SACRAMENTO | 2531 | 1344 | 0.0081042454 | 1 |
| 23234 | CA | SAN FRANCISCO | 2584 | 214 | 0.0087316501 | 3 |
| 24012 | ND | DICKINSON | 9526 | 183 | 0.0055502263 | 6 |
| 24023 | NE | NORTH PLATTE | 6872 | 534 | 0.0066847 | 1 |
| 24033 | MT | BILLINGS | 6695 | 623 | 0.0047439218 | 1 |
| 24090 | SD | RAPID CITY | 7752 | 354 | 0.0054756864 | 34 |
| 24130 | OR | BAKER CITY | 7660 | 192 | 0.0051141527 | 1 |
| 24143 | MT | GREAT FALLS | 7940 | 288 | 0.0043370561 | 1 |
| 24153 | MT | MISSOULA | 7492 | 353 | 0.0048594245 | 1 |
| 24216 | CA | RED BLUFF | 2518 | 2096 | 0.0070521959 | 2 |
| 24221 | OR | EUGENE | 5046 | 330 | 0.0076039356 | 1 |
| 24225 | OR | MEDFORD | 4456 | 1024 | 0.0064759087 | 1 |
| 24229 | OR | PORTLAND | 4282 | 628 | 0.0074672022 | 1 |
| 24232 | OR | SALEM | 4701 | 454 | 0.0073914877 | 1 |
| 24234 | WA | SEATTLE | 4706 | 374 | 0.0074312216 | 6 |
| 53120 | CA | RAMONA | 2304 | 980 | 0.0076951935 | 1 |
| 53866 | IN | SHELBYVILLE | 5427 | 732 | 0.0083896808 | 7 |
| 53867 | SC | COLUMBIA | 2391 | 2329 | 0.0110377232 | 1 |
| 53872 | NC | MONROE | 3197 | 1720 | 0.0101469551 | 4 |
| 53903 | TX | HUNTSVILLE | 1637 | 3151 | 0.0125537826 | 8 |
| 53909 | TX | FORT WORTH | 2220 | 2704 | 0.0106132655 | 3 |
| 54737 | PA | LANCASTER | 5366 | 764 | 0.0081751608 | 24 |
| 54740 | VT | SPRINGFIELD | 7388 | 298 | 0.0065290992 | 1 |
| 54743 | NJ | CALDWELL | 5368 | 761 | 0.0076220114 | 17 |
| 54756 | MA | ORANGE | 7079 | 377 | 0.0068937208 | 43 |
| 54769 | MA | PLYMOUTH | 6050 | 453 | 0.0079864434 | 43 |
| 54777 | MA | TAUNTON | 6099 | 468 | 0.0076840108 | 43 |
| 54781 | VT | BENNINGTON | 7145 | 244 | 0.0068121386 | 9 |
| 54782 | PA | POTTSTOWN | 4980 | 844 | 0.0082301142 | 19 |
| 54788 | CT | MERIDEN | 5924 | 548 | 0.0077707976 | 23 |
| 93084 | AZ | SAFFORD | 1968 | 2942 | 0.004977519 | 1 |
| 93134 | CA | LOS ANGELES | 844 | 1371 | 0.0093026134 | 4 |
| 93193 | CA | FRESNO | 2274 | 2383 | 0.0074362585 | 2 |
| 93778 | PA | YORK | 5485 | 707 | 0.008171033 | 7 |
| 93780 | NJ | MOUNT HOLLY | 4881 | 859 | 0.0085453221 | 17 |
| 93801 | GA | ROME | 3155 | 1695 | 0.0107720384 | 26 |
| 93805 | FL | TALLAHASSEE | 1564 | 2808 | 0.0132476954 | 4 |
| 93814 | KY | COVINGTON | 4884 | 881 | 0.0086178081 | 3 |
| 93817 | IN | EVANSVILLE | 4363 | 1281 | 0.0092907246 | 2 |
| 93821 | KY | LOUISVILLE | 4132 | 1324 | 0.009041761 | 5 |

| WBAN | State | City | HDD | CDD | Vapor Density | Count |
|---|---|---|---|---|---|---|
| 93990 | KS | HILL CITY | 5569 | 1047 | 0.0074465493 | 3 |
| 93992 | AR | EL DORADO | 2620 | 2112 | 0.011859783 | 1 |
| 94014 | ND | WILLISTON | 9630 | 296 | 0.0053011177 | 14 |
| 94040 | NE | MC COOK | 5994 | 852 | 0.0070509402 | 2 |
| 94227 | WA | SHELTON | 5714 | 176 | 0.0072152937 | 2 |
| 94240 | WA | QUILLAYUTE | 5885 | 42 | 0.0074349835 | 2 |
| 94741 | NJ | TETERBORO | 4884 | 944 | 0.0077413683 | 17 |
| 94822 | IL | ROCKFORD | 6656 | 433 | 0.0072514877 | 50 |
| 94823 | PA | PITTSBURGH | 5627 | 631 | 0.0073981585 | 6 |
| 94847 | MI | DETROIT | 6062 | 597 | 0.0072827025 | 19 |
| 94943 | SD | CHAMBERLAIN | 7314 | 556 | 0.00654522 | 26 |
| 94950 | SD | MITCHELL | 7295 | 576 | 0.0069465882 | 23 |
| 94963 | MN | MINNEAPOLIS | 7592 | 544 | 0.0062048826 | 24 |
| 94971 | IA | ESTHERVILLE | 7931 | 362 | 0.0066166922 | 6 |
| 94982 | IA | DAVENPORT | 6533 | 542 | 0.0075225903 | 4 |
| 94988 | IA | MARSHALLTOWN | 7105 | 442 | 0.0073512376 | 14 |
| 94993 | SD | SISSETON | 8780 | 321 | 0.0062633651 | 5 |

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3 National Oceanic And Atmospheric Administration, *Degree Days Archives,* 1997-Present. <ftp://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/>

4 American Society for Heating Refrigeration and Air-Conditioning Engineers (ASHRAE), *ASHRAE Handbook: Fundamentals*. 1993.

# APPENDIX 8A. USER INSTRUCTIONS FOR LIFE-CYCLE COST AND PAYBACK PERIOD SPREADSHEET

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# APPENDIX 8A. USER INSTRUCTIONS FOR LIFE-CYCLE COST AND PAYBACK PERIOD SPREADSHEET

## 8A.1 DEFINITIONS

The interested reader can examine and reproduce detailed results of the U.S. Department of Energy's (DOE's) life-cycle cost (LCC) and payback period (PBP) analysis for residential dehumidifiers by using Microsoft Excel spreadsheets available on DOE's website at http://www1.eere.energy.gov/buildings/appliance_standards/residential/dehumidifiers.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 2010. The LCC and PBP workbook for residential dehumidifiers comprises the following worksheets.

**Summary** Presents the results of an analysis in terms of average LCC, LCC savings, and simple PBP for all dehumidifier product classes. A table includes, for each efficiency level considered, installed price; lifetime operating cost; LCC average savings; and the percentage of customers that would incur a net cost from each standard level. The user can stipulate three parameters for a simulation run: whether the AEO energy price trend reflects an economic case that is reference, low-growth, or high-growth (reference is default); the number of simulation runs to be performed within a range of 1000–10,000 (10,000 is default); and equipment price trend, i.e., price based on PPI trend, or constant equipment price.

**LCC & Payback** The *LCC&Payback* worksheet shows LCC and PBP calculation results for different efficiency levels for a single Residential Energy Consumption Survey (RECS) 2009 household. During a Crystal Ball simulation, the spreadsheet records the LCC and PBP values for every sampled household.

**Rebuttable Payback** The *Rebuttable Payback* worksheet contains the installation costs, energy use calculations, and the simple PBP calculations for each efficiency level.

**RECS Sample** The *RECS Sample* worksheet contains the RECS 2009 household data for each product type. During a Crystal Ball simulation, DOE uses these household characteristics to determine the analysis parameters.

| | |
|---|---|
| **Weather Data** | The *Weather Data* sheet contains the RECS 2009 household data matched with the National Oceanic and Atmospheric Administration's National Climatic Data Center (NCDC) weather stations data. |
| **Vapor Density Table** | Calculates the average vapor density for each month. It also calculates the annual operating hours by mode for the sampled household with a portable unit dehumidifier. |
| **Usage** | Contains probability distribution of operating hours by mode for whole-home dehumidifiers. It also contains information of fan-only and standby power demand for each product type. |
| **Base-Case Efficiency Distribution** | Gives the market shares for efficiency levels in the base case. |
| **Equipment Prices** | Develops total installed cost for dehumidifiers in 2013$. This sheet provides baseline and incremental manufacturer costs, retail price, sales tax, and installation cost for both product classes and each efficiency level. Includes the assumptions used about markups and sales tax. |
| **Energy Prices** | Contains the regional prices in 2013$ for electricity used in the LCC and PBP analysis. |
| **Energy Price Trends** | Contains the electricity price trends for the reference, high, and low economic growth scenarios based on AEO 2015. |
| **Discount Rate** | Contains data from which an average discount rate and a distribution of discount rates are determined. |
| **Lifetime** | Presents the average lifetime, in years, for portable unit and whole-home dehumidifiers, the Weibull parameters used for the survival function, and a graph of the Weibull retirement function for portable unit and whole-home dehumidifiers, respectively. |
| **Forecast Cells** | Gives details regarding base-case efficiency distributions for all dehumidifier product classes. Median, minimum, maximum, and average values are given, along with $5^{th}$, $25^{th}$, $50^{th}$, $75^{th}$, and $95^{th}$ percentile values. Included are product prices and details of the LCC and PBP (LCC savings in terms of money, energy, and the percentages of customers that would experience a net cost, no impact, or net savings from each efficiency level). |

## 8A.2 BASIC INSTRUCTIONS

Basic instructions for operating the LCC spreadsheet are provided below.

1. After downloading the LCC file from DOE's website, use Microsoft Excel to open it. At the bottom of the workbook, click on the tab for the sheet labeled *Summary*.

2. Use Excel's "View/Zoom" command in the top menu bar to change the size of the display so that it fits your monitor.

3. Use the graphical interface in the spreadsheet to choose parameters or enter data. You can change the default choices for the three inputs listed under "User Input" (energy price trend, start year, and number of simulation runs). To change a default input, select the desired value from the drop-down choices by the input box.

4. After selecting the desired parameters, click the "Run" button. The spreadsheet will minimize until the simulation is complete, and will then re-open with the updated results.

# APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN LCC ANALYSIS FOR DEHUMIDIFIERS

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# APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN LCC ANALYSIS FOR DEHUMIDIFIERS

## 8B.1 INTRODUCTION

Analysis of energy conservation standards involves calculations of impacts, for example, the impact of a standard on consumer life-cycle cost (LCC). In order to perform the calculation, the analyst must first: 1) specify the equation or model that will be used; 2) define the quantities in the equation; and 3) provide numerical values for each quantity. In the simplest case, the equation is unambiguous (contains all relevant quantities and no others), each quantity has a single numerical value, and the calculation results in a single value. However, unambiguity and precision are rarely the case. In almost all cases, the model and/or the numerical values for each quantity in the model are not completely known (i.e., there is uncertainty) or the model and/or the numerical values for each quantity in the model depend upon other conditions (i.e., there is variability).

Thorough analysis involves accounting for uncertainty and variability. While the simplest analysis involves a single numerical value for each quantity in a calculation, arguments can arise about what the appropriate value is for each quantity. Explicit analysis of uncertainty and variability is intended to provide more complete information to the decision-making process.

## 8B.2 UNCERTAINTY

When making observations of past events or speculating about the future, imperfect knowledge is the rule rather than the exception. For example, the energy actually consumed by a particular appliance type (such as the average U.S. water heater, direct heating equipment, or pool heater) is not directly recorded, but rather estimated based upon available information. Even direct laboratory measurements have some margin of error. When estimating numerical values expected for quantities at some future date, the exact outcome is rarely known in advance.

## 8B.3 VARIABILITY

Variability means that different applications or situations produce different numerical values when calculating a quantity. Specifying an exact value for a quantity may be difficult because the value depends on something else. For example, water heater energy consumption depends upon the specific circumstances and behaviors of the occupants (e.g., number of persons, length and temperature of showers, etc.). Variability makes specifying an appropriate population value more difficult in as much as anyone value may not be representative of the entire population. Surveys can be helpful here, and analysis of surveys can relate the variable of interest (e.g., hours of use) to other variables that are better known or easier to forecast (e.g., persons per household).

## 8B.4 APPROACHES TO UNCERTAINTY AND VARIABILITY

This section describes two approaches to uncertainty and variability:

- scenario analysis, and
- probability analysis.

Scenario analysis uses a single numerical value for each quantity in a calculation, then changes one (or more) of the numerical values and repeats the calculation. A number of calculations are done, which provide some indication of the extent to which the result depends upon the assumptions. For example, the life-cycle cost of an appliance could be calculated for energy rates of 2, 8, and 14¢ per kWh.

The advantages of scenario analysis are that each calculation is simple; a range of estimates is used and crossover points can be identified. (An example of a crossover point is the energy rate above which the life-cycle cost is reduced, holding all other inputs constant. That is, the crossover point is the energy rate at which the consumer achieves savings in operating expense that more than compensate for the increased purchase expense.) The disadvantage of scenario analysis is that there is no information about the likelihood of each scenario.

Probability analysis considers the probabilities within a range of values. For quantities with variability (e.g., electricity rates in different households), surveys can be used to generate a frequency distribution of numerical values (e.g., the number of households with electricity rates at particular levels) to estimate the probability of each value. For quantities with uncertainty, statistical or subjective measures can be used to provide probabilities (e.g., manufacturing cost to improve energy efficiency to some level may be estimated to be $10 ± $3).

The major disadvantage of the probability approach is that it requires more information, namely information about the shapes and magnitudes of the variability and uncertainty of each quantity. The advantage of the probability approach is that it provides greater information about the outcome of the calculations, that is, it provides the probability that the outcome will be in a particular range.

Scenario and probability analysis provide some indication of the robustness of the policy given the uncertainties and variability. A policy is robust when the impacts are acceptable over a wide range of possible conditions.

## 8B.5 PROBABILITY ANALYSIS AND THE USE OF CRYSTAL BALL

To quantify the uncertainty and variability that exist in inputs to the engineering, LCC, and payback period (PBP) analyses, DOE used Microsoft Excel spreadsheets combined with Crystal Ball, a commercially available add-in, to conduct probability analyses. The probability analyses used Monte Carlo simulation and probability distributions.

Simulation refers to any analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce. Without the aid of simulation, a spreadsheet model will only reveal a single outcome, generally the most likely or average scenario. Spreadsheet risk analysis uses both a spreadsheet model and simulation to automatically analyze the effect of varying inputs on outputs of the modeled system. One type of spreadsheet simulation is Monte Carlo simulation, which randomly generates values for uncertain variables again and again to simulate a model. Monte Carlo simulation was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance. Games of chance such as roulette wheels, dice, and slot machines, exhibit random behavior. The random behavior in games of chance is similar to how Monte Carlo simulation selects variable values at random to simulate a model. When you roll a die, you know that either a 1, 2, 3, 4, 5, or 6 will come up, but you do not know which for any particular roll. It's the same with the variables that have a known range of values but an uncertain value for any particular time or event (e.g., equipment lifetime, discount rate, and installation cost).

For each uncertain variable (one that has a range of possible values), possible values are defined with a probability distribution. The type of distribution selected is based on the conditions surrounding that variable. Types of probability distributions include those in Figure 8B.5.1.

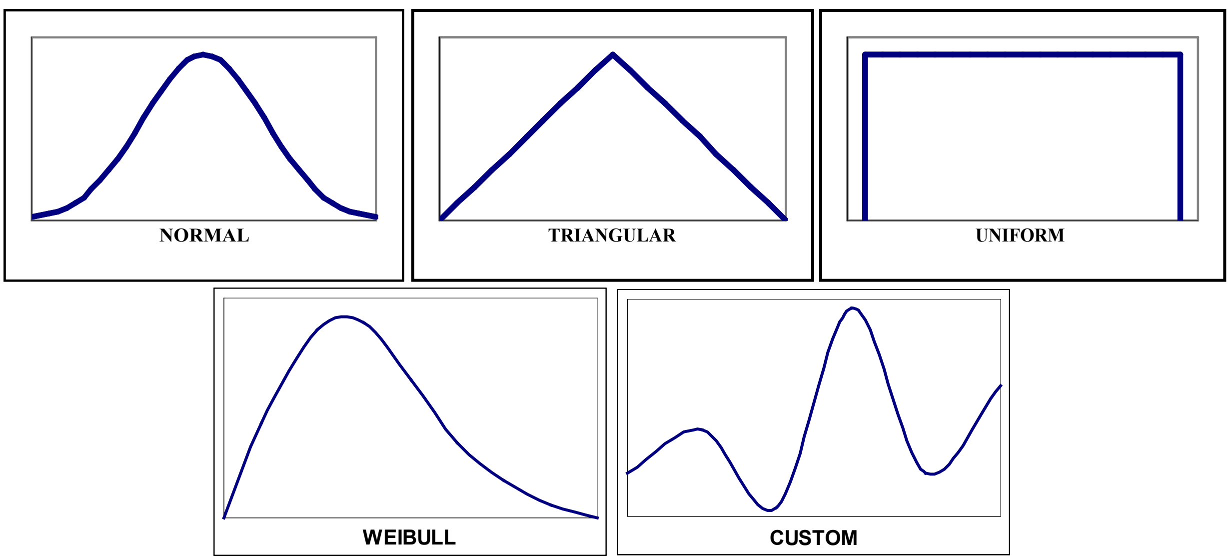


**Figure 8B.5.1** **Normal, Triangular, Uniform, Weibull, and Custom Probability Distributions**

During a simulation, multiple scenarios of a model are calculated by repeatedly sampling values from the probability distributions for the uncertain variables and using those values for the cell. Crystal Ball simulations can consist of as many trials (or scenarios) as desired—hundreds or even thousands. During a single trial, Crystal Ball randomly selects a value from the defined possibilities (the range and shape of the probability distribution) for each uncertain variable and then recalculates the spreadsheet.

# APPENDIX 8C. LIFETIME DISTRIBUTIONS

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# APPENDIX 8C. LIFETIME DISTRIBUTIONS

## 8C.1 INTRODUCTION

The U.S. Department of Energy (DOE) characterized the lifetime of both product types of dehumidifiers (i.e. portable unit dehumidifiers, whole-home dehumidifiers) being considered for new energy efficiency standards. DOE characterized residential dehumidifier lifetimes using a Weibull probability distribution that ranged from the minimum to maximum lifetime estimates, as described in chapter 8, section 8.2.2. The Weibull distribution is recommended for evaluating lifetime data, because it can be shaped to match low, average, and high values. The probability of exceeding the high value is contained in the long tail of the Weibull distribution.[1,2]

## 8C.2 DERIVATION OF WEIBULL DISTRIBUTION PARAMETERS

Weibull distributions utilize available data to assign low, average, and high values to a random variable that has unknown distribution parameters. DOE applied Weibull distributions to product lifetime data to derive low, average, and high lifetime values, along with a percentile containing a high value. A similar approach is described in a technical note to the software Crystal Ball, which uses a most likely value in place of an average value.[3] The Weibull distribution can be defined as:

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x-L}{\alpha}\right)^{\beta-1} \exp^{-\left(\frac{x-L}{\alpha}\right)^{\beta}}$$

Where:

*L* = location,
*α* (alpha) = scale, and
*β* (beta) = 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 (1) specifying a Weibull distribution that has the calculated parameters (location, scale, and shape) in an assumption cell, then (2) generating a forecast that equals that assumption. The forecast histogram and statistics will confirm whether the Weibull distribution matches the desired shape.

This solution can be checked using Crystal Ball by specifying a Weibull distribution with the calculated parameters (location, scale, and shape) in an assumption cell and generate a forecast that equals the assumption. Forecast histogram and statistics verify that the Weibull distribution matches the desired shape.

Table 8C.2.1 shows the average, minimum, maximum lifetime, and maximum percentile values used to determine the Weibull distribution parameters alpha and beta. For portable unit dehumidifiers, DOE used lifetime estimates from the previous DOE rulemaking for dehumidifiers.[4] DOE estimated that portable unit dehumidifier lifetimes do not vary by capacity size. DOE assumed whole-home dehumidifiers have the same life span as residential room air conditioner. DOE therefore applied the lifetime parameters derived for room air conditioners to whole-home dehumidifiers.[5] DOE estimated that the maximum lifetime percentile for both product types was 99 percent.

**Table 8C.2.1 Residential Dehumidifier Lifetime Parameters**

| Product Type | Average (Years) | Weibull Parameters | |
|---|---|---|---|
| | | Alpha (Scale) | Beta (Shape) |
| Portable dehumidifiers | 11.0 | 11.00 | 4.20 |
| Whole-home dehumidifiers | 19.01 | 20.30 | 2.50 |

Figures 8C.2.1 to 8C.2.4 show the Weibull distribution as well as the cumulative Weibull distribution for each product type of residential dehumidifiers.

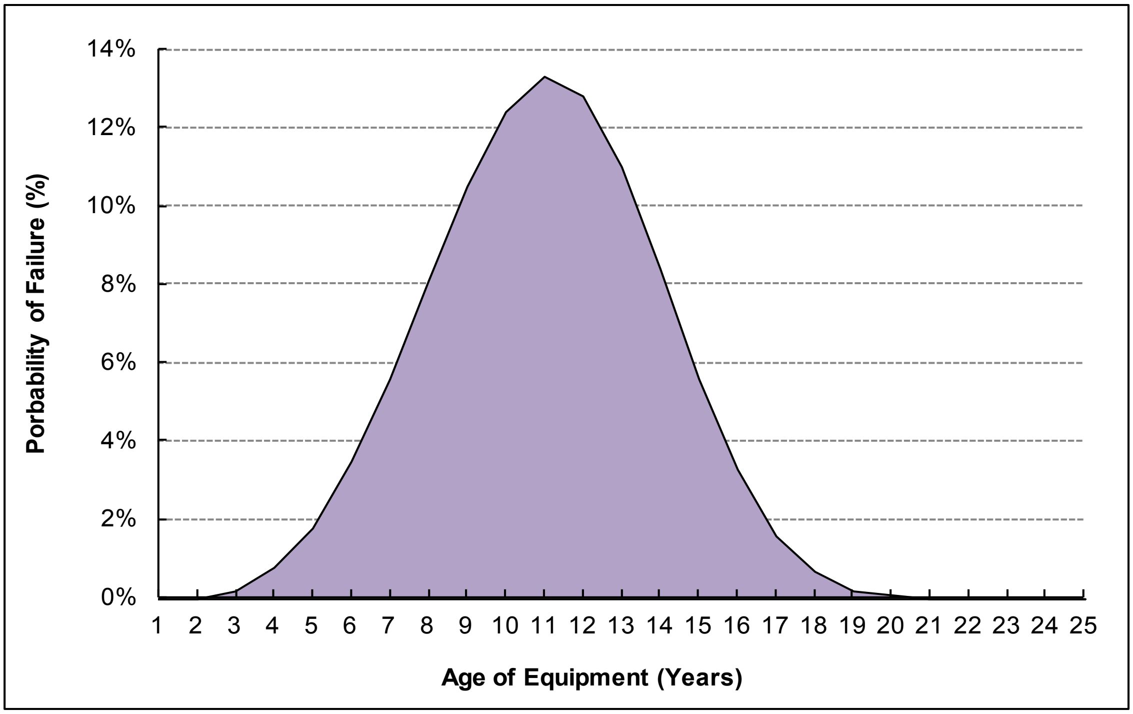


**Figure 8C.2.1 Fraction of Portable Unit Dehumidifier Failing**

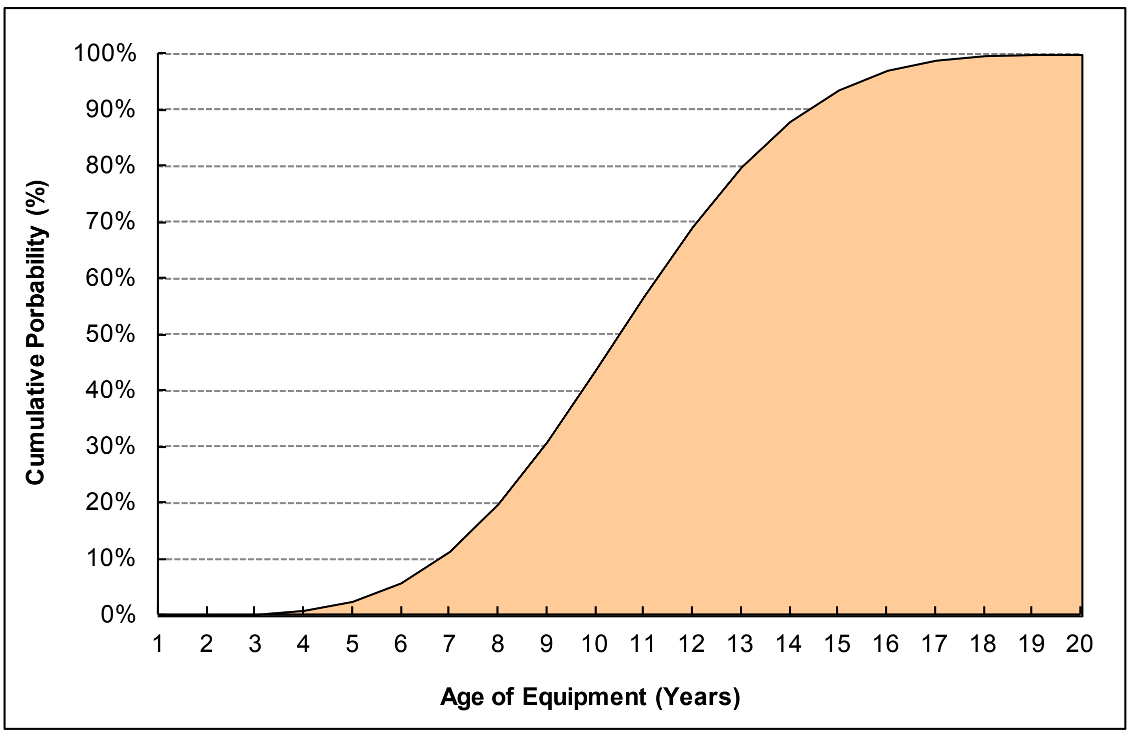


**Figure 8C.2.2 Cumulative Lifetime Length of Portable Unit Dehumidifiers**

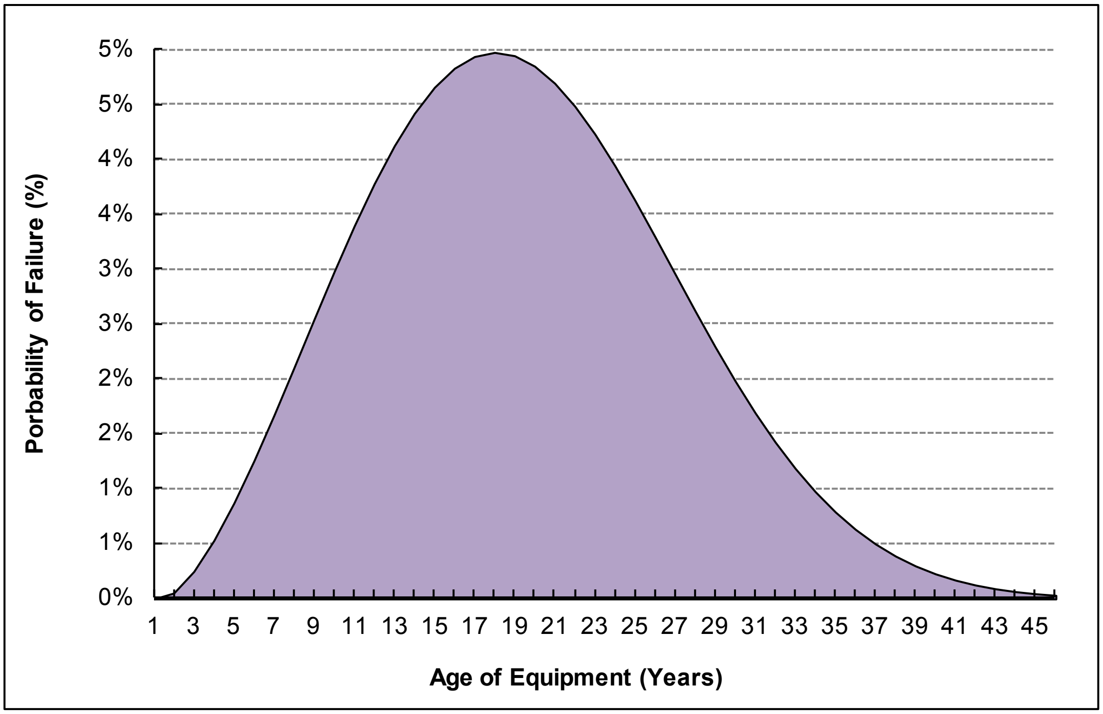


**Figure 8C.2.3 Fraction of Whole-home Dehumidifier Failing**

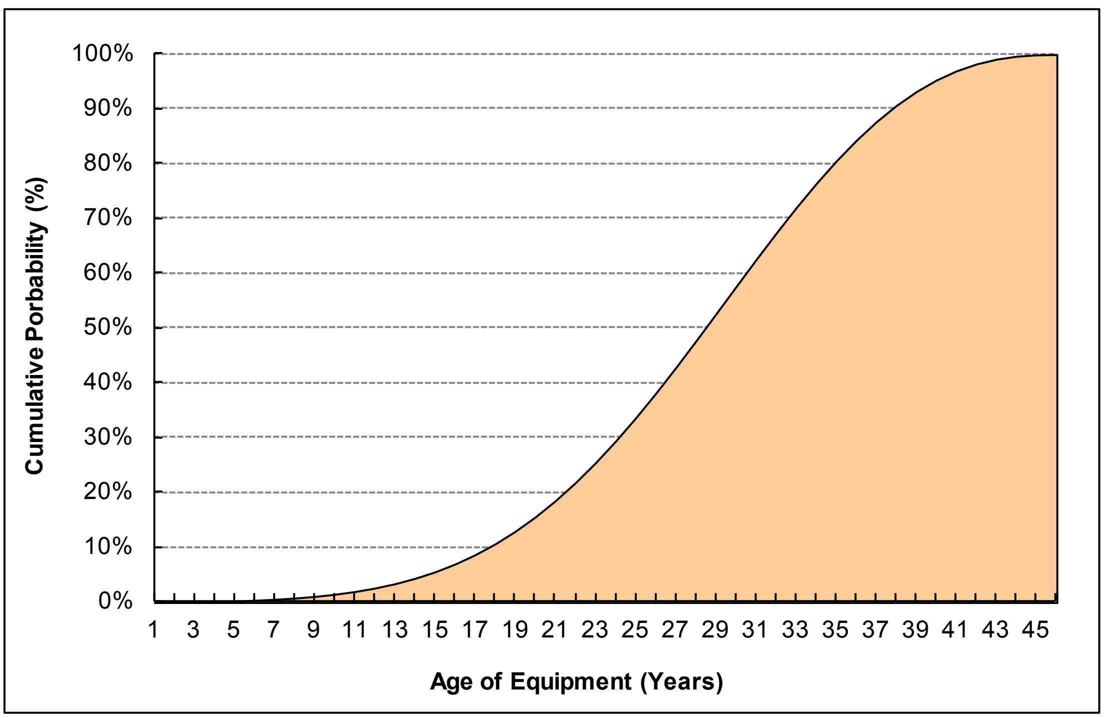


**Figure 8C.2.4 Cumulative Lifetime Length of Whole-home Dehumidifiers**

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# APPENDIX 8D. DISTRIBUTIONS FOR DISCOUNT RATES

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# APPENDIX 8D. DISTRIBUTIONS FOR DISCOUNT RATES

## 8D.1 INTRODUCTION

The U.S. Department of Energy (DOE) derived discount rates for the life-cycle cost (LCC) analysis using data on interest or return rates for various types of debt and equity to calculate a real effective discount rate for each household in the Federal Reserve Board's *Survey of Consumer Finances (SCF)* in 1995, 1998, 2001, 2004, 2007, and 2010.[1] To account for variation among households in rates for each of the types, DOE sampled a rate for each household in its building sample from a distribution of discount rates for each of six income groups. This appendix describes the distributions used.

## 8D.2 DISTRIBUTIONS OF RATES FOR DEBT CLASSES

Figure 8D.2.1 through Figure 8D.2.6 show the distribution of real interest rates for different types of household debt. The data source for the interest rates for mortgages, home equity loans, credit cards, installment loans, other residence loans, and other lines of credit is the Federal Reserve Board's *SCF* in 1995, 1998, 2001, 2004, 2007, and 2010.[1] DOE adjusted the nominal rates to real rates using the annual inflation rate in each year.

Using the appropriate SCF data for each year, DOE adjusted the nominal mortgage interest rate and the nominal home equity loan interest rate for each relevant household in the SCF for mortgage tax deduction and inflation. In cases where the effective interest rate is equal to or below the inflation rate (resulting in a negative real interest rate), DOE set the real effective interest rate to zero.

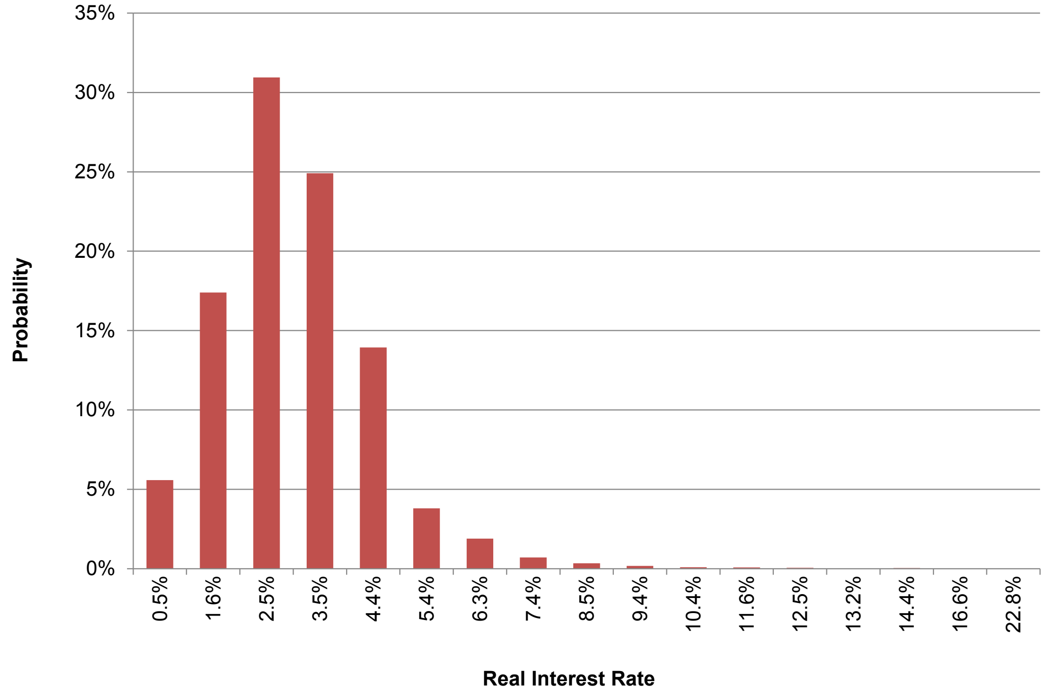


**Figure 8D.2.1 Distribution of Mortgage Interest Rates**

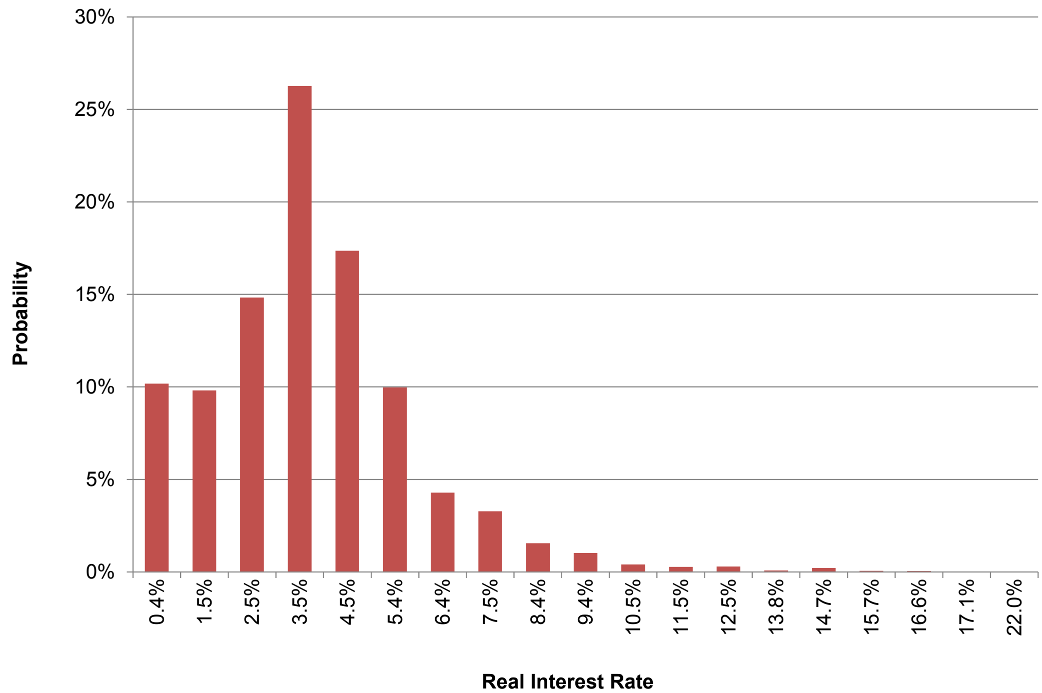


**Figure 8D.2.2 Distribution of Home Equity Loa Interest Rates**

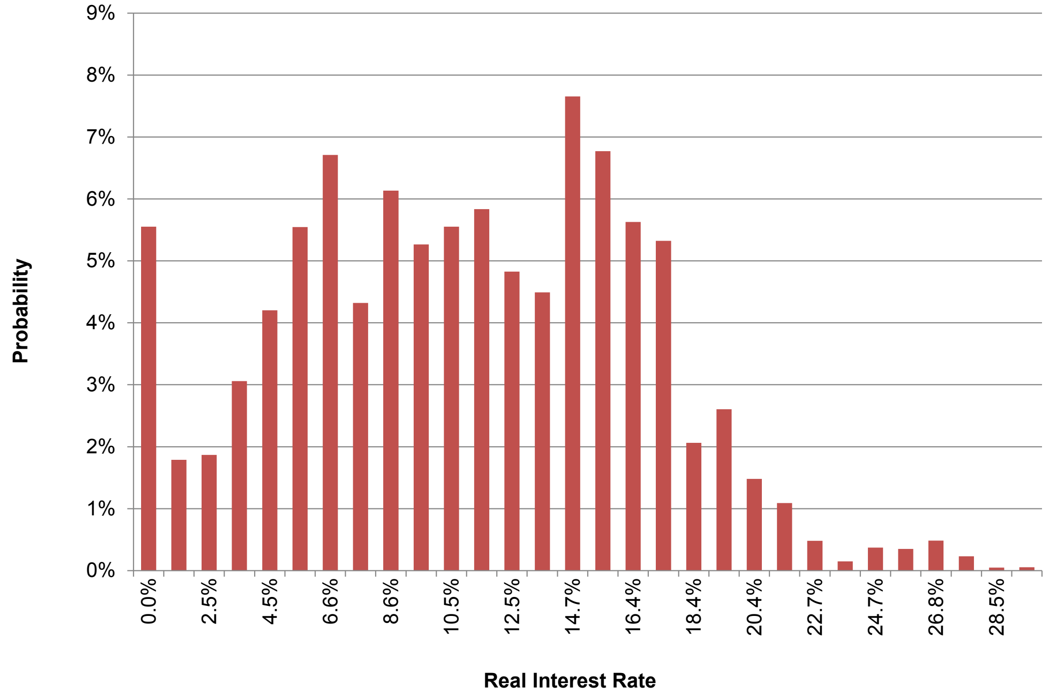


**Figure 8D.2.3 Distribution of Credit Card Interest Rates**

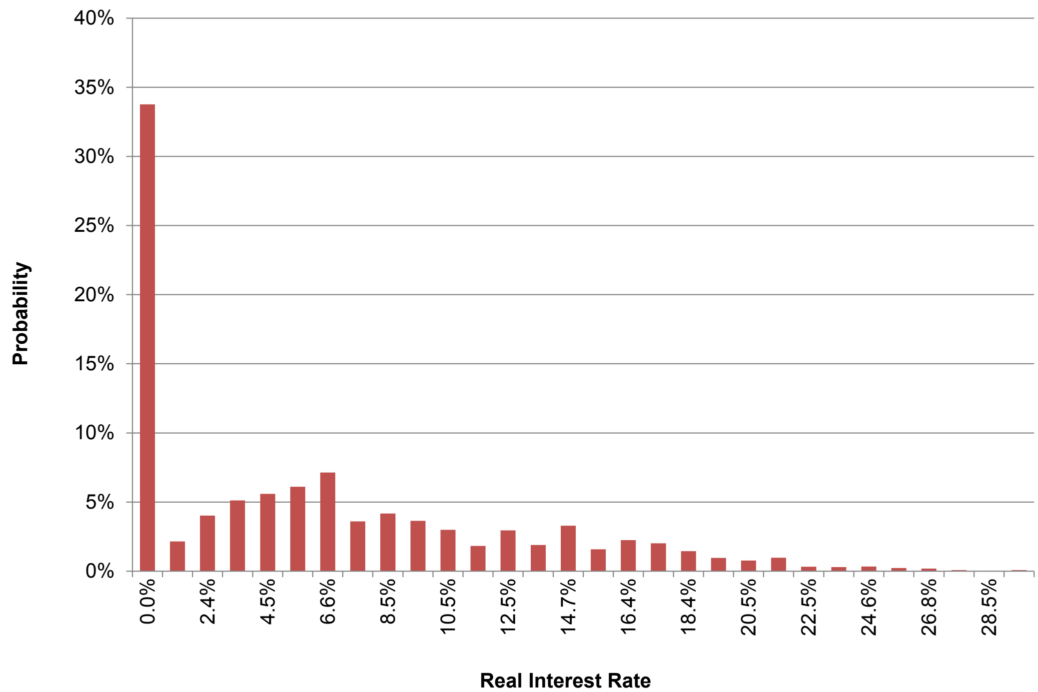


**Figure 8D.2.4 Distribution of Installment Loan Interest Rates**

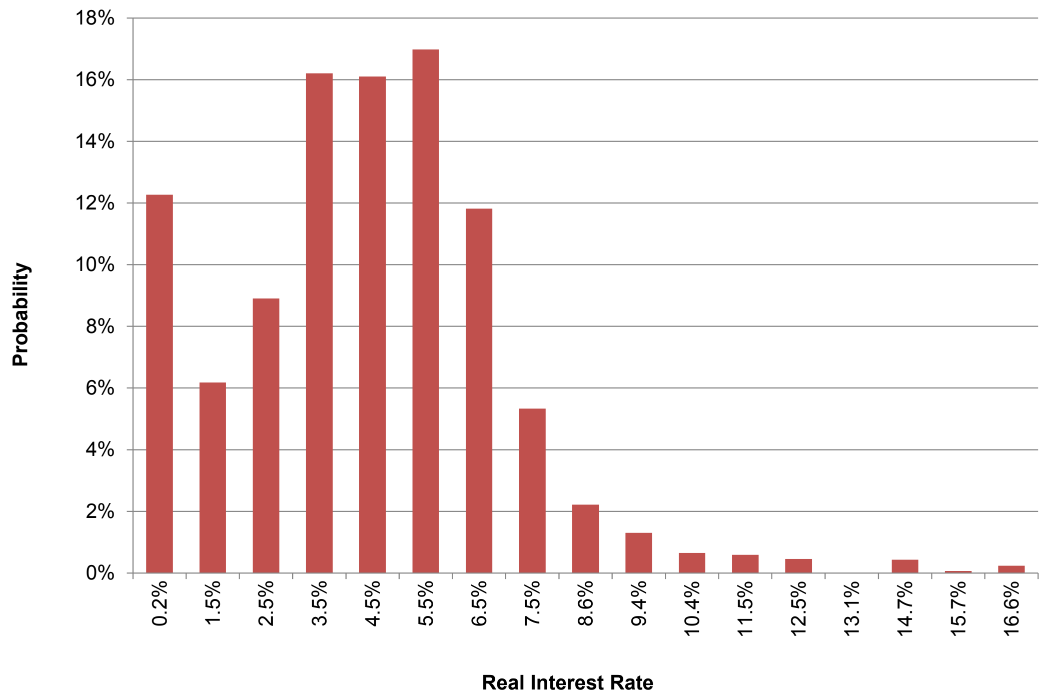


**Figure 8D.2.5 Distribution of Other Residence Loan Interest Rates**

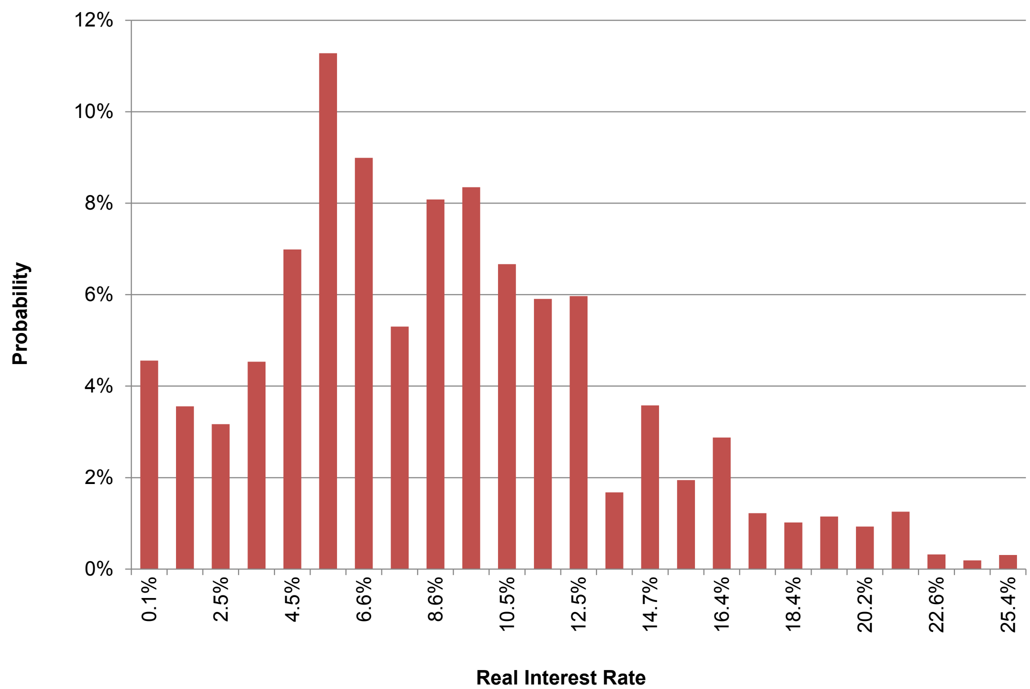


**Figure 8D.2.6 Distribution Other Lines of Credit Loan Interest Rates**

## 8D.3 DISTRIBUTIONS OF RATES FOR EQUITY CLASSES

Figure 8D.3.1 through Figure 8D.3.7 show the distribution of real interest rates for different types of equity. Data for equity classes are not available from the Federal Reserve Board's *SCF*, so DOE derived data for these classes from national-level historical data (1984-2013). The interest rates associated with certificates of deposit (CDs),[2] savings bonds,[3] and AAA corporate bonds[4] are from Federal Reserve Board time-series data. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts are from Cost of Savings Index data.[5] The rates for stocks are the annual returns on the Standard and Poor's (S&P) 500.[6] The mutual fund rates are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year.

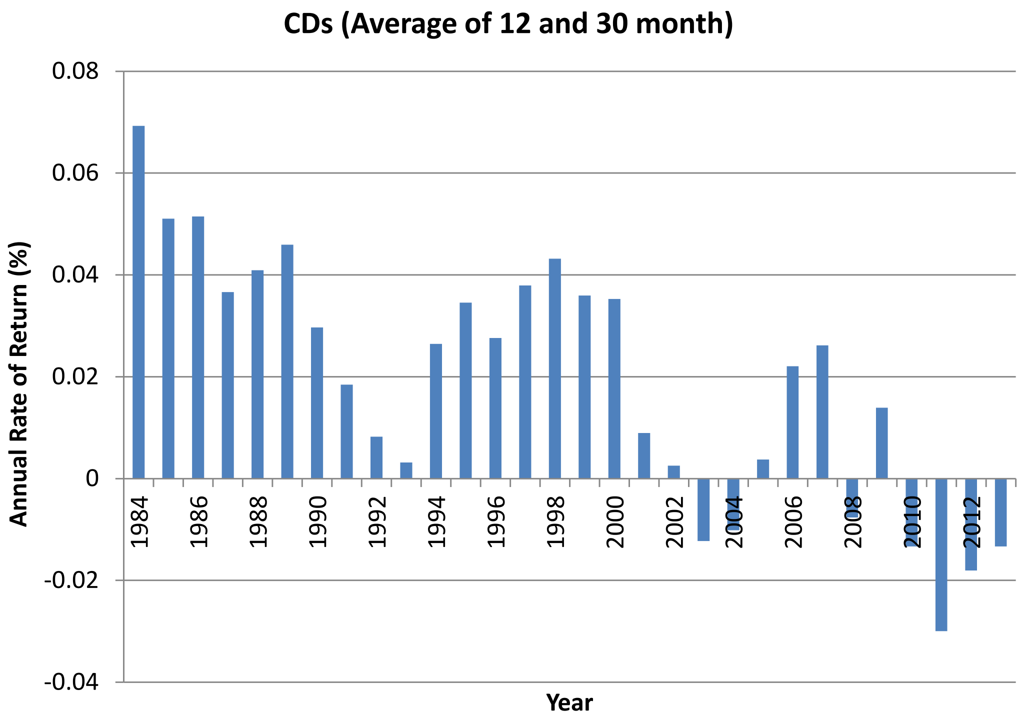


**Figure 8D.3.1 Distribution of Annual Rates of Return on CDs**

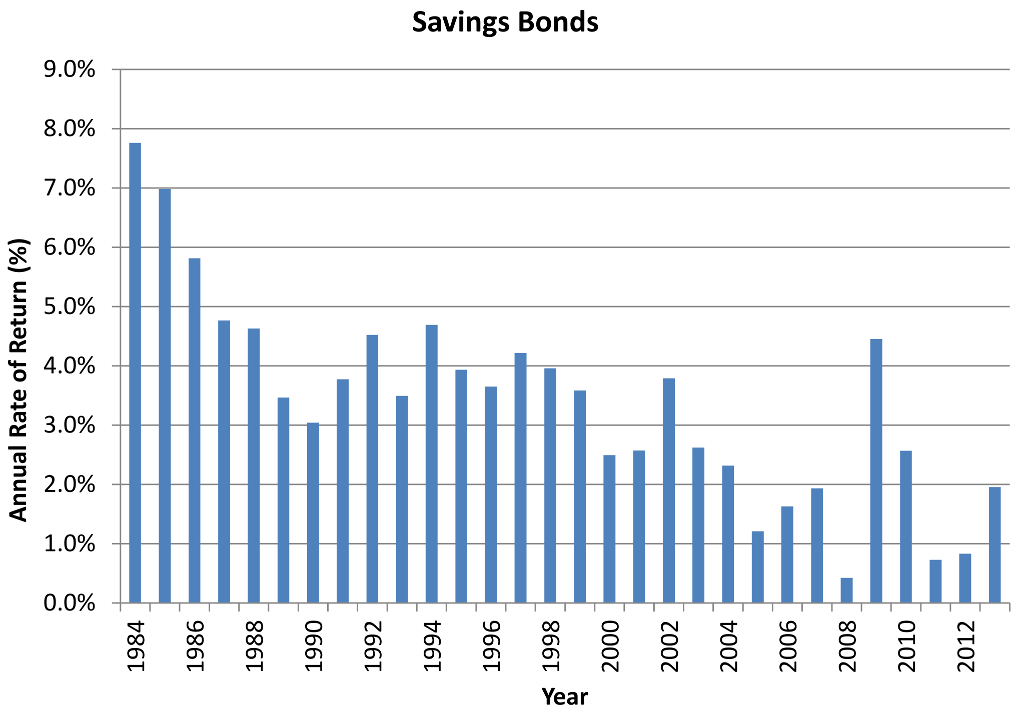


**Figure 8D.3.2 Distribution of Annual Rates of Return on Savings Bonds**

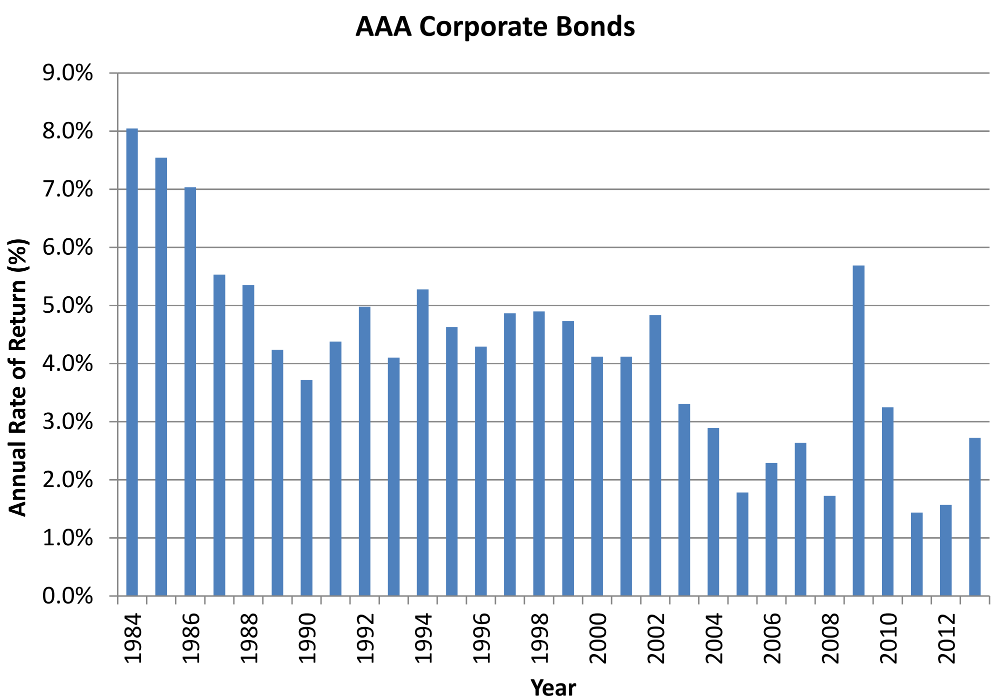


**Figure 8D.3.3 Distribution of Annual Rates of Return on Corporate AAA Bonds**

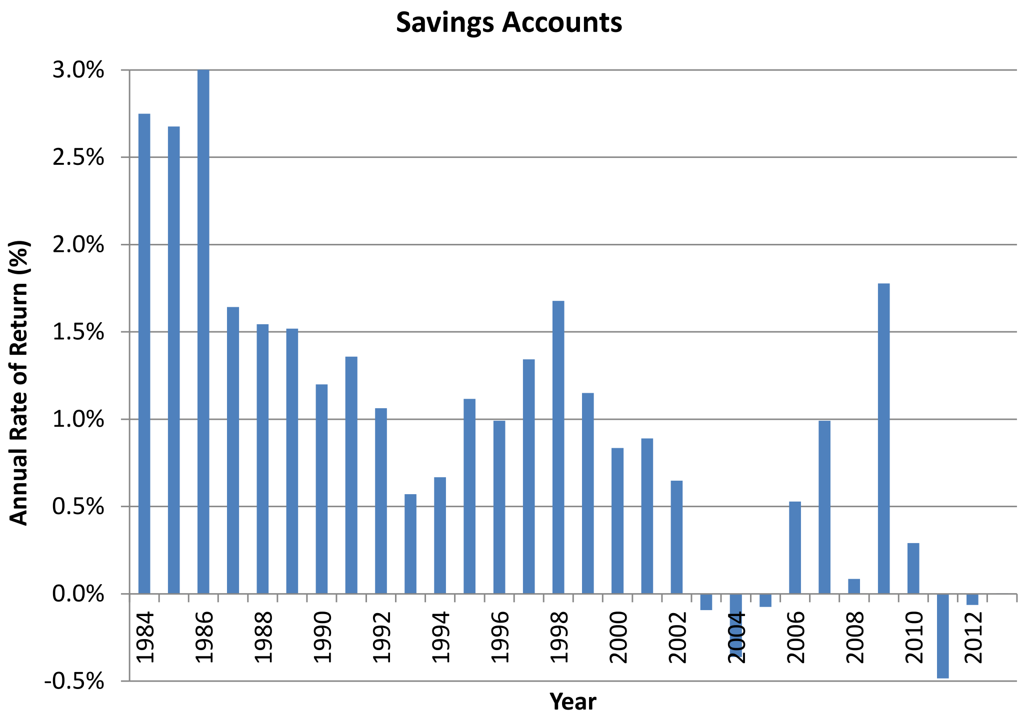


**Figure 8D.3.4 Distribution of Annual Rates of Return on Savings Accounts**

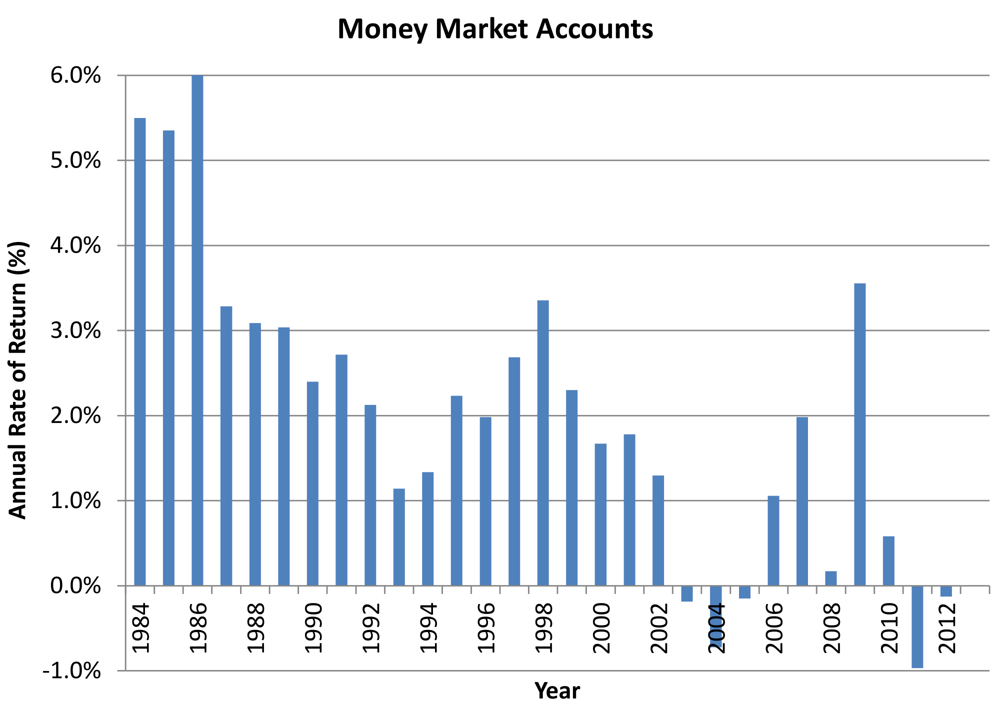


**Figure 8D.3.5 Distribution of Annual Rates of Return on Money Market Accounts**

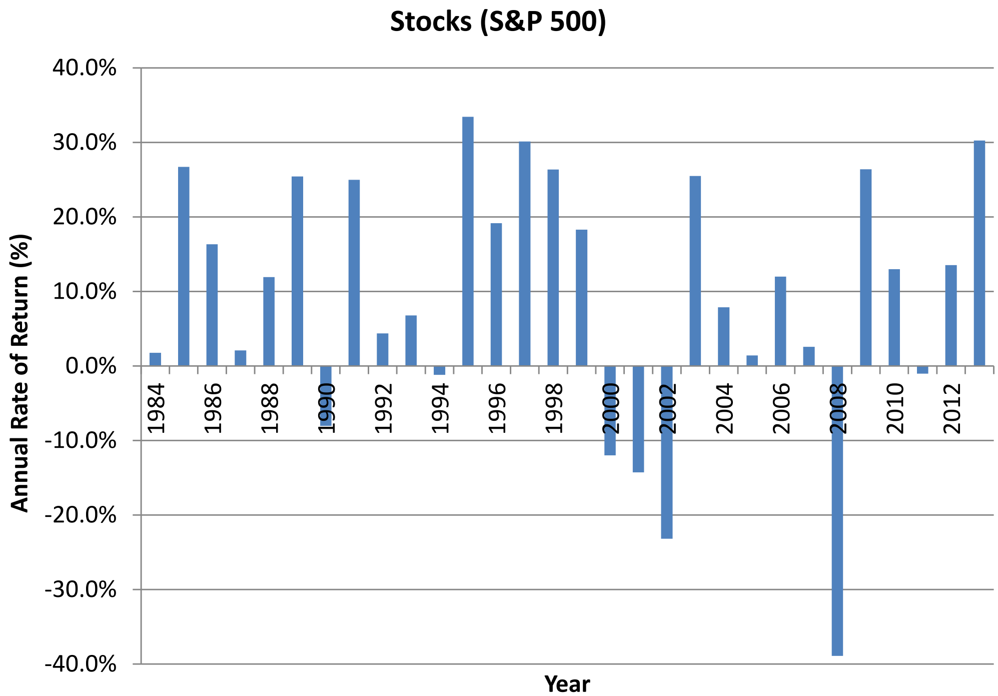


**Figure 8D.3.6 Distribution of Annual Rates of Return on the S&P 500**

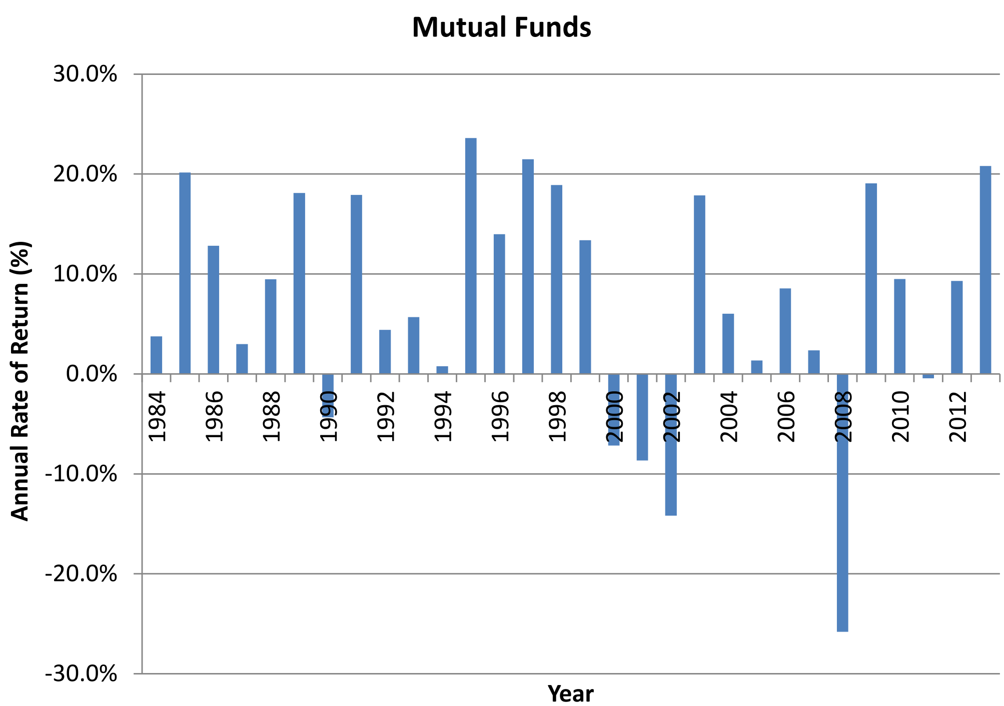


**Figure 8D.3.7 Distribution of Annual Rates of Return on Mutual Funds**

## 8D.4 DISTRIBUTION OF REAL EFFECTIVE DISCOUNT RATES BY INCOME GROUP

Figure 8D.4.1 and Table 8D.4.1 presents the distributions of real discount rates for each income group.

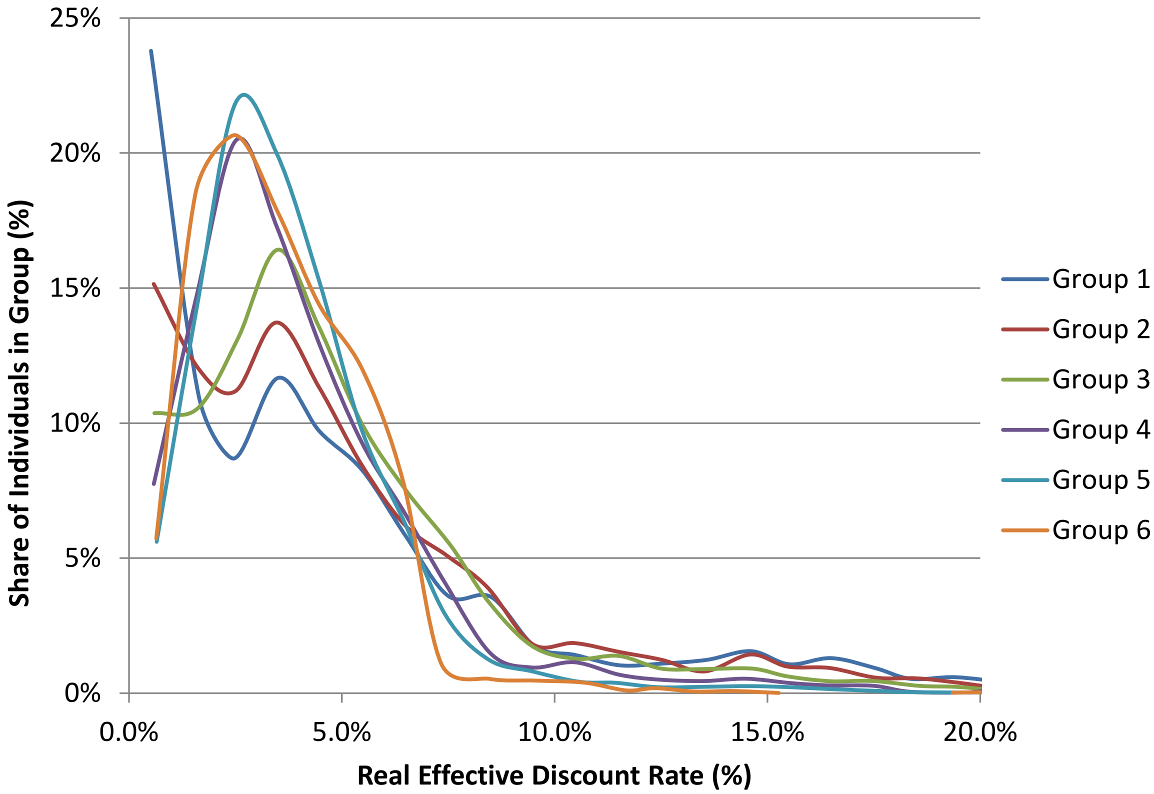


**Figure 8D.4.1 Distribution of Real Discount Rates by Income Group**

## Table 8D.4.1 Distribution of Real Discount Rates by Income Group

| DR Bin | Income Group 1 (1-20 percentile) | | Income Group 2 (21-40 percentile) | | Income Group 3 (41-60 percentile) | | Income Group 4 (61-80 percentile) | | Income Group 5 (81-90 percentile) | | Income Group 6 (90-99 percentile) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | rate | weight | rate | weight | rate | weight | rate | weight | rate | weight | rate | weight |
| 0-1 | 0.5% | 0.238 | 0.6% | 0.152 | 0.6% | 0.104 | 0.6% | 0.077 | 0.6% | 0.056 | 0.6% | 0.057 |
| 1-2 | 1.6% | 0.110 | 1.6% | 0.120 | 1.6% | 0.105 | 1.6% | 0.146 | 1.6% | 0.142 | 1.6% | 0.185 |
| 2-3 | 2.5% | 0.087 | 2.5% | 0.112 | 2.6% | 0.131 | 2.5% | 0.205 | 2.5% | 0.219 | 2.5% | 0.207 |
| 3-4 | 3.5% | 0.117 | 3.5% | 0.137 | 3.5% | 0.164 | 3.5% | 0.173 | 3.5% | 0.200 | 3.5% | 0.178 |
| 4-5 | 4.5% | 0.097 | 4.5% | 0.113 | 4.5% | 0.136 | 4.5% | 0.129 | 4.5% | 0.153 | 4.5% | 0.144 |
| 5-6 | 5.5% | 0.083 | 5.5% | 0.084 | 5.5% | 0.100 | 5.5% | 0.093 | 5.5% | 0.098 | 5.5% | 0.120 |
| 6-7 | 6.5% | 0.058 | 6.5% | 0.062 | 6.5% | 0.075 | 6.5% | 0.067 | 6.5% | 0.063 | 6.4% | 0.079 |
| 7-8 | 7.5% | 0.036 | 7.5% | 0.051 | 7.6% | 0.054 | 7.4% | 0.041 | 7.4% | 0.029 | 7.3% | 0.011 |
| 8-9 | 8.5% | 0.036 | 8.4% | 0.039 | 8.4% | 0.034 | 8.5% | 0.015 | 8.4% | 0.012 | 8.5% | 0.005 |
| 9-10 | 9.5% | 0.017 | 9.5% | 0.018 | 9.5% | 0.017 | 9.5% | 0.010 | 9.5% | 0.008 | 9.6% | 0.005 |
| 10-11 | 10.5% | 0.014 | 10.5% | 0.019 | 10.5% | 0.013 | 10.5% | 0.011 | 10.6% | 0.004 | 10.7% | 0.004 |
| 11-12 | 11.5% | 0.010 | 11.5% | 0.015 | 11.5% | 0.014 | 11.5% | 0.007 | 11.4% | 0.004 | 11.7% | 0.001 |
| 12-13 | 12.5% | 0.011 | 12.5% | 0.012 | 12.5% | 0.009 | 12.4% | 0.005 | 12.4% | 0.002 | 12.4% | 0.002 |
| 13-14 | 13.6% | 0.012 | 13.5% | 0.008 | 13.5% | 0.009 | 13.5% | 0.004 | 13.5% | 0.002 | 13.3% | 0.001 |
| 14-15 | 14.6% | 0.016 | 14.6% | 0.014 | 14.6% | 0.009 | 14.5% | 0.005 | 14.6% | 0.003 | 14.2% | 0.001 |
| 15-16 | 15.5% | 0.011 | 15.5% | 0.010 | 15.5% | 0.006 | 15.6% | 0.004 | 15.6% | 0.002 | 15.3% | 0.000 |
| 16-17 | 16.5% | 0.013 | 16.5% | 0.009 | 16.5% | 0.004 | 16.5% | 0.003 | 16.5% | 0.001 | 0.0% | 0.000 |
| 17-18 | 17.5% | 0.009 | 17.6% | 0.006 | 17.5% | 0.005 | 17.5% | 0.003 | 17.6% | 0.001 | 17.7% | 0.001 |
| 18-19 | 18.4% | 0.005 | 18.5% | 0.005 | 18.6% | 0.003 | 18.4% | 0.001 | 18.2% | 0.000 | 0.0% | 0.000 |
| 19-20 | 19.4% | 0.006 | 19.4% | 0.004 | 19.4% | 0.002 | 19.7% | 0.000 | 19.7% | 0.000 | 19.4% | 0.000 |
| 20-21 | 20.6% | 0.004 | 20.4% | 0.002 | 20.5% | 0.001 | 20.3% | 0.001 | 20.5% | 0.000 | 20.3% | 0.000 |
| 21-22 | 21.4% | 0.003 | 21.4% | 0.002 | 21.4% | 0.001 | 21.5% | 0.001 | 0.0% | 0.000 | 21.4% | 0.000 |
| 22-23 | 22.5% | 0.002 | 22.4% | 0.001 | 22.6% | 0.001 | 22.9% | 0.000 | 22.8% | 0.000 | 22.3% | 0.000 |
| 23-24 | 23.6% | 0.001 | 23.4% | 0.001 | 23.6% | 0.001 | 0.0% | 0.000 | 0.0% | 0.000 | 24.0% | 0.000 |
| 24-25 | 24.6% | 0.001 | 24.5% | 0.000 | 24.6% | 0.000 | 24.1% | 0.000 | 24.3% | 0.000 | 0.0% | 0.000 |
| 25-26 | 25.4% | 0.001 | 25.4% | 0.001 | 25.5% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 |
| 26-27 | 26.5% | 0.001 | 26.5% | 0.000 | 26.4% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 |
| 27-28 | 27.8% | 0.000 | 27.6% | 0.000 | 27.8% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 |
| 28-29 | 28.2% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 |
| 29-23 | 29.9% | 0.000 | 29.3% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 |
| >30 | 59.1% | 0.001 | 142.7% | 0.002 | 0.0% | 0.000 | 53.3% | 0.000 | 0.0% | 0.000 | 0.0% | 0.000 |

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# APPENDIX 9A. RELATIVE PRICE ELASTICITY OF DEMAND FOR APPLIANCES

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# APPENDIX 9A. RELATIVE PRICE ELASTICITY OF DEMAND FOR APPLIANCES

## 9A.1 INTRODUCTION

This appendix summarizes DOE's study of the price elasticity of demand for home appliances, including refrigerators, clothes washers and dishwashers. DOE chose this particular set of appliances because of the availability of data to determine a price elasticity. Section 9A.2 reviews the existing economics literature describing the impact of economic variables on the sale of durable goods. Section 9A.3 describes the market for home appliances and the changes that have occurred over the past 20 years. In section 9A.4, DOE summarizes the results of its regression analysis and presents estimates of the price elasticity of demand for the three appliances. In section 9A.5, DOE presents development of an 'effective' purchase price elasticity. DOE's interpretation of its results is presented in section 9A.6. Finally, section 9A.7 describes the data used in DOE's analysis.

## 9A.2 LITERATURE REVIEW

Relatively few studies measure the impact of price, income and efficiency on the sale of household appliances. This section briefly reviews the literature that describes the likely importance of these variables on the purchase of household appliances.

### 9A.2.1 Price

DOE reviewed many studies that sought to measure the impact of price on sales in a dynamic market. One study of the automobile market prior to 1970 finds the price elasticity of demand to decline over time. The author explains this as the result of buyers delaying purchases after a price increase but eventually making the purchase (Table 9A.2.1).[1] A contrasting study of household white goods also prior to 1970, finds the elasticity of demand to increase over time as more price-conscious buyers enter the market.[2] An analysis of refrigerator market survey data finds that consumer purchase probability decreases with survey asking price.[3] Estimates of the price elasticity of demand for different brands of the same product tend to vary. A review of 41 studies of the impact of price on market share found the average price elasticity to be -1.75.[4] The average estimate of price elasticity of demand reported in these studies is -0.33 in the appliance market and -0.47 in the combined automobile and appliance markets.

### 9A.2.2 Income

Higher income households are more likely to own household appliances.[5] The impact of income on appliance shipments is explored in two econometric studies of the automobile and appliance markets.[1, 2] The average income elasticity of demand is 0.50 in the appliance study cited in the literature review, much larger in the automobile study (Table 9A.2.1).

### 9A.2.3 Appliance Efficiency and Discount Rates

Many studies estimate the impact of appliance efficiency on consumers' choice of appliance. Typically, this impact is summarized by the implicit discount rate; that is, the rate consumers use to compare future savings in appliance operating costs against a higher initial purchase price of an appliance. One early and much cited study concludes that consumers use a 20 percent implicit discount rate when purchasing room air conditioners (Table 9A.2.1).[6] A survey of several studies of different appliances suggests that the consumer implicit discount rate has a broad range and averages about 37 percent.[7]

**Table 9A.2.1 Estimates of the Impact of Price, Income and Efficiency on Automobile and Appliance Sales**

| Durable Good | Price Elasticity | Income Elasticity | Brand Price Elasticity | Implicit Discount Rate | Model | Data Years | Time Period |
|---|---|---|---|---|---|---|---|
| Automobiles[1] | -1.07 | 3.08 | - | - | Linear Regression, stock adjustment | - | Short run |
| Automobiles[1] | -0.36 | 1.02 | - | - | Linear Regression, stock adjustment | - | Long run |
| Clothes Dryers[2] | -0.14 | 0.26 | - | - | Cobb-Douglas, diffusion | 1947-1961 | Mixed |
| Room Air Conditioners[2] | -0.37[8] | 0.45 | - | - | Cobb-Douglas, diffusion | 1946-1962 | Mixed |
| Dishwashers[2] | -0.42 | 0.79 | - | - | Cobb-Douglas, diffusion | 1947-1968 | Mixed |
| Refrigerators[3] | -0.37 | - | - | 39% | Logit probability, survey data | 1997 | Short run |
| Various[4] | - | - | -1.76[9] | - | Multiplicative regression | - | Mixed |
| Room Air Conditioners[5] | - | - | -1.72 | - | Non-linear diffusion | 1949-1961 | Short run |
| Clothes Dryers[5] | - | - | -1.32 | - | Non-linear diffusion | 1963-1970 | Short run |
| Room Air Conditioners[6] | - | - | - | 20% | Qualitative choice, survey data | - | - |
| Household Appliances[7] | - | - | - | 37%[10] | Assorted | - | - |

**Sources:** [1] S. Hymens. 1971; [2] P. Golder and G. Tellis, 1998; [3] D. Revelt and K. Train, 1997; [4] G. Tellis, 1988; [5] D. Jain and R. Rao; [6] J. Hausman; [7] K. Train, 1985.

**Notes:** [8] Logit probability results are not directly comparable to other elasticity estimates in this table.
[9] Average brand price elasticity across 41 studies.
[10] Averaged across several household appliance studies referenced in this work.

## 9A.3 VARIABLES DESCRIBING THE MARKET FOR REFRIGERATORS, CLOTHES WASHERS, AND DISHWASHERS

In this section DOE evaluates variables that appear to account for refrigerator, clothes washer and dishwasher shipments, including physical household/appliance variables and economic variables.

### 9A.3.1 Physical Household/Appliance Variables

Several variables influence the sale of refrigerators, clothes washers and dishwashers. The most important for explaining appliance sales trends are the annual number of new households formed (housing starts) and the number of appliances reaching the end of their operating life (replacements). Housing starts influence sales because new homes are often provided with, or soon receive, new appliances, including dishwashers and refrigerators. Replacements are correlated with sales because new appliances are typically purchased when old ones wear out. In principle, if households maintain a fixed number of appliances, shipments should equal housing starts plus appliance replacements.

### 9A.3.2 Economic variables

Appliance price, appliance operating cost and household income are important economic variables affecting shipments. Low prices and costs encourage household appliance purchases and a rise in income increases householder ability to purchase appliances. In principle, changes in economic variables should explain changes in the number of appliances per household.

During a 1980–2002 study period, annual shipments grew 69 percent for clothes washers, 81 percent for refrigerators and 105 percent for dishwashers (Table 9A.3.1). This rising shipments trend is explained in part by housing starts, which increased 6 percent and by appliance replacements, which rose between 49 percent and 90 percent, depending on the appliance, over the period (Table 9A.3.1).[a] For mature markets such as these, replacements exceed appliance sales associated with new housing construction.

**Table 9A.3.1 Physical Household/Appliance Variables**

| | Shipments[i] (millions) | | | Housing Starts[ii] (millions) | | | Replacements[iii] (millions) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Appliance** | **1980** | **2002** | **Change** | **1980** | **2002** | **Change** | **1980** | **2002** | **Change** |
| Refrigerators | 5.124 | 9.264 | 81% | 1.723 | 1.822 | 6% | 3.93 | 5.84 | 49% |
| Clothes Washers | 4.426 | 7.492 | 69% | 1.723 | 1.822 | 6% | 3.66 | 5.50 | 50% |
| Dishwashers | 2.738 | 5.605 | 105% | 1.723 | 1.822 | 6% | 1.99 | 3.79 | 90% |

[i]Shipments: Number of units sold. **Sources:** AHAM Fact Book and Appliance Magazine.
[ii]Housing Starts: Annual number of new homes constructed. **Source:** U.S. Census.
[iii]Replacements: Average of annual lagged shipments, with lag equal to expected appliance operating life, ± 5 years.

Shipments increased somewhat more rapidly than housing starts and replacements. This is shown by comparing the beginning and end points of lines that represent “starts plus replacements” (uppermost solid line in Figure 9A.3.1) and “shipments” (diamond linked line in Figure 9A.3.1). In 1980 the “shipment” line begins below the “starts plus replacements” line. In 2002, the “shipments” line ends above the “starts plus replacements” line. This more rapid

[a] Appliance replacements are determined from the expected operating life of refrigerators (19 years), clothes washers (14 years), and dishwashers (12 years) and from past shipments. Replacements are further discussed in section 9-A.3. The dishwasher lifetime used in this analysis does not match the dishwasher used in the primary analysis.

increase in shipments, compared to housing starts plus replacements, suggests that the appliance per household ratio increased over the study period.

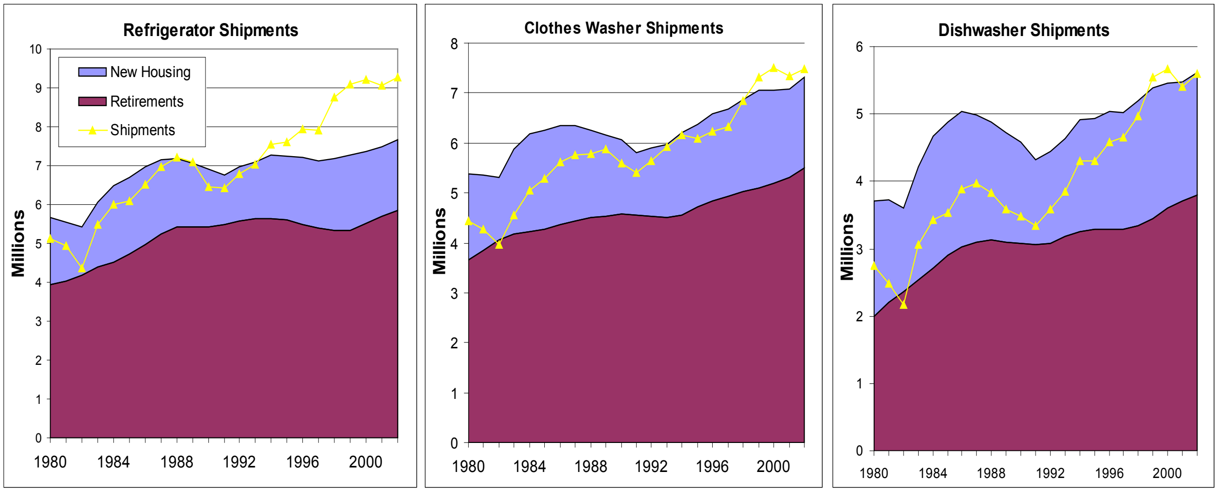


**Figure 9A.3.1 Trends in Appliance Shipment, Housing Starts and Replacements**

Economic variables, including price, cost and income, may explain this increase in appliances per household. Over the period, appliance prices decreased 40 percent to 50 percent, operating costs fell between 33 percent and 72 percent, and median household income rose 16 percent (Table 9A.3.2).

**Table 9A.3.2 Economic Variables**

| | **Price[i] (1999\$)** | | | **Operating Cost[ii] (1999\$)** | | | **Household Income[iii] (1999\$)** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Appliance** | **1980** | **2002** | **Change** | **1980** | **2002** | **Change** | **1980** | **2002** | **Change** |
| Refrigerators | 1208 | 726 | -40% | 333 | 94 | -72% | 37,447 | 43,381 | 16% |
| Clothes Washers | 779 | 392 | -50% | 262 | 175 | -33% | 37,447 | 43,381 | 16% |
| Dishwashers | 713 | 369 | -48% | 183 | 95 | -48% | 37,447 | 43,381 | 16% |

[i]Price: Shipment weighted retail sales price. **Sources:** AHAM Fact Book and Appliance Magazine.
[ii]Operating Cost: Annual electricity price times electricity consumption. **Source:** AHAM Fact Book.
[iii]Income: Mean Household income. **Source:** U.S. Census.

## 9A.4 REGRESSION ANALYSIS OF VARIABLES AFFECTING APPLIANCE SHIPMENTS

Few data are available to estimate the impact of economic variables on the demand for appliances. Industry operating cost data is incomplete—appliance energy use data are available for only 12 years of the 1980-2002 study period. Industry price data are also incomplete—available for only 8 years of the study period for each of the appliances.

The lack of data suggests that regression analysis can at best evaluate broad data trends, utilizing relatively few explanatory variables. This section begins by describing broad trends apparent in the economic and physical household data sets and then specifies a simple regression model to measure these trends, making assumptions to minimize the number of explanatory variables. Finally, results of the regression analysis are presented along with an estimate of the price elasticity of demand for appliances. In section 9-A.4.5, DOE presents the results of regression analysis performed with more complex models, which are used to test assumptions underlying the simple model. These results support the specification of the simple model and the price elasticity of appliance demand estimated with that model.

### 9A.4.1 Broad Trends

In this section DOE reviews trends in the physical household and economic data sets and posits a simple approach for estimating the price elasticity of appliance demand. As noted above, the physical household variables (housing starts and appliance replacements) explain most of the variability in appliance shipments during the study period (1980-2002).[b] DOE assumes the rest of the variability in shipments (referred to as "residual shipments") is explained by economic variables. Below, DOE presents a tabular method for measuring price elasticities.

To illustrate this tabular approach, DOE defines two new variables—residual shipments and total price. Residual shipments are defined as the difference between shipments and physical household demand (starts plus replacements). Total price, represented by the following equation, is defined as appliance price plus the present value of lifetime appliance operating cost:[c]

$$\boldsymbol{TP = PP + PVOC}$$

where:

$TP$ = Total price,
$PP$ = Appliance purchase price, and
$PVOC$ = Present value of operating cost.

Over the study period, residual shipments increased in proportion to total shipments by 30 percent for refrigerators, 19 percent for clothes washers, and 23 percent for dishwashers. At the same time, total prices declined 47 percent, 45 percent and 48 percent for refrigerators, clothes washers, and dishwashers, respectively. Assuming that total price explains the entire change in per household appliance usage, a rough estimate is calculated of the total price

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[b] A log regression of the form: Shipments = a + b • Housing Starts + c • Retirements, indicates that these two variables explain 89 percent of the variation in refrigerator shipments, 97 percent of the variation in clothes washer shipments, and 97 percent of the variation in dishwasher shipments.

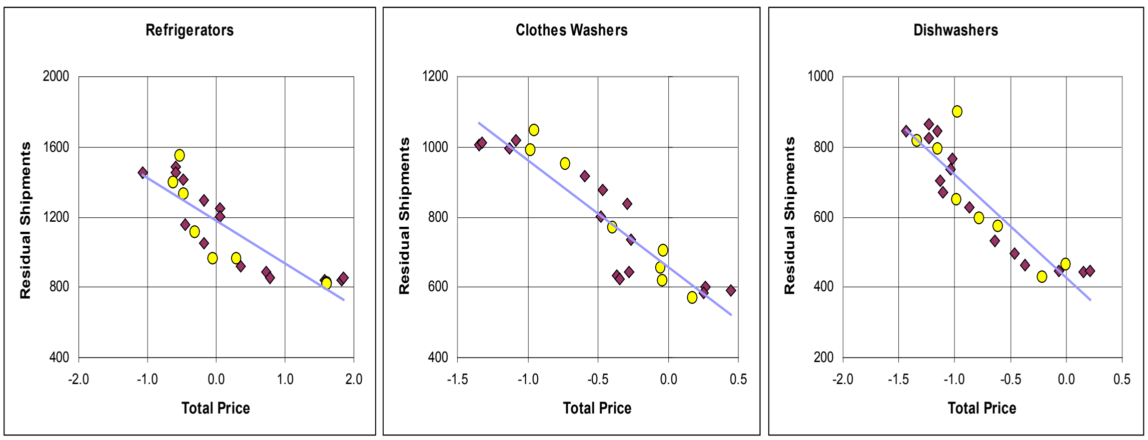
[c] Present value operating cost is calculated assuming a 19-year operating life for refrigerators, 14-year operating life for clothes washers, and a 12-year operating life for dishwashers. A 37 percent discount rate is used to sum annual operating costs into a present value operating cost.

elasticity of demand equal to -0.48 for refrigerators, -0.32 for clothes washers and -0.37 for dishwashers (Table 9A.4.1).

**Table 9A.4.1 Estimate of Total Price Elasticity of Demand**

| | Residual Shipments (millions) | | | | Total Price (1999$) | | | |
|---|---|---|---|---|---|---|---|---|
| **Appliance** | **1980** | **2002** | **Difference** | **Change** | **1980** | **2002** | **Change** | **Elasticity** |
| Refrigerators | -0.5 | 1.6 | 2.1 | 30% | 1541 | 820 | -61% | -0.48 |
| Clothes Washers | -1.0 | 0.2 | 1.1 | 19% | 1042 | 567 | -59% | -0.32 |
| Dishwashers | -1.0 | -0.01 | 1.0 | 23% | 896 | 464 | -64% | -0.37 |

The negative correlation between total price and residual shipments suggested by these negative price elasticities is illustrated in a graph of residual shipments on the y-axis and total price on the x-axis (Figure 9A.4.1).




Yellow points are observed price data; red points are interpolated price data.

**Figure 9A.4.1 Residual Shipments and Appliance Price**

Household income rose during the study period, making it easier for households to purchase appliances. Assuming that a rise in income has a similar impact on shipments as a decline in price, the impact of income is incorporated by defining a third variable, termed *relative* price, which is calculated as total price divided by household income and represented by the following equation.[d]

$$RP = \frac{TP}{Income}$$

where:

$RP$ = Relative price,
$TP$ = Total price, and

[d] Recall that the income elasticity of demand cited in the literature review is 0.50 and the price elasticity of demand cited in the review averages -0.35. This suggests that combining the effects of income and price will yield an elasticity less negative than price elasticity alone.

*Income* = Household income.

The percent decline in *relative* price for the three appliances divided by the percent decline in residual shipments suggests a rough estimate of *relative* price elasticity equal to -0.40 for refrigerators, -0.26 for clothes washers and -0.30 for dishwashers (Table 9A.4.2).

**Table 9A.4.2 Tabular Estimate of Relative Price Elasticity of Appliance Demand**

| | Residual Shipments (millions) | | | Relative Price (1999$) | | | |
|---|---|---|---|---|---|---|---|
| **Appliance** | **1980** | **2002** | **Change** | **1980** | **2002** | **Change** | **Elasticity** |
| Refrigerators | -0.532 | 1.597 | 30% | 0.041 | 0.019 | -74% | -0.40 |
| Clothes Washers | -0.953 | 0.174 | 19% | 0.028 | 0.013 | -72% | -0.26 |
| Dishwashers | -0.974 | -0.005 | 23% | 0.024 | 0.011 | -76% | -0.30 |

### 9A.4.2 Specification of Model

The limited price data suggest it is appropriate to use a simple regression model to estimate the impact of economic variables on shipments, using few explanatory variables. The following equation, chosen for this analysis, includes one physical household variable (housing starts plus replacements) and one *relative* price variable (the sum of purchase price plus operating cost, divided by income).

$$\boldsymbol{Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor} \qquad \textbf{Eq. 9A.1}$$

where:

*Ship* = Quantity of appliance sold,
*RP* = Relative price,
*Starts* = Number of new homes, and
*Rplc* = Number of appliances at the end of their operating life.

The natural logs are taken of all variables so that the estimated coefficients for each variable in the model may be interpreted as the percent change in shipments associated with the percent change in the variable. Thus, the coefficient *b* in this model is interpreted as the *relative* price elasticity of demand for the three appliances.

DOE used the following combined regression equation to estimate an average price elasticity of demand across the three appliances, using pooled data in a single regression. A combined regression specification is justified, given the limited data available and the similarity in price and shipment behavior across appliances (see Figure 9A.4.1). Thus, the model represented by the combined regression equation is considered the basic model in DOE's analysis of appliance shipments.

$$\boldsymbol{Ship = a + b \times RP + c \times \lfloor Starts + Rplc \rfloor + d \times CW + e \times DW} \qquad \textbf{Eq. 9A.2}$$

where:

$CW =$ Quantity of clothes washers sold, and
$DW =$ Quantify of dishwashers sold.

### 9A.4.3 Discussion of Model

The most important assumption used to specify this model is that changes in economic variables over the study period—income, price, and operating cost—are responsible for all observed growth in residual appliance shipments. In other words, DOE assumes no impact from other possible factors, such as changing consumer preferences or increases in the quality of appliances. This assumption seems unlikely, but without additional data, the impact of this assumption on the price elasticity of demand cannot be measured. DOE effectively assumes that changes in consumer preferences and appliance characteristics, while affecting which models are purchased, have relatively little impact on the total number of appliances purchased in a year.

Three additional assumptions used to specify this model deserve comment. The *relative* price variable is specified in the model, assuming that (1) the correct implicit discount rate is used to combine appliance price and operating cost and that (2) rising income has the same impact on shipments as falling total price. The "starts + replacements" variable is specified, assuming (3) that starts and replacements have similar impacts on shipments.

To investigate the first assumption about discount rates, DOE calculated "present value operating cost" using a 20 percent implicit discount rate and performed a second regression analysis based on the models described in equations 9A.1 and 9A.2. The results of this analysis, presented in section 9A.4.5, indicate that the elasticity of *relative* price is fairly insensitive to changes in the discount rate.

To investigate the second and third assumptions, DOE specified a regression model separating income from total price and replacements from starts, thereby adding two additional explanatory variables to the basic model as shown in the following equation:

$$Ship = a + b \times TP + c \times Incone + d \times Start + e \times Rplc + f \times CW + g \times DW \qquad \textbf{Eq. 9A.3}$$

The results of the regression analysis of this model are presented in section 9A.4.5. These results suggest that the elasticity of total price (coefficient *b*) is relatively insensitive to changes in the treatment of income and "starts + replacements" in the model.

### 9A.4.4 Analysis Results

The following sections describe results of analyses using both the individual and combined models for appliances and the effects of a lower consumer discount rate and disaggregated variables.

#### 9A.4.4.1 Individual Appliance Model

The individual appliance regression equations are specified in the following equation.

$$\boldsymbol{Ship} = \boldsymbol{a} + \boldsymbol{b} \times \boldsymbol{RP} + \boldsymbol{c} \times \lfloor \boldsymbol{Starts} + \boldsymbol{Rplc} \rfloor$$

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 9A.4.3), averaging -0.35. These elasticities are similar to those reported in the literature survey for appliances (Table 9A.2.1). They are remarkably similar to the price elasticity calculated using a tabular approach (Table 9A.4.2).

The estimated coefficient associated with the "starts + replacements" variable is close to one. A coefficient equal to one for this variable would imply that, holding economic variables constant, shipments increase in direct proportion to an increase in "starts + replacements." The high R-squared values (above 95) and t-statistics (above 5) in the results provide a measure of confidence in this analysis, despite the very small data set.

**Table 9A.4.3 Individual Appliance Model Results**

| | Refrigerator | | Clothes Washer | | Dishwasher | |
|---|---|---|---|---|---|---|
| **Variable** | **Coefficient** | **t-stat** | **Coefficient** | **t-stat** | **Coefficient** | **t-stat** |
| Intercept | -1.51 | -7.26 | -1.47 | -8.23 | -2.08 | -16.78 |
| Relative Price | -0.40 | -6.60 | -0.31 | -5.69 | -0.32 | -7.03 |
| Starts + Replacements | 1.05 | 5.90 | 1.08 | 6.41 | 1.35 | 11.46 |
| $R^2$ | 0.954 | | 0.954 | | 0.975 | |
| Observations | 23 | | 23 | | 23 | |

#### 9A.4.4.2 Combined Appliance Model

The combined appliance regression equation is specified in the following equation.

$$\boldsymbol{Ship} = \boldsymbol{a} + \boldsymbol{b} \times \boldsymbol{RP} + \boldsymbol{c} \times \lfloor \boldsymbol{Starts} + \boldsymbol{Rplc} \rfloor + \boldsymbol{d} \times \boldsymbol{CW} + \boldsymbol{e} \times \boldsymbol{DW}$$

This regression analysis indicates that the model fits the existing shipments data well (high R-squared) and that the variables included in the model are statistically significant (Table 9A.4.4). Estimated with this model, the elasticity of *relative* price is -0.34, close to the average value estimated in the individual appliance models (-0.35). It is also similar to elasticity estimates reported in the literature survey and calculated using the tabular approach in Table 9A.4.2.

**Table 9A.4.4 Combined Appliance Model Result**

| Variable | Coefficient | t-statistic |
|---|---|---|
| Intercept | -1.60 | -15.54 |
| Relative Price | -0.34 | -10.74 |

| | | |
|---|---|---|
| Starts + Replacements | 1.21 | 13.95 |
| CW | -0.20 | -9.04 |
| DW | -0.32 | -6.58 |
| $R^2$ | 0.983 | |
| Observations | 69 | |

### 9A.4.5 Additional Regression Specifications and Results

As described in section 9A.4.3, DOE used three assumptions to specify its appliance models. The first, made to aggregate appliance price and operating cost, is that the implicit price variable in the basic regression model is specified using a 37 percent implicit discount rate. The second states that the implicit price variable is defined assuming that rising income has the same impact on shipments as falling total price. The third states that the "starts + replacements" variable is defined assuming that housing starts have a similar impact on shipments as appliance replacements.

#### 9A.4.5.1 Lower Consumer Discount Rate

To investigate the first assumption about discount rates, DOE calculated "present value operating cost" using a 20 percent implicit discount rate and performed a second regression analysis based on the models described in equations 9A.1 and 9A.2. The estimated coefficient associated with the *relative* price variable in these regressions is almost identical to the coefficients estimated for the same variable based on a 37 percent implicit discount rate. The elasticity of *relative* price calculated using a 20 percent discount rate is -0.33 in the combined regression and averages -0.35 for the three appliances (Table 9A.4.5). The elasticity of price calculated using a 37 percent discount rate is -0.34 in the combined regression and averages -0.35 for the three appliances. DOE concludes from this analysis that the elasticity of *relative* price is fairly insensitive to changes in the discount rate.

**Table 9A.4.5 Combined and Individual Results, 20 percent discount rate**

| Three Appliances Variable | Coefficient | t-Stat |
|---|---|---|
| Intercept | -1.53 | -14.61 |
| Total Price / Income | -0.33 | -10.69 |
| Starts + Retirements | 1.20 | 13.65 |
| CW | -0.18 | -8.69 |
| DW | -0.32 | -6.57 |
| $R^2$ | 0.982 | |
| Observations | 69 | |

| Variable | Refrigerator Coefficient | t-Stat | Clothes Washers Coefficient | t-Stat | Dishwasher Coefficient | t-Stat |
|---|---|---|---|---|---|---|
| Intercept | -1.36 | -6.26 | -1.41 | -7.49 | -2.04 | -17.23 |
| Total Price / Income | -0.38 | -6.50 | -0.32 | -5.29 | -0.33 | -7.30 |
| Starts + Retirements | 1.04 | 5.73 | 1.06 | 5.83 | 1.34 | 11.64 |
| $R^2$ | | 0.953 | | 0.950 | | 0.977 |
| Observations | | 23 | | 23 | | 23 |

### 9A.4.5.2 Disaggregated Variables

To investigate the second and third assumptions, DOE constructed a regression model that separates income from total price and replacements from starts, thus adding two additional explanatory variables to the basic model (as shown earlier as Eq. 9A.3 and shown below).

$$Ship = a + b \times TP + c \times Income + d \times Start + e \times Rplc + f \times CW + g \times DW$$

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 9A.4.6). The elasticity of *relative* price based on the model described in equation 9A.2 is -0.34 in the combined regression (Table 9A.4.4) and averages -0.35 across the individual appliances (Table 9A.4.3). DOE concludes that the price elasticity calculated in this analysis is relatively insensitive to the specification of household income and “starts + replacements” variables in the model.

**Table 9A.4.6 Disaggregated Regression Results, 37 percent discount rate**

| Three Appliances | | |
|---|---|---|
| **Variable** | **Coefficient** | **t-Stat** |
| Intercept | -2.92 | -1.26 |
| Income | 0.58 | 2.92 |
| Total Price | -0.36 | -7.06 |
| Housing Starts | 0.44 | 10.02 |
| Retirements | 0.62 | 8.12 |
| CW | -0.24 | -9.25 |
| DW | -0.46 | -7.68 |
| $R^2$ | | 0.985 |
| Observations | | 69 |

| | Refrigerator | | Clothes Washers | | Dishwasher | |
|---|---|---|---|---|---|---|
| **Variable** | **Coefficient** | **t-Stat** | **Coefficient** | **t-Stat** | **Coefficient** | **t-Stat** |
| Intercept | -6.19 | -2.24 | -6.64 | -1.63 | 1.00 | 0.23 |
| Income | 0.89 | 3.80 | 0.87 | 2.31 | 0.20 | 0.52 |
| Total Price | -0.35 | -5.48 | -0.27 | -2.51 | -0.43 | -5.18 |
| Housing Starts | 0.41 | 7.38 | 0.25 | 3.29 | 0.62 | 8.24 |
| Retirements | 0.56 | 6.06 | 0.56 | 2.09 | 0.65 | 5.86 |
| $R^2$ | | 0.984 | | 0.958 | | 0.979 |
| Observations | | 23 | | 23 | | 23 |

## 9A.5 LONG RUN IMPACTS

As noted above in Table 9A.2.1, the literature review provides price elasticities over short and long time periods, also referred to as short run and long run price elasticities. As noted in the first two rows of Table 9A.2.1, one source (i.e., Hymans) shows that the price elasticity of demand is significantly different over the short run and long run for automobiles.[1] Because DOE's forecasts of shipments and national impacts due to standards is over a 30-year time period, consideration must be given to how the *relative* price elasticity is affected once a new standard takes effect.

DOE considers the *relative* price elasticities determined above in section 9A.4 to be short run elasticities. DOE was unable to identify sources specific to household durable goods, such as appliances, to indicate how short run and long run price elasticities differ. Therefore, to estimate how the *relative* price elasticity changes over time, DOE relied on the Hymans study pertaining to automobiles. Based on the Hymans study, Table 9A.5.1 shows how the automobile price elasticity of demand changes in the years following a purchase price change. With increasing years after the price change, the price elasticity becomes more inelastic until it reaches a terminal value around the tenth year after the price change.

**Table 9A.5.1 Change in Price Elasticity of Demand for Automobiles following a Purchase Price Change**

| | Years Following Price Change | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **5** | **10** | **20** |
| Price Elasticity of Demand | -1.20 | -0.93 | -0.75 | -0.55 | -0.42 | -0.40 |
| Relative Change in Elasticity to 1st year | 1.00 | 0.78 | 0.63 | 0.46 | 0.35 | 0.33 |

**Source:** Hymans, 1971.

Based on the relative change in the automobile price elasticity of demand shown in Table 9A.5.1, DOE developed a time series of *relative* price elasticities for home appliances. Table 9A.5.2 presents the time series.

**Table 9A.5.2 Change in Relative Price Elasticity for Home Appliances following a Purchase Price Change**

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

## 9A.6 SUMMARY

This appendix describes the results of a literature search, tabular analysis, and regression analyses of the impact of price and other variables on appliance shipments. In the literature, DOE found only a few studies of appliance markets that are relevant to this analysis and no studies after 1980 using time series price and shipments data. The information that can be summarized from the literature suggests that the demand for appliances is price inelastic. Other information in the literature suggests that appliances are a normal good, such that rising incomes increase the demand for appliances. Finally, the literature suggests that consumers use relatively high implicit discount rates, when comparing appliance prices and appliance operating costs.

There are too few price and operating cost data available to perform complex analysis of dynamic changes in the appliance market. In this analysis, DOE used data available for refrigerators, clothes washers, and dishwashers to evaluate broad market trends and perform simple regression analysis.

These data indicate an increase in appliance shipments and a decline in appliance price and operating cost over the study period 1980-2002. Household income has also risen during this time. To simplify the analysis, DOE combined the available economic information into one variable, termed *relative* price, and used that variable in a tabular analysis of market trends and a regression analysis.

DOE's tabular analysis of trends in the number of appliances per household suggests that the price elasticity of demand for the three appliances is inelastic. Our regression analysis of these same variables suggests that the *relative* price elasticity of demand is -0.34. The price elasticity is consistent with estimates in the literature. Nevertheless, DOE stresses that the measure is based on a small data set, using very simple statistical analysis. More important, the measure is based on an assumption that economic variables, including price, income and operating costs, explain most of the trend in appliances per household in the United States since 1980. Changes in appliance quality and consumer preferences may have occurred during this period, but they are not accounted for in this analysis.

## 9A.7 DATA USED IN THE ANALYSIS

- **Appliance Shipments** are defined as the annual number of units shipped in millions. These data were collected from the Association of Home Appliance Manufacturers (AHAM)[8, 9] and Appliance Magazine[10] as annual values for each year, 1980–2002. AHAM was used for the period 1989–2002 while Appliance Magazine was used for the period 1980–1988.

- **Appliance Price** is defined as the shipments weighted retail sales price of the unit in 1999 dollars. Price values for 1980, 1985, 1986, 1991, 1993, 1994, 1998, and 2002 were collected from AHAM Fact Books.[11] Price values for other years were interpolated from these eight years of data.

- **Housing Starts** data were collected from the U.S. Census construction statistics (C25 reports) as annual values for each year, 1980–2002.[12]

- **Replacements**, driven by equipment retirements, are estimated with the assumption that some fraction of sales arise from consumers replacing equipment at the end of its useful life. Since each appliance has a different expected lifespan (19 years for refrigerators,[13] 14 years for clothes washers,[14] 12 years for dishwashers[15]), replacements are calculated differently for each appliance type. Replacements are estimated as the average of shipments 14–24 years previous for refrigerators, 9–19 years previous for clothes washers, and 7–17 years previous for dishwashers. Historical shipments data were collected from AHAM and Appliance Magazine.

- **Annual Electricity Consumption** (UEC) is defined as the energy consumption of the unit in kilowatt-hours. Electricity consumption depends on appliance capacity and efficiency. These data were provided by AHAM for 1980, 1990–1997 and 1999–2002.[9] Data were interpolated in the years for which data were not available.

- **Operating Cost** is the present value of the electricity consumption of an appliance over its expected lifespan. The lifespans of refrigerators, clothes washers and dishwashers are assumed to be 19, 14, and 12 years respectively. Discount rates of 20 percent[6] and 37 percent[16] were used, producing similar estimates of price elasticity. A study by Hausman recommended a discount rate of “about 20 percent” in its introduction and presented results ranging from 24.1 percent to 29 percent based on his calculations for room air conditioners. A study by Train suggests a range of implicit discount rates averaging 35 percent for appliances.

- **Income:** Median annual household income in 2003 dollars. These data were collected for each year, 1980–2002, from Table H-6 of the U.S. Census.[17]

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# APPENDIX 10A. USER INSTRUCTIONS FOR NATIONAL IMPACT ANALYSIS SPREADSHEET MODEL

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# APPENDIX 10A. USER INSTRUCTIONS FOR NATIONAL IMPACT ANALYSIS SPREADSHEET MODEL

## 10A.1 USER INSTRUCTIONS

The results obtained in this analysis can be examined and reproduced using the Microsoft Excel® spreadsheets accessible on the Internet from the Department of Energy's (DOE's) residential dehumidifier rulemaking page: http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx?ruleid=62. From that page, follow the links to the Preliminary Analysis phase of the rulemaking and then to the analytical tools.

## 10A.2 STARTUP

The NIA spreadsheets enable the user to perform a National Impact Analysis (NIA) for residential dehumidifiers. To utilize the spreadsheet, the Department assumes that the user has access to a PC with a hardware configuration capable of running Windows 2010 or later. To use the NIA spreadsheets, the user requires Microsoft Excel® 2010 or later installed under the Windows operating system.

## 10A.3 DESCRIPTION OF NATIONAL IMPACT ANALYSIS WORKSHEETS

The NIA spreadsheets perform calculations to project the change in national energy use and net present value of financial impacts due to revised energy efficiency standards. The energy use and associated costs for a given standard level are determined by calculating the shipments and then calculating the energy use and costs for all dehumidifiers shipped under that standard. The differences between the standards and base case can then be compared and the overall energy savings and net present values determined. The NIA spreadsheets consist of the following worksheets:

| | |
|---|---|
| **Input and Summary** | This sheet contains user input selections under "User Inputs" and a summary table, Cumulative Energy Savings and NPV for the selected standard level efficiency distribution. The sheet contains the efficiency levels being considered for residential dehumidifiers and the associated incremental prices. This sheet also contains efficiency weighted average energy use and equipment price for the base and standards cases for all the product classes. |
| **Efficiency Distribution** | This sheet contains base and standards case efficiency trends for each product class. |
| **Historical Shipment** | This sheet contains data for historical sales of the equipment. |
| **Base Case** | This sheet calculates the estimation of shipments for selected product class. The sheet starts with the stock accounting of the equipment and uses the survival function to calculate the surviving |

| | |
|---|---|
| | stock. It then performs calculations of replacements, and shipments going into new ownership, thus yielding total shipments for selected product class. It also calculates the energy consumption and operating cost for selected product class. |
| **Standards Case** | This sheet estimates shipments for selected product class by taking price elasticity into account for the standards case. It also calculates the energy savings and cost savings. The energy and cost savings in a single year are the difference between the base case energy use and costs for that year and the standard case energy use and costs in the same year. |
| **Housing Projection** | This sheet includes *Annual Energy Outlook* (AEO) projection of housing stocks and housing starts for residential buildings. |
| **Electricity Prices** | This worksheet contains projected average electricity for the three economic growth scenarios. |
| **Learning Rate** | It includes the learning multipliers to adjust the manufacturer's cost over the entire analysis period. |
| **Site-to-Power Plant** | The sheet contains the marginal site-to-power plant and upstream to power plant conversion factors that are used in the source and FFC energy savings calculations, respectively. |
| **Lifetime** | This sheet contains the lifetime and the retirement function for each product class. |

## 10A.4 BASIC INSTRUCTIONS FOR OPERATING THE NATIONAL IMPACT ANALYSIS SPREADSHEETS

Basic instructions for operating the NIA spreadsheets are as follows:

1. Once the NIA spreadsheet file has been downloaded from the Department's web site, open the file using MS Excel. Click "Enable Macro" when prompted and then click on the tab for the worksheet User Inputs.

2. Use MS Excel's View/Zoom commands at the top menu bar to change the size of the display to make it fit your monitor.

3. The user can change the parameters in the sheet "NIA Summary". The default parameters are:

    (a) Discount Rate: Set to 7%. To change value, click on the drop-down arrow and interchange value (7% or 3%).

    (b) Product Class: To change product class, click on the drop-down arrow and interchange value (Product Class 1, 2, 3, 4, or 5).

(c) Trial Standards Level: To change standards level, click on the drop-down arrow and interchange value (TSL 1, 2, 3, or 4).

(d) Relative Price Elasticity: To change the applicable elasticity, use the drop-down arrow and select the desired value (No impact or RP elasticity = - 0.34)

(e) Economic Growth: To change the value, use the drop-down arrow and select the desired Growth level (Reference, Low, or High).

(f) Learning Sensitivity: To change value, use the drop-down arrow and select the desired learning level (Default, High, or Low).

(g) Current Year: Set to 2014. To change the value, click on cell D6 and change to desired year.

4. Once the parameters have been set, the results are automatically updated and are reported in the "National Impact Summary" table for each product class to the right of the "User Inputs" box.

**APPENDIX 10B. FULL-FUEL-CYCLE MULTIPLIERS**

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## APPENDIX 10B. FULL-FUEL-CYCLE MULTIPLIERS

### 10B.1 INTRODUCTION

This appendix summarizes the methods the U.S. Department of Energy (DOE) used to calculate the full-fuel-cycle (FFC) energy savings estimated from potential standards for residential dehumidifiers. The FFC measure includes point-of-use (site) energy; the energy losses associated with generation, transmission, and distribution of electricity; and the energy consumed in extracting, processing, and transporting or distributing primary fuels. DOE's method of analysis previously encompassed only site energy and the energy lost through generation, transmission, and distribution of electricity. In 2011 DOE announced its intention, based on recommendations from the National Academy of Sciences, to use FFC measures of energy use and emissions when analyzing proposed energy conservation standards.[1] This appendix summarizes the methods DOE used to incorporate impacts of the full fuel cycle into the analysis.

This analysis uses several terms to describe aspects of energy use. The physical sources of energy are primary fuels such as coal, natural gas, or liquid fuel. Primary energy is equal to the heat content (British thermal units [Btu]) of the primary fuel used to produce an end-use service. Site energy use is defined as the energy consumed at the point of use in a house or establishment. When natural gas or petroleum fuels are consumed at the site (for example in an on-site furnace), site energy is identical to primary energy, with both equal to the heat content of the primary fuel consumed.

For electricity generated by an off-site power plant, site energy is measured in kilowatt-hours (kWh). In such a case the primary energy is equal to the quads (quadrillion Btu) of primary energy required to generate and deliver electricity to the site. For the FFC analysis, upstream energy use is defined as the energy consumed in extracting, processing, and transporting or distributing primary fuels. FFC energy use is the sum of primary plus upstream energy use.

Both primary fuels and electricity are used in upstream activities. The treatment of electricity in full-fuel-cycle analysis must distinguish between electricity generated by fossil fuels and uranium and electricity generated from renewable sources (wind, solar, and hydro). For the former, the upstream fuel cycle relates to the amount of fuel consumed at the power plant. There is no upstream component for the latter, because no fuel *per se* is used.

### 10B.2 METHODOLOGY

The mathematical approach to determining FCC is discussed in Coughlin (2012).[2] Details on analyzing the fuel production chain are presented in Coughlin (2013).[3] The methods used to calculate FFC energy use are summarized here. When all energy quantities are normalized to the same units, FFC energy use can be represented as the product of the primary energy use and an FFC multiplier. Mathematically the FFC multiplier is a function of a set of parameters that represent the energy intensity and material losses at each stage of energy production. Those parameters depend only on physical data, so the calculations require no assumptions about prices or other economic factors. Although the parameter values often differ by geographic region, this analysis utilizes national averages.

The fuel cycle parameters are defined as follows.

- $a_x$ is the quantity of fuel *x* burned per unit of electricity produced, on average, for grid electricity. The calculation of $a_x$ includes a factor to account for losses incurred through the transmission and distribution systems.
- $b_y$ is the amount of grid electricity used in producing fuel *y*, in MWh per physical unit of fuel *y*.
- $c_{xy}$ is the amount of fuel *x* consumed in producing one unit of fuel *y*.
- $q_x$ is the heat content of fuel *x* (MBtu/physical unit).
- $z_x(s)$ is the emissions intensity for fuel *x* (mass of pollutant *s* per physical unit of *x* produced).

All the parameters are calculated as functions of an annual time step; hence, when evaluating the effects of potential new standards, a time series of annual values is used to estimate the FFC energy and emissions savings in each year of the analysis period and cumulatively. Fossil fuel quantities are converted to energy units using the heat content factor $q_x$. To convert electricity in kWh to primary energy units, on-site electricity consumption is multiplied by the site-to-power-plant energy use factor, described in chapter 10. The site-to-power-plant energy use factor is defined as the ratio of the total primary energy consumption by the electric power sector (in quads) divided by the total electricity generated each year.

The FFC multiplier is denoted μ (mu). A separate multiplier is calculated for each fuel used on site. Also calculated is a multiplier for electricity that reflects the fuel mix used in its generation. The multipliers are dimensionless numbers applied to primary energy savings to obtain the FFC energy savings. The upstream component of the energy savings is proportional to (μ-1). The fuel type is denoted by a subscript on the multiplier μ.

When DOE estimates energy savings attributable to appliance standards, the method for performing the full-fuel-cycle analysis utilizes data and projections published in the *Annual Energy Outlook (AEO)*; in the case of residential dehumidifiers, the *AEO2014*.[4] Table 10B.2.1 summarizes the *AEO2014* data used as inputs to the calculation of various parameters. The column titled "AEO Table" gives the name of the table that provided the reference data.

**Table 10B.2.1 Dependence of FFC Parameters on *AEO* Inputs**

| Parameter(s) | Fuel(s) | *AEO* Table | Variables |
|---|---|---|---|
| $q_x$ | All | Conversion factors | MMBtu per physical unit |
| $a_x$ | All | Electricity supply, disposition, prices, and emissions<br>Energy consumption by sector and source | Generation by fuel type<br>Electric energy consumption by the power sector |
| $b_c$, $c_{nc}$, $c_{pc}$ | Coal | Coal production by region and type | Coal production by type and sulfur content |
| $b_p$, $c_{np}$, $c_{pp}$ | Petroleum | Refining industry energy consumption<br>Liquid fuels supply and disposition<br>International liquids supply and disposition<br>Oil and gas supply | Refining-only energy use<br>Crude supply by source<br>Crude oil imports<br>Domestic crude oil production |
| $c_{nn}$ | Natural gas | Oil and gas supply<br>Natural gas supply, disposition, and prices | U.S. dry gas production<br>Pipeline, lease, and plant fuel |
| $z_x$ | All | Electricity supply, disposition, prices, and emissions | Power sector emissions |

The AEO2014 does not provide all the information needed to estimate total energy use in the fuel production chain. Coughlin (2013) describes the additional data sources needed to complete the analysis. The time dependence in the FFC multipliers for dehumidifiers, however, arises exclusively from variables taken from the AEO2014.

## 10B.3 ENERGY MULTIPLIERS FOR THE FULL FUEL CYCLE

FFC energy multipliers for selected years are presented in Table 10B.3.1. The 2040 value was held constant for the analysis period beyond 2040, which is the last year in the AEO2014 projection. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation throughout the forecast period.

**Table 10B.3.1 Energy Multipliers for the Full Fuel Cycle (Based on *AEO2014*)**

| | 2019 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| Electricity | 1.043 | 1.044 | 1.045 | 1.046 | 1.047 | 1.047 |
| Natural gas | 1.108 | 1.109 | 1.111 | 1.113 | 1.114 | 1.114 |
| Petroleum fuels | 1.176 | 1.176 | 1.176 | 1.174 | 1.172 | 1.170 |

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# APPENDIX 10C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS USING ALTERNATIVE PRODUCT PRICE FORECASTS

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# APPENDIX 10C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS USING ALTERNATIVE PRODUCT PRICE FORECASTS

## 10C.1 INTRODUCTION

The NPV results presented in chapter 10 are based on future price projection derived from historical PPI data from the Bureau of Labor Statistics (BLS). DOE collected PPI data of "small electric household appliances, except fans" from 1983 to 2012 to project future price for portable dehumidifiers and PPI data of "room AC and dehumidifiers" from 1990 to 2009 to project future price for whole-home dehumidifiers. DOE also investigated the impact of different product price forecasts on the consumer net present value (NPV) for the trial standard levels of both types of dehumidifiers. For portable dehumidifiers, DOE considered two price sensitivity scenarios: (1) a low price decline trend based on the experience curve approach, and (2) a high price decline trend based on the "furniture and appliances" that was forecasted in *AEO2013*. Similarly, DOE also considered two price sensitivity scenarios for whole-home dehumidifiers: (1) a low price decline trend based on "air-conditioning, refrigeration, and forced air heating equipment" PPI, and (2) a high price decline trend based on the "furniture and appliances" that was forecasted in *AEO2013.*

## 10C.2 EXPERIENCE CURVE ESTIMATION – LOW PRICE DECLINE SCENARIO FOR PORTABLE DEHUMIDIFIERS

For this sensitivity case, DOE is using the experience curve approach to forecast future prices of portable dehumidifiers. In the experience curve method, the real cost of production is related to the cumulative production, or experience, with a manufactured product. That experience usually is measured in terms of cumulative production. As experience (production) accumulates, the cost of producing the next unit decreases. The percentage reduction in cost that occurs with each doubling of cumulative production is known as the learning rate. DOE was not able to apply the same shipment-based learning curve approach to whole-home dehumidifiers because the historical shipment data are insufficient.

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.

To derive an experience rate parameter for residential portable dehumidifiers, DOE obtained historical Producer Price Index (PPI) data for small electric household appliances spanning the time period 1983-2012 from the Bureau of Labor Statistics' (BLS). [a] DOE used PPI data for this industry as representative of residential portable dehumidifiers because PPI data specific to residential portable dehumidifiers are not available. An inflation-adjusted price index for small electric household appliances was calculated by dividing the PPI series by the Gross Domestic Product Chained Price Index for the same years. This inflation-adjusted price index (shown in Figure 10C.2.1) was used in subsequent analysis steps.

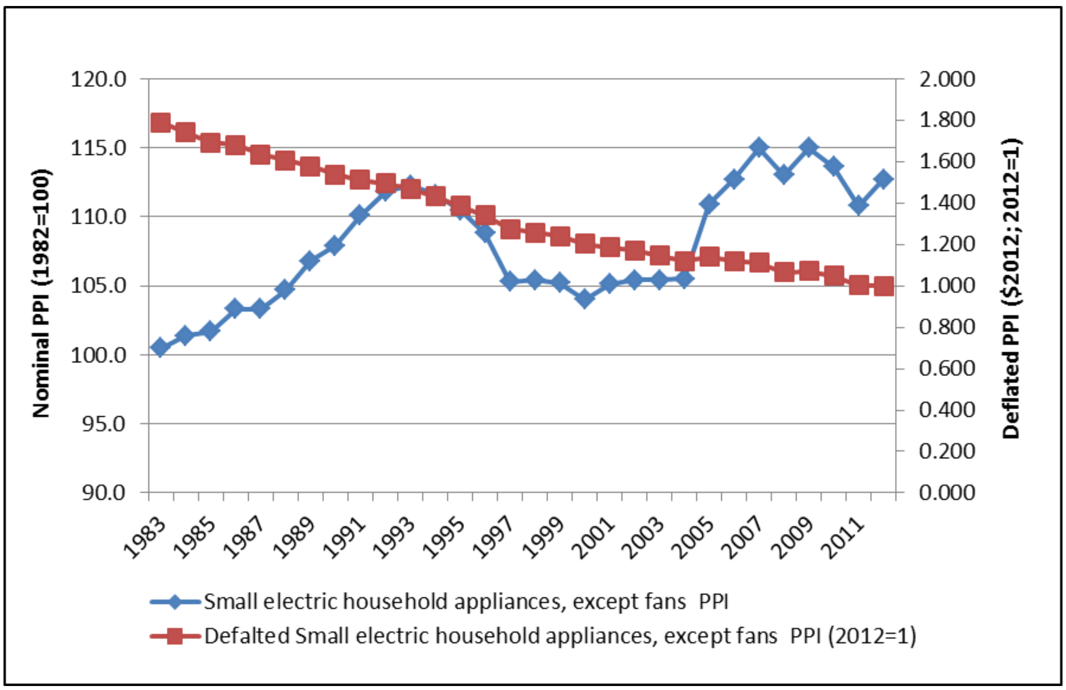


**Figure 10C.2.1 Historical Real Price Index for Small Electric Household Appliances**

[a] Series ID PCU33521033521014; http://www.bls.gov/ppi/

DOE assembled a time-series of annual shipments from 1972-2010 for portable dehumidifiers, which were obtained from the AHAM Fact Book. This annual historical shipments data were used to estimate cumulative shipments (production) for portable dehumidifiers. Projected shipments after 2010 were obtained from the base case projections made for the NIA. Figure 10C.2.2 shows the shipments time series used in the analysis.

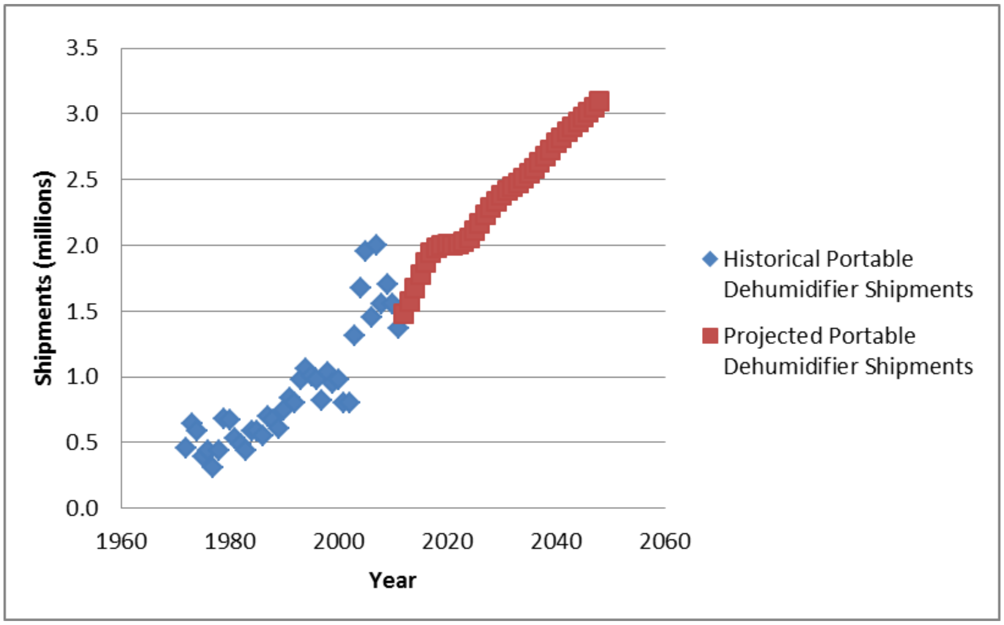


**Figure 10C.2.2 Historical and Projected Shipments of Portable Dehumidifiers**

To estimate an experience rate parameter, a least-squares power-law fit was performed on the unified price index versus cumulative shipments. See Figure 10C.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.

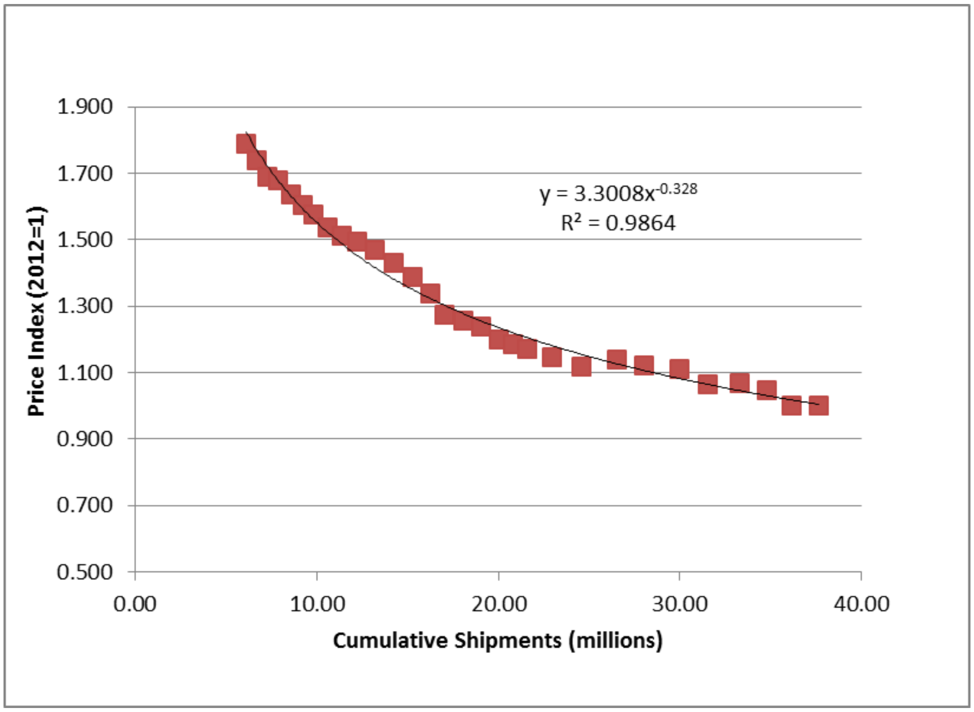


**Figure 10C.2.3 Relative Price versus Cumulative Shipments of Portable Dehumidifiers, with Power Law Fit**

The regression performed as power-law fit results in an R-square of 0.986, which indicates a great fit to the data. The parameter values obtained are:

$P_o = 3.301^{+1.613}_{-1.462}$ (95% confidence) for household laundry equipment, and
b = 0.328±0.015 (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 $20.3^{+0.8}_{-0.8}$% (95% confidence). DOE then derived a price factor index for this scenario, and 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.

## 10C.3 EXPONENTIAL FIT APPROACH – LOW PRICE DECLINE SCENARIO FOR WHOLE-HOME DEHUMIDIFIERS

The historical shipments for whome-home dehumidifiers are not sufficient enough to perform an experence curve estimation. Therefore, for this scenario, DOE used an inflation-adjusted "air-conditioning, refrigerationm and forced air heating equipment" Producer Price

Index (PPI) from 1978-2012 to fit an exponential model with *year* as the explanatory variable.[b] DOE chose this PPI series because this is the more aggregated industry including whole-home dehumidifiers than the "room AC and dehumidifiers" industry used in the default price scenario. The PPI data reflect nominal prices, adjusted for product quality changes. An inflation-adjusted (deflated) price index for air-conditioning, refrigeration and forced air heating equipment was calculated by dividing the PPI series by the Gross Domestic Product Chained Price Index. The deflated price index is now presented in 2012 dollar values. In this case, the exponential function takes the form of:

$$Y = a \cdot e^{bX}$$

where Y is the "air-conditioning, refrigerationm and forced air heating equipment" price index, X is the time variable, *a* is the constant and *b* is the slope parameter of the time variable.

To estimate these exponential parameters, a least-square fit was performed on the inflation-adjusted air-conditioning, refrigerationm and forced air heating equipment PPI versus *year* from 1978 to 2012. See Figure 10C.3.1.

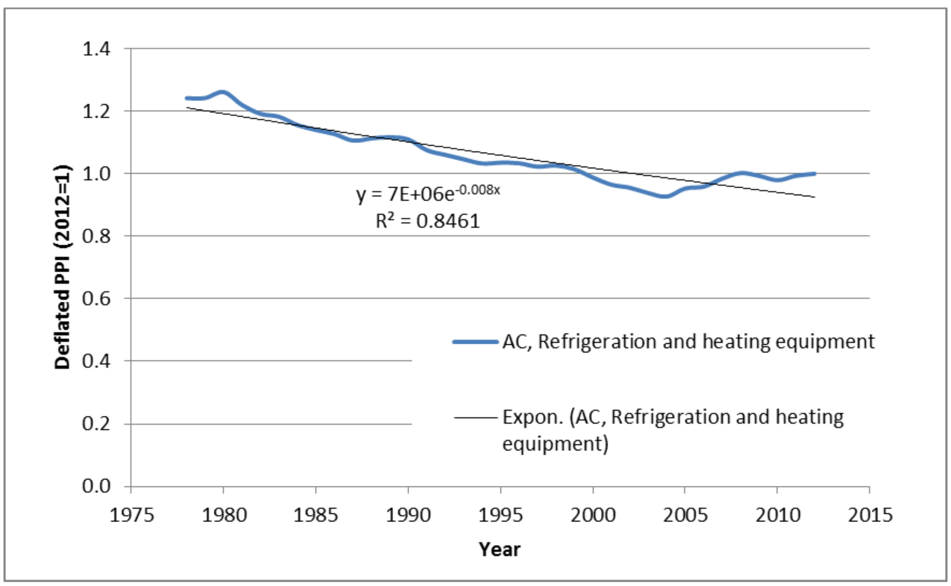


**Figure 10C.3.1 Relative Price of Air-Conditioning, Refrigeration, and Forced Air Heating Equipment versus Year, with Exponential Fit**

The regression performed as an exponential trend line fit results in an R-square of 0.85, which indicates a reasonable fit to the data. The final estimated exponential function is:

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[b] Series ID PCU333415333415; http://www.bls.gov/ppi/

$$Y = 7.393 \times 10^6 \cdot e^{(-0.0079)X}$$

DOE then derived a price factor index for this scenario, with 2012 equal to 1, to project prices in each future year in the analysis period considered in the NIA since 2012. The index value in a given year is a function of the exponential parameter and *year*.

## 10C.4 ANNUAL ENERGY OUTLOOK 2013 PRICE FORECAST – HIGH PRICE DECLINE SCENARIO FOR PORTABLE AND WHOLE-HOME DEHUMIDIFIERS

DOE also examined a forecast based on the "chained price index—furniture and appliances" that was forecasted for *AEO2013* out to 2040. This index is the most disaggregated category that includes both types of dehumidifiers. To develop an inflation-adjusted index, DOE normalized the above index with the "chained price index—gross domestic product" forecasted for *AEO2013*. To extend the price index beyond 2040, DOE used the average annual price growth rate in 2031 to 2040.

## 10C.5 SUMMARY

Table 10C.5.1 shows the summary of the average annual rates of changes for the product price index in each scenario. Figure 10C.5.1 and Figure 10C.5.2 show the resulting price trends for portable and whole-home dehumidifiers respectively.

**Table 10C.5.1 Price Trend Scenarios**

| Product | Scenario | Price Trend | Average Annual Rate of Change % |
|---|---|---|---|
| Portable Dehumidifier | Default | Exponential Fit using Small Electric Household Appliances PPI (1983 to 2012) | -2.02 |
| | High Price Decline | AEO2013 "chained price index—furniture and appliances" | -2.41 |
| | Low Price Decline | Experience Curve Estimation using Small Electric Household Appliances PPI (1983 to 2012) | -1.08 |
| Whole-Home Dehumidifier | Default | Exponential Fit using Room AC and Dehumidifiers (1990 to 2009) | -2.32 |
| | High Price Decline | AEO2013 "chained price index—furniture and appliances" | -2.41 |
| | Low Price Decline | Exponential Fit using Air-Conditioning, Refrigeration, and Forced Air Heating Equipment PPI (1978 to 2012) | -0.79 |

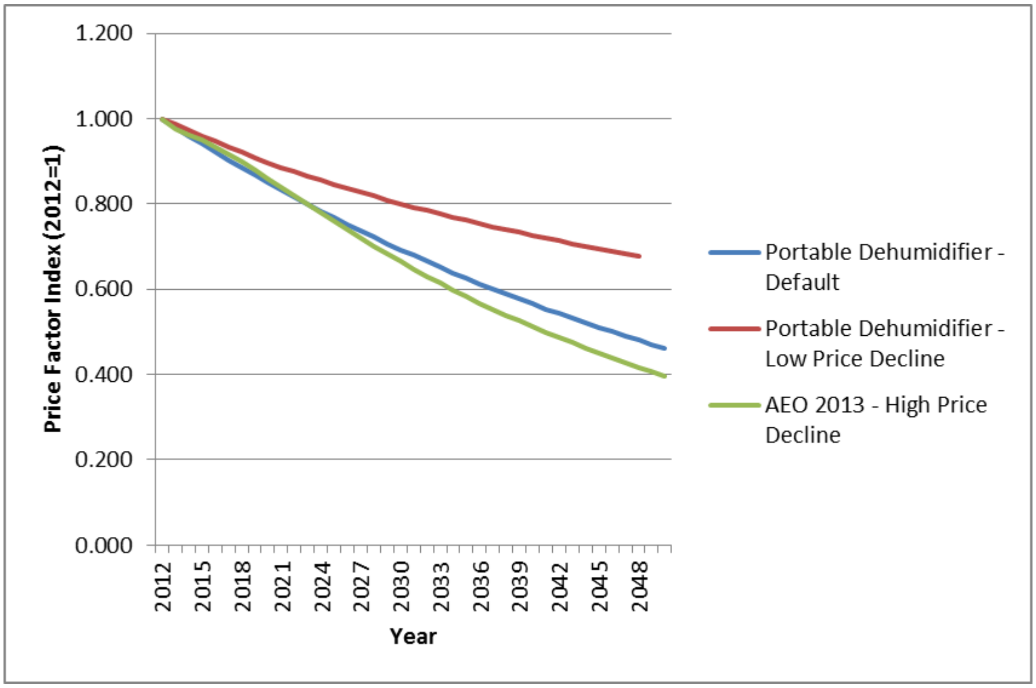


**Figure 10C.5.1 Portable Dehumidifier Price Factor Indexes for the Default Case and Sensitivity Cases**

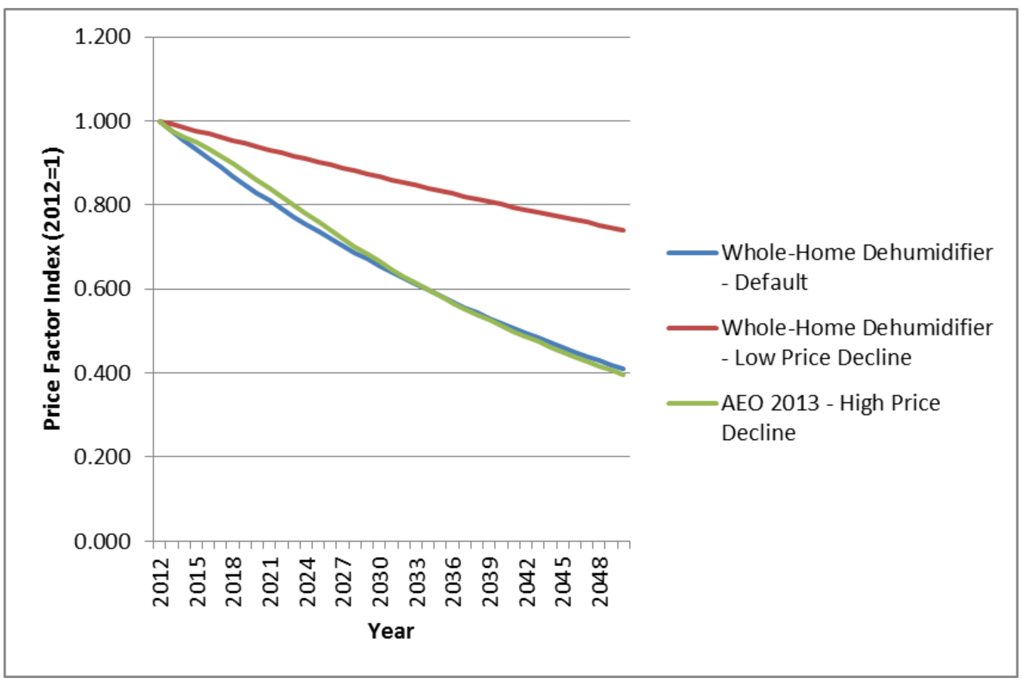


**Figure 10C.5.2 Whole-Home Dehumidifier Price Factor Indexes for the Default Case and Sensitivity Cases**

## 10C.6 RESIDENTIAL DEHUMIDIFIERS NPV RESULTS USING ALTERNATIVE LEARNING RATES

**Table 10C.6.1 Residential Dehumidifiers: Net Present Value of Consumer Impacts Under Alternative Product Price Forecasts (3 Percent Discount Rate)**

| Price Trend | Product Class (pints/day) | Trial Standard Levels ( billion 2013$) | | | |
|---|---|---|---|---|---|
| | | TSL1 | TSL 2 | TSL 3 | TSL 4 |
| Default | ≤30.00 | 0.216 | 0.440 | 0.675 | 2.228 |
| | 30.01-45.00 | 0.096 | 0.096 | 1.345 | 2.356 |
| | >45.00 | 0.158 | 0.202 | 0.202 | 0.324 |
| | ≤8.0ft$^3$ Case Volume (Whole-home) | 0.023 | 0.023 | 0.023 | 0.027 |
| | >8.0ft$^3$ Case Volume (Whole-home) | 0.003 | 0.022 | 0.022 | 0.025 |
| Low Price Decline | ≤30.00 | 0.216 | 0.439 | 0.671 | 2.178 |
| | 30.01-45.00 | 0.095 | 0.095 | 1.331 | 2.311 |
| | >45.00 | 0.152 | 0.194 | 0.194 | 0.304 |
| | ≤8.0ft$^3$ Case Volume (Whole-home) | 0.023 | 0.023 | 0.023 | 0.022 |
| | >8.0ft$^3$ Case Volume (Whole-home) | 0.003 | 0.021 | 0.021 | 0.022 |
| High Price Decline | ≤30.00 | 0.217 | 0.441 | 0.677 | 2.252 |
| | 30.01-45.00 | 0.096 | 0.096 | 1.352 | 2.377 |
| | >45.00 | 0.161 | 0.205 | 0.205 | 0.333 |
| | ≤8.0ft$^3$ Case Volume (Whole-home) | 0.023 | 0.023 | 0.023 | 0.030 |
| | >8.0ft$^3$ Case Volume (Whole-home) | 0.003 | 0.022 | 0.022 | 0.027 |

**Table 10C.6.2 Residential Dehumidifiers: Net Present Value of Consumer Impacts Under Alternative Product Price Forecasts (7 Percent Discount Rate)**

| Price Trend | Product Class (pints/day) | Trial Standard Levels (billion 2013$) | | | |
|---|---|---|---|---|---|
| | | TSL1 | TSL 2 | TSL 3 | TSL 4 |
| **Default** | ≤30.00 | 0.125 | 0.226 | 0.334 | 0.970 |
| | 30.01-45.00 | 0.040 | 0.040 | 0.600 | 1.019 |
| | >45.00 | 0.059 | 0.081 | 0.081 | 0.123 |
| | ≤8.0ft$^3$ Case Volume (Whole-home) | 0.010 | 0.010 | 0.010 | 0.007 |
| | >8.0ft$^3$ Case Volume (Whole-home) | 0.001 | 0.009 | 0.009 | 0.008 |
| **Low Price Decline** | ≤30.00 | 0.125 | 0.225 | 0.332 | 0.949 |
| | 30.01-45.00 | 0.039 | 0.039 | 0.595 | 1.000 |
| | >45.00 | 0.057 | 0.078 | 0.078 | 0.114 |
| | ≤8.0ft$^3$ Case Volume (Whole-home) | 0.010 | 0.010 | 0.010 | 0.005 |
| | >8.0ft$^3$ Case Volume (Whole-home) | 0.001 | 0.009 | 0.009 | 0.007 |
| **High Price Decline** | ≤30.00 | 0.125 | 0.226 | 0.335 | 0.980 |
| | 30.01-45.00 | 0.040 | 0.040 | 0.603 | 1.028 |
| | >45.00 | 0.060 | 0.082 | 0.082 | 0.127 |
| | ≤8.0ft$^3$ Case Volume (Whole-home) | 0.010 | 0.010 | 0.010 | 0.008 |
| | >8.0ft$^3$ Case Volume (Whole-home) | 0.001 | 0.009 | 0.009 | 0.009 |

# APPENDIX 10D. NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE USING ALTERNATIVE GROWTH SCENARIOS

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# APPENDIX 10D. NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE USING ALTERNATIVE GROWTH SCENARIOS

## 10D.1 INTRODUCTION

This appendix presents national energy savings (NES) and net present value (NPV) results using inputs from alternative economic growth scenarios. The scenarios use the energy price and housing starts forecasts in the High Economic Growth case and the Low Economic Growth case from EIA's *Annual Energy Outlook 2015* (AEO 2015).[1]

Figure 10D.1.1 and Figure 10D.1.2 show the forecasts for total housing stock and residential electricity prices under the different economic growth scenarios. *AEO2015* provides a forecast to 2040. To estimate the trend after 2040, DOE followed guidelines that the EIA had provided to the Federal Energy Management Program, which called for using the average rate of change for electricity during 2030–2040.

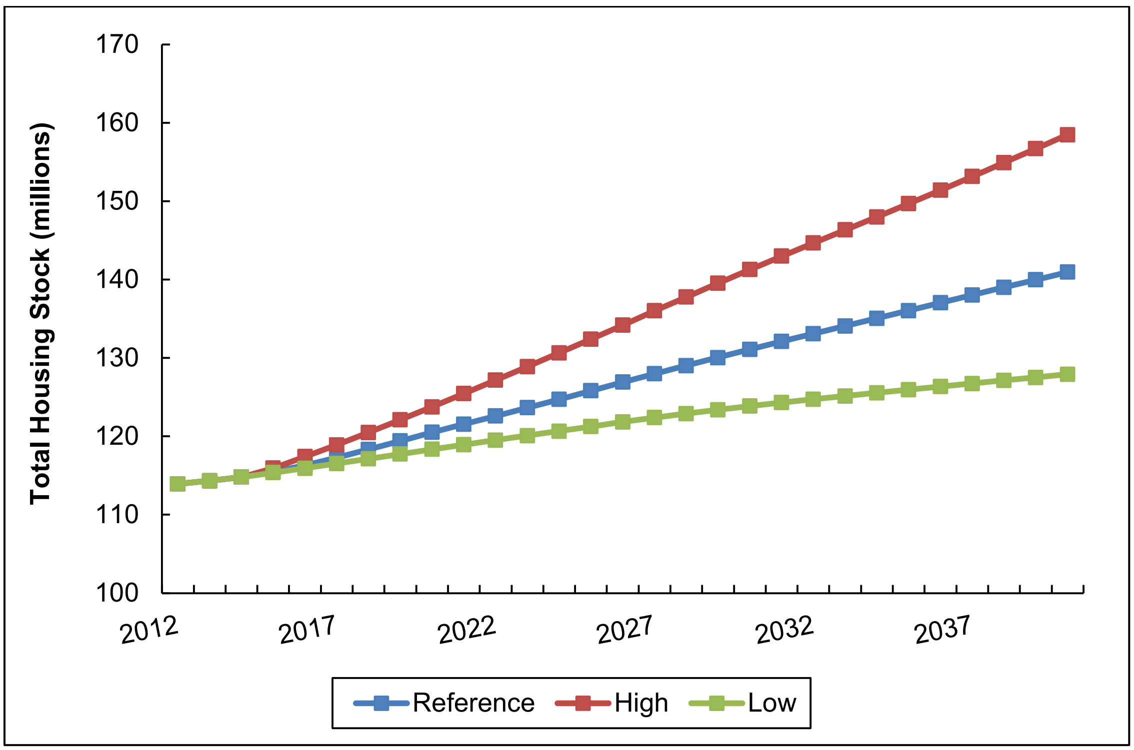


**Figure 10D.1.1 Total Housing Stock Forecast Under Alternative AEO2015 Economic Growth Scenarios**

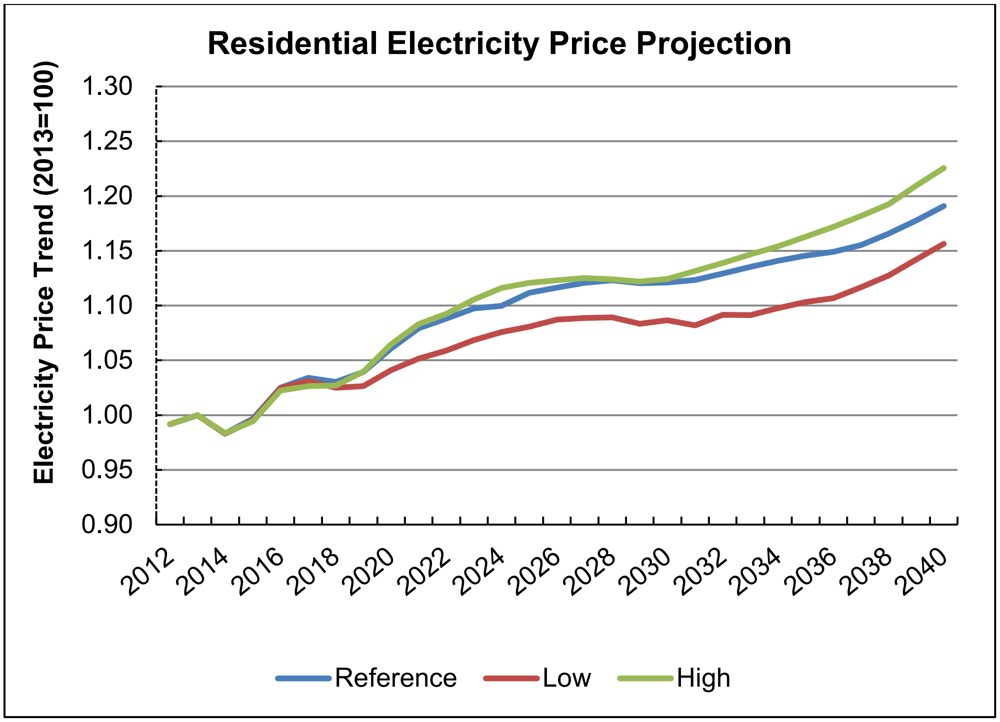


**Figure 10D.1.2 Average Residential Electricity Price Forecasts under Alternative AEO2015 Economic Growth Scenarios**

## 10D.2 NIA RESULTS FOR HIGH ECONOMIC GROWTH SCENARIO

**Table 10D.2.1 Cumulative National Primary Energy Savings in Quads, High Economic Growth Scenario**

| TSL | ≤30.00 pints/day | 30.01-45.00 pints/day | >45.00 pints/day | Whole-home - ≤8.0ft^3 Case Volume | Whole-home - >8.0ft^3 Case Volume | All |
|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.01 | 0.03 | 0.00 | 0.00 | 0.07 |
| 2 | 0.05 | 0.01 | 0.03 | 0.00 | 0.00 | 0.11 |
| 3 | 0.09 | 0.19 | 0.03 | 0.00 | 0.00 | 0.31 |
| 4 | 0.34 | 0.35 | 0.06 | 0.01 | 0.01 | 0.77 |

**Table 10D.2.2 Cumulative Full-Fuel Cycle Energy Savings in Quads, High Economic Growth Scenario**

| TSL | ≤30.00 pints/day | 30.01-45.00 pints/day | >45.00 pints/day | Whole-home - ≤8.0ft^3 Case Volume | Whole-home - >8.0ft^3 Case Volume | All |
|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.01 | 0.03 | 0.00 | 0.00 | 0.07 |
| 2 | 0.06 | 0.01 | 0.04 | 0.00 | 0.00 | 0.11 |
| 3 | 0.09 | 0.20 | 0.04 | 0.00 | 0.00 | 0.33 |
| 4 | 0.36 | 0.37 | 0.07 | 0.01 | 0.01 | 0.81 |

**Table 10D.2.3 Cumulative Net Present Value of Consumer Benefits, High Economic Growth Scenario**

| Price Trend | Product Class (pints/day) | Trial Standard Levels | | | |
|---|---|---|---|---|---|
| | | TSL1 | TSL 2 | TSL 3 | TSL 4 |
| 3% (billion 2013$) | ≤30.00 | 0.22 | 0.46 | 0.70 | 2.34 |
| | 30.01-45.00 | 0.10 | 0.10 | 1.41 | 2.48 |
| | >45.00 | 0.17 | 0.21 | 0.21 | 0.35 |
| | ≤8.0ft$^3$ Case Volume (Whole-home) | 0.02 | 0.02 | 0.02 | 0.03 |
| | >8.0ft$^3$ Case Volume (Whole-home) | 0.00 | 0.02 | 0.02 | 0.03 |
| 7% (billion 2013$) | ≤30.00 | 0.13 | 0.23 | 0.34 | 1.01 |
| | 30.01-45.00 | 0.04 | 0.04 | 0.62 | 1.06 |
| | >45.00 | 0.06 | 0.08 | 0.08 | 0.13 |
| | ≤8.0ft$^3$ Case Volume (Whole-home) | 0.01 | 0.01 | 0.01 | 0.01 |
| | >8.0ft$^3$ Case Volume (Whole-home) | 0.00 | 0.01 | 0.01 | 0.01 |

## 10D.3 NIA RESULTS FOR LOW ECONOMIC GROWTH SCENARIO

**Table 10D.3.1 Cumulative National Primary Energy Savings in Quads, Low Economic Growth Scenario**

| TSL | ≤30.00 pints/day | 30.01-45.00 pints/day | >45.00 pints/day | Whole-home - ≤8.0ft^3 Case Volume | Whole-home - >8.0ft^3 Case Volume | All |
|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.01 | 0.03 | 0.00 | 0.00 | 0.07 |
| 2 | 0.05 | 0.01 | 0.03 | 0.00 | 0.00 | 0.11 |
| 3 | 0.08 | 0.18 | 0.03 | 0.00 | 0.00 | 0.30 |
| 4 | 0.33 | 0.34 | 0.06 | 0.01 | 0.01 | 0.74 |

**Table 10D.3.2 Cumulative Full-Fuel Cycle Energy Savings in Quads, Low Economic Growth Scenario**

| TSL | ≤30.00 pints/day | 30.01-45.00 pints/day | >45.00 pints/day | Whole-home - ≤8.0ft^3 Case Volume | Whole-home - >8.0ft^3 Case Volume | All |
|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.01 | 0.03 | 0.00 | 0.00 | 0.07 |
| 2 | 0.05 | 0.01 | 0.03 | 0.00 | 0.00 | 0.11 |
| 3 | 0.09 | 0.19 | 0.03 | 0.00 | 0.00 | 0.32 |
| 4 | 0.34 | 0.35 | 0.06 | 0.01 | 0.01 | 0.77 |

**Table 10D.3.3 Cumulative Net Present Value of Consumer Benefits, Low Economic Growth Scenario**

| Price Trend | Product Class (pints/day) | Trial Standard Levels | | | |
|---|---|---|---|---|---|
| | | TSL1 | TSL 2 | TSL 3 | TSL 4 |
| 3% (billion 2013$) | ≤30.00 | 0.21 | 0.42 | 0.65 | 2.11 |
| | 30.01-45.00 | 0.09 | 0.09 | 1.28 | 2.24 |
| | >45.00 | 0.15 | 0.19 | 0.19 | 0.30 |
| | ≤8.0ft$^3$ Case Volume (Whole-home) | 0.02 | 0.02 | 0.02 | 0.02 |
| | >8.0ft$^3$ Case Volume (Whole-home) | 0.00 | 0.02 | 0.02 | 0.02 |
| 7% (billion 2013$) | ≤30.00 | 0.12 | 0.22 | 0.32 | 0.92 |
| | 30.01-45.00 | 0.04 | 0.04 | 0.57 | 0.97 |
| | >45.00 | 0.06 | 0.08 | 0.08 | 0.11 |
| | ≤8.0ft$^3$ Case Volume (Whole-home) | 0.01 | 0.01 | 0.01 | 0.01 |
| | >8.0ft$^3$ Case Volume (Whole-home) | 0.00 | 0.01 | 0.01 | 0.01 |

## REFERENCES

1 U.S. Department of Energy-Energy Information Administration. *Annual Energy Outlook 2015 with Projections to 2040,* 2015. Washington, DC. Report Number: DOE/EIA-0383(2015).
< http://www.eia.gov/forecasts/aeo/>

# APPENDIX 12A. MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

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# APPENDIX 12A. MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

## 12A.1 RESIDENTIAL DEHUMIDIFIERS

**Residential Dehumidifier Rulemaking**
**Manufacturer Impact Analysis Interview Guide for**
**Residential Dehumidifier**

August 6. 2014

The U.S. Department of Energy (DOE) conducts the manufacturer impact analysis (MIA) as part of the rulemaking process for amended energy conservation standards for residential portable and whole-home dehumidifiers. In this analysis, DOE uses publicly available information and information provided by manufacturers during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

DOE published a notice of public meeting and availability of the preliminary technical support document (TSD) regarding energy conservation standards for dehumidifiers on May 22, 2014. 79 FR 29380. Based on feedback received from stakeholders, DOE is revising the preliminary analyses in preparation for a notice of proposed rulemaking (NOPR). DOE requests manufacturer feedback on a number of issues covered in the sections below in support of updating its analyses.

# 1 PRODUCT CLASSES

As specified in the preliminary TSD, DOE conducted its analyses on the following product classes and efficiency levels for portable and whole-home dehumidifiers. The capacities and efficiency levels reflect results obtained using the test procedure proposed in the NOPR published in the Federal Register on May 21, 2014. 79 FR 29271.

**Table 1.1 Preliminary Analysis Portable Dehumidifier Efficiency Levels at 65 °F**

| Efficiency Level | Efficiency Level Source | Integrated Energy Factor Efficiency Levels (*L/kWh*) | | | | |
|---|---|---|---|---|---|---|
| | | 20.00 pints/day or less | 20.01–30.00 pints/day | 30.01–35.00 pints/day | 35.01–45.00 pints/day | 45.01 pints/day or more |
| Baseline | DOE Standard with Fan-only Mode | 0.77 | 0.80 | 0.94 | 1.00 | 2.07 |
| 1 | DOE Standard with no Fan-only Mode | 1.10 | 1.10 | 1.20 | 1.30 | 2.40 |
| 2 | Gap Fill 1* | 1.20 | 1.20 | 1.40 | 1.40 | 2.80 |
| 3 | Gap Fill 2 | 1.30 | 1.30 | 1.60 | 1.60 | 3.52 |
| 4 | Maximum Available | 1.42 | 1.52 | 1.75 | 1.75 | N/A |

1.1 Should DOE consider collapsing portable dehumidifiers into fewer product classes? If so, what capacity bins would be appropriate?

1.2 Is there any unique consumer utility associated with portable products in the different capacity bins that would warrant maintaining separate product classes?

**Table 1.2 Preliminary Analysis Whole-Home Dehumidifier Efficiency Levels 65 °F**

| Efficiency Level | Efficiency Level Source | Integrated Energy Factor Efficiency Levels *(L/kWh)* | |
|---|---|---|---|
| | | Less than or equal to 8.0 $ft^3$ (Case Volume) | Greater than 8.0 $ft^3$ (Case Volume) |
| Baseline | Minimum Available | 1.10 | 1.68 |
| 1 | Gap Fill 1 | 1.40 | 1.90 |
| 2 | Gap Fill 2/Maximum Available | 1.59 | 2.80 |
| 3 | Maximum Available | N/A | 3.41 |

1.3 Is case volume an appropriate differentiator between whole-home dehumidifier product classes? If so, is 8 $ft^3$ the appropriate cutoff point between the small and large product classes?

1.4 If case volume is not an appropriate metric for separating whole-home dehumidifier product classes, are multiple product classes necessary? If so, what would be the appropriate product classes and differentiators?

## 2 ENGINEERING

In the preliminary analysis, DOE developed cost estimates associated with improving product efficiencies beyond the baseline for the product classes listed in Table 1.1 and Table 1.2. Table 2.1 below lists the incremental manufacturing costs determined in the preliminary analysis.

**Table 2.3 Incremental Dehumidifier Manufacturing Costs at Higher Efficiencies**

| | **Portable Product Class Capacities** *(pints/day)* | | | | | **Whole-Home Product Class Case Volume** *($ft^3$)* | |
|---|---|---|---|---|---|---|---|
| **Efficiency Level** | **≤ 20** | **20.01-30** | **30.01-35** | **35.01-45** | **> 45** | **≤ 8.0** | **> 8.0** |
| **EL1** | $- | $- | $- | $- | $38.40 | $15.22 | $6.14 |
| **EL2** | $1.56 | $1.85 | $2.94 | $1.98 | $49.16 | $76.18 | $37.05 |
| **EL3** | $4.64 | $3.78 | $8.72 | $7.56 | $100.13 | | $112.01 |
| **EL4** | $7.77 | $10.82 | $13.40 | $11.24 | | | |

2.1 Are the costs presented in Table 2.1 appropriate for the corresponding efficiency improvements in each product class? DOE assumed in the preliminary analysis that manufacturers would primarily rely on increased compressor efficiencies and improvements to the heat exchangers to reach higher efficiency levels.

2.2 DOE assumed in its preliminary analysis that rotary R-410A compressor efficiencies may reach energy efficiency ratios (EERs) up to 10.5 British thermal units per hour per Watt (Btu/h/W). Is this maximum EER appropriate for the entire range of rotary R-410A compressor capacities (*i.e.*, <3,000 Btu/h up to roughly 15,000 Btu/h)? What price premium is associated with more efficient compressors?

2.3 DOE relied on information from the room air conditioners final rule published in 2011 in determining compressor pricing information (described in chapter 5 of the preliminary TSD). Are the costs shown on this curve appropriate for compressors included in dehumidifiers? What price-capacity trend should DOE use for low-capacity compressors (below 5,000 Btu/h) beyond the range of the room air conditioners pricing curve?

2.4 What efficiency gains would be associated with moving to more efficient blower motors (*i.e.*, permanent magnet motors)? What price premium would these motors have compared to the typical permanent-split capacitor motors used in most dehumidifiers?

2.5 In the preliminary analysis, DOE considered improvements to the evaporator and condenser by increasing the cross-sectional area of these heat exchangers. What factors limit the extent to which manufacturers may increase the heat exchanger sizes? Would manufacturers consider improvements to the heat exchangers other than increasing cross-sectional area (*e.g.*, increasing the number of tube passes in the direction of the air flow)?

2.6 For the portable product classes with capacities less than 45 pints/day, DOE assumed that manufacturers would improve efficiencies from the baseline to EL1 by eliminating fan-only mode. Would removing fan-only mode have any impact on consumer utility?

2.7 Testing

2.7.a What should the inlet air condition (dry-bulb temperature and relative humidity) be for testing whole-home dehumidifiers? How would an inlet air temperature of 73 °F affect measured efficiencies and capacities compared to the 65 °F used for the preliminary analysis?

2.7.b What should the test external static pressure be for whole-home dehumidifiers? How would an external static pressure of 0.25 inches of water affect measured efficiencies and capacities compared to 0.5 in. water as proposed in the preliminary analysis?

2.7.c Should the test procedure require an additional test duct for units with ventilation/fresh air collars or should these collars be capped closed for testing?

2.7.d Is 65 °F the most appropriate inlet temperature condition for portable dehumidifiers? If not, what should it be?

2.7.e The proposed test procedure does not account for dehumidifier performance under varying ambient conditions. Should DOE consider testing at multiple ambient conditions to assess potential efficiency improvements associated with certain design options (*e.g.*, variable speed compressors, flow control devices, improved defrost control)? If so, what ambient conditions should be tested?

2.7.f If multiple ambient conditions were assessed, how would the increased test burden associated with these additional test points impact profitability and overall manufacturing costs? Also, how much energy would a field unit with these design options save when compared with a unit without these design options.

## 3 KEY ISSUES

3.1 Since the preliminary interview, are there any **new** key issues for your company regarding amended energy conservation standards for residential dehumidifiers?

## 4 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

DOE is interested in understanding manufacturer impacts at the plant or profit center level directly pertinent to dehumidifier production. However, the context within which this profit center operates and the details of plant production are not always readily available from public sources. Understanding the organizational setting around the dehumidifier industry profit center will help DOE understand the probable future of the manufacturing activity with and without amended energy conservation standards.

4.1 What percentage of your dehumidifier manufacturing corresponds to each product class, in terms of both revenue and shipments within the U.S.? If known, please also indicate your company's approximate market share for each product class. Please also indicate whether you purchase your dehumidifiers from other manufacturers, and whether the factory that supplies the products is located in the United States.

**Table 4.4 Portable Dehumidifier U.S. Revenue and Shipment Volumes by Product Class**

| Product Class Number | Product Class | 2013 Revenue | 2013 Shipments | % Made | % Bought | % Made in U.S. | Market Share |
|---|---|---|---|---|---|---|---|
| 1 | 20.00 pints/day or less** | | | | | | |
| 2 | 20.01–30.00 pints/day | | | | | | |
| 3 | 30.01–35.00 pints/day | | | | | | |
| 4 | 35.01–45.00 pints/day | | | | | | |
| 5 | 45.01 pints/day or more | | | | | | |

**Table 4.2 Whole-Home Dehumidifier U.S. Revenue and Shipment Volumes by Product Class**

| Product Class Number | Product Class | 2013 Revenue | 2013 Shipments | % Made | % Bought | % Made in U.S. | Market Share |
|---|---|---|---|---|---|---|---|
| 1 | <= 8.0 $ft^3$ (Case Volume) | | | | | | |
| 2 | > 8.0 $ft^3$ (Case Volume) | | | | | | |

## 5 MARKUPS AND PROFITABILITY

One of the primary objectives of the MIA is to assess the impact of amended energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how amended energy conservation standards would impact your company's markup structure and profitability.

DOE will estimate the manufacturer production costs for each product classes of residential dehumidifiers. DOE defines manufacturer production cost as all direct costs associated with manufacturing a product: direct labor, direct materials, overhead, and 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 times 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.

**DOE estimated a baseline markup of 1.43 for residential dehumidifiers.**

5.1 Is the 1.43 baseline markup representative of an average industry markup?

5.2 Please comment on the baseline markups DOE calculated as compared to your company's baseline markups for the dehumidifier product classes. How would revised standards potentially impact your baseline markups and margins for each product class?

**Table 5.5 Portable Dehumidifier Baseline Manufacturer Markups by Product Class**

| Product Class | Product Type | Estimated Baseline Markup | Manufacturer Comments or Revised Estimates |
|---|---|---|---|
| 1 | 20.00 pints/day or less** | 1.43 | |
| 2 | 20.01–30.00 pints/day | 1.43 | |
| 3 | 30.01–35.00 pints/day | 1.43 | |
| 4 | 35.01–45.00 pints/day | 1.43 | |
| 5 | 45.01 pints/day or more | 1.43 | |

**Table 5.6 Whole-Home Dehumidifier Baseline Manufacturer Markups by Product Class**

| Product Class | Product Type | Estimated Baseline Markup | Manufacturer Comments or Revised Estimates |
|---|---|---|---|
| 1 | <= 8.0 $ft^3$ (Case Volume) | 1.43 | |
| 2 | > 8.0 $ft^3$ (Case Volume) | 1.43 | |

5.3 DOE is interested in understanding if efficiency is a feature that earns a premium or whether it would cut into profit margins (and reduce markups). Within each product class, would markups vary by efficiency level? If yes, please provide estimates for your markups by product class and efficiency level in Table 5.3 and Table 5.4.

**Table 5.7 Estimated Markups for Portable Dehumidifiers**

| Efficiency Level | Efficiency Level Source | Integrated Energy Factor Efficiency Levels (*L/kWh*) | | | | |
|---|---|---|---|---|---|---|
| | | 20.00 pints/day or less | 20.01–30.00 pints/day | 30.01–35.00 pints/day | 35.01–45.00 pints/day | 45.01 pints/day or more |
| 1 | DOE Standard with no Fan-only Mode | | | | | |
| 2 | Gap Fill 1 | | | | | |
| 3 | Gap Fill 2 | | | | | |
| 4 | Maximum Available | | | | | |

**Table 5.8 Estimated Markups for Whole-Home Dehumidifiers**

| Efficiency Level | Efficiency Level Source | Integrated Energy Factor Efficiency Levels *(L/kWh)* | |
|---|---|---|---|
| | | Less than or equal to 8.0 $ft^3$ (Case Volume) | Greater than 8.0 $ft^3$ (Case Volume) |
| 1 | Gap Fill 1 | | |
| 2 | Gap Fill 2/Maximum Available | | |
| 3 | Maximum Available | | |

5.4 What factors or product attributes besides efficiency affect the profitability of dehumidifiers within a product class?

5.5 Would you expect changes in your estimated profitability following an amended energy conservation standard? If so, please explain why.

## 6 FINANCIAL PARAMETERS

DOE's contractor has developed a draft model of the dehumidifier industry financial performance called the Government Regulatory Impact Model (GRIM), using publicly available data. However, this public information might not be reflective of manufacturing at the dehumidifier profit center. This section attempts to understand the financial parameters for dehumidifier manufacturing and how your company's financial situation could differ from the industry aggregate picture.

6.1 In order to accurately collect information about dehumidifier manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

**1.**

**Table 6.9 Financial Parameters for Residential Dehumidifier 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) | 31.1% | |
| Discount Rate | Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity) | 8.4% | |
| Working Capital | Current assets less current liabilities (percentage of revenues) | 20.1% | |
| Net PPE | Net plant property and equipment (percentage of revenues) | 13.4% | |
| SG&A | Selling, general, and administrative expenses (percentage of revenues) | 20.9% | |
| R&D | Research and development expenses (percentage of revenues) | 1.3% | |
| Depreciation | Amortization of fixed assets (percentage of revenues) | 2.5% | |
| 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) | 71.7% | |

6.2 Relative to the sale of dehumidifiers, do you typically pay for shipping costs? Does the customer reimburse you for some or all of the costs associated with the shipment of your dehumidifier products?

6.3 DOE accounts for one time product and capital conversion costs including research and development, as well as capital expenditures for facility changes and the depreciation of these fixed assets. Beyond these short term changes in cost structure, how would you expect an amended energy conservation standard to impact any of the financial parameters for the industry over time?

## 7 CONVERSION COSTS

Amended energy conservation standards may cause your company to incur capital and product conversion costs to redesign existing products and make changes to existing production lines to be compliant with the amended energy conservation standard. Depending on their magnitude, the conversion costs can have a substantial impact on the outputs used by DOE to evaluate the industry impacts. Understanding the nature and magnitude of the conversion costs is critical portion of the MIA. 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 and certification, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.

CAPITAL CONVERSION COSTS

7.1 Please provide estimates for your capital conversion costs by product class and efficiency level in Table 7.1 through Table 7.7. 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, etc. that would be required to implement the specified design changes.

For each of the product categories, please note which efficiency level changes could be made within existing platform designs and which would result in major product redesigns. Also note which design options would require only minor changes to production lines, and which would require major changes to production lines, substantial modifications to existing facilities, or the development of entirely new manufacturing facilities.

*Portable Dehumidifiers*

**Table 7.10 Expected Capital Conversion Costs for Portable Dehumidifiers – 20.00 pints/day of less**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.10 | | |
| 2 | 1.20 | | |
| 3 | 1.30 | | |
| 4 | 1.42 | | |

**Table 7.11 Expected Capital Conversion Costs for Portable Dehumidifiers – 20.01 to 30.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.10 | | |
| 2 | 1.20 | | |
| 3 | 1.30 | | |
| 4 | 1.52 | | |

**Table 7.12 Expected Capital Conversion Costs for Portable Dehumidifiers – 30.01 to 35.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.20 | | |
| 2 | 1.40 | | |
| 3 | 1.60 | | |
| 4 | 1.75 | | |

**Table 7.13 Expected Capital Conversion Costs for Portable Dehumidifiers – 35.01 to 45.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.30 | | |
| 2 | 1.40 | | |
| 3 | 1.60 | | |
| 4 | 1.75 | | |

**Table 7.14 Expected Capital Conversion Costs for Portable Dehumidifiers – 45.01 pints/day or more**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 2.40 | | |
| 2 | 2.80 | | |
| 3 | 3.52 | | |
| 4 | N/A | | |

*Whole-Home Dehumidifiers*

**Table 7.15 Expected Capital Conversion Costs for Whole-Home Dehumidifiers - Less than or equal to 8.0 ft$^3$**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.40 | | |
| 2 | 1.59 | | |
| 3 | N/A | | |

**Table 7.16 Expected Capital Conversion Costs for Whole-Home Dehumidifiers - 8.0 ft$^3$ or more**

| Efficiency Level | IEF *L/kwh* | Total Capital Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.90 | | |
| 2 | 2.80 | | |
| 3 | 3.41 | | |

PRODUCT CONVERSION COSTS

7.2 What level of product conversion costs would you expect to incur at each of these efficiency levels for each product class? Please provide your estimates in Table 7.8 through Table 7.14 (where applicable) considering such expenses as product development expenses, prototyping, testing, certification, and marketing [if you have not previously certified your products with the DOE, please be sure to breakout an estimate of the costs associated with testing and certification, if possible]. In the description column, please describe the assumptions behind the estimates provided.

*Portable Dehumidifiers*

**Table 7.17 Expected Product Conversion Costs for Portable Dehumidifiers – 20.00 pints/day of less**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.10 | | |
| 2 | 1.20 | | |
| 3 | 1.30 | | |
| 4 | 1.42 | | |

**Table 7.18 Expected Product Conversion Costs for Portable Dehumidifiers – 20.01 to 30.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.10 | | |
| 2 | 1.20 | | |
| 3 | 1.30 | | |
| 4 | 1.52 | | |

**Table 7.19 Expected Product Conversion Costs for Portable Dehumidifiers – 30.01 to 35.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.20 | | |
| 2 | 1.40 | | |
| 3 | 1.60 | | |
| 4 | 1.75 | | |

**Table 7.20 Expected Product Conversion Costs for Portable Dehumidifiers – 35.01 to 45.00 pints/day**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.30 | | |
| 2 | 1.40 | | |
| 3 | 1.60 | | |
| 4 | 1.75 | | |

**Table 7.21 Expected Product Conversion Costs for Portable Dehumidifiers – 45.01 pints/day or more**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 2.40 | | |
| 2 | 2.80 | | |
| 3 | 3.52 | | |
| 4 | N/A | | |

*Whole-Home Dehumidifiers*

**Table 7.22 Expected Product Conversion Costs for Whole-Home Dehumidifiers - Less than or equal to 8.0 $ft^3$**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.40 | | |
| 2 | 1.59 | | |
| 3 | N/A | | |

**Table 7.23 Expected Product Conversion Costs for Whole-Home Dehumidifiers - 8.0 $ft^3$ or more**

| Efficiency Level | IEF *L/kwh* | Total Product Conversion Costs | Description |
|---|---|---|---|
| 1 | 1.90 | | |
| 2 | 2.80 | | |
| 3 | 3.41 | | |

## 8 DIRECT EMPLOYMENT IMPACT ASSESSMENT AND MANUFACTURING CAPACITY

8.1 Where are your dehumidifier manufacturing facilities that produce products for the United States located? What types of products are manufactured at each location? Please provide employment levels and annual shipment figures for your company's dehumidifier manufacturing at each location by product class.

**Table 8.24 Dehumidifiers Employment and Shipment Volumes by Product Class***

| Facility | Location | Product Types Manufactured | Employees | Annual Shipments |
|---|---|---|---|---|
| *Example* | *Sheboygan, WI* | *Portable dehumidifiers* | *200* | *100,000* |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

*For manufacturing facilities that produce products for the U.S.

8.2 Would your domestic employment levels be expected to change significantly under amended energy conservation standards? If so, please explain how they would change if higher efficiency levels are required.

8.3 How would amended energy conservation standards impact your company's manufacturing capacity? How much, if any, downtime would be required?

8.4 What percentage of your company's overall dehumidifier sales is made within the United States?

8.5 Would amended energy conservation standards impact your domestic vs. foreign manufacturing or sourcing decisions? Is there an efficiency level that would cause you to move domestic production facilities outside the U.S.?

## 9 IMPACTS ON SMALL BUSINESS

9.1 The Small Business Administration (SBA) denotes a small business in the dehumidifier manufacturing industry as having less than 750 total employees, including the parent company and all subsidiaries.[a] By this definition, is your company considered a small business?

9.2 Are there any reasons that a small business manufacturer might be at a disadvantage relative to a larger business under amended energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

9.3 To your knowledge, are there any small businesses, niche manufacturers or component manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, why?

[a] DOE uses the small business size standards published on January 1, 2012, as amended, by the SBA to determine whether a company is a small business. The products covered by this rulemaking are classified under NAICS codes 333415: Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing and 335210: Small Electrical Appliance Manufacturing. To be categorized as a small business, a manufacturer (and its affiliates) classified by one of these NAICS codes may employ a maximum of 750 employees. The 750 employee threshold includes all employees in a business's parent company and any other subsidiaries.

# APPENDIX 12B. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

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# APPENDIX 12B. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

## 12B.1 INTRODUCTION AND PURPOSE

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards on manufacturers. The basic mode of analysis is to estimate the change in value of the industry 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 annual cash flows and then determines the present value of those cash flows both without an amended 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.

## 12B.2 MODEL DESCRIPTION

The basic structure of the GRIM is a standard annual cash flow analysis that uses manufacturer selling prices, manufacturing costs, a shipments forecast, and financial parameters as inputs and accepts a set of regulatory conditions such as changes in costs and investments. The analysis is separated into two major sections: 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 12.B.3).

*Unit Sales:* Total annual shipments for the industry were obtained from the National Impact Analysis Spreadsheet;

*Revenues:* Annual revenues - computed by multiplying unit prices 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 *Revenues*. While included in overhead, the depreciation is shown as a separate line item;

*Stranded Assets:* In the compliance year of the standard, a one-time write-off of net property, plant, and equipment (PPE) assets to account for the book value of these assets that would have enjoyed a longer life if not for the standard;

*Standard SG&A:* Selling, general, and administrative costs are computed as a percentage of *Revenues*;

*R&D:* the GRIM separately accounts for ordinary research and development (R&D) as a percentage of *Revenues*;

*Product Conversion Costs:* Product conversion costs are one-time investments in research, development, testing, marketing, and other costs focused on making equipment designs comply with the new energy conservation standard. The GRIM allocates these costs over the period between the standard's announcement and the effective date;

*Earnings Before Interest and Taxes (EBIT):* Includes profit before deductions for interest paid and taxes;

*EBIT as a Percentage of Sales (EBIT/Revenues):* the GRIM calculates EBIT as a percentage of sales to compare with the industry's average reported in financial statements;

*Taxes:* Taxes on *EBIT* are calculated by multiplying the tax rate contained in Major Assumptions by *EBIT*;

*Net Operating Profits After Taxes (NOPAT):* Computed by subtracting *Cost of Goods Sold*, *SG&A*, *R&D*, *Product Conversion Costs*, and *Taxes* from *Revenues*;

*NOPAT repeated*: NOPAT is repeated in the Statement of Cash Flows;

*Depreciation repeated*: Depreciation and Stranded Assets are added back in the Statement of Cash Flows because they 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*, adding back non-cash items such as a *Depreciation*, and subtracting out *Change in Working Capital*;

*Ordinary Capital Expenditures:* Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of *Revenues*;

*Capital Conversion Costs:* Capital conversion costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new product designs can be fabricated and assembled under the new regulation;

*Capital Investment:* Total investments in property, plant, and equipment are computed by adding *Ordinary Capital Expenditures* and *Capital Conversion Costs*;

*Free Cash Flow:* Annual cash flow from operations and investments; computed by subtracting *Capital Investment* from *Cash Flow from Operations*;

*Terminal Value:* Estimate of the continuing value of the industry after 2048. Computed by growing the Free Cash Flow in year 2048 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* multiplied by the *Present Value Factor*. For 2048 the discounted cash flow includes the discounted *Terminal Value*; and

*Industry Value thru 2047:* The sum of *Discounted Cash Flows*.

## 12B.3 DETAILED CASH FLOW EXAMPLE

| | | Base Yr | Ancmt Yr | | | Std Yr | |
|---|---|---|---|---|---|---|---|
| **Industry Income Statement (in 2013$ millions)** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** |
| Revenues | $ 361.4 | $ 383.5 | $ 401.2 | $ 411.7 | $ 414.1 | $ 422.4 | $ 413.1 |
| Total Shipments *(million units)* | 1.668 | 1.775 | 1.870 | 1.942 | 1.986 | 2.004 | 2.004 |
| - Materials | $ 210.6 | $ 222.8 | $ 232.5 | $ 238.1 | $ 239.2 | $ 245.1 | $ 239.7 |
| - Labor | $ 12.1 | $ 13.3 | $ 14.4 | $ 15.1 | $ 15.4 | $ 15.6 | $ 15.2 |
| - Depreciation | $ 8.9 | $ 9.4 | $ 9.9 | $ 10.1 | $ 10.2 | $ 10.4 | $ 10.2 |
| - Overhead | $ 17.7 | $ 18.9 | $ 20.0 | $ 20.6 | $ 20.8 | $ 20.3 | $ 19.8 |
| - Standard SG&A | $ 86.0 | $ 91.3 | $ 95.5 | $ 98.0 | $ 98.5 | $ 100.5 | $ 98.3 |
| - R&D | $ 4.7 | $ 5.0 | $ 5.2 | $ 5.4 | $ 5.4 | $ 5.5 | $ 5.4 |
| - Product Conversion Costs | $ - | $ - | $ 5.9 | $ 10.4 | $ 13.3 | $ 0.6 | $ - |
| - Stranded Assets | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Earnings Before Interest and Taxes (EBIT) | $ 21.4 | $ 22.8 | $ 17.9 | $ 14.1 | $ 11.2 | $ 24.5 | $ 24.5 |
| Per Unit EBIT *($/unit)* | $ 12.86 | $ 12.82 | $ 9.56 | $ 7.24 | $ 5.67 | $ 12.21 | $ 12.23 |
| *EBIT/Revenues (%)* | *5.9%* | *5.9%* | *4.5%* | *3.4%* | *2.7%* | *5.8%* | *5.9%* |
| - Taxes | $ 6.7 | $ 7.1 | $ 5.6 | $ 4.4 | $ 3.5 | $ 7.6 | $ 7.6 |
| **Net Operating Profit after Taxes (NOPAT)** | **$ 14.8** | **$ 15.7** | **$ 12.3** | **$ 9.7** | **$ 7.8** | **$ 16.9** | **$ 16.9** |

| **Cash Flow Statement** | | | | | | | |
|---|---|---|---|---|---|---|---|
| NOPAT | $ 14.8 | $ 15.7 | $ 12.3 | $ 9.7 | $ 7.8 | $ 16.9 | $ 16.9 |
| + Depreciation | $ 8.9 | $ 9.4 | $ 9.9 | $ 10.1 | $ 10.2 | $ 10.4 | $ 10.2 |
| + Loss on Disposal of Stranded Assets | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| - Change in Working Capital | $ - | $ 2.5 | $ 2.0 | $ 1.2 | $ 0.3 | $ 0.9 | $ (1.1) |
| Cash Flows from Operations | $ 23.7 | $ 22.6 | $ 20.2 | $ 18.6 | $ 17.7 | $ 26.3 | $ 28.1 |
| - Ordinary Capital Expenditures | $ 9.6 | $ 10.2 | $ 10.6 | $ 10.9 | $ 11.0 | $ 11.2 | $ 10.9 |
| - Capital Conversion Costs | $ - | $ - | $ 4.1 | $ 7.2 | $ 9.2 | $ - | $ - |
| **Free Cash Flow** | **$ 14.1** | **$ 12.5** | **$ 5.5** | **$ 0.6** | **$ (2.5)** | **$ 15.1** | **$ 17.2** |

| **Discounted Cash Flow** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Free Cash Flow | $ 14.1 | $ 12.5 | $ 5.5 | $ 0.6 | $ (2.5) | $ 15.1 | $ 17.2 |
| Terminal Value | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| *Present Value Factor* | *0.000* | *1.000* | *0.922* | *0.851* | *0.784* | *0.723* | *0.667* |
| Discounted Cash Flow | **$ -** | **$ 12.5** | **$ 5.0** | **$ 0.5** | **$ (2.0)** | **$ 10.9** | **$ 11.5** |

| | |
|---|---|
| **INPV at TSL 3** | **$ 155.8** |

# APPENDIX 14A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

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# APPENDIX 14A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866[a]

## 14A.1 EXECUTIVE SUMMARY

Under Executive Order 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the "social cost of carbon" (SCC) estimates presented here is to allow agencies to incorporate the social benefits of reducing carbon dioxide ($CO_2$) emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

This document presents a summary of the interagency process that developed these SCC estimates. Technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

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[a] Prepared by Interagency Working Group on Social Cost of Carbon, United States Government.
With participation by:
Council of Economic Advisers
Council on Environmental Quality
Department of Agriculture
Department of Commerce
Department of Energy
Department of Transportation
Environmental Protection Agency
National Economic Council
Office of Energy and Climate Change
Office of Management and Budget
Office of Science and Technology Policy
Department of the Treasury

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95$^{th}$ percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution.

**Table 14A.1.1 Social Cost of $CO_2$, 2010 – 2050 (in 2007 dollars)**

| | *Discount Rate* | | | |
|---|---|---|---|---|
| | 5% | 3% | 2.5% | 3% |
| Year | Avg | Avg | Avg | 95th |
| 2010 | 4.7 | 21.4 | 35.1 | 64.9 |
| 2015 | 5.7 | 23.8 | 38.4 | 72.8 |
| 2020 | 6.8 | 26.3 | 41.7 | 80.7 |
| 2025 | 8.2 | 29.6 | 45.9 | 90.4 |
| 2030 | 9.7 | 32.8 | 50.0 | 100.0 |
| 2035 | 11.2 | 36.0 | 54.2 | 109.7 |
| 2040 | 12.7 | 39.2 | 58.4 | 119.3 |
| 2045 | 14.2 | 42.1 | 61.7 | 127.8 |
| 2050 | 15.7 | 44.9 | 65.0 | 136.2 |

## 14A.2 MONETIZING CARBON DIOXIDE EMISSIONS

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. We report estimates of the SCC in dollars per metric ton of carbon dioxide throughout this document.[b]

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Under Executive

[b] In this document, we present all values of the SCC as the cost per metric ton of $CO_2$ emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of $CO_2$ and the mass of carbon is 3.67 (the molecular weight of $CO_2$ divided by the molecular weight of carbon = 44/12 = 3.67).

Order 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. Most federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the benefits from reduced (or costs from increased) emissions in any future year can be estimated by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions; we do not attempt to answer that question here.

An interagency group convened on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key inputs and assumptions in order to generate SCC estimates. Agencies that actively participated in the interagency process include the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury. This process was convened by the Council of Economic Advisers and the Office of Management and Budget, with active participation and regular input from the Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions that are grounded in the existing literature. In this way, key uncertainties and model differences can more transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are \$5, \$21, \$35, and \$65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socioeconomic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95$^{th}$ percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of $CO_2$ in 2015 and \$26 per ton of $CO_2$ in 2020. See section 14-A.9 for the full range of annual SCC estimates from 2010 to 2050.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, we have set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, we will continue to explore the issues raised in this document and consider public comments as part of the ongoing interagency process.

## 14A.3 SOCIAL COST OF CARBON VALUES USED IN PAST REGULATORY ANALYSES

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing carbon dioxide emissions. In the final model year 2011 CAFE rule, the Department of Transportation (DOT) used both a "domestic" SCC value of \$2 per ton of $CO_2$ and a "global" SCC value of \$33 per ton of $CO_2$ for 2007 emission reductions (in 2007 dollars), increasing both values at 2.4 percent per year. It also included a sensitivity analysis at \$80 per ton of $CO_2$. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in carbon dioxide emissions, while a global SCC value is meant to reflect the value of damages worldwide.

A 2008 regulation proposed by DOT assumed a domestic SCC value of \$7 per ton $CO_2$ (in 2006 dollars) for 2011 emission reductions (with a range of \$0-\$14 for sensitivity analysis), also increasing at 2.4 percent per year. A regulation finalized by DOE in October of 2008 used a domestic SCC range of \$0 to \$20 per ton $CO_2$ for 2007 emission reductions (in 2007 dollars). In addition, EPA's 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as "very preliminary" SCC estimates subject to revision. EPA's global mean values were \$68 and \$40 per ton $CO_2$ for discount rates of approximately 2 percent and 3 percent, respectively (in 2006 dollars for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced $CO_2$ emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted.

The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006 dollars) of \$55, \$33, \$19, \$10, and \$5 per ton of $CO_2$. The \$33 and \$5 values represented model-weighted means of the published estimates produced from the most recently available versions of three integrated assessment models—DICE, PAGE, and FUND—at approximately 3 and 5 percent discount rates. The \$55 and \$10 values were derived by adjusting the published estimates for uncertainty in the discount rate (using factors developed by Newell and Pizer (2003)) at 3 and 5 percent discount rates, respectively. The \$19 value was chosen as a central value between the \$5 and \$33 per ton estimates. All of these values were assumed to increase at 3 percent annually to represent growth in incremental damages over time as the magnitude of climate change increases.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and $CO_2$ tailpipe emission proposed rules.

## 14A.4 APPROACH AND KEY ASSUMPTIONS

Since the release of the interim values, the interagency group has reconvened on a regular basis to generate improved SCC estimates. Specifically, the group has considered public comments and further explored the technical literature in relevant fields. This section details the several choices and assumptions that underlie the resulting estimates of the SCC.

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable, since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Academy of Science (2009) points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. Throughout this document, we highlight a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC.

The U.S. Government will periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance. The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them and with a sincere promise to continue work to improve them.

### 14A.4.1 Integrated Assessment Models

We rely on three integrated assessment models (IAMs) commonly used to estimate the SCC: the FUND, DICE, and PAGE models.[c] These models are frequently cited in the peer-reviewed literature and used in the IPCC assessment. Each model is given equal weight in the SCC values developed through this process, bearing in mind their different limitations (discussed below).

[c] The DICE (Dynamic Integrated Climate and Economy) model by William Nordhaus evolved from a series of energy models and was first presented in 1990 (Nordhaus and Boyer 2000, Nordhaus 2008). The PAGE (Policy Analysis of the Greenhouse Effect) model was developed by Chris Hope in 1991 for use by European decision-makers in assessing the marginal impact of carbon emissions (Hope 2006, Hope 2008). The FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model, developed by Richard Tol in the early 1990s, originally to study international capital transfers in climate policy. is now widely used to study climate impacts (*e.g.*, Tol 2002a, Tol 2002b, Anthoff et al. 2009, Tol 2009).

These models are useful because they combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework. At the same time, they gain this advantage at the expense of a more detailed representation of the underlying climatic and economic systems. DICE, PAGE, and FUND all take stylized, reduced-form approaches (see NRC 2009 for a more detailed discussion; see Nordhaus 2008 on the possible advantages of this approach). Other IAMs may better reflect the complexity of the science in their modeling frameworks but do not link physical impacts to economic damages. There is currently a limited amount of research linking climate impacts to economic damages, which makes this exercise even more difficult. Underlying the three IAMs selected for this exercise are a number of simplifying assumptions and judgments reflecting the various modelers' best attempts to synthesize the available scientific and economic research characterizing these relationships.

The three IAMs translate emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. The emissions projections used in the models are based on specified socioeconomic (GDP and population) pathways. These emissions are translated into concentrations using the carbon cycle built into each model, and concentrations are translated into warming based on each model's simplified representation of the climate and a key parameter, climate sensitivity. Each model uses a different approach to translate warming into damages. Finally, transforming the stream of economic damages over time into a single value requires judgments about how to discount them.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. In PAGE, for example, the consumption-equivalent damages in each period are calculated as a fraction of GDP, depending on the temperature in that period relative to the pre-industrial average temperature in each region. In FUND, damages in each period also depend on the rate of temperature change from the prior period. In DICE, temperature affects both consumption and investment. We describe each model in greater detail here. In a later section, we discuss key gaps in how the models account for various scientific and economic processes (*e.g.* the probability of catastrophe, and the ability to adapt to climate change and the physical changes it causes).

The parameters and assumptions embedded in the three models vary widely. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches to quantifying damages taken by the key modelers in the field. An extensive review of the literature was conducted to select three sets of input parameters for these models: climate sensitivity, socioeconomic and emissions trajectories, and discount rates. A probability distribution for climate sensitivity was specified as an input into all three models. In addition, the interagency group used a range of scenarios for the socioeconomic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments. In DICE, these parameters are handled deterministically and represented by fixed constants; in PAGE, most parameters are represented by probability distributions. FUND was also run in a mode in which parameters were treated probabilistically.

The sensitivity of the results to other aspects of the models (*e.g.* the carbon cycle or damage function) is also important to explore in the context of future revisions to the SCC but has not been incorporated into these estimates. Areas for future research are highlighted at the end of this document.

*The DICE Model*

The DICE model is an optimal growth model based on a global production function with an extra stock variable (atmospheric carbon dioxide concentrations). Emission reductions are treated as analogous to investment in "natural capital." By investing in natural capital today through reductions in emissions—implying reduced consumption—harmful effects of climate change can be avoided and future consumption thereby increased.

For purposes of estimating the SCC, carbon dioxide emissions are a function of global GDP and the carbon intensity of economic output, with the latter declining over time due to technological progress. The DICE damage function links global average temperature to the overall impact on the world economy. It varies quadratically with temperature change to capture the more rapid increase in damages expected to occur under more extreme climate change, and is calibrated to include the effects of warming on the production of market and nonmarket goods and services. It incorporates impacts on agriculture, coastal areas (due to sea level rise), "other vulnerable market sectors" (based primarily on changes in energy use), human health (based on climate-related diseases, such as malaria and dengue fever, and pollution), non-market amenities (based on outdoor recreation), and human settlements and ecosystems. The DICE damage function also includes the expected value of damages associated with low probability, high impact "catastrophic" climate change. This last component is calibrated based on a survey of experts (Nordhaus 1994). The expected value of these impacts is then added to the other market and non-market impacts mentioned above.

No structural components of the DICE model represent adaptation explicitly, though it is included implicitly through the choice of studies used to calibrate the aggregate damage function. For example, its agricultural impact estimates assume that farmers can adjust land use decisions in response to changing climate conditions, and its health impact estimates assume improvements in healthcare over time. In addition, the small impacts on forestry, water systems, construction, fisheries, and outdoor recreation imply optimistic and costless adaptation in these sectors (Nordhaus and Boyer, 2000; Warren et al., 2006). Costs of resettlement due to sea level rise are incorporated into damage estimates, but their magnitude is not clearly reported. Mastrandrea's (2009) review concludes that "in general, DICE assumes very effective adaptation, and largely ignores adaptation costs."

Note that the damage function in DICE has a somewhat different meaning from the damage functions in FUND and PAGE. Because GDP is endogenous in DICE and because damages in a given year reduce investment in that year, damages propagate forward in time and reduce GDP in future years. In contrast, GDP is exogenous in FUND and PAGE, so damages in any given year do not propagate forward.[d]

*The PAGE Model*

PAGE2002 (version 1.4epm) treats GDP growth as exogenous. It divides impacts into economic, non-economic, and catastrophic categories and calculates these impacts separately for eight geographic regions. Damages in each region are expressed as a fraction of output, where the fraction lost depends on the temperature change in each region. Damages are expressed as power functions of temperature change. The exponents of the damage function are the same in all regions but are treated as uncertain, with values ranging from 1 to 3 (instead of being fixed at 2 as in DICE).

PAGE2002 includes the consequences of catastrophic events in a separate damage sub-function. Unlike DICE, PAGE2002 models these events probabilistically. The probability of a "discontinuity" (*i.e.*, a catastrophic event) is assumed to increase with temperature above a specified threshold. The threshold temperature, the rate at which the probability of experiencing a discontinuity increases above the threshold, and the magnitude of the resulting catastrophe are all modeled probabilistically.

Adaptation is explicitly included in PAGE. Impacts are assumed to occur for temperature increases above some tolerable level (2°C for developed countries and 0°C for developing countries for economic impacts, and 0°C for all regions for non-economic impacts), but adaptation is assumed to reduce these impacts. Default values in PAGE2002 assume that the developed countries can ultimately eliminate up to 90 percent of all economic impacts beyond the tolerable 2°C increase and that developing countries can eventually eliminate 50 percent of their economic impacts. All regions are assumed to be able to mitigate 25 percent of the non-economic impacts through adaptation (Hope 2006).

*The FUND Model*

Like PAGE, the FUND model treats GDP growth as exogenous. It includes separately calibrated damage functions for eight market and nonmarket sectors: agriculture, forestry, water, energy (based on heating and cooling demand), sea level rise (based on the value of land lost and the cost of protection), ecosystems, human health (diarrhea, vector-borne diseases, and cardiovascular and respiratory mortality), and extreme weather. Each impact sector has a different functional form, and is calculated separately for sixteen geographic regions. In some impact sectors, the fraction of output lost or gained due to climate change depends not only on

[d] Using the default assumptions in DICE 2007, this effect generates an approximately 25 percent increase in the SCC relative to damages calculated by fixing GDP. In DICE2007, the time path of GDP is endogenous. Specifically, the path of GDP depends on the rate of saving and level of abatement in each period chosen by the optimizing representative agent in the model. We made two modifications to DICE to make it consistent with EMF GDP trajectories (see next section): we assumed a fixed rate of savings of 20%, and we re-calibrated the exogenous path of total factor productivity so that DICE would produce GDP projections in the absence of warming that exactly matched the EMF scenarios.

the absolute temperature change but also on the rate of temperature change and level of regional income.[e] In the forestry and agricultural sectors, economic damages also depend on $CO_2$ concentrations.

Tol (2009) discusses impacts not included in FUND, noting that many are likely to have a relatively small effect on damage estimates (both positive and negative). However, he characterizes several omitted impacts as "big unknowns": for instance, extreme climate scenarios, biodiversity loss, and effects on economic development and political violence. With regard to potentially catastrophic events, he notes, "Exactly what would cause these sorts of changes or what effects they would have are not well-understood, although the chance of any one of them happening seems low. But they do have the potential to happen relatively quickly, and if they did, the costs could be substantial. Only a few studies of climate change have examined these issues."

Adaptation is included both implicitly and explicitly in FUND. Explicit adaptation is seen in the agriculture and sea level rise sectors. Implicit adaptation is included in sectors such as energy and human health, where wealthier populations are assumed to be less vulnerable to climate impacts. For example, the damages to agriculture are the sum of three effects: (1) those due to the rate of temperature change (damages are always positive); (2) those due to the level of temperature change (damages can be positive or negative depending on region and temperature); and (3) those from $CO_2$ fertilization (damages are generally negative but diminishing to zero).

Adaptation is incorporated into FUND by allowing damages to be smaller if climate change happens more slowly. The combined effect of $CO_2$ fertilization in the agricultural sector, positive impacts to some regions from higher temperatures, and sufficiently slow increases in temperature across these sectors can result in negative economic damages from climate change.

*Damage Functions*

To generate revised SCC values, we rely on the IAM modelers' current best judgments of how to represent the effects of climate change (represented by the increase in global-average surface temperature) on the consumption-equivalent value of both market and non-market goods (represented as a fraction of global GDP). We recognize that these representations are incomplete and highly uncertain. But given the paucity of data linking the physical impacts to economic damages, we were not able to identify a better way to translate changes in climate into net economic damages, short of launching our own research program.

The damage functions for the three IAMs are presented in Figure 14A.4.1 and Figure 14A.4.2, using the modeler's default scenarios and mean input assumptions. There are significant differences between the three models both at lower (Figure 14A.4.2) and higher (Figure 14A.4.1) increases in global-average temperature.

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[e] In the deterministic version of FUND, the majority of damages are attributable to increased air conditioning demand, while reduced cold stress in Europe, North America, and Central and East Asia results in health benefits in those regions at low to moderate levels of warming (Warren et al., 2006).

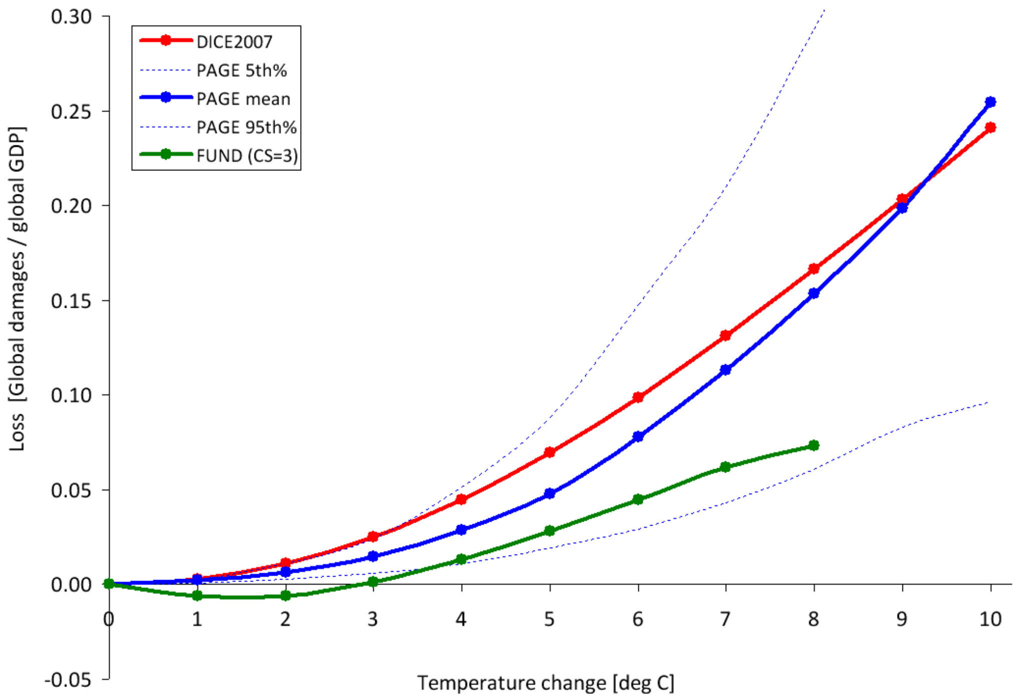


**Figure 14A.4.1 Annual Consumption Loss as a Fraction of Global GDP in 2100 Due to an Increase in Annual Global Temperature in the DICE, FUND, and PAGE models**[f]

The lack of agreement among the models at lower temperature increases is underscored by the fact that the damages from FUND are well below the 5th percentile estimated by PAGE, while the damages estimated by DICE are roughly equal to the 95th percentile estimated by PAGE. This is significant because at higher discount rates we expect that a greater proportion of the SCC value is due to damages in years with lower temperature increases. For example, when the discount rate is 2.5 percent, about 45 percent of the 2010 SCC value in DICE is due to damages that occur in years when the temperature is less than or equal to 3 °C. This increases to approximately 55 percent and 80 percent at discount rates of 3 and 5 percent, respectively.

These differences underscore the need for a thorough review of damage functions—in particular, how the models incorporate adaptation, technological change, and catastrophic damages. Gaps in the literature make modifying these aspects of the models challenging, which highlights the need for additional research. As knowledge improves, the Federal government is committed to exploring how these (and other) models can be modified to incorporate more accurate estimates of damages.

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[f] The x-axis represents increases in annual, rather than equilibrium, temperature, while the y-axis represents the annual stream of benefits as a share of global GDP. Each specific combination of climate sensitivity, socioeconomic, and emissions parameters will produce a different realization of damages for each IAM. The damage functions represented in Figures 1A and 1B are the outcome of default assumptions. For instance, under alternate assumptions, the damages from FUND may cross from negative to positive at less than or greater than 3 °C.

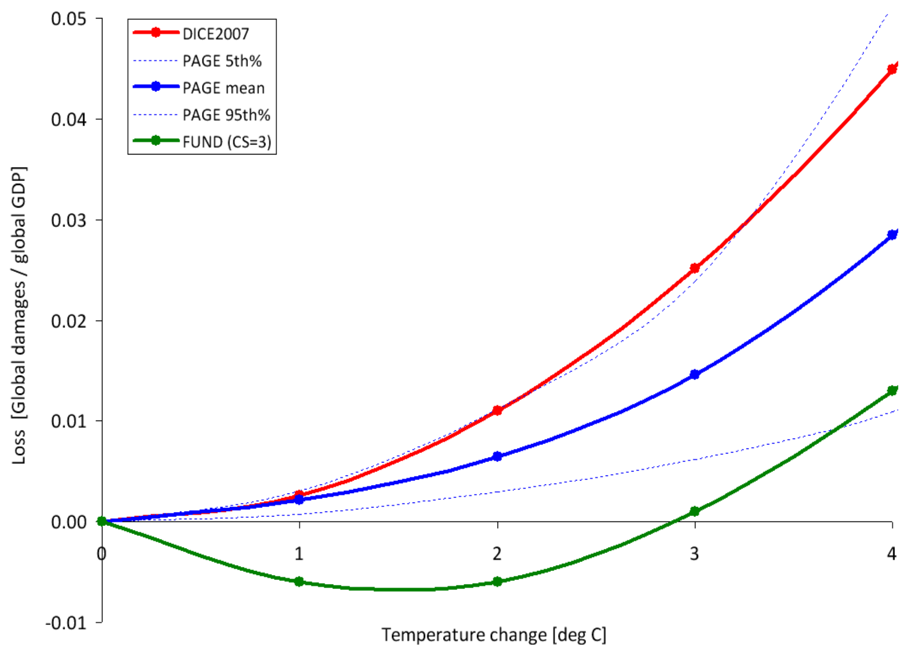


**Figure 14A.4.2 Annual Consumption Loss for Lower Temperature Changes in DICE, FUND, and PAGE**

### 14A.4.2 Global versus Domestic Measures of SCC

Because of the distinctive nature of the climate change problem, we center our current attention on a global measure of SCC. This approach is the same as that taken for the interim values, but it otherwise represents a departure from past practices, which tended to put greater emphasis on a domestic measure of SCC (limited to impacts of climate change experienced within U.S. borders). As a matter of law, consideration of both global and domestic values is generally permissible; the relevant statutory provisions are usually ambiguous and allow selection of either measure.[g]

*Global SCC*

Under current OMB guidance contained in Circular A-4, analysis of economically significant proposed and final regulations from the domestic perspective is required, while analysis from the international perspective is optional. However, the climate change problem is highly unusual in at least two respects. First, it involves a global externality: emissions of most greenhouse gases contribute to damages around the world even when they are emitted in the United States. Consequently, to address the global nature of the problem, the SCC must incorporate the full (global) damages caused by GHG emissions. Second, climate change

[g] It is true that federal statutes are presumed not to have extraterritorial effect, in part to ensure that the laws of the United States respect the interests of foreign sovereigns. But use of a global measure for the SCC does not give extraterritorial effect to federal law and hence does not intrude on such interests.

presents a problem that the United States alone cannot solve. Even if the United States were to reduce its greenhouse gas emissions to zero, that step would be far from enough to avoid substantial climate change. Other countries would also need to take action to reduce emissions if significant changes in the global climate are to be avoided. Emphasizing the need for a global solution to a global problem, the United States has been actively involved in seeking international agreements to reduce emissions and in encouraging other nations, including emerging major economies, to take significant steps to reduce emissions. When these considerations are taken as a whole, the interagency group concluded that a global measure of the benefits from reducing U.S. emissions is preferable.

When quantifying the damages associated with a change in emissions, a number of analysts (*e.g.*, Anthoff, et al. 2009a) employ "equity weighting" to aggregate changes in consumption across regions. This weighting takes into account the relative reductions in wealth in different regions of the world. A per-capita loss of $500 in GDP, for instance, is weighted more heavily in a country with a per-capita GDP of $2,000 than in one with a per-capita GDP of $40,000. The main argument for this approach is that a loss of $500 in a poor country causes a greater reduction in utility or welfare than does the same loss in a wealthy nation. Notwithstanding the theoretical claims on behalf of equity weighting, the interagency group concluded that this approach would not be appropriate for estimating a SCC value used in domestic regulatory analysis.[h] For this reason, the group concluded that using the global (rather than domestic) value, without equity weighting, is the appropriate approach.

*Domestic SCC*

As an empirical matter, the development of a domestic SCC is greatly complicated by the relatively few region- or country-specific estimates of the SCC in the literature. One potential source of estimates comes from the FUND model. The resulting estimates suggest that the ratio of domestic to global benefits of emission reductions varies with key parameter assumptions. For example, with a 2.5 or 3 percent discount rate, the U.S. benefit is about 7-10 percent of the global benefit, on average, across the scenarios analyzed. Alternatively, if the fraction of GDP lost due to climate change is assumed to be similar across countries, the domestic benefit would be proportional to the U.S. share of global GDP, which is currently about 23 percent.[i]

On the basis of this evidence, the interagency workgroup determined that a range of values from 7 to 23 percent should be used to adjust the global SCC to calculate domestic effects. Reported domestic values should use this range. It is recognized that these values are approximate, provisional, and highly speculative. There is no a priori reason why domestic benefits should be a constant fraction of net global damages over time. Further, FUND does not

[h] It is plausible that a loss of $X inflicts more serious harm on a poor nation than on a wealthy one, but development of the appropriate "equity weight" is challenging. Emissions reductions also impose costs, and hence a full account would have to consider that a given cost of emissions reductions imposes a greater utility or welfare loss on a poor nation than on a wealthy one. Even if equity weighting—for both the costs and benefits of emissions reductions—is appropriate when considering the utility or welfare effects of international action, the interagency group concluded that it should not be used in developing an SCC for use in regulatory policy at this time.
[i] Based on 2008 GDP (in current US dollars) from the *World Bank Development Indicators Report*.

account for how damages in other regions could affect the United States (*e.g.*, global migration, economic and political destabilization). If more accurate methods for calculating the domestic SCC become available, the Federal government will examine these to determine whether to update its approach.

### 14A.4.3 Valuing Non-$CO_2$ Emissions

While $CO_2$ is the most prevalent greenhouse gas emitted into the atmosphere, the U.S. included five other greenhouse gases in its recent endangerment finding: methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The climate impact of these gases is commonly discussed in terms of their 100-year global warming potential (GWP). GWP measures the ability of different gases to trap heat in the atmosphere (*i.e.*, radiative forcing per unit of mass) over a particular timeframe relative to $CO_2$. However, because these gases differ in both radiative forcing and atmospheric lifetimes, their relative damages are not constant over time. For example, because methane has a short lifetime, its impacts occur primarily in the near term and thus are not discounted as heavily as those caused by longer-lived gases. Impacts other than temperature change also vary across gases in ways that are not captured by GWP. For instance, $CO_2$ emissions, unlike methane and other greenhouse gases, contribute to ocean acidification. Likewise, damages from methane emissions are not offset by the positive effect of $CO_2$ fertilization. Thus, transforming gases into $CO_2$-equivalents using GWP, and then multiplying the carbon-equivalents by the SCC, would not result in accurate estimates of the social costs of non-$CO_2$ gases.

In light of these limitations, and the significant contributions of non-$CO_2$ emissions to climate change, further research is required to link non-$CO_2$ emissions to economic impacts. Such work would feed into efforts to develop a monetized value of reductions in non-$CO_2$ greenhouse gas emissions. As part of ongoing work to further improve the SCC estimates, the interagency group hopes to develop methods to value these other greenhouse gases. The goal is to develop these estimates by the time we issue revised SCC estimates for carbon dioxide emissions.

### 14A.4.4 Equilibrium Climate Sensitivity

Equilibrium climate sensitivity (ECS) is a key input parameter for the DICE, PAGE, and FUND models.[j] It is defined as the long-term increase in the annual global-average surface temperature from a doubling of atmospheric $CO_2$ concentration relative to pre-industrial levels (or stabilization at a concentration of approximately 550 parts per million (ppm)). Uncertainties in this important parameter have received substantial attention in the peer-reviewed literature.

The most authoritative statement about equilibrium climate sensitivity appears in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC):

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[j] The equilibrium climate sensitivity includes the response of the climate system to increased greenhouse gas concentrations over the short to medium term (up to 100-200 years), but it does not include long-term feedback effects due to possible large-scale changes in ice sheets or the biosphere, which occur on a time scale of many hundreds to thousands of years (*e.g.* Hansen et al. 2007).

*Basing our assessment on a combination of several independent lines of evidence…including observed climate change and the strength of known feedbacks simulated in [global climate models], we conclude that the global mean equilibrium warming for doubling $CO_2$, or 'equilibrium climate sensitivity', is likely to lie in the range 2 °C to 4.5 °C, with a most likely value of about 3 °C. Equilibrium climate sensitivity is very likely larger than 1.5 °C.* [k]

*For fundamental physical reasons as well as data limitations, values substantially higher than 4.5 °C still cannot be excluded, but agreement with observations and proxy data is generally worse for those high values than for values in the 2 °C to 4.5 °C range.* (Meehl et al., 2007, p 799)

After consulting with several lead authors of this chapter of the IPCC report, the interagency workgroup selected four candidate probability distributions and calibrated them to be consistent with the above statement: Roe and Baker (2007), log-normal, gamma, and Weibull. Table 14A.4.1 included below gives summary statistics for the four calibrated distributions.

**Table 14A.4.1 Summary Statistics for Four Calibrated Climate Sensitivity Distributions**

| | Roe & Baker | Log-normal | Gamma | Weibull |
|---|---|---|---|---|
| Pr(ECS < 1.5°C) | 0.013 | 0.050 | 0.070 | 0.102 |
| Pr(2°C < ECS < 4.5°C) | 0.667 | 0.667 | 0.667 | 0.667 |
| 5th percentile | 1.72 | 1.49 | 1.37 | 1.13 |
| 10th percentile | 1.91 | 1.74 | 1.65 | 1.48 |
| Mode | 2.34 | 2.52 | 2.65 | 2.90 |
| Median (50th percentile) | 3.00 | 3.00 | 3.00 | 3.00 |
| Mean | 3.50 | 3.28 | 3.19 | 3.07 |
| 90th percentile | 5.86 | 5.14 | 4.93 | 4.69 |
| 95th percentile | 7.14 | 5.97 | 5.59 | 5.17 |

Each distribution was calibrated by applying three constraints from the IPCC:

(1) a median equal to 3°C, to reflect the judgment of "a most likely value of about 3 °C";[l]

[k] This is in accord with the judgment that it "is likely to lie in the range 2 °C to 4.5 °C" and the IPCC definition of "likely" as greater than 66 percent probability (Le Treut et al.2007). "Very likely" indicates a greater than 90 percent probability.

[l] Strictly speaking, "most likely" refers to the mode of a distribution rather than the median, but common usage would allow the mode, median, or mean to serve as candidates for the central or "most likely" value and the IPCC report is not specific on this point. For the distributions we considered, the median was between the mode and the mean. For the Roe and Baker distribution, setting the median equal to 3°C, rather than the mode or mean, gave a 95th percentile that is more consistent with IPCC judgments and the literature. For example, setting the mean and mode equal to 3°C produced 95th percentiles of 5.6 and 8.6 °C, respectively, which are in the lower and upper end of the range in the literature. Finally, the median is closer to 3°C than is the mode for the truncated distributions selected by the IPCC (Hegerl, et al., 2006); the average median is 3.1 °C and the average mode is 2.3 °C, which is most consistent with a Roe and Baker distribution with the median set equal to 3 °C.

(2) two-thirds probability that the equilibrium climate sensitivity lies between 2 and 4.5 °C; and
(3) zero probability that it is less than 0°C or greater than 10°C (see Hegerl et al. 2006, p. 721).

We selected the calibrated Roe and Baker distribution from the four candidates for two reasons. First, the Roe and Baker distribution is the only one of the four that is based on a theoretical understanding of the response of the climate system to increased greenhouse gas concentrations (Roe and Baker 2007, Roe 2008). In contrast, the other three distributions are mathematical functions that are arbitrarily chosen based on simplicity, convenience, and general shape. The Roe and Baker distribution results from three assumptions about climate response: (1) absent feedback effects, the equilibrium climate sensitivity is equal to 1.2 °C; (2) feedback factors are proportional to the change in surface temperature; and (3) uncertainties in feedback factors are normally distributed. There is widespread agreement on the first point and the second and third points are common assumptions.

Second, the calibrated Roe and Baker distribution better reflects the IPCC judgment that "values substantially higher than 4.5°C still cannot be excluded." Although the IPCC made no quantitative judgment, the 95$^{th}$ percentile of the calibrated Roe & Baker distribution (7.1 °C) is much closer to the mean and the median (7.2 °C) of the 95$^{th}$ percentiles of 21 previous studies summarized by Newbold and Daigneault (2009). It is also closer to the mean (7.5 °C) and median (7.9 °C) of the nine truncated distributions examined by the IPCC (Hegerl, et al., 2006) than are the 95$^{th}$ percentiles of the three other calibrated distributions (5.2-6.0 °C).

Finally, we note the IPCC judgment that the equilibrium climate sensitivity "is very likely larger than 1.5°C." Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5 °C is almost 99 percent, is not inconsistent with the IPCC definition of "very likely" as "greater than 90 percent probability," it reflects a greater degree of certainty about very low values of ECS than was expressed by the IPCC.

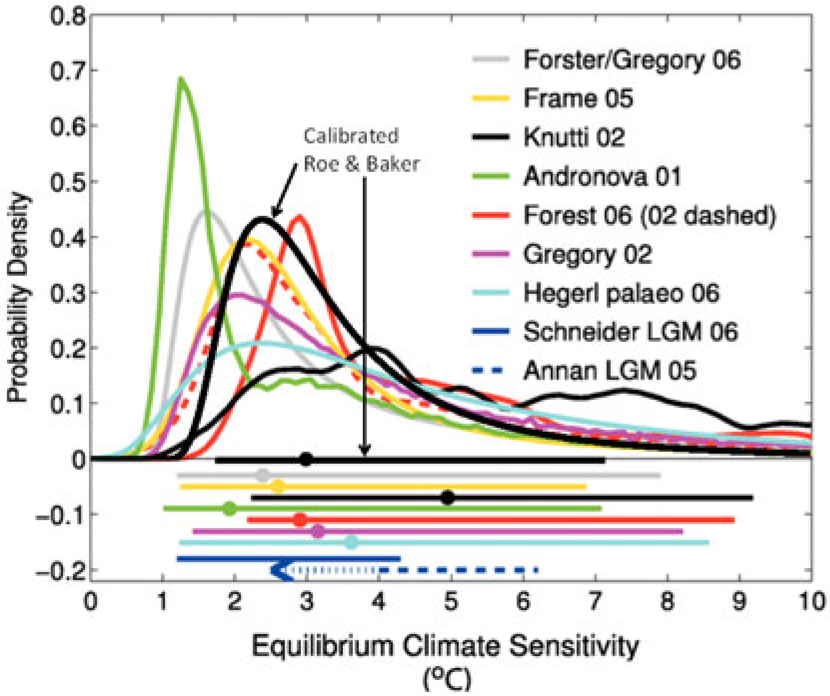


**Figure 14A.4.3 Estimates of the Probability Density Function for Equilibrium Climate Sensitivity (°C)**

To show how the calibrated Roe and Baker distribution compares to different estimates of the probability distribution function of equilibrium climate sensitivity in the empirical literature, Figure 14A.4.3 (above) overlays it on Figure 9.20 from the IPCC Fourth Assessment Report. These functions are scaled to integrate to unity between 0 °C and 10 °C. The horizontal bars show the respective 5 percent to 95 percent ranges; dots indicate the median estimate.[m]

### 14A.4.5 Socioeconomic and Emissions Trajectories

Another key issue considered by the interagency group is how to select the set of socioeconomic and emissions parameters for use in PAGE, DICE, and FUND. Socioeconomic pathways are closely tied to climate damages because, all else equal, more and wealthier people tend to emit more greenhouse gases and also have a higher (absolute) willingness to pay to avoid climate disruptions. For this reason, we consider how to model several input parameters in tandem: GDP, population, $CO_2$ emissions, and non-$CO_2$ radiative forcing. A wide variety of scenarios have been developed and used for climate change policy simulations (*e.g.*, SRES 2000, CCSP 2007, EMF 2009). In determining which scenarios are appropriate for inclusion, we aimed to select scenarios that span most of the plausible ranges of outcomes for these variables.

[m] The estimates based on instrumental data are from Andronova and Schlesinger (2001), Forest et al. (2002; dashed line, anthropogenic forcings only), Forest et al. (2006; solid line, anthropogenic and natural forcings), Gregory et al. (2002a), Knutti et al. (2002), Frame et al. (2005), and Forster and Gregory (2006). Hegerl et al. (2006) are based on multiple palaeoclimatic reconstructions of north hemisphere mean temperatures over the last 700 years. Also shown are the 5-95 percent approximate ranges for two estimates from the last glacial maximum (dashed, Annan et al. 2005; solid, Schneider von Deimling et al. 2006), which are based on models with different structural properties.

To accomplish this task in a transparent way, we decided to rely on the recent Stanford Energy Modeling Forum exercise, EMF-22. EMF-22 uses ten well-recognized models to evaluate substantial, coordinated global action to meet specific stabilization targets. A key advantage of relying on these data is that GDP, population, and emission trajectories are internally consistent for each model and scenario evaluated. The EMF-22 modeling effort also is preferable to the IPCC SRES due to their age (SRES were developed in 1997) and the fact that 3 of 4 of the SRES scenarios are now extreme outliers in one or more variables. Although the EMF-22 scenarios have not undergone the same level of scrutiny as the SRES scenarios, they are recent, peer-reviewed, published, and publicly available.

To estimate the SCC for use in evaluating domestic policies that will have a small effect on global cumulative emissions, we use socioeconomic and emission trajectories that span a range of plausible scenarios. Five trajectories were selected from EMF-22 (see Table 14A.4.2 below). Four of these represent potential business-as-usual (BAU) growth in population, wealth, and emissions and are associated with $CO_2$ (only) concentrations ranging from 612 to 889 ppm in 2100. One represents an emissions pathway that achieves stabilization at 550 ppm $CO_2$e (i*i.e.*, $CO_2$-only concentrations of 425 – 484 ppm or a radiative forcing of 3.7 W/m$^2$) in 2100, a lower-than-BAU trajectory.[n] Out of the 10 models included in the EMF-22 exercise, we selected the trajectories used by MiniCAM, MESSAGE, IMAGE, and the optimistic scenario from MERGE. For the BAU pathways, we used the GDP, population, and emission trajectories from each of these four models. For the 550 ppm $CO_2$e scenario, we averaged the GDP, population, and emission trajectories implied by these same four models.

[n] Such an emissions path would be consistent with widespread action by countries to mitigate GHG emissions, though it could also result from technological advances. It was chosen because it represents the most stringent case analyzed by the EMF-22 where all the models converge: a 550 ppm, not to exceed, full participation scenario.

**Table 14A.4.2 Socioeconomic and Emissions Projections from Select EMF-22 Reference Scenarios**

**Reference Fossil and Industrial $CO_2$ Emissions ($GtCO_2$/yr)**

| EMF – 22 Based Scenarios | 2000 | 2010 | 2020 | 2030 | 2050 | 2100 |
|---|---|---|---|---|---|---|
| IMAGE | 26.6 | 31.9 | 36.9 | 40.0 | 45.3 | 60.1 |
| MERGE Optimistic | 24.6 | 31.5 | 37.6 | 45.1 | 66.5 | 117.9 |
| MESSAGE | 26.8 | 29.2 | 37.6 | 42.1 | 43.5 | 42.7 |
| MiniCAM | 26.5 | 31.8 | 38.0 | 45.1 | 57.8 | 80.5 |
| 550 ppm average | 26.2 | 31.1 | 33.2 | 32.4 | 20.0 | 12.8 |

**Reference GDP (using market exchange rates in trillion 2005$)[o]**

| EMF – 22 Based Scenarios | 2000 | 2010 | 2020 | 2030 | 2050 | 2100 |
|---|---|---|---|---|---|---|
| IMAGE | 38.6 | 53.0 | 73.5 | 97.2 | 156.3 | 396.6 |
| MERGE Optimistic | 36.3 | 45.9 | 59.7 | 76.8 | 122.7 | 268.0 |
| MESSAGE | 38.1 | 52.3 | 69.4 | 91.4 | 153.7 | 334.9 |
| MiniCAM | 36.1 | 47.4 | 60.8 | 78.9 | 125.7 | 369.5 |
| 550 ppm average | 37.1 | 49.6 | 65.6 | 85.5 | 137.4 | 337.9 |

**Global Population (billions)**

| EMF – 22 Based Scenarios | 2000 | 2010 | 2020 | 2030 | 2050 | 2100 |
|---|---|---|---|---|---|---|
| IMAGE | 6.1 | 6.9 | 7.6 | 8.2 | 9.0 | 9.1 |
| MERGE Optimistic | 6.0 | 6.8 | 7.5 | 8.2 | 9.0 | 9.7 |
| MESSAGE | 6.1 | 6.9 | 7.7 | 8.4 | 9.4 | 10.4 |
| MiniCAM | 6.0 | 6.8 | 7.5 | 8.1 | 8.8 | 8.7 |
| 550 ppm average | 6.1 | 6.8 | 7.6 | 8.2 | 8.7 | 9.1 |

We explore how sensitive the SCC is to various assumptions about how the future will evolve without prejudging what is likely to occur. The interagency group considered formally assigning probability weights to different states of the world, but this proved challenging to do in an analytically rigorous way given the dearth of information on the likelihood of a full range of future socioeconomic pathways.

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[o] While the EMF-22 models used market exchange rates (MER) to calculate global GDP, it is also possible to use purchasing power parity (PPP). PPP takes into account the different price levels across countries, so it more accurately describes relative standards of living across countries. MERs tend to make low-income countries appear poorer than they actually are. Because many models assume convergence in per capita income over time, use of MER-adjusted GDP gives rise to projections of higher economic growth in low income countries. There is an ongoing debate about how much this will affect estimated climate impacts. Critics of the use of MER argue that it leads to overstated economic growth and hence a significant upward bias in projections of greenhouse gas emissions, and unrealistically high future temperatures (*e.g.*, Castles and Henderson 2003). Others argue that convergence of the emissions-intensity gap across countries at least partially offset the overstated income gap so that differences in exchange rates have less of an effect on emissions (Holtsmark and Alfsen, 2005; Tol, 2006). Nordhaus (2007b) argues that the ideal approach is to use superlative PPP accounts (i.e., using cross-sectional PPP measures for relative incomes and outputs and national accounts price and quantity indexes for time-series extrapolations). However, he notes that it important to keep this debate in perspective; it is by no means clear that exchange-rate-conversion issues are as important as uncertainties about population, technological change, or the many geophysical uncertainties.

There are a number of caveats. First, EMF BAU scenarios represent the modelers' judgment of the most likely pathway absent mitigation policies to reduce greenhouse gas emissions, rather than the wider range of possible outcomes. Nevertheless, these views of the most likely outcome span a wide range, from the more optimistic (*e.g.*, abundant low-cost, low-carbon energy) to more pessimistic (*e.g.*, constraints on the availability of nuclear and renewables).[p] Second, the socioeconomic trajectories associated with a 550 ppm $CO_2e$ concentration scenario are not derived from an assessment of what policy is optimal from a benefit-cost standpoint. Rather, it is indicative of one possible future outcome. The emission trajectories underlying some BAU scenarios (*e.g.*, MESSAGE's 612 ppm) also are consistent with some modest policy action to address climate change.[q] We chose not to include socioeconomic trajectories that achieve even lower GHG concentrations at this time, given the difficulty many models had in converging to meet these targets.

For comparison purposes, the Energy Information Agency in its 2009 Annual Energy Outlook projected that global carbon dioxide emissions will grow to 30.8, 35.6, and 40.4 gigatons in 2010, 2020, and 2030, respectively, while world GDP is projected to be $51.8, $71.0 and $93.9 trillion (in 2005 dollars using market exchange rates) in 2010, 2020, and 2030, respectively. These projections are consistent with one or more EMF-22 scenarios. Likewise, the United Nations' 2008 Population Prospect projects population will grow from 6.1 billion people in 2000 to 9.1 billion people in 2050, which is close to the population trajectories for the IMAGE, MiniCAM, and MERGE models.

In addition to fossil and industrial $CO_2$ emissions, each EMF scenario provides projections of methane, nitrous oxide, fluorinated greenhouse gases, and net land use $CO_2$ emissions out to 2100. These assumptions also are used in the three models while retaining the default radiative forcings due to other factors (*e.g.*, aerosols and other gases). See the Annex for greater detail.

### 14A.4.6 Discount Rate

The choice of a discount rate, especially over long periods of time, raises highly contested and exceedingly difficult questions of science, economics, philosophy, and law. Although it is well understood that the discount rate has a large influence on the current value of future damages, there is no consensus about what rates to use in this context. Because carbon dioxide emissions are long-lived, subsequent damages occur over many years. In calculating the SCC, we first estimate the future damages to agriculture, human health, and other market and non-market sectors from an additional unit of carbon dioxide emitted in a particular year in terms of reduced consumption (or consumption equivalents) due to the impacts of elevated temperatures, as represented in each of the three IAMs. Then we discount the stream of future damages to its present value in the year when the additional unit of emissions was released using

[p] For instance, in the MESSAGE model's reference case total primary energy production from nuclear, biomass, and non-biomass renewables is projected to increase from about 15 percent of total primary energy in 2000 to 54 percent in 2100. In comparison, the MiniCAM reference case shows 10 percent in 2000 and 21 percent in 2100.
[q] For example, MiniCAM projects if all non-US OECD countries reduce $CO_2$ emissions to 83 percent below 2005 levels by 2050 (per the G-8 agreement) but all other countries continue along a BAU path $CO_2$ concentrations in 2100 would drop from 794 ppmv in its reference case to 762 ppmv.

the selected discount rate, which is intended to reflect society's marginal rate of substitution between consumption in different time periods.

For rules with both intra- and intergenerational effects, agencies traditionally employ constant discount rates of both 3 percent and 7 percent in accordance with OMB Circular A-4. As Circular A-4 acknowledges, however, the choice of discount rate for intergenerational problems raises distinctive problems and presents considerable challenges. After reviewing those challenges, Circular A-4 states, "If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent." For the specific purpose of developing the SCC, we adapt and revise that approach here.

Arrow et al. (1996) outlined two main approaches to determine the discount rate for climate change analysis, which they labeled "descriptive" and "prescriptive." The descriptive approach reflects a positive (non-normative) perspective based on observations of people's actual choices—*e.g.*, savings versus consumption decisions over time, and allocations of savings among more and less risky investments. Advocates of this approach generally call for inferring the discount rate from market rates of return "because of a lack of justification for choosing a social welfare function that is any different than what decision makers [individuals] actually use" (Arrow et al. 1996).

One theoretical foundation for the cost-benefit analyses in which the social cost of carbon will be used—the Kaldor-Hicks potential-compensation test—also suggests that market rates should be used to discount future benefits and costs, because it is the market interest rate that would govern the returns potentially set aside today to compensate future individuals for climate damages that they bear (*e.g.*, Just et al. 2004). As some have noted, the word "potentially" is an important qualification; there is no assurance that such returns will actually be set aside to provide compensation, and the very idea of compensation is difficult to define in the intergenerational context. On the other hand, societies provide compensation to future generations through investments in human capital and the resulting increase in knowledge, as well as infrastructure and other physical capital.

The prescriptive approach specifies a social welfare function that formalizes the normative judgments that the decision-maker wants explicitly to incorporate into the policy evaluation—*e.g.*, how inter-personal comparisons of utility should be made, and how the welfare of future generations should be weighed against that of the present generation. Ramsey (1928), for example, has argued that it is "ethically indefensible" to apply a positive pure rate of time preference to discount values across generations, and many agree with this view.

Other concerns also motivate making adjustments to descriptive discount rates. In particular, it has been noted that the preferences of future generations with regard to consumption versus environmental amenities may not be the same as those today, making the current market rate on consumption an inappropriate metric by which to discount future climate-related damages. Others argue that the discount rate should be below market rates to correct for market distortions and uncertainties or inefficiencies in intergenerational transfers of wealth, which in the Kaldor-Hicks logic are presumed to compensate future generations for damage (a potentially controversial assumption, as noted above) (Arrow et al. 1996, Weitzman 1999).

Further, a legitimate concern about both descriptive and prescriptive approaches is that they tend to obscure important heterogeneity in the population. The utility function that underlies the prescriptive approach assumes a representative agent with perfect foresight and no credit constraints. This is an artificial rendering of the real world that misses many of the frictions that characterize individuals' lives and indeed the available descriptive evidence supports this. For instance, many individuals smooth consumption by borrowing with credit cards that have relatively high rates. Some are unable to access traditional credit markets and rely on payday lending operations or other high-cost forms of smoothing consumption. Whether one puts greater weight on the prescriptive or descriptive approach, the high interest rates that credit-constrained individuals accept suggest that some account should be given to the discount rates revealed by their behavior.

We draw on both approaches but rely primarily on the descriptive approach to inform the choice of discount rate. With recognition of its limitations, we find this approach to be the most defensible and transparent given its consistency with the standard contemporary theoretical foundations of benefit-cost analysis and with the approach required by OMB's existing guidance. The logic of this framework also suggests that market rates should be used for discounting future consumption-equivalent damages. Regardless of the theoretical approach used to derive the appropriate discount rate(s), we note the inherent conceptual and practical difficulties of adequately capturing consumption trade-offs over many decades or even centuries. While relying primarily on the descriptive approach in selecting specific discount rates, the interagency group has been keenly aware of the deeply normative dimensions of both the debate over discounting in the intergenerational context and the consequences of selecting one discount rate over another.

*Historically Observed Interest Rates*

In a market with no distortions, the return to savings would equal the private return on investment, and the market rate of interest would be the appropriate choice for the social discount rate. In the real world risk, taxes, and other market imperfections drive a wedge between the risk-free rate of return on capital and the consumption rate of interest. Thus, the literature recognizes two conceptual discount concepts—the consumption rate of interest and the opportunity cost of capital.

According to OMB's Circular A-4, it is appropriate to use the rate of return on capital when a regulation is expected to displace or alter the use of capital in the private sector. In this case, OMB recommends Agencies use a discount rate of 7 percent. When regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services—a lower discount rate of 3 percent is appropriate to reflect how private individuals trade-off current and future consumption.

The interagency group examined the economics literature and concluded that the consumption rate of interest is the correct concept to use in evaluating the benefits and costs of a marginal change in carbon emissions (see Lind 1990, Arrow et al 1996, and Arrow 2000). The consumption rate of interest also is appropriate when the impacts of a regulation are measured in consumption (-equivalent) units, as is done in the three integrated assessment models used for estimating the SCC.

Individuals use a variety of savings instruments that vary with risk level, time horizon, and tax characteristics. The standard analytic framework used to develop intuition about the discount rate typically assumes a representative agent with perfect foresight and no credit constraints. The risk-free rate is appropriate for discounting certain future benefits or costs, but the benefits calculated by IAMs are uncertain. To use the risk-free rate to discount uncertain benefits, these benefits first must be transformed into "certainty equivalents," that is the maximum certain amount that we would exchange for the uncertain amount. However, the calculation of the certainty-equivalent requires first estimating the correlation between the benefits of the policy and baseline consumption.

If the IAM projections of future impacts represent expected values (not certainty-equivalent values), then the appropriate discount rate generally does not equal the risk-free rate. If the benefits of the policy tend to be high in those states of the world in which consumption is low, then the certainty-equivalent benefits will be higher than the expected benefits (and vice versa). Since many (though not necessarily all) of the important impacts of climate change will flow through market sectors such as agriculture and energy, and since willingness to pay for environmental protections typically increases with income, we might expect a positive (though not necessarily perfect) correlation between the net benefits from climate policies and market returns. This line of reasoning suggests that the proper discount rate would exceed the riskless rate. Alternatively, a negative correlation between the returns to climate policies and market returns would imply that a discount rate below the riskless rate is appropriate.

This discussion suggests that both the post-tax riskless and risky rates can be used to capture individuals' consumption-equivalent interest rate. As a measure of the post-tax riskless rate, we calculate the average real return from Treasury notes over the longest time period available (those from Newell and Pizer 2003) and adjust for Federal taxes (the average marginal rate from tax years 2003 through 2006 is around 27 percent).[r] This calculation produces a real interest rate of about 2.7 percent, which is roughly consistent with Circular A-4's recommendation to use 3 percent to represent the consumption rate of interest.[s] A measure of the post-tax risky rate for investments whose returns are positively correlated with overall equity market returns can be obtained by adjusting pre-tax rates of household returns to risky investments (approximately 7 percent) for taxes, which yields a real rate of roughly 5 percent.[t]

[r] The literature argues for a risk-free rate on government bonds as an appropriate measure of the consumption rate of interest. Arrow (2000) suggests that it is roughly 3-4 percent. OMB cites evidence of a 3.1 percent pre-tax rate for 10-year Treasury notes in the A-4 guidance. Newell and Pizer (2003) find real interest rates between 3.5 and 4 percent for 30-year Treasury securities.
[s] The positive approach reflects how individuals make allocation choices across time, but it is important to keep in mind that we wish to reflect preferences for society as a whole, which generally has a longer planning horizon.
[t] Cambell et al (2001) estimates that the annual real return from stocks for 1900-1995 was about 7 percent. The annual real rate of return for the S&P 500 from 1950 – 2008 was about 6.8 percent. In the absence of a better way to population-weight the tax rates, we use the middle of the 20 – 40 percent range to derive a post-tax interest rate (Kotlikoff and Rapson 2006).

*The Ramsey Equation*

Ramsey discounting also provides a useful framework to inform the choice of a discount rate. Under this approach, the analyst applies either positive or normative judgments in selecting values for the key parameters of the Ramsey equation: η (coefficient of relative risk aversion or elasticity of the marginal utility of consumption) and ρ (pure rate of time preference).[u] These are then combined with g (growth rate of per-capita consumption) to equal the interest rate at which future monetized damages are discounted: $\rho + \eta \cdot g$.[v] In the simplest version of the Ramsey model, with an optimizing representative agent with perfect foresight, what we are calling the "Ramsey discount rate," $\rho + \eta \cdot g$, will be equal to the rate of return to capital, *i.e.*, the market interest rate.

A review of the literature provides some guidance on reasonable parameter values for the Ramsey discounting equation, based on both prescriptive and descriptive approaches.

- η. Most papers in the climate change literature adopt values for η in the range of 0.5 to 3 (Weitzman cites plausible values as those ranging from 1 to 4), although not all authors articulate whether their choice is based on prescriptive or descriptive reasoning.[w] Dasgupta (2008) argues that η should be greater than 1 and may be as high as 3, because η equal to 1 suggests savings rates that do not conform to observed behavior.

- ρ. With respect to the pure rate of time preference, most papers in the climate change literature adopt values for ρ in the range of 0 to 3 percent per year. The very low rates tend to follow from moral judgments involving intergenerational neutrality. Some have argued that to use any value other than $\rho = 0$ would unjustly discriminate against future generations (*e.g.*, Arrow et al. 1996, Stern et al. 2006). However, even in an inter-

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[u] The parameter ρ □measures the *pure rate of time preference*: people's behavior reveals a preference for an increase in utility today versus the future. Consequently, it is standard to place a lower weight on utility in the future. The parameter η captures *diminishing marginal utility*: consumption in the future is likely to be higher than consumption today, so diminishing marginal utility of consumption implies that the same monetary damage will cause a smaller reduction of utility for wealthier individuals, either in the future or in current generations. If $\eta = 0$, then a one dollar increase in income is equally valuable regardless of level of income; if $\eta = 1$, then a one percent increase in income is equally valuable no matter the level of income; and if $\eta > 1$, then a one percent increase in income is less valuable to wealthier individuals.

[v] In this case, g could be taken from the selected EMF socioeconomic scenarios or alternative assumptions about the rate of consumption growth.

[w] Empirical estimates of η span a wide range of values. A benchmark value of 2 is near the middle of the range of values estimated or used by Szpiro (1986), Hall and Jones (2007), Arrow (2007), Dasgupta (2006, 2008), Weitzman (2007, 2009), and Nordhaus (2008). However, Chetty (2006) developed a method of estimating η using data on labor supply behavior. He shows that existing evidence of the effects of wage changes on labor supply imposes a tight upper bound on the curvature of utility over wealth (CRRA < 2) with the mean implied value of 0.71 and concludes that the standard expected utility model cannot generate high levels of risk aversion without contradicting established facts about labor supply. Recent work has jointly estimated the components of the Ramsey equation. Evans and Sezer (2005) estimate $\eta = 1.49$ for 22 OECD countries. They also estimate $\rho = 1.08$ percent per year using data on mortality rates. Anthoff, et al. (2009b) estimate $\eta = 1.18$, and $\rho = 1.4$ percent. When they multiply the bivariate probability distributions from their work and Evans and Sezer (2005) together, they find $\eta = 1.47$, and $\rho = 1.07$.

generational setting, it may make sense to use a small positive pure rate of time preference because of the small probability of unforeseen cataclysmic events (Stern et al. 2006).

- g. A commonly accepted approximation is around 2 percent per year. For the socioeconomic scenarios used for this exercise, the EMF models assume that g is about 1.5-2 percent to 2100.

Some economists and non-economists have argued for constant discount rates below 2 percent based on the prescriptive approach. When grounded in the Ramsey framework, proponents of this approach have argued that a ρ of zero avoids giving preferential treatment to one generation over another. The choice of η has also been posed as an ethical choice linked to the value of an additional dollar in poorer countries compared to wealthier ones. Stern et al. (2006) applies this perspective through his choice of $\rho = 0.1$ percent per year, $\eta = 1$ and $g = 1.3$ percent per year, which yields an annual discount rate of 1.4 percent. In the context of permanent income savings behavior, however, Stern's assumptions suggest that individuals would save 93 percent of their income.[x]

Recently, Stern (2008) revisited the values used in Stern et al. (2006), stating that there is a case to be made for raising η due to the amount of weight lower values place on damages far in the future (over 90 percent of expected damages occur after 2200 with $\eta = 1$). Using Stern's assumption that $\rho = 0.1$ percent, combined with a η of 1.5 to 2 and his original growth rate, yields a discount rate of greater than 2 percent.

We conclude that arguments made under the prescriptive approach can be used to justify discount rates between roughly 1.4 and 3.1 percent. In light of concerns about the most appropriate value for η, we find it difficult to justify rates at the lower end of this range under the Ramsey framework.

*Accounting for Uncertainty in the Discount Rate*

While the consumption rate of interest is an important driver of the benefits estimate, it is uncertain over time. Ideally, we would formally model this uncertainty, just as we do for climate sensitivity. Weitzman (1998, 2001) showed theoretically and Newell and Pizer (2003) and Groom et al. (2006) confirm empirically that discount rate uncertainty can have a large effect on net present values. A main result from these studies is that if there is a persistent element to the uncertainty in the discount rate (*e.g.*, the rate follows a random walk), then it will result in an effective (or certainty-equivalent) discount rate that declines over time. Consequently, lower discount rates tend to dominate over the very long term (see Weitzman 1998, 1999, 2001; Newell and Pizer 2003; Groom et al. 2006; Gollier 2008; Summers and Zeckhauser 2008; and Gollier and Weitzman 2009).

[x] Stern (2008) argues that building in a positive rate of exogenous technical change over time reduces the implied savings rate and that η at or above 2 are inconsistent with observed behavior with regard to equity. (At the same time, adding exogenous technical change—all else equal—would increase g as well.)

The proper way to model discount rate uncertainty remains an active area of research. Newell and Pizer (2003) employ a model of how long-term interest rates change over time to forecast future discount rates. Their model incorporates some of the basic features of how interest rates move over time, and its parameters are estimated based on historical observations of long-term rates. Subsequent work on this topic, most notably Groom et al. (2006), uses more general models of interest rate dynamics to allow for better forecasts. Specifically, the volatility of interest rates depends on whether rates are currently low or high and the variation in the level of persistence over time.

While Newell and Pizer (2003) and Groom et al (2006) attempt formally to model uncertainty in the discount rate, others argue for a declining scale of discount rates applied over time (*e.g.*, Weitzman 2001, and the UK's "Green Book" for regulatory analysis). This approach uses a higher discount rate initially, but applies a graduated scale of lower discount rates further out in time.[y] A key question that has emerged with regard to both of these approaches is the trade-off between potential time inconsistency and giving greater weight to far future outcomes (see the EPA Science Advisory Board's recent comments on this topic as part of its review of their *Guidelines for Economic Analysis*).[z]

*The Discount Rates Selected for Estimating SCC*

In light of disagreement in the literature on the appropriate market interest rate to use in this context and uncertainty about how interest rates may change over time, we use three discount rates to span a plausible range of certainty-equivalent constant discount rates: 2.5, 3, and 5 percent per year. Based on the review in the previous sections, the interagency workgroup determined that these three rates reflect reasonable judgments under both descriptive and prescriptive approaches.

The central value, 3 percent, is consistent with estimates provided in the economics literature and OMB's Circular A-4 guidance for the consumption rate of interest. As previously mentioned, the consumption rate of interest is the correct discounting concept to use when future damages from elevated temperatures are estimated in consumption-equivalent units. Further, 3 percent roughly corresponds to the after-tax riskless interest rate. The upper value of 5 percent is included to represent the possibility that climate damages are positively correlated with market returns. Additionally, this discount rate may be justified by the high interest rates that many consumers use to smooth consumption across periods.

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[y] For instance, the UK applies a discount rate of 3.5 percent to the first 30 years; 3 percent for years 31 - 75; 2.5 percent for years 76 - 125; 2 percent for years 126 - 200; 1.5 percent for years 201 - 300; and 1 percent after 300 years. As a sensitivity, it recommends a discount rate of 3 percent for the first 30 years, also decreasing over time.

[z] Uncertainty in future damages is distinct from uncertainty in the discount rate. Weitzman (2008) argues that Stern's choice of a low discount rate was "right for the wrong reasons." He demonstrates how the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. Newbold and Daigneault, (2009) and Nordhaus (2009) find that Weitzman's result is sensitive to the functional forms chosen for climate sensitivity, utility, and consumption. Summers and Zeckhauser (2008) argue that uncertainty in future damages can also work in the other direction by increasing the benefits of waiting to learn the appropriate level of mitigation required.

The low value, 2.5 percent, is included to incorporate the concern that interest rates are highly uncertain over time. It represents the average certainty-equivalent rate using the mean-reverting and random walk approaches from Newell and Pizer (2003) starting at a discount rate of 3 percent. Using this approach, the certainty equivalent is about 2.2 percent using the random walk model and 2.8 percent using the mean reverting approach.[aa] Without giving preference to a particular model, the average of the two rates is 2.5 percent. Further, a rate below the riskless rate would be justified if climate investments are negatively correlated with the overall market rate of return. Use of this lower value also responds to certain judgments using the prescriptive or normative approach and to ethical objections that have been raised about rates of 3 percent or higher.

## 14A.5 REVISED SCC ESTIMATES

Our general approach to estimating SCC values is to run the three integrated assessment models (FUND, DICE, and PAGE) using the following inputs agreed upon by the interagency group:

- A Roe and Baker distribution for the climate sensitivity parameter bounded between 0 and 10 with a median of 3 °C and a cumulative probability between 2 and 4.5 °C of two-thirds.
- Five sets of GDP, population, and carbon emissions trajectories based on EMF-22.
- Constant annual discount rates of 2.5, 3, and 5 percent.

Because the climate sensitivity parameter is modeled probabilistically, and because PAGE and FUND incorporate uncertainty in other model parameters, the final output from each model run is a distribution over the SCC in year *t*.

For each of the IAMs, the basic computational steps for calculating the SCC in a particular year *t* are:

1. Input the path of emissions, GDP, and population from the selected EMF-22 scenarios, and the extrapolations based on these scenarios for post-2100 years.

2. Calculate the temperature effects and (consumption-equivalent) damages in each year resulting from the baseline path of emissions.

    a. In PAGE, the consumption-equivalent damages in each period are calculated as a fraction of the EMF GDP forecast, depending on the temperature in that period relative to the pre-industrial average temperature in each region.
    b. In FUND, damages in each period depend on both the level and the rate of temperature change in that period.

[aa] Calculations done by Pizer et al. using the original simulation program from Newell and Pizer (2003).

c. In DICE, temperature affects both consumption and investment, so we first adjust the EMF GDP paths as follows: Using the Cobb-Douglas production function with the DICE2007 parameters, we extract the path of exogenous technical change implied by the EMF GDP and population paths, then we recalculate the baseline GDP path taking into account climate damages resulting from the baseline emissions path.

3. Add an additional unit of carbon emissions in year *t.* (The exact unit varies by model.)

4. Recalculate the temperature effects and damages expected in all years beyond *t* resulting from this adjusted path of emissions, as in step 2.

5. Subtract the damages computed in step 2 from those in step 4 in each year. (DICE is run in 10-year time steps, FUND in annual time steps, while the time steps in PAGE vary.)

6. Discount the resulting path of marginal damages back to the year of emissions using the agreed upon fixed discount rates.

7. Calculate the SCC as the net present value of the discounted path of damages computed in step 6, divided by the unit of carbon emissions used to shock the models in step 3.

8. Multiply by 12/44 to convert from dollars per ton of carbon to dollars per ton of $CO_2$ (2007 dollars) in DICE and FUND. (All calculations are done in tons of $CO_2$ in PAGE).

The steps above were repeated in each model for multiple future years to cover the time horizons anticipated for upcoming rulemaking analysis. To maintain consistency across the three IAMs, climate damages are calculated as lost consumption in each future year.

It is important to note that each of the three models has a different default end year. The default time horizon is 2200 for PAGE, 2595 for DICE, and 3000 for the latest version of FUND. This is an issue for the multi-model approach because differences in SCC estimates may arise simply due to the model time horizon. Many consider 2200 too short a time horizon because it could miss a significant fraction of damages under certain assumptions about the growth of marginal damages and discounting, so each model is run here through 2300. This step required a small adjustment in the PAGE model only. This step also required assumptions about GDP, population, and greenhouse gas emission trajectories after 2100, the last year for which these data are available from the EMF-22 models. (A more detailed discussion of these assumptions is included in the Annex.)

This exercise produces 45 separate distributions of the SCC for a given year, the product of 3 models, 3 discount rates, and 5 socioeconomic scenarios. This is clearly too many separate distributions for consideration in a regulatory impact analysis.

To produce a range of plausible estimates that still reflects the uncertainty in the estimation exercise, the distributions from each of the models and scenarios are equally weighed and combined to produce three separate probability distributions for SCC in a given year, one for each assumed discount rate. These distributions are then used to define a range of point estimates for the global SCC. In this way, no IAM or socioeconomic scenario is given greater weight than another. Because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context, we present SCCs based on the average values across models and socioeconomic scenarios for each discount rate.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC across models and socioeconomic and emissions scenarios at the 2.5, 3, and 5 percent discount rates. The fourth value is included to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95$^{th}$ percentile at a 3 percent discount rate. (The full set of distributions by model and scenario combination is included in the Annex.) As noted above, the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range.

As previously discussed, low probability, high impact events are incorporated into the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high-temperature outcomes, which in turn lead to higher projections of damages. Although FUND does not include catastrophic damages (in contrast to the other two models), its probabilistic treatment of the equilibrium climate sensitivity parameter will directly affect the non-catastrophic damages that are a function of the rate of temperature change.

In Table 14A.5.1, we begin by presenting SCC estimates for 2010 by model, scenario, and discount rate to illustrate the variability in the SCC across each of these input parameters. As expected, higher discount rates consistently result in lower SCC values, while lower discount rates result in higher SCC values for each socioeconomic trajectory. It is also evident that there are differences in the SCC estimated across the three main models. For these estimates, FUND produces the lowest estimates, while PAGE generally produces the highest estimates.

**Table 14A.5.1 Disaggregated Social Cost of $CO_2$ Values by Model, Socioeconomic Trajectory, and Discount Rate for 2010 (in 2007 dollars)**

| | *Discount rate:* | **5%** | **3%** | **2.5%** | **3%** |
|---|---|---|---|---|---|
| *Model* | *Scenario* | Avg | Avg | Avg | 95th |
| **DICE** | IMAGE | 10.8 | 35.8 | 54.2 | 70.8 |
| | MERGE | 7.5 | 22.0 | 31.6 | 42.1 |
| | Message | 9.8 | 29.8 | 43.5 | 58.6 |
| | MiniCAM | 8.6 | 28.8 | 44.4 | 57.9 |
| | 550 Average | 8.2 | 24.9 | 37.4 | 50.8 |
| **PAGE** | IMAGE | 8.3 | 39.5 | 65.5 | 142.4 |
| | MERGE | 5.2 | 22.3 | 34.6 | 82.4 |
| | Message | 7.2 | 30.3 | 49.2 | 115.6 |
| | MiniCAM | 6.4 | 31.8 | 54.7 | 115.4 |
| | 550 Average | 5.5 | 25.4 | 42.9 | 104.7 |
| **FUND** | IMAGE | -1.3 | 8.2 | 19.3 | 39.7 |
| | MERGE | -0.3 | 8.0 | 14.8 | 41.3 |
| | Message | -1.9 | 3.6 | 8.8 | 32.1 |
| | MiniCAM | -0.6 | 10.2 | 22.2 | 42.6 |
| | 550 Average | -2.7 | -0.2 | 3.0 | 19.4 |

These results are not surprising when compared to the estimates in the literature for the latest versions of each model. For example, adjusting the values from the literature that were used to develop interim SCC values to 2007 dollars for the year 2010 (assuming, as we did for the interim process, that SCC grows at 3 percent per year), FUND yields SCC estimates at or near zero for a 5 percent discount rate and around $9 per ton for a 3 percent discount rate. There are far fewer estimates using the latest versions of DICE and PAGE in the literature: Using similar adjustments to generate 2010 estimates, we calculate a SCC from DICE (based on Nordhaus 2008) of around $9 per ton for a 5 percent discount rate, and a SCC from PAGE (based on Hope 2006, 2008) close to $8 per ton for a 4 percent discount rate. Note that these comparisons are only approximate since the literature generally relies on Ramsey discounting, while we have assumed constant discount rates.[bb]

[bb] Nordhaus (2008) runs DICE2007 with $\rho = 1.5$ and $\eta = 2$. The default approach in PAGE2002 (version 1.4epm) treats $\rho$ and $\eta$ as random parameters, specified using a triangular distribution such that the min, mode, and max = 0.1, 1, and 2 for $\rho$, and 0.5, 1, and 2 for $\eta$, respectively. The FUND default value for $\eta$ is 1, and Tol generates SCC estimates for values of $\rho$ = 0, 1, and 3 in many recent papers (*e.g.* Anthoff et al. 2009). The path of per-capita consumption growth, g, varies over time but is treated deterministically in two of the three models. In DICE, g is

The SCC estimates from FUND are sensitive to differences in emissions paths but relatively insensitive to differences in GDP paths across scenarios, while the reverse is true for DICE and PAGE. This likely occurs because of several structural differences among the models. Specifically in DICE and PAGE, the fraction of economic output lost due to climate damages increases with the level of temperature alone, whereas in FUND the fractional loss also increases with the rate of temperature change. Furthermore, in FUND increases in income over time decrease vulnerability to climate change (a form of adaptation), whereas this does not occur in DICE and PAGE. These structural differences among the models make FUND more sensitive to the path of emissions and less sensitive to GDP compared to DICE and PAGE.

Figure 14A.5.1 shows that IMAGE has the highest GDP in 2100 while MERGE Optimistic has the lowest. The ordering of global GDP levels in 2100 directly corresponds to the rank ordering of SCC for PAGE and DICE. For FUND, the correspondence is less clear, a result that is to be expected given its less direct relationship between its damage function and GDP.

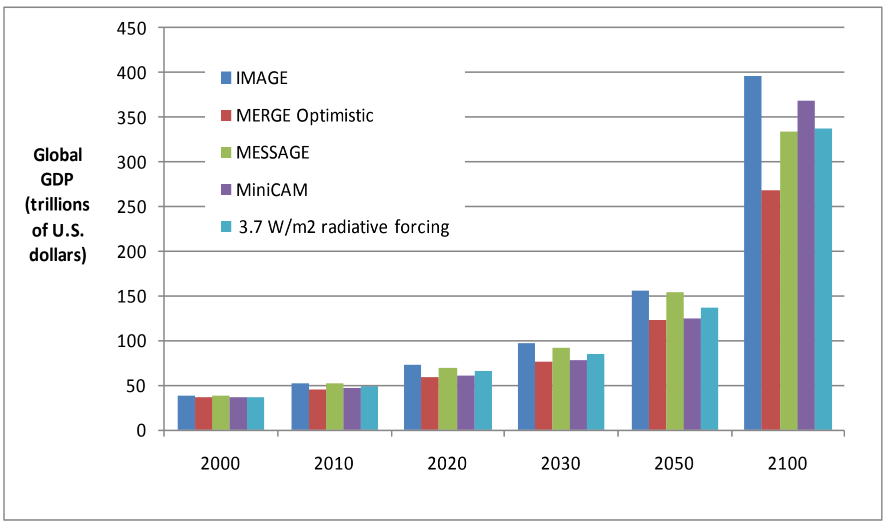


**Figure 14A.5.1 Level of Global GDP across EMF Scenarios**

Table 14A.5.2 shows the four selected SCC values in five-year increments from 2010 to 2050. Values for 2010, 2020, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using a simple linear interpolation.

endogenous. Under Ramsey discounting, as economic growth slows in the future, the large damages from climate change that occur far out in the future are discounted at a lower rate than impacts that occur in the nearer term.

**Table 14A.5.2 Social Cost of $CO_2$, 2010 – 2050 (in 2007 dollars)**

| Discount<br>Year | 5%<br>Avg | 3%<br>Avg | 2.5%<br>Avg | 3%<br>95th |
|---|---|---|---|---|
| 2010 | 4.7 | 21.4 | 35.1 | 64.9 |
| 2015 | 5.7 | 23.8 | 38.4 | 72.8 |
| 2020 | 6.8 | 26.3 | 41.7 | 80.7 |
| 2025 | 8.2 | 29.6 | 45.9 | 90.4 |
| 2030 | 9.7 | 32.8 | 50.0 | 100.0 |
| 2035 | 11.2 | 36.0 | 54.2 | 109.7 |
| 2040 | 12.7 | 39.2 | 58.4 | 119.3 |
| 2045 | 14.2 | 42.1 | 61.7 | 127.8 |
| 2050 | 15.7 | 44.9 | 65.0 | 136.2 |

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that this approach allows us to estimate the growth rate of the SCC directly using DICE, PAGE, and FUND rather than assuming a constant annual growth rate as was done for the interim estimates (using 3 percent). This helps to ensure that the estimates are internally consistent with other modeling assumptions. Table 14A.5.3 illustrates how the growth rate for these four SCC estimates varies over time. The full set of annual SCC estimates between 2010 and 2050 is reported in the Annex.

**Table 14A.5.3 Changes in the Average Annual Growth Rates of SCC Estimates between 2010 and 2050**

| Average Annual<br>Growth Rate (%) | **5%**<br>Avg | **3%**<br>Avg | **2.5%**<br>Avg | **3.0%**<br>95th |
|---|---|---|---|---|
| 2010-2020 | 3.6% | 2.1% | 1.7% | 2.2% |
| 2020-2030 | 3.7% | 2.2% | 1.8% | 2.2% |
| 2030-2040 | 2.7% | 1.8% | 1.6% | 1.8% |
| 2040-2050 | 2.1% | 1.4% | 1.1% | 1.3% |

While the SCC estimate grows over time, the future monetized value of emissions reductions in each year (the SCC in year *t* multiplied by the change in emissions in year *t*) must be discounted to the present to determine its total net present value for use in regulatory analysis. Damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency—*i.e.*, future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate. For example, climate damages in the year 2020 that are calculated using a SCC based on a 5 percent discount rate also should be discounted back to the analysis year using a 5 percent discount rate.[cc]

## 14A.6 LIMITATIONS OF THE ANALYSIS

As noted, any estimate of the SCC must be taken as provisional and subject to further refinement (and possibly significant change) in accordance with evolving scientific, economic, and ethical understandings. During the course of our modeling, it became apparent that there are several areas in particular need of additional exploration and research. These caveats, and additional observations in the following section, are necessary to consider when interpreting and applying the SCC estimates.

*Incomplete treatment of non-catastrophic damages.* The impacts of climate change are expected to be widespread, diverse, and heterogeneous. In addition, the exact magnitude of these impacts is uncertain because of the inherent complexity of climate processes, the economic behavior of current and future populations, and our inability to accurately forecast technological change and adaptation. Current IAMs do not assign value to all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature (some of which are discussed above) because of lack of precise information on the nature of damages and because the science incorporated into these models understandably lags behind the most recent research. Our ability to quantify and monetize impacts will undoubtedly improve with time. But it is also likely that even in future applications, a number of potentially significant damage categories will remain non-monetized. (Ocean acidification is one example of a potentially large damage from $CO_2$ emissions not quantified by any of the three models. Species and wildlife loss is another example that is exceedingly difficult to monetize.)

*Incomplete treatment of potential catastrophic damages.* There has been considerable recent discussion of the risk of catastrophic impacts and how best to account for extreme scenarios, such as the collapse of the Atlantic Meridional Overturning Circulation or the West Antarctic Ice Sheet, or large releases of methane from melting permafrost and warming oceans. Weitzman (2009) suggests that catastrophic damages are extremely large—so large, in fact, that the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. However, Nordhaus (2009) concluded that the conditions under which Weitzman's results hold "are limited and do not apply to a wide range of potential uncertain scenarios."

Using a simplified IAM, Newbold and Daigneault (2009) confirmed the potential for large catastrophe risk premiums but also showed that the aggregate benefit estimates can be highly sensitive to the shapes of both the climate sensitivity distribution and the damage function at high temperature changes. Pindyck (2009) also used a simplified IAM to examine high-

[cc] However, it is possible that other benefits or costs of proposed regulations unrelated to $CO_2$ emissions will be discounted at rates that differ from those used to develop the SCC estimates.

impact, low-probability risks, using a right-skewed gamma distribution for climate sensitivity as well as an uncertain damage coefficient, but in most cases found only a modest risk premium. Given this difference in opinion, further research in this area is needed before its practical significance can be fully understood and a reasonable approach developed to account for such risks in regulatory analysis. (The next section discusses the scientific evidence on catastrophic impacts in greater detail.)

*Uncertainty in extrapolation of damages to high temperatures:* The damage functions in these IAMs are typically calibrated by estimating damages at moderate temperature increases (*e.g.*, DICE was calibrated at 2.5 °C) and extrapolated to far higher temperatures by assuming that damages increase as some power of the temperature change. Hence, estimated damages are far more uncertain under more extreme climate change scenarios.

*Incomplete treatment of adaptation and technological change:* Each of the three integrated assessment models used here assumes a certain degree of low- or no-cost adaptation. For instance, Tol assumes a great deal of adaptation in FUND, including widespread reliance on air conditioning; so much so, that the largest single benefit category in FUND is the reduced electricity costs from not having to run air conditioning as intensively (NRC 2009).

Climate change also will increase returns on investment to develop technologies that allow individuals to cope with adverse climate conditions, and IAMs to do not adequately account for this directed technological change.[dd] For example, scientists may develop crops that are better able to withstand higher and more variable temperatures. Although DICE and FUND have both calibrated their agricultural sectors under the assumption that farmers will change land use practices in response to climate change (Mastrandrea, 2009), they do not take into account technological changes that lower the cost of this adaptation over time. On the other hand, the calibrations do not account for increases in climate variability, pests, or diseases, which could make adaptation more difficult than assumed by the IAMs for a given temperature change. Hence, models do not adequately account for potential adaptation or technical change that might alter the emissions pathway and resulting damages. In this respect, it is difficult to determine whether the incomplete treatment of adaptation and technological change in these IAMs understate or overstate the likely damages.

*Risk aversion:* A key question unanswered during this interagency process is what to assume about relative risk aversion with regard to high-impact outcomes. These calculations do not take into account the possibility that individuals may have a higher willingness to pay to reduce the likelihood of low-probability, high-impact damages than they do to reduce the likelihood of higher-probability, but lower-impact, damages with the same expected cost. (The inclusion of the 95$^{th}$ percentile estimate in the final set of SCC values was largely motivated by this concern.) If individuals do show such a higher willingness to pay, a further question is whether that fact should be taken into account for regulatory policy. Even if individuals are not risk-averse for such scenarios, it is possible that regulatory policy should include a degree of risk-aversion.

[dd] However these research dollars will be diverted from whatever their next best use would have been in the absence of climate change (so productivity/GDP would have been still higher).

Assuming a risk-neutral representative agent is consistent with OMB's Circular A-4, which advises that the estimates of benefits and costs used in regulatory analysis are usually based on the average or the expected value and that "emphasis on these expected values is appropriate as long as society is 'risk neutral' with respect to the regulatory alternatives. While this may not always be the case, [analysts] should in general assume 'risk neutrality' in [their] analysis."

Nordhaus (2008) points to the need to explore the relationship between risk and income in the context of climate change across models and to explore the role of uncertainty regarding various parameters in the results. Using FUND, Anthoff et al (2009) explored the sensitivity of the SCC to Ramsey equation parameter assumptions based on observed behavior. They conclude that "the assumed rate of risk aversion is at least as important as the assumed rate of time preference in determining the social cost of carbon." Since Circular A-4 allows for a different assumption on risk preference in regulatory analysis if it is adequately justified, we plan to continue investigating this issue.

## 14A.7 A FURTHER DISCUSSION OF CATASTROPHIC IMPACTS AND DAMAGE FUNCTIONS

As noted above, the damage functions underlying the three IAMs used to estimate the SCC may not capture the economic effects of all possible adverse consequences of climate change and may therefore lead to underestimates of the SCC (Mastrandrea 2009). In particular, the models' functional forms may not adequately capture: (1) potentially discontinuous "tipping point" behavior in Earth systems, (2) inter-sectoral and inter-regional interactions, including global security impacts of high-end warming, and (3) limited near-term substitutability between damage to natural systems and increased consumption.

It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling. In the meantime, we discuss some of the available evidence.

*Extrapolation of climate damages to high levels of warming*

The damage functions in the models are calibrated at moderate levels of warming and should therefore be viewed cautiously when extrapolated to the high temperatures found in the upper end of the distribution. Recent science suggests that there are a number of potential climatic "tipping points" at which the Earth system may exhibit discontinuous behavior with potentially severe social and economic consequences (*e.g.*, Lenton et al, 2008, Kriegler et al., 2009). These tipping points include the disruption of the Indian Summer Monsoon, dieback of the Amazon Rainforest and boreal forests, collapse of the Greenland Ice Sheet and the West Antarctic Ice Sheet, reorganization of the Atlantic Meridional Overturning Circulation, strengthening of El Niño-Southern Oscillation, and the release of methane from melting permafrost. Many of these tipping points are estimated to have thresholds between about 3 °C and 5 °C (Lenton et al., 2008). Probabilities of several of these tipping points were assessed through expert elicitation in 2005–2006 by Kriegler et al. (2009); results from this study are highlighted in Table 14A.7.1. Ranges of probability are averaged across core experts on each topic.

As previously mentioned, FUND does not include potentially catastrophic effects. DICE assumes a small probability of catastrophic damages that increases with increased warming, but the damages from these risks are incorporated as expected values (*i.e.*, ignoring potential risk aversion). PAGE models catastrophic impacts in a probabilistic framework (see Figure 14A.4.1), so the high-end output from PAGE potentially offers the best insight into the SCC if the world were to experience catastrophic climate change. For instance, at the 95$^{th}$ percentile and a 3 percent discount rate, the SCC estimated by PAGE across the five socioeconomic and emission trajectories of $113 per ton of $CO_2$ is almost double the value estimated by DICE, $58 per ton in 2010. We cannot evaluate how well the three models account for catastrophic or non-catastrophic impacts, but this estimate highlights the sensitivity of SCC values in the tails of the distribution to the assumptions made about catastrophic impacts.

**Table 14A.7.1 Probabilities of Various Tipping Points from Expert Elicitation**

| Possible Tipping Points | Duration before effect is fully realized (in years) | Additional Warming by 2100 | | |
|---|---|---|---|---|
| | | 0.5-1.5 C | 1.5-3.0 C | 3-5 C |
| Reorganization of Atlantic Meridional Overturning Circulation | about 100 | 0-18% | 6-39% | 18-67% |
| Greenland Ice Sheet collapse | at least 300 | 8-39% | 33-73% | 67-96% |
| West Antarctic Ice Sheet collapse | at least 300 | 5-41% | 10-63% | 33-88% |
| Dieback of Amazon rainforest | about 50 | 2-46% | 14-84% | 41-94% |
| Strengthening of El Niño-Southern Oscillation | about 100 | 1-13% | 6-32% | 19-49% |
| Dieback of boreal forests | about 50 | 13-43% | 20-81% | 34-91% |
| Shift in Indian Summer Monsoon | about 1 | Not formally assessed | | |
| Release of methane from melting permafrost | Less than 100 | Not formally assessed. | | |

PAGE treats the possibility of a catastrophic event probabilistically, while DICE treats it deterministically (that is, by adding the expected value of the damage from a catastrophe to the aggregate damage function). In part, this results in different probabilities being assigned to a catastrophic event across the two models. For instance, PAGE places a probability near zero on a catastrophe at 2.5 °C warming, while DICE assumes a 4 percent probability of a catastrophe at 2.5 °C. By comparison, Kriegler et al. (2009) estimate a probability of at least 16-36 percent of crossing at least one of their primary climatic tipping points in a scenario with temperatures about 2-4 °C warmer than pre-Industrial levels in 2100.

It is important to note that crossing a climatic tipping point will not necessarily lead to an economic catastrophe in the sense used in the IAMs. A tipping point is a critical threshold across which some aspect of the Earth system starts to shifts into a qualitatively different state (for instance, one with dramatically reduced ice sheet volumes and higher sea levels). In the IAMs, a catastrophe is a low-probability environmental change with high economic impact.

*Failure to incorporate inter-sectoral and inter-regional interactions*

The damage functions do not fully incorporate either inter-sectoral or inter-regional interactions. For instance, while damages to the agricultural sector are incorporated, the effects of changes in food supply on human health are not fully captured and depend on the modeler's choice of studies used to calibrate the IAM. Likewise, the effects of climate damages in one region of the world on another region are not included in some of the models (FUND includes the effects of migration from sea level rise). These inter-regional interactions, though difficult to quantify, are the basis for climate-induced national and economic security concerns (*e.g.*, Campbell et al., 2007; U.S. Department of Defense 2010) and are particularly worrisome at higher levels of warming. High-end warming scenarios, for instance, project water scarcity affecting 4.3-6.9 billion people by 2050, food scarcity affecting about 120 million additional people by 2080, and the creation of millions of climate refugees (Easterling et al., 2007; Campbell et al., 2007).

*Imperfect substitutability of environmental amenities*

Data from the geological record of past climate changes suggests that 6 °C of warming may have severe consequences for natural systems. For instance, during the Paleocene-Eocene Thermal Maximum about 55.5 million years ago, when the Earth experienced a geologically rapid release of carbon associated with an approximately 5 °C increase in global mean temperatures, the effects included shifts of about 400-900 miles in the range of plants (Wing et al., 2005), and dwarfing of both land mammals (Gingerich, 2006) and soil fauna (Smith et al., 2009).

The three IAMs used here assume that it is possible to compensate for the economic consequences of damages to natural systems through increased consumption of non-climate goods, a common assumption in many economic models. In the context of climate change, however, it is possible that the damages to natural systems could become so great that no increase in consumption of non-climate goods would provide complete compensation (Levy et al., 2005). For instance, as water supplies become scarcer or ecosystems become more fragile and less bio-diverse, the services they provide may become increasingly more costly to replace. Uncalibrated attempts to incorporate the imperfect substitutability of such amenities into IAMs (Sterner and Persson, 2008) indicate that the optimal degree of emissions abatement can be considerably greater than is commonly recognized.

## 14A.8 CONCLUSION

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are \$5, \$21, \$35, and \$65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socioeconomic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95$^{th}$ percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of $CO_2$ in 2015 and \$26 per ton of $CO_2$ in 2020.

We noted a number of limitations to this analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking climate impacts to economic damages makes this modeling exercise even more difficult. It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling.

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## 14A.9 ANNEX

**Table 14A.9.1 Annual SCC Values: 2010–2050 (in 2007 dollars)**

| Discount Rate<br>Year | 5%<br>Avg | 3%<br>Avg | 2.5%<br>Avg | 3%<br>95th |
|---|---|---|---|---|
| 2010 | 4.7 | 21.4 | 35.1 | 64.9 |
| 2011 | 4.9 | 21.9 | 35.7 | 66.5 |
| 2012 | 5.1 | 22.4 | 36.4 | 68.1 |
| 2013 | 5.3 | 22.8 | 37.0 | 69.6 |
| 2014 | 5.5 | 23.3 | 37.7 | 71.2 |
| 2015 | 5.7 | 23.8 | 38.4 | 72.8 |
| 2016 | 5.9 | 24.3 | 39.0 | 74.4 |
| 2017 | 6.1 | 24.8 | 39.7 | 76.0 |
| 2018 | 6.3 | 25.3 | 40.4 | 77.5 |
| 2019 | 6.5 | 25.8 | 41.0 | 79.1 |
| 2020 | 6.8 | 26.3 | 41.7 | 80.7 |
| 2021 | 7.1 | 27.0 | 42.5 | 82.6 |
| 2022 | 7.4 | 27.6 | 43.4 | 84.6 |
| 2023 | 7.7 | 28.3 | 44.2 | 86.5 |
| 2024 | 7.9 | 28.9 | 45.0 | 88.4 |
| 2025 | 8.2 | 29.6 | 45.9 | 90.4 |
| 2026 | 8.5 | 30.2 | 46.7 | 92.3 |
| 2027 | 8.8 | 30.9 | 47.5 | 94.2 |
| 2028 | 9.1 | 31.5 | 48.4 | 96.2 |
| 2029 | 9.4 | 32.1 | 49.2 | 98.1 |
| 2030 | 9.7 | 32.8 | 50.0 | 100.0 |
| 2031 | 10.0 | 33.4 | 50.9 | 102.0 |
| 2032 | 10.3 | 34.1 | 51.7 | 103.9 |
| 2033 | 10.6 | 34.7 | 52.5 | 105.8 |
| 2034 | 10.9 | 35.4 | 53.4 | 107.8 |
| 2035 | 11.2 | 36.0 | 54.2 | 109.7 |
| 2036 | 11.5 | 36.7 | 55.0 | 111.6 |
| 2037 | 11.8 | 37.3 | 55.9 | 113.6 |
| 2038 | 12.1 | 37.9 | 56.7 | 115.5 |
| 2039 | 12.4 | 38.6 | 57.5 | 117.4 |
| 2040 | 12.7 | 39.2 | 58.4 | 119.3 |
| 2041 | 13.0 | 39.8 | 59.0 | 121.0 |
| 2042 | 13.3 | 40.4 | 59.7 | 122.7 |
| 2043 | 13.6 | 40.9 | 60.4 | 124.4 |
| 2044 | 13.9 | 41.5 | 61.0 | 126.1 |
| 2045 | 14.2 | 42.1 | 61.7 | 127.8 |
| 2046 | 14.5 | 42.6 | 62.4 | 129.4 |
| 2047 | 14.8 | 43.2 | 63.0 | 131.1 |
| 2048 | 15.1 | 43.8 | 63.7 | 132.8 |
| 2049 | 15.4 | 44.4 | 64.4 | 134.5 |
| 2050 | 15.7 | 44.9 | 65.0 | 136.2 |

This Annex provides additional technical information about the non-$CO_2$ emission projections used in the modeling and the method for extrapolating emissions forecasts through 2300 and shows the full distribution of 2010 SCC estimates by model and scenario combination.

### 14A.9.1 Other (non-$CO_2$) gases

In addition to fossil and industrial $CO_2$ emissions, each EMF scenario provides projections of methane ($CH_4$), nitrous oxide ($N_2O$), fluorinated gases, and net land use $CO_2$ emissions to 2100. These assumptions are used in all three IAMs while retaining each model's default radiative forcings (RF) due to other factors (*e.g.*, aerosols and other gases). Specifically, to obtain the RF associated with the non-$CO_2$ EMF emissions only, we calculated the RF associated with the EMF atmospheric $CO_2$ concentrations and subtracted them from the EMF total RF.[ee] This approach respects the EMF scenarios as much as possible and at the same time takes account of those components not included in the EMF projections. Since each model treats non-$CO_2$ gases differently (*e.g.*, DICE lumps all other gases into one composite exogenous input), this approach was applied slightly differently in each of the models.

FUND: Rather than relying on RF for these gases, the actual emissions from each scenario were used in FUND. The model default trajectories for $CH_4$, $N_20$, $SF_6$, and the $CO_2$ emissions from land were replaced with the EMF values.

PAGE: PAGE models $CO_2$, $CH_4$, sulfur hexafluoride ($SF_6$), and aerosols and contains an "excess forcing" vector that includes the RF for everything else. To include the EMF values, we removed the default $CH_4$ and $SF_6$ factors[ff], decomposed the excess forcing vector, and constructed a new excess forcing vector that includes the EMF RF for $CH_4$, $N_20$, and fluorinated gases, as well as the model default values for aerosols and other factors. Net land use $CO_2$ emissions were added to the fossil and industrial $CO_2$ emissions pathway.

DICE: DICE presents the greatest challenge because all forcing due to factors other than industrial $CO_2$ emissions is embedded in an exogenous non-$CO_2$ RF vector. To decompose this exogenous forcing path into EMF non-$CO_2$ gases and other gases, we relied on the references in DICE2007 to the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) and the discussion of aerosol forecasts in the IPCC's Third Assessment Report (TAR) and in AR4, as explained below. In DICE2007, Nordhaus assumes that exogenous forcing from all non-$CO_2$ sources is -0.06 $W/m^2$ in 2005, as reported in AR4, and increases linearly to 0.3 $W/m^2$ in 2105, based on GISS projections, and then stays constant after that time.

According to AR4, the RF in 2005 from $CH_4$, $N_20$, and halocarbons (approximately similar to the F-gases in the EMF-22 scenarios) was 0.48 + 0.16 + 0.34 = 0.98 $W/m^2$ and RF from total aerosols was -1.2 $W/m^2$. Thus, the -.06 $W/m^2$ non-$CO_2$ forcing in DICE can be

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[ee] Note EMF did not provide $CO_2$ concentrations for the IMAGE reference scenario. Thus, for this scenario, we fed the fossil, industrial, and land $CO_2$ emissions into MAGICC (considered a "neutral arbiter" model, which is tuned to emulate the major global climate models) and the resulting $CO_2$ concentrations were used. Note also that MERGE assumes a neutral biosphere so net land $CO_2$ emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (i.e., we add up the land use emissions from the other three models and divide by 4).

[ff] Both the model default $CH_4$ emissions and the initial atmospheric $CH_4$ is set to zero to avoid double counting the effect of past $CH_4$ emissions.

decomposed into: 0.98 $W/m^2$ due to the EMF non-$CO_2$ gases, -1.2 $W/m^2$ due to aerosols, and the remainder, 0.16 $W/m^2$, due to other residual forcing.

For subsequent years, we calculated the DICE default RF from aerosols and other non-$CO_2$ gases based on the following two assumptions:

> (1) RF from aerosols declines linearly from 2005 to 2100 at the rate projected by the TAR and then stays constant thereafter; and
> (2) With respect to RF from non-$CO_2$ gases not included in the EMF-22 scenarios, the share of non-aerosol RF matches the share implicit in the AR4 summary statistics cited above and remains constant over time.

Assumption (1) means that the RF from aerosols in 2100 equals 66 percent of that in 2000, which is the fraction of the TAR projection of total RF from aerosols (including sulfates, black carbon, and organic carbon) in 2100 vs. 2000 under the A1B SRES emissions scenario. Since the SRES marker scenarios were not updated for the AR4, the TAR provides the most recent IPCC projection of aerosol forcing. We rely on the A1B projection from the TAR because it provides one of the lower aerosol forecasts among the SRES marker scenarios and is more consistent with the AR4 discussion of the post-SRES literature on aerosols:

> *Aerosols have a net cooling effect and the representation of aerosol and aerosol precursor emissions, including sulfur dioxide, black carbon and organic carbon, has improved in the post-SRES scenarios. Generally, these emissions are projected to be lower than reported in SRES. {WGIII 3.2, TS.3, SPM}.*[gg]

Assuming a simple linear decline in aerosols from 2000 to 2100 also is more consistent with the recent literature on these emissions. For example, the figure below shows that the sulfur dioxide emissions peak over the short term of some SRES scenarios above the upper bound estimates of the more recent scenarios.[hh] Recent scenarios project sulfur emissions to peak earlier and at lower levels compared to the SRES in part because of new information about present and planned sulfur legislation in some developing countries, such as India and China.[ii] The lower-bound projections of the recent literature have also shifted downward slightly compared to the SRES scenario (IPCC 2007).

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[gg] AR4 Synthesis Report, p. 44, http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

[hh] See Smith, S.J., R. Andres, E. Conception, and J. Lurz, 2004: Historical sulfur dioxide emissions, 1850-2000: methods and results. Joint Global Research Institute, College Park, 14 pp.

[ii] See Carmichael, G., D. Streets, G. Calori, M. Amann, M. Jacobson, J. Hansen, and H. Ueda, 2002: Changing trends in sulphur emissions in Asia: implications for acid deposition, air pollution, and climate. Environmental Science and Technology, 36(22):4707- 4713; Streets, D., K. Jiang, X. Hu, J. Sinton, X.-Q. Zhang, D. Xu, M. Jacobson, and J. Hansen, 2001: Recent reductions in China's greenhouse gas emissions. Science, 294(5548): 1835-1837.

With these assumptions, the DICE aerosol forcing changes from -1.2 in 2005 to -0.792 in 2105 W/m$^2$; forcing due to other non-$CO_2$ gases not included in the EMF scenarios declines from 0.160 to 0.153 W/m$^2$.

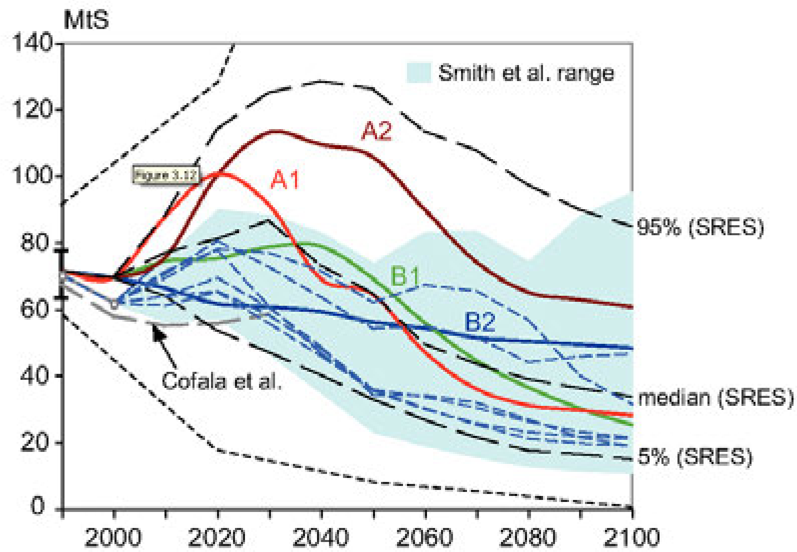


**Figure 14A.9.2 Sulfur Dioxide Emission Scenarios**

Notes: Thick colored lines depict the four SRES marker scenarios and black dashed lines show the median, 5$^{th}$, and 95$^{th}$ percentile of the frequency distribution for the full ensemble of 40 SRES scenarios. The blue area (and the thin dashed lines in blue) illustrates individual scenarios and the range of Smith et al. (2004). Dotted lines indicate the minimum and maximum of $SO_2$ emissions scenarios developed pre-SRES.
Source: IPCC (2007), AR4 WGIII 3.2,
http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch3-ens3-2-2-4.html.

Although other approaches to decomposing the DICE exogenous forcing vector are possible, initial sensitivity analysis suggests that the differences among reasonable alternative approaches are likely to be minor. For example, adjusting the TAR aerosol projection above to assume that aerosols will be maintained at 2000 levels through 2100 reduces average SCC values (for 2010) by approximately 3 percent (or less than $2); assuming all aerosols are phased out by 2100 increases average 2010 SCC values by 6-7 percent (or $0.50-$3)–depending on the discount rate. These differences increase slightly for SCC values in later years but are still well within 10 percent of each other as far out as 2050.

Finally, as in PAGE, the EMF net land use $CO_2$ emissions are added to the fossil and industrial $CO_2$ emissions pathway.

### 14A.9.2 Extrapolating Emissions Projections to 2300

To run each model through 2300 requires assumptions about GDP, population, greenhouse gas emissions, and radiative forcing trajectories after 2100, the last year for which these projections are available from the EMF-22 models. These inputs were extrapolated from 2100 to 2300 as follows:

1. Population growth rate declines linearly, reaching zero in the year 2200.
2. GDP/per capita growth rate declines linearly, reaching zero in the year 2300.
3. The decline in the fossil and industrial carbon intensity ($CO_2$/GDP) growth rate over 2090-2100 is maintained from 2100 through 2300.
4. Net land use $CO_2$ emissions decline linearly, reaching zero in the year 2200.
5. Non-$CO_2$ radiative forcing remains constant after 2100.

Long run stabilization of GDP per capita was viewed as a more realistic simplifying assumption than a linear or exponential extrapolation of the pre-2100 economic growth rate of each EMF scenario. This is based on the idea that increasing scarcity of natural resources and the degradation of environmental sinks available for assimilating pollution from economic production activities may eventually overtake the rate of technological progress. Thus, the overall rate of economic growth may slow over the very long run. The interagency group also considered allowing an exponential decline in the growth rate of GDP per capita. However, since this would require an additional assumption about how close to zero the growth rate would get by 2300, the group opted for the simpler and more transparent linear extrapolation to zero by 2300.

The population growth rate is also assumed to decline linearly, reaching zero by 2200. This assumption is reasonably consistent with the United Nations long run population forecast, which estimates global population to be fairly stable after 2150 in the medium scenario (UN 2004).[jj] The resulting range of EMF population trajectories (figure below) also encompass the UN medium scenario forecasts through 2300—global population of 8.5 billion by 2200, and 9 billion by 2300.

Maintaining the decline in the 2090-2100 carbon intensity growth rate (*i.e.*, $CO_2$ per dollar of GDP) through 2300 assumes that technological improvements and innovations in the areas of energy efficiency and other carbon reducing technologies (possibly including currently unavailable methods) will continue to proceed at roughly the same pace that is projected to occur towards the end of the forecast period for each EMF scenario. This assumption implies that total cumulative emissions in 2300 will be between 5,000 and 12,000 GtC, which is within the range of the total potential global carbon stock estimated in the literature.

Net land use $CO_2$ emissions are expected to stabilize in the long run, so in the absence of any post 2100 projections, the group assumed a linear decline to zero by 2200. Given no a priori reasons for assuming a long run increase or decline in non-$CO_2$ radiative forcing, it is assumed to remain at the 2100 levels for each EMF scenario through 2300.

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[jj] United Nations. 2004. *World Population to 2300*.
http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf

Figures below show the paths of global population, GDP, fossil and industrial $CO_2$ emissions, net land $CO_2$ emissions, non-$CO_2$ radiative forcing, and $CO_2$ intensity (fossil and industrial $CO_2$ emissions/GDP) resulting from these assumptions.

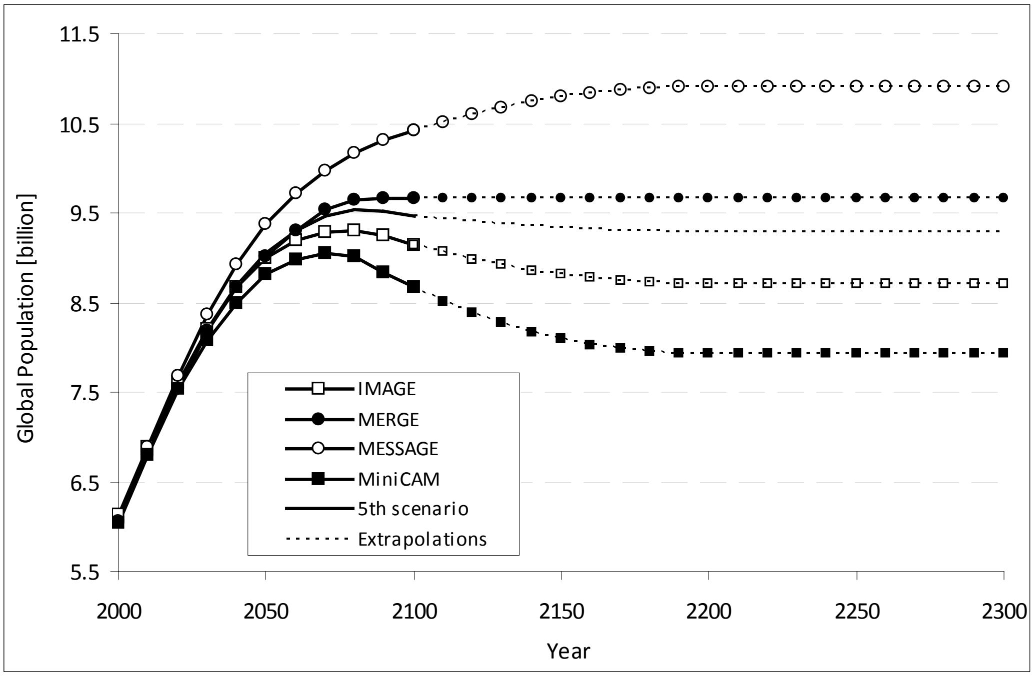


**Figure 14A.9.3 Global Population, 2000-2300 (Post-2100 extrapolations assume the population growth rate changes linearly to reach a zero growth rate by 2200.)**

Note: In the fifth scenario, 2000-2100 population is equal to the average of the population under the 550 ppm $CO_2$e, full-participation, not-to-exceed scenarios considered by each of the four models.

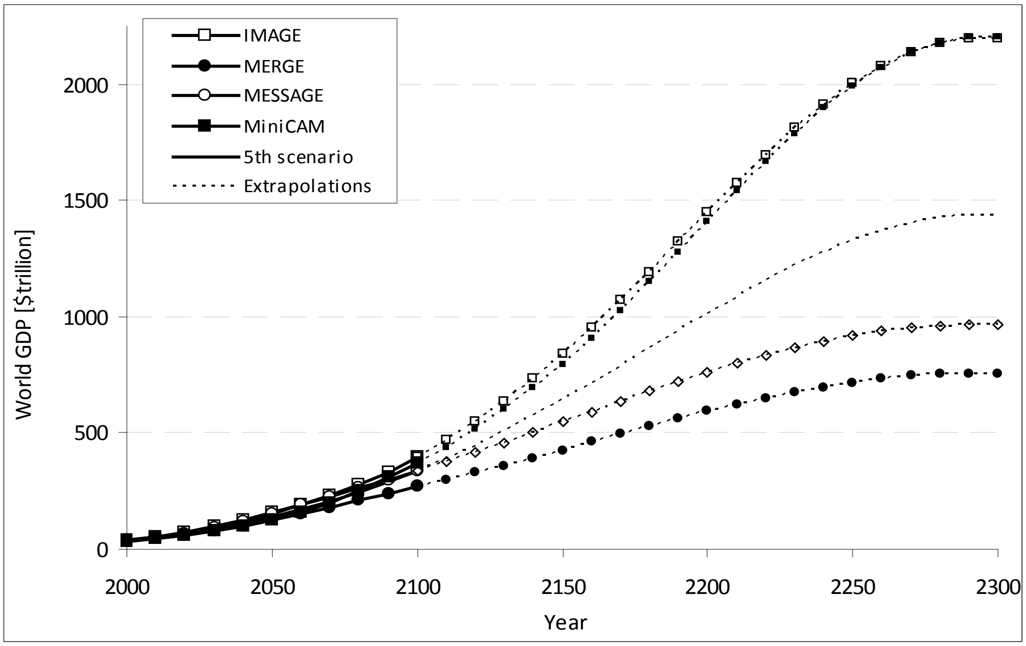


**Figure 14A.9.4 World GDP, 2000-2300 (Post-2100 extrapolations assume GDP per capita growth declines linearly, reaching zero in the year 2300)**

Note: In the fifth scenario, 2000-2100 GDP is equal to the average of the GDP under the 550 ppm $CO_2$e, full-participation, not-to-exceed scenarios considered by each of the four models.

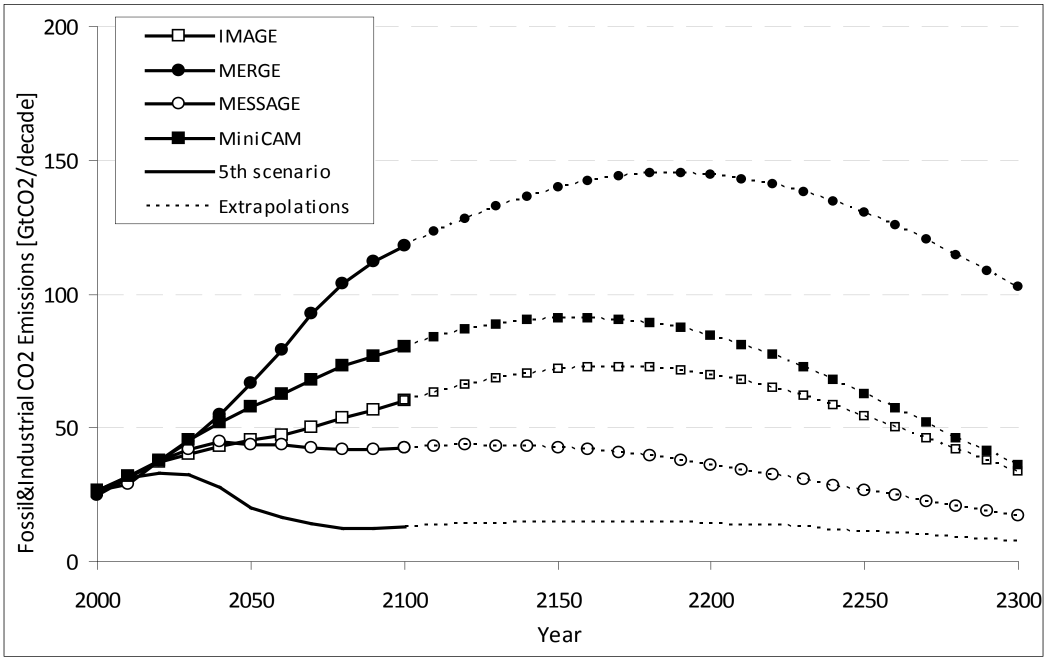


**Figure 14A.9.5 Global Fossil and Industrial $CO_2$ Emissions, 2000-2300 (Post-2100 extrapolations assume growth rate of $CO_2$ intensity ($CO_2$/GDP) over 2090-2100 is maintained through 2300)**

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm $CO_2$e, full-participation, not-to-exceed scenarios considered by each of the four models.

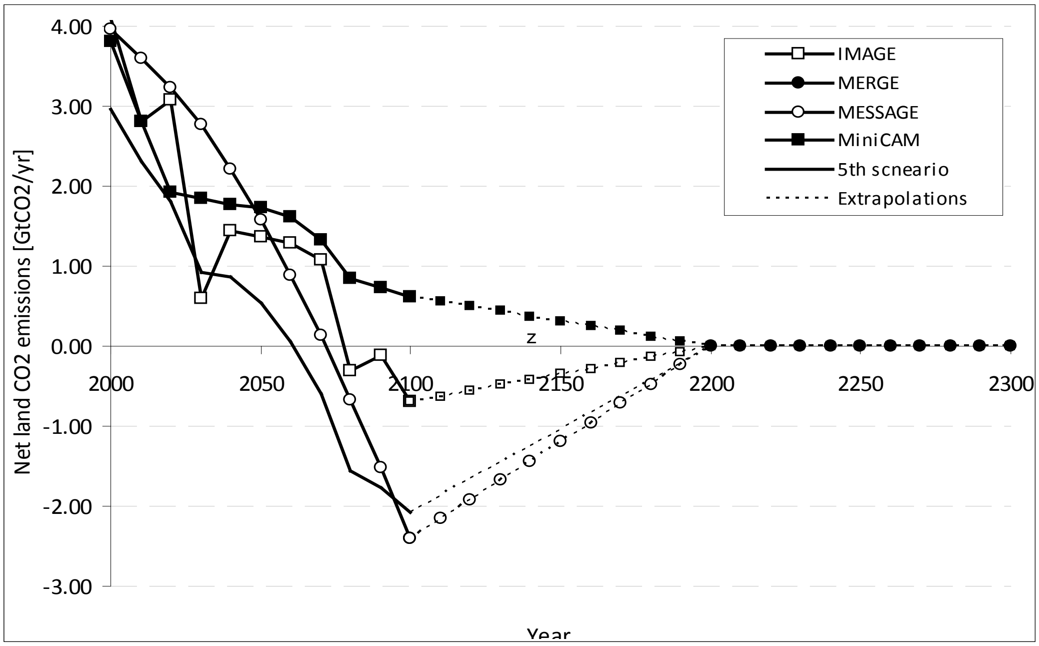


**Figure 14A.9.6 Global Net Land Use $CO_2$ Emissions, 2000-2300 (Post-2100 extrapolations assume emissions decline linearly, reaching zero in the year 2200)**[kk]

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm $CO_2$e, full-participation, not-to-exceed scenarios considered by each of the four models.

[kk] MERGE assumes a neutral biosphere so net land $CO_2$ emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (i.e., we add up the land use emissions from the other three models and divide by 4).

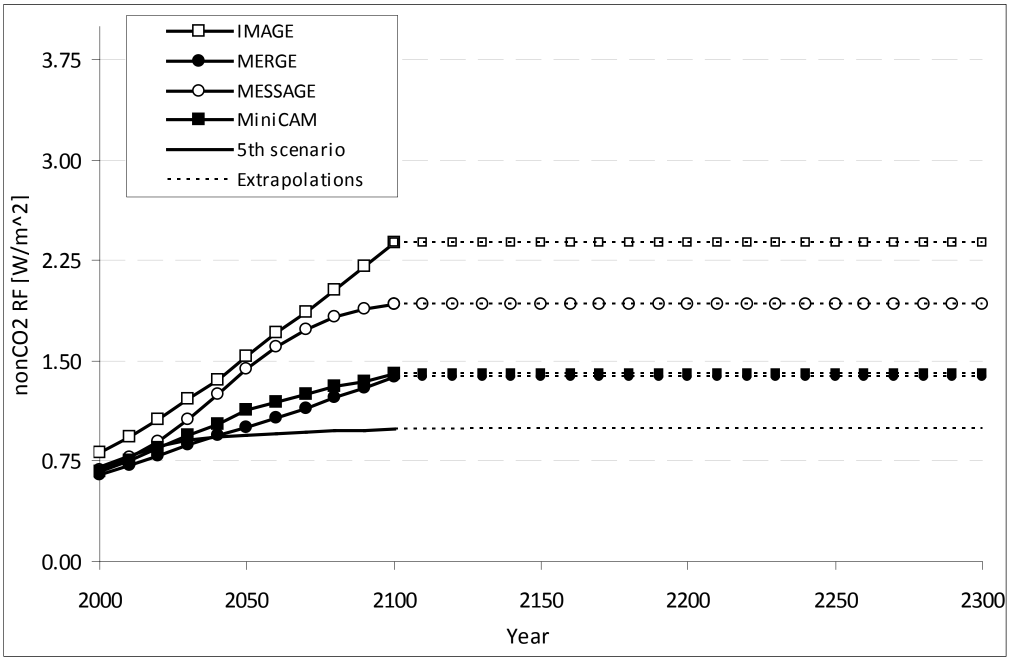


**Figure 14A.9.7 Global Non-$CO_2$ Radiative Forcing, 2000-2300 (Post-2100 extrapolations assume constant non-$CO_2$ radiative forcing after 2100)**

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm $CO_2$e, full-participation, not-to-exceed scenarios considered by each of the four models.

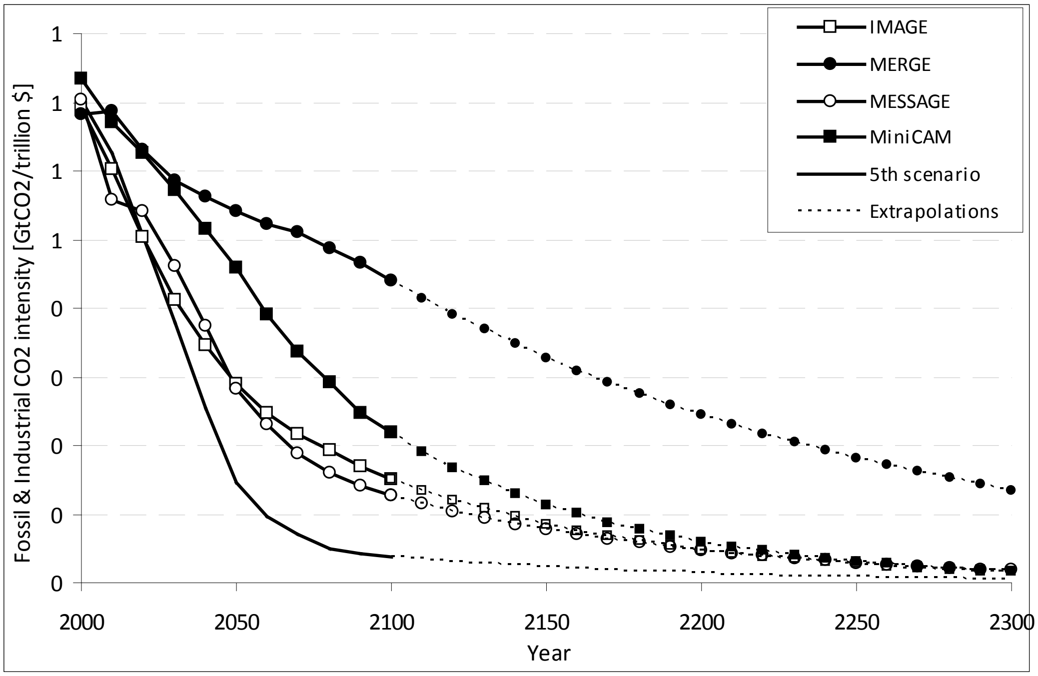


**Figure 14A.9.8 Global $CO_2$ Intensity (fossil & industrial $CO_2$ emissions/GDP), 2000-2300 (Post-2100 extrapolations assume decline in $CO_2$/GDP growth rate over 2090-2100 is maintained through 2300)**

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm $CO_2$e, full-participation, not-to-exceed scenarios considered by each of the four models.

**Table 14A.9.2 2010 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton $CO_2$)**

| *Percentile* | 1st | 5th | 10th | 25th | 50th | Avg | 75th | 90th | 95th | 99th |
|---|---|---|---|---|---|---|---|---|---|---|
| *Scenario* | **PAGE** | | | | | | | | | |
| **IMAGE** | 3.3 | 5.9 | 8.1 | 13.9 | 28.8 | 65.5 | 68.2 | 147.9 | 239.6 | 563.8 |
| **MERGE optimistic** | 1.9 | 3.2 | 4.3 | 7.2 | 14.6 | 34.6 | 36.2 | 79.8 | 124.8 | 288.3 |
| **Message** | 2.4 | 4.3 | 5.8 | 9.8 | 20.3 | 49.2 | 50.7 | 114.9 | 181.7 | 428.4 |
| **MiniCAM base** | 2.7 | 4.6 | 6.4 | 11.2 | 22.8 | 54.7 | 55.7 | 120.5 | 195.3 | 482.3 |
| **5th scenario** | 2.0 | 3.5 | 4.7 | 8.1 | 16.3 | 42.9 | 41.5 | 103.9 | 176.3 | 371.9 |

| *Scenario* | **DICE** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **IMAGE** | 16.4 | 21.4 | 25 | 33.3 | 46.8 | 54.2 | 69.7 | 96.3 | 111.1 | 130.0 |
| **MERGE optimistic** | 9.7 | 12.6 | 14.9 | 19.7 | 27.9 | 31.6 | 40.7 | 54.5 | 63.5 | 73.3 |
| **Message** | 13.5 | 17.2 | 20.1 | 27 | 38.5 | 43.5 | 55.1 | 75.8 | 87.9 | 103.0 |
| **MiniCAM base** | 13.1 | 16.7 | 19.8 | 26.7 | 38.6 | 44.4 | 56.8 | 79.5 | 92.8 | 109.3 |
| **5th scenario** | 10.8 | 14 | 16.7 | 22.2 | 32 | 37.4 | 47.7 | 67.8 | 80.2 | 96.8 |

| *Scenario* | **FUND** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **IMAGE** | -33.1 | -18.9 | -13.3 | -5.5 | 4.1 | 19.3 | 18.7 | 43.5 | 67.1 | 150.7 |
| **MERGE optimistic** | -33.1 | -14.8 | -10 | -3 | 5.9 | 14.8 | 20.4 | 43.9 | 65.4 | 132.9 |
| **Message** | -32.5 | -19.8 | -14.6 | -7.2 | 1.5 | 8.8 | 13.8 | 33.7 | 52.3 | 119.2 |
| **MiniCAM base** | -31.0 | -15.9 | -10.7 | -3.4 | 6 | 22.2 | 21 | 46.4 | 70.4 | 152.9 |
| **5th scenario** | -32.2 | -21.6 | -16.7 | -9.7 | -2.3 | 3 | 6.7 | 20.5 | 34.2 | 96.8 |

Table 14A.9.3 2010 Global SCC Estimates at 3 Percent Discount Rate (2007$/ton $CO_2$)

| *Percentile* | 1st | 5th | 10th | 25th | 50th | Avg | 75th | 90th | 95th | 99th |
|---|---|---|---|---|---|---|---|---|---|---|
| *Scenario* | | | | | **PAGE** | | | | | |
| **IMAGE** | 2.0 | 3.5 | 4.8 | 8.1 | 16.5 | 39.5 | 41.6 | 90.3 | 142.4 | 327.4 |
| **MERGE optimistic** | 1.2 | 2.1 | 2.8 | 4.6 | 9.3 | 22.3 | 22.8 | 51.3 | 82.4 | 190.0 |
| **Message** | 1.6 | 2.7 | 3.6 | 6.2 | 12.5 | 30.3 | 31 | 71.4 | 115.6 | 263.0 |
| **MiniCAM base** | 1.7 | 2.8 | 3.8 | 6.5 | 13.2 | 31.8 | 32.4 | 72.6 | 115.4 | 287.0 |
| **5th scenario** | 1.3 | 2.3 | 3.1 | 5 | 9.6 | 25.4 | 23.6 | 62.1 | 104.7 | 222.5 |
| *Scenario* | | | | | **DICE** | | | | | |
| **IMAGE** | 11.0 | 14.5 | 17.2 | 22.8 | 31.6 | 35.8 | 45.4 | 61.9 | 70.8 | 82.1 |
| **MERGE optimistic** | 7.1 | 9.2 | 10.8 | 14.3 | 19.9 | 22 | 27.9 | 36.9 | 42.1 | 48.8 |
| **Message** | 9.7 | 12.5 | 14.7 | 19 | 26.6 | 29.8 | 37.8 | 51.1 | 58.6 | 67.4 |
| **MiniCAM base** | 8.8 | 11.5 | 13.6 | 18 | 25.2 | 28.8 | 36.9 | 50.4 | 57.9 | 67.8 |
| **5th scenario** | 7.9 | 10.1 | 11.8 | 15.6 | 21.6 | 24.9 | 31.8 | 43.7 | 50.8 | 60.6 |
| *Scenario* | | | | | **FUND** | | | | | |
| **IMAGE** | -25.2 | -15.3 | -11.2 | -5.6 | 0.9 | 8.2 | 10.4 | 25.4 | 39.7 | 90.3 |
| **MERGE optimistic** | -24.0 | -12.4 | -8.7 | -3.6 | 2.6 | 8 | 12.2 | 27 | 41.3 | 85.3 |
| **Message** | -25.3 | -16.2 | -12.2 | -6.8 | -0.5 | 3.6 | 7.7 | 20.1 | 32.1 | 72.5 |
| **MiniCAM base** | -23.1 | -12.9 | -9.3 | -4 | 2.4 | 10.2 | 12.2 | 27.7 | 42.6 | 93.0 |
| **5th scenario** | -24.1 | -16.6 | -13.2 | -8.3 | -3 | -0.2 | 2.9 | 11.2 | 19.4 | 53.6 |

**Table 14A.9.4 2010 Global SCC Estimates at 5 Percent Discount Rate (2007$/ton $CO_2$)**

| *Percentile* | 1st | 5th | 10th | 25th | 50th | Avg | 75th | 90th | 95th | 99th |
|---|---|---|---|---|---|---|---|---|---|---|
| *Scenario* | | | | | PAGE | | | | | |
| **IMAGE** | 0.5 | 0.8 | 1.1 | 1.8 | 3.5 | 8.3 | 8.5 | 19.5 | 31.4 | 67.2 |
| **MERGE optimistic** | 0.3 | 0.5 | 0.7 | 1.2 | 2.3 | 5.2 | 5.4 | 12.3 | 19.5 | 42.4 |
| **Message** | 0.4 | 0.7 | 0.9 | 1.6 | 3 | 7.2 | 7.2 | 17 | 28.2 | 60.8 |
| **MiniCAM base** | 0.3 | 0.6 | 0.8 | 1.4 | 2.7 | 6.4 | 6.6 | 15.9 | 24.9 | 52.6 |
| **5th scenario** | 0.3 | 0.6 | 0.8 | 1.3 | 2.3 | 5.5 | 5 | 12.9 | 22 | 48.7 |

| *Scenario* | | | | | DICE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **IMAGE** | 4.2 | 5.4 | 6.2 | 7.6 | 10 | 10.8 | 13.4 | 16.8 | 18.7 | 21.1 |
| **MERGE optimistic** | 2.9 | 3.7 | 4.2 | 5.3 | 7 | 7.5 | 9.3 | 11.7 | 12.9 | 14.4 |
| **Message** | 3.9 | 4.9 | 5.5 | 7 | 9.2 | 9.8 | 12.2 | 15.4 | 17.1 | 18.8 |
| **MiniCAM base** | 3.4 | 4.2 | 4.7 | 6 | 7.9 | 8.6 | 10.7 | 13.5 | 15.1 | 16.9 |
| **5th scenario** | 3.2 | 4 | 4.6 | 5.7 | 7.6 | 8.2 | 10.2 | 12.8 | 14.3 | 16.0 |

| *Scenario* | | | | | FUND | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **IMAGE** | -11.7 | -8.4 | -6.9 | -4.6 | -2.2 | -1.3 | 0.7 | 4.1 | 7.4 | 17.4 |
| **MERGE optimistic** | -10.6 | -7.1 | -5.6 | -3.6 | -1.3 | -0.3 | 1.6 | 5.4 | 9.1 | 19.0 |
| **Message** | -12.2 | -8.9 | -7.3 | -4.9 | -2.5 | -1.9 | 0.3 | 3.5 | 6.5 | 15.6 |
| **MiniCAM base** | -10.4 | -7.2 | -5.8 | -3.8 | -1.5 | -0.6 | 1.3 | 4.8 | 8.2 | 18.0 |
| **5th scenario** | -10.9 | -8.3 | -7 | -5 | -2.9 | -2.7 | -0.8 | 1.4 | 3.2 | 9.2 |

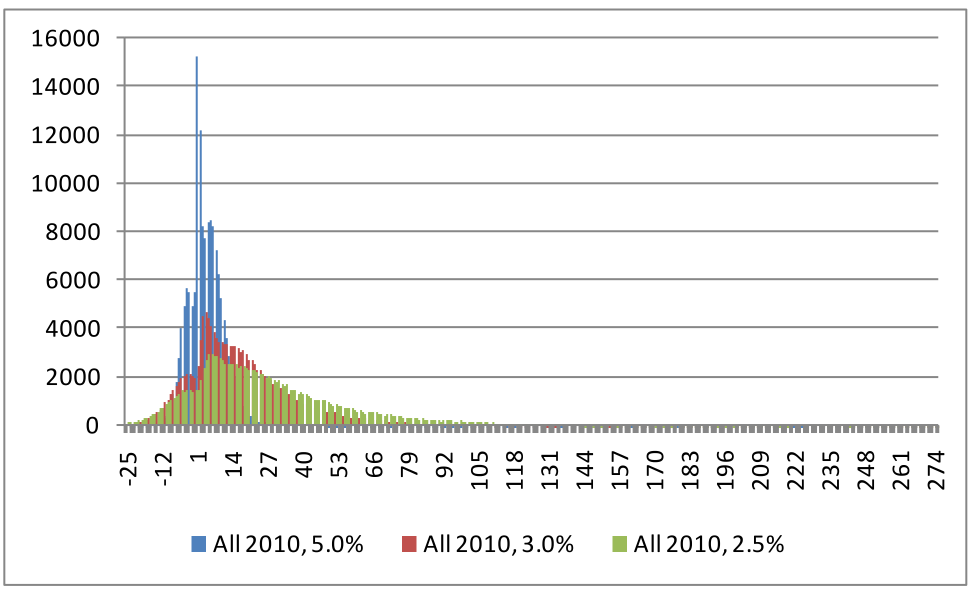


**Figure 14A.9.9 Histogram of Global SCC Estimates in 2010 (2007$/ton $CO_2$), by discount rate**

* The distribution of SCC values ranges from -$5,192 to $66,116, but the X-axis has been truncated at approximately the 1st and 99th percentiles to better show the data.

**Table 14A.9.5 Additional Summary Statistics of 2010 Global SCC Estimates**

| Discount Rate | | Scenario | | |
|---|---|---|---|---|
| | | DICE | PAGE | FUND |
| 5% | Mean | 9 | 6.5 | -1.3 |
| | Variance | 13.1 | 136 | 70.1 |
| | Skewness | 0.8 | 6.3 | 28.2 |
| | Kurtosis | 0.2 | 72.4 | 1,479.00 |
| 3% | Mean | 28.3 | 29.8 | 6 |
| | Variance | 209.8 | 3,383.70 | 16,382.50 |
| | Skewness | 1.1 | 8.6 | 128 |
| | Kurtosis | 0.9 | 151 | 18,976.50 |
| 2.50% | Mean | 42.2 | 49.3 | 13.6 |
| | Variance | 534.9 | 9,546.00 | ####### |
| | Skewness | 1.2 | 8.7 | 149 |
| | Kurtosis | 1.1 | 143.8 | 23,558.30 |

## APPENDIX 14B. TECHNICAL UPDATE OF SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

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## APPENDIX 14B. TECHNICAL UPDATE OF SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

### 14B.1 PREFACE

The following text is reproduced almost verbatim from the May 2013 report of the Interagency Working Group on the Social Cost of Carbon of the United States Government. Minor changes were made to the working group's report to make it more consistent with the rest of this technical support document.

### 14B.2 PURPOSE

The purpose of this document is to update the schedule of social cost of carbon (SCC) [a] estimates from the 2010 interagency technical support document (TSD) (Interagency Working Group on Social Cost of Carbon 2010).[1] E.O. 13563 commits the Administration to regulatory decision making "based on the best available science."[b] Additionally, the interagency group recommended in 2010 that the SCC estimates be revisited on a regular basis or as model updates that reflect the growing body of scientific and economic knowledge become available.[c] New versions of the three integrated assessment models used by the U.S. government to estimate the SCC (DICE, FUND, and PAGE), are now available and have been published in the peer reviewed literature. While acknowledging the continued limitations of the approach taken by the interagency group in 2010 (documented in the original 2010 TSD), this document provides an update of the SCC estimates based solely on the latest peer-reviewed version of the models, replacing model versions that were developed up to ten years ago in a rapidly evolving field. It does not revisit other assumptions with regard to the discount rate, reference case socioeconomic and emission scenarios, or equilibrium climate sensitivity. Improvements in the way damages are modeled are confined to those that have been incorporated into the latest versions of the models by the developers themselves in the peer-reviewed literature. The Environmental Protection Agency (EPA), in collaboration with other Federal agencies such as the Department of Energy (DOE), continues to investigate potential improvements to the way in which economic damages associated with changes in $CO_2$ emissions are quantified.

Section 14B.3 summarizes the major updates relevant to SCC estimation that are contained in the new versions of the integrated assessment models released since the 2010 interagency report. Section 14B.4 presents the updated schedule of SCC estimates for 2010 – 2050 based on these versions of the models.

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[a] In this document, we present all values of the SCC as the cost per metric ton of $CO_2$ emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of $CO_2$ and the mass of carbon is 3.67.
[b] http://www.whitehouse.gov/sites/default/files/omb/inforeg/eo12866/eo13563_01182011.pdf
[c] See p. 1, 3, 4, 29, and 33 (Interagency Working Group on Social Cost of Carbon 2010).[1]

## 14B.3 SUMMARY OF MODEL UPDATES

This section briefly summarizes changes integrated into the most recent versions of the three integrated assessment models (IAMs) used by the interagency group in 2010. We focus on describing those model updates that are relevant to estimating the social cost of carbon. For example, both the DICE and PAGE models now include an explicit representation of sea level rise damages. Other revisions to PAGE include: updated adaptation assumptions, revisions to ensure damages are constrained GDP, updated regional scaling of damages, and a revised treatment of potentially abrupt shifts in climate damages. In the most recent version of DICE, the model's simple carbon cycle has been updated to be more consistent with a relatively more complex climate model. The FUND model includes updated damage functions for sea level rise impacts, the agricultural sector, and reduced space heating requirements, as well as changes to the response of temperature to the buildup of GHG concentrations and the inclusion of indirect effects of methane emissions. Changes made to parts of the models that are superseded by the interagency working group's modeling assumptions – regarding climate sensitivity, discounting, and socioeconomic variables – are not discussed.

### 14B.3.1 DICE

Changes in the DICE model relevant for the SCC estimates developed by the interagency working group include: 1) updated parameter values for the carbon cycle model, 2) an explicit representation of sea level dynamics, and 3) a re-calibrated damage function that includes an explicit representation of economic damages from sea level rise. Changes were also made to other parts of the DICE model—including the equilibrium climate sensitivity parameter, the rate of change of total factor productivity, and the elasticity of the marginal utility of consumption—but these components of DICE are superseded by the interagency working group's assumptions and so will not be discussed here. More details on DICE2007 can be found in Nordhaus (2008)[2] and on DICE2010 in Nordhaus (2010)[3] and the associated on-line appendix containing supplemental information.

#### 14B.3.1.1 Carbon Cycle Parameters

DICE uses a three-box model of carbon stocks and flows to represent the accumulation and transfer of carbon among the atmosphere, the shallow ocean and terrestrial biosphere, and the deep ocean. These parameters are "calibrated to match the carbon cycle in the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC)" (Nordhaus 2008 p 44).[2d] Carbon cycle transfer coefficient values in DICE2010 are based on re-calibration of the model to match the newer version of MAGICC (Nordhaus 2010 p 2).[3] For example, in DICE2010 in each decade, 12 percent of the carbon in the atmosphere is transferred to the shallow ocean, 4.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 94.8 percent remains in the shallow ocean, and 0.5 percent is transferred to the deep ocean. For comparison, in DICE 2007, 18.9 percent of the carbon in the atmosphere is transferred to the shallow ocean each decade, 9.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 85.3 percent remains in the shallow ocean, and 5 percent is transferred to the deep ocean.

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[d] MAGICC is a simple climate model initially developed within the U.S. National Center for Atmospheric Research that has been used heavily by the Intergovernmental Panel on Climate Change (IPCC) to emulate projections from much more sophisticated state of the art earth system simulation models (Randall et al. 2007).[4]

The implication of these changes for DICE2010 is in general a weakening of the ocean as a carbon sink and therefore a higher concentration of carbon in the atmosphere than in DICE2007, for a given path of emissions. All else equal, these changes will generally increase the level of warming and therefore the SCC estimates in DICE2010 relative to those from DICE2007.

#### 14B.3.1.2 Sea Level Dynamics

A new feature of DICE2010 is an explicit representation of the dynamics of the global average sea level anomaly to be used in the updated damage function (discussed below). This section contains a brief description of the sea level rise (SLR) module; a more detailed description can be found on the model developer's website.[e] The average global sea level anomaly is modeled as the sum of four terms that represent contributions from: 1) thermal expansion of the oceans, 2) melting of glaciers and small ice caps, 3) melting of the Greenland ice sheet, and 4) melting of the Antarctic ice sheet.

The parameters of the four components of the SLR module are calibrated to match consensus results from the IPCC's Fourth Assessment Report.[4,f] The rise in sea level from thermal expansion in each time period (decade) is 2 percent of the difference between the sea level in the previous period and the long run equilibrium sea level, which is 0.5 meters per degree Celsius (°C) above the average global temperature in 1900. The rise in sea level from the melting of glaciers and small ice caps occurs at a rate of 0.008 meters per decade per °C above the average global temperature in 1900.

The contribution to sea level rise from melting of the Greenland ice sheet is more complex. The equilibrium contribution to SLR is 0 meters for temperature anomalies less than 1 °C and increases linearly from 0 meters to a maximum of 7.3 meters. The contribution to SLR in each period is proportional to the difference between the previous period's sea level anomaly and the equilibrium sea level anomaly, where the constant of proportionality increases with the temperature anomaly in the current period.

The contribution to SLR from the melting of the Antarctic ice sheet is -0.001 meters per decade when the temperature anomaly is below 3 °C and increases linearly to a maximum rate of 0.025 meters per decade at a temperature anomaly of 6 °C.

#### 14B.3.1.3 Re-calibrated Damage Function

Economic damages from climate change in the DICE model are represented by a fractional loss of gross economic output in each period. A portion of the remaining economic output in each period (net of climate change damages) is consumed and the remainder is invested in the physical capital stock to support future production, so each period's climate damages will reduce consumption in that period and in all future periods due to the lost investment. The

[e] Documentation on the new sea level rise module of DICE is available on William Nordhaus' website at: http://nordhaus.econ.yale.edu/documents/SLR_021910.pdf.
[f] For a review of post-IPCC AR4 research on sea level rise, see Nicholls et al. (2011)[5] and NAS (2011).[6]

fraction of output in each period that is lost due to climate change impacts is represented as one minus a fraction, which is one divided by a quadratic function of the temperature anomaly, producing a sigmoid ("S"-shaped) function. The loss function in DICE2010 has been expanded by adding a quadratic function of SLR to the quadratic function of temperature. In DICE2010 the temperature anomaly coefficients have been recalibrated to avoid double-counting damages from sea level rise that were implicitly included in these parameters in DICE2007.

The aggregate damages in DICE2010 are illustrated by Nordhaus (2010 p 3),[3] who notes that "…damages in the uncontrolled (baseline) (*i.e.*, reference) case … in 2095 are $12 trillion, or 2.8 percent of global output, for a global temperature increase of 3.4 $^{o}$C above 1900 levels." This compares to a loss of 3.2 percent of global output at 3.4 $^{o}$C in DICE2007. However, in DICE2010 (as downloaded from the homepage of William Nordhaus), annual damages are lower in most of the early periods but higher in later periods of the time horizon than would be calculated using the DICE2007 damage function. Specifically, the percent difference between damages in the base run of DICE2010 and those that would be calculated using the DICE2007 damage function starts at +7 percent in 2005, decreases to a low of -14 percent in 2065, then continuously increases to +20 percent by 2300 (the end of the interagency analysis time horizon), and to +160 percent by the end of the model time horizon in 2595. The large increases in the far future years of the time horizon are due to the permanence associated with damages from sea level rise, along with the assumption that the sea level is projected to continue to rise long after the global average temperature begins to decrease. The changes to the loss function generally decrease the interagency working group SCC estimates slightly, all else equal.

### 14B.3.2 FUND

FUND version 3.8 includes a number of changes over the previous version 3.5 used in the interagency report. Documentation supporting FUND and the model's source code for all versions of the model is available from the model authors.[g] Notable changes, due to their impact on the estimates of expected SCC, are adjustments to the space heating, agriculture, and sea level rise damage functions in addition to changes to the temperature response function and the inclusion of indirect effects from methane emissions.[h] We discuss each of these in turn.

#### 14B.3.2.1 Space Heating

In FUND, the damages associated with the change in energy needs for space heating are based on the estimated impact due to one degree of warming. These baseline damages are scaled based on the forecasted temperature anomaly's deviation from the one degree benchmark and adjusted for changes in vulnerability due to economic and energy efficiency growth. In FUND 3.5, the function that scales the base year damages adjusted for vulnerability allows for the possibility that in some simulations the benefits associated with reduced heating needs may be an unbounded convex function of the temperature anomaly. In FUND 3.8, the form of the scaling

[g] http://www.fund-model.org/. This report uses version 3.8 of the FUND model, which represents a modest update to the most recent version of the model to appear in the literature (version 3.7) (Anthoff and Tol, 2013).[7] For the purpose of computing the SCC, the relevant changes are associated with improving consistency with IPCC AR4 by adjusting the atmospheric lifetimes of CH4 and N2O and incorporating the indirect forcing effects of CH4, along with making minor stability improvements in the sea wall construction algorithm.

[h] The other damage sectors (water resources, space cooling, land loss, migration, ecosystems, human health, and extreme weather) were not the subject of significant updates.

has been modified to ensure that the function is everywhere concave, meaning that for every simulation there will exist an upper bound on the benefits a region may receive from reduced space heating needs. The new formulation approaches a value of two in the limit as the temperature anomaly increases, or in other words, assuming no decrease in vulnerability, the reduced expenditures on space heating at any level of warming will not exceed two times the reductions experienced at one degree of warming. Since the reduced need for space heating represents a benefit of climate change in the model, or a negative damage, this change will increase the estimated SCC. This update accounts for a significant portion of the difference in the expected SCC estimates reported by the two versions of the model when run probabilistically.

#### 14B.3.2.2 Sea Level Rise and Land Loss

The FUND model explicitly includes damages associated with the inundation of dry land due to sea level rise. The amount of land lost within a region is dependent upon the proportion of the coastline being protected by adequate sea walls and the amount of sea level rise. In FUND 3.5 the function defining the potential land lost in a given year due to sea level rise is linear in the rate of sea level rise for that year. This assumption implicitly assumes that all regions are well represented by a homogeneous coastline in length and a constant uniform slope moving inland. In FUND 3.8 the function defining the potential land lost has been changed to be a non-linear function of sea level rise, thereby assuming that the slope of the shore line is not constant moving inland, with a positive first derivative. The effect of this change is to typically reduce the vulnerability of some regions to sea level rise based land loss, therefore having an effect of lowering the expected SCC estimate. The model has also been updated to assume that the value of dry land at risk of inundation is not uniform across a region but will be a decreasing function of protection measure, thereby implicitly assuming that the most valuable land will be protected first.

#### 14B.3.2.3 Agriculture

In FUND, the damages associated with the agricultural sector are measured as proportional to the sector's value. The fraction is made up of three additively separable components that represent the effects from carbon fertilization, the rate of temperature change, and the level of the temperature anomaly. In both FUND 3.5 and FUND 3.8, the fraction of the sector's value lost due to the level of the temperature anomaly is modeled as a quadratic function with an intercept of zero. In FUND 3.5, the linear and quadratic coefficients are modeled as the ratio of two normal distributions. Within this specification, as draws from the distribution in the denominator approached zero the share of the sector's value "lost" approaches (+/-) infinity independent of the temperature anomaly itself. In FUND 3.8, the linear and quadratic coefficients are drawn directly from truncated normal distributions so that they remain in the range $[0,\infty)$ and $(-\infty,0]$, respectively, where the means for the new distributions are set equal to the ratio of the means from the normal distributions used in the previous version. In general the impact of this change has been to increase the likelihood that increases in the temperature level will have either larger positive or negative effects on the agricultural sector relative to the previous version (through eliminating simulations in which the "lost" value approached (+/-) infinity). The net effect of this change on the SCC estimates is difficult to predict.

#### 14B.3.2.4 Temperature Response Model

The temperature response model translates changes in global levels of radiative forcing into the current expected temperature anomaly. In FUND, a given year's increase in the cumulative temperature anomaly is based on a mean reverting function where the mean equals the equilibrium temperature anomaly that would eventually be reached if that year's level of radiative forcing were sustained. The rate of mean reversion defines the rate at which the transient temperature approaches the equilibrium. In FUND 3.5, the rate of temperature response is defined as a decreasing linear function of equilibrium climate sensitivity to capture the fact that the progressive heat uptake of the deep ocean causes the rate to slow at higher values of the equilibrium climate sensitivity. In FUND 3.8, the rate of temperature response has been updated to a quadratic function of the equilibrium climate sensitivity. This change reduces the sensitivity of the rate of temperature response to the level of the equilibrium climate sensitivity. Therefore in FUND 3.8, the temperature response will typically be faster than in the previous version. The overall effect of this change is likely to increase estimates of the SCC as higher temperatures are reached during the timeframe analyzed and as the same damages experienced in the previous version of the model are now experienced earlier and therefore discounted less.

#### 14B.3.2.5 Methane

The IPCC notes a series of indirect effects of methane emissions, and has developed methods for proxying such effects when computing the global warming potential of methane (Forster et al. 2007).[8] FUND 3.8 now includes the same methods for incorporating the indirect effects of methane emissions. Specifically, the average atmospheric lifetime of methane has been set to 12 years to account for the feedback of CH4 emissions on its own lifetime. The radiative forcing associated with atmospheric methane has also been increase by 40% to account for its net impact on ozone production and increase in stratospheric water vapor. The general effect of this increased radiative forcing will be to increase the estimated SCC values, where the degree to which this occurs will be dependent upon the relative curvature of the damage functions with respect to the temperature anomaly.

### 14B.3.3 PAGE

PAGE09 (Hope 2012)[9] includes a number of changes from PAGE2002, the version used in the 2009 SCC interagency report. The changes that most directly affect the SCC estimates include: explicitly modeling the impacts from sea level rise, revisions to the damage function to ensure damages are constrained by GDP, a change in the regional scaling of damages, a revised treatment for the probability of a discontinuity within the damage function, and revised assumptions on adaptation. The model also includes revisions to the carbon cycle feedback and the calculation of regional temperatures. More details on PAGE2009 can be found in three working papers (Hope 2011a, 2011b, 2011c).[10, 11, 12] A description of PAGE2002 can be found in Hope (2006).[13]

#### 14B.3.3.1 Sea Level Rise

While PAGE2002 aggregates all damages into two categories – economic and non-economic impacts - PAGE2009 adds a third explicit category: damages from sea level rise. In the previous version of the model, damages from sea level rise were subsumed by the other damage categories. PAGE09 models damages from sea level rise as increasing less than linearly with sea level based on the assumption that low-lying shoreline areas will be associated with higher damages than current inland areas. Damages from the economic and non-economic sector were adjusted to account for the introduction of this new category.

#### 14B.3.3.2 Revised Damage Function to Account for Saturation

In PAGE09, small initial economic and non-economic benefits (negative damages) are modeled for small temperature increases, but all regions eventually experience positive economic damages from climate change, where damages are the sum of additively separable polynomial functions of temperature and sea level rise. Damages transition from this polynomial function to a logistic path once they exceed a certain proportion of remaining Gross Domestic Product (GDP) to ensure that damages do not exceed 100 percent of GDP. This differs from PAGE2002, which allowed Eastern Europe to potentially experience large benefits from temperature increases, and which also did not bound the possible damages that could be experienced.

#### 14B.3.3.3 Regional Scaling Factors

As in the previous version of PAGE, the PAGE09 model calculates the damages for the European Union (EU) and then, assumes that damages for other regions are proportional based on a given scaling factor. The scaling factor in PAGE09 is based on the length of a region's coastline relative to the EU (Hope 2011b).[11] Because of the long coastline in the EU, other regions are, on average, less vulnerable than the EU for the same sea level and temperature increase, but all regions have a positive scaling factor. PAGE2002 based its scaling factors on four studies reported in the IPCC's third assessment report, and allowed for benefits from temperature increase in Eastern Europe, smaller impacts in developing countries, and higher damages in developing countries.

#### 14B.3.3.4 Probability of a Discontinuity

In PAGE2002, the damages associated with a "discontinuity" were modeled as an expected value. That is, additional damages from an extreme event, such as extreme melting of the Greenland ice sheet, were multiplied by the probability of the event occurring and added to the damage estimate. In PAGE09, the probability of "discontinuity" is treated as a discrete event for each year in the model. The damages for each model run are estimated with or without a discontinuity occurring, rather than as an expected value. A large-scale discontinuity becomes possible when the temperature rises beyond some threshold value between 2 and 4°C. The probability that a discontinuity will occur beyond this threshold then increases by between 10 and 30 percent for every 1°C rise in temperature beyond the threshold. If a discontinuity occurs, the EU loses an additional 5 to 25 percent of its GDP (drawn from a triangular distribution with a mean of 15 percent) in addition to other damages, and other regions lose an amount determined by the regional scaling factor. The threshold value for a possible discontinuity is lower than in PAGE2002, while the rate at which the probability of a discontinuity increases with the temperature anomaly and the damages that result from a discontinuity are both higher than in PAGE2002. The model assumes that only one discontinuity can occur and that the impact is phased in over a period of time, but once it occurs, its effect is permanent.

#### 14B.3.3.5 Adaptation

As in PAGE2002, adaptation is available to increase the tolerable level of temperature change and can help mitigate any climate change impacts that still occur. In PAGE this adaptation is the same regardless of the temperature change or sea level rise and is therefore akin to what is more commonly considered a reduction in vulnerability. It is modeled by modifying the temperature change and sea level rise used in the damage function or by reducing the damages by some percentage. PAGE09 assumes a smaller decrease in vulnerability than the previous version of the model and assumes that it will take longer for this change in vulnerability to be realized. In the aggregated economic sector, at the time of full implementation, this adaptation will mitigate all damages up to a temperature increase of 1°C, and for temperature anomalies between 1°C and 3°C, it will reduce damages by 15-30 percent (depending on the region). However, it takes 20 years to fully implement this adaptation. In PAGE2002, adaptation was assumed to reduce economic sector damages up to 3°C by 50-90 percent after 20 years. Beyond 3°C, no adaptation is assumed to be available to mitigate the impacts of climate change. For the non-economic sector, in PAGE09 adaptation is available to reduce 15 percent of the damages due to a temperature increase between 0°C and 2°C and is assumed to take 40 years to fully implement, instead of 25 percent of the damages over 20 years assumed in PAGE2002. Similarly, adaptation is assumed to alleviate 25-50 percent of the damages from the first 0.20 to 0.25 meters of sea level rise but is assumed to be ineffective thereafter. Hope (2011c)[12] estimates that the less optimistic assumptions regarding the ability to offset impacts of temperature and sea level rise via adaptation increase the SCC by approximately 30 percent.

#### 14B.3.3.6 Other Noteworthy Changes

Two other changes in the model are worth noting. A revised carbon cycle feedback is introduced to simulate decreased $CO_2$ absorption by the terrestrial biosphere and ocean as the temperature rises. This feedback is linear in the average global and annual temperature anomaly but is capped at a maximum value. In the previous version of PAGE, an additional amount was added to the $CO_2$ emissions each period to account for a decrease in ocean absorption and a loss of soil carbon. Also updated is the method by which the average global and annual temperature anomaly is downscaled to determine annual average regional temperature anomalies to be used in the regional damage functions. In the previous version of PAGE, the scaling was determined solely based on regional difference in emissions of sulfate aerosols. In PAGE09, this regional temperature anomaly is further adjusted using an additive factor that is based on the average absolute latitude of a region relative to the area weighted average absolute latitude of the Earth's landmass.

## 14B.4 REVISED SCC ESTIMATES

The updated versions of the three integrated assessment models were run using the same methodology detailed in the 2010 TSD.[1] The approach along with the inputs for the socioeconomic emissions scenarios, equilibrium climate sensitivity distribution, and discount rate remains the same. This includes the five reference scenarios based on the EMF-22 modeling exercise, the Roe and Baker equilibrium climate sensitivity distribution calibrated to the Fourth Assessment Report of the IPCC, and three constant discount rates of 2.5, 3, and 5 percent.

As was previously the case, the use of three models, three discount rates, and five scenarios produces 45 separate distributions for the SCC. The approach laid out in the TSD applied equal weight to each model and socioeconomic scenario in order to reduce the dimensionality down to three separate distributions representative of the three discount rates. The interagency group selected four values from these distributions for use in regulatory analysis. Three values are based on the average SCC across models and socio-economic-emissions scenarios at the 2.5, 3, and 5 percent discount rates, respectively. The fourth value was chosen to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, the 95th percentile of the SCC estimates at a 3 percent discount rate was chosen. (A detailed set of percentiles by model and scenario combination is available in the Annex.) As noted in the original TSD, "the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate" (TSD, p. 25). However, for purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance and value of including all four SCC values.

Table 14B.4.1 shows the four selected SCC estimates in five year increments from 2010 to 2050. Values for 2010, 2020, 2030, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using basic linear interpolation. The full set of annual SCC estimates between 2010 and 2050 is reported in the Annex.

**Table 14B.4.1 Revised Social Cost of $CO_2$, 2010 – 2050 (in 2007 dollars per ton of $CO_2$)**

| Discount Rate<br>Year | 5.0%<br>Avg | 3.0%<br>Avg | 2.5%<br>Avg | 3.0%<br>95th |
|---|---|---|---|---|
| 2010 | 11 | 32 | 51 | 89 |
| 2015 | 11 | 37 | 57 | 109 |
| 2020 | 12 | 43 | 64 | 128 |
| 2025 | 14 | 47 | 69 | 143 |
| 2030 | 16 | 52 | 75 | 159 |
| 2035 | 19 | 56 | 80 | 175 |
| 2040 | 21 | 61 | 86 | 191 |
| 2045 | 24 | 66 | 92 | 206 |
| 2050 | 26 | 71 | 97 | 220 |

The SCC estimates using the updated versions of the models are higher than those reported in the TSD due to the changes to the models outlined in the previous section. Figure 14B.4.1 illustrates where the four SCC values for 2020 fall within the full distribution for each discount rate based on the combined set of runs for each model and scenario (150,000 estimates in total for each discount rate). In general, the distributions are skewed to the right and have long tails. The Figure also shows that the lower the discount rate, the longer the right tail of the distribution.

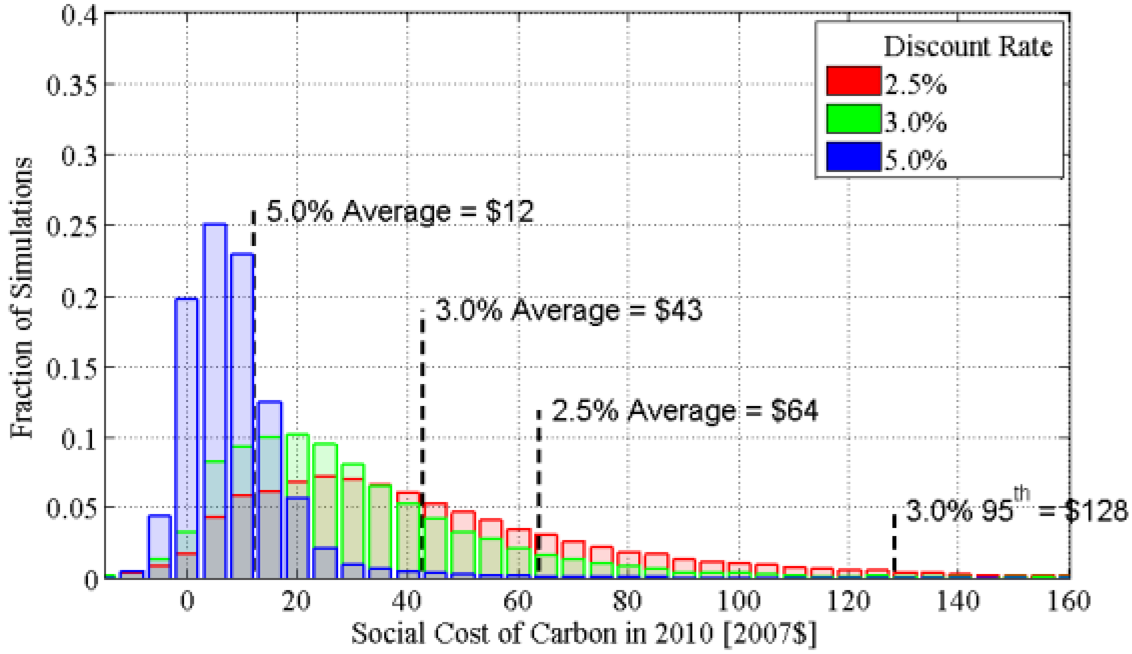


**Figure 14B.4.1 Distribution of SCC Estimates for 2010 (in 2007$ per ton $CO_2$)**

As was the case in the original TSD, the SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. The approach taken by the interagency group is to allow the growth rate to be determined endogenously by the models through running them for a set of perturbation years out to 2050. Table 14B.4.2 illustrates how the growth rate for these four SCC estimates varies over time.

**Table 14B.4.2 Average Annual Growth Rates of SCC Estimates between 2010 and 2050**

| Average Annual Rate (%) | 5.0% Avg | 3.0% Avg | 2.5% Avg | 3.0% 95th |
|---|---|---|---|---|
| 2010-2020 | 1.2% | 3.3% | 2.4% | 4.4% |
| 2020-2030 | 3.4% | 2.1% | 1.7% | 2.4% |
| 2030-2040 | 3.0% | 1.9% | 1.5% | 2.1% |
| 2040-2050 | 2.6% | 1.6% | 1.3% | 1.5% |

The future monetized value of emission reductions in each year (the SCC in year t multiplied by the change in emissions in year t) must be discounted to the present to determine its total net present value for use in regulatory analysis. As previously discussed in the original TSD, damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency – *i.e.*, future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate.

## 14B.5 OTHER MODEL LIMITATIONS OR RESEARCH GAPS

The 2010 interagency SCC technical support report discusses a number of important limitations for which additional research is needed. In particular, the document highlights the need to improve the quantification of both non-catastrophic and catastrophic damages, the treatment of adaptation and technological change, and the way in which inter-regional and inter-sectoral linkages are modeled. It also discusses the need to more carefully assess the implications of risk aversion for SCC estimation as well as the inability to perfectly substitute between climate and non-climate goods at higher temperature increases, both of which have implications for the discount rate used. EPA, DOE, and other agencies continue to engage in long-term research work on modeling and valuation of climate impacts that we expect will inform improvements in SCC estimation in the future.

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## 14B.6 ANNEX

**Table 14B.6.1 Annual SCC Values: 2010-2050 (2007$/ton $CO_2$)**

| Discount Rate<br>Year | 5.0%<br>Avg | 3.0%<br>Avg | 2.5%<br>Avg | 3.0%<br>95th |
|---|---|---|---|---|
| 2010 | 11 | 32 | 51 | 89 |
| 2011 | 11 | 33 | 52 | 93 |
| 2012 | 11 | 34 | 54 | 97 |
| 2013 | 11 | 35 | 55 | 101 |
| 2014 | 11 | 36 | 56 | 105 |
| 2015 | 11 | 37 | 57 | 109 |
| 2016 | 12 | 38 | 59 | 112 |
| 2017 | 12 | 39 | 60 | 116 |
| 2018 | 12 | 40 | 61 | 120 |
| 2019 | 12 | 42 | 62 | 124 |
| 2020 | 12 | 43 | 64 | 128 |
| 2021 | 12 | 43 | 65 | 131 |
| 2022 | 13 | 44 | 66 | 134 |
| 2023 | 13 | 45 | 67 | 137 |
| 2024 | 14 | 46 | 68 | 140 |
| 2025 | 14 | 47 | 69 | 143 |
| 2026 | 15 | 48 | 70 | 146 |
| 2027 | 15 | 49 | 71 | 149 |
| 2028 | 15 | 50 | 72 | 152 |
| 2029 | 16 | 51 | 73 | 155 |
| 2030 | 16 | 52 | 75 | 159 |
| 2031 | 17 | 52 | 76 | 162 |
| 2032 | 17 | 53 | 77 | 165 |
| 2033 | 18 | 54 | 78 | 168 |
| 2034 | 18 | 55 | 79 | 172 |
| 2035 | 19 | 56 | 80 | 175 |
| 2036 | 19 | 57 | 81 | 178 |
| 2037 | 20 | 58 | 83 | 181 |
| 2038 | 20 | 59 | 84 | 185 |
| 2039 | 21 | 60 | 85 | 188 |
| 2040 | 21 | 61 | 86 | 191 |
| 2041 | 22 | 62 | 87 | 194 |
| 2042 | 22 | 63 | 88 | 197 |
| 2043 | 23 | 64 | 89 | 200 |
| 2044 | 23 | 65 | 90 | 203 |
| 2045 | 24 | 66 | 92 | 206 |
| 2046 | 24 | 67 | 93 | 209 |
| 2047 | 25 | 68 | 94 | 211 |
| 2048 | 25 | 69 | 95 | 214 |
| 2049 | 26 | 70 | 96 | 217 |
| 2050 | 26 | 71 | 97 | 220 |

**Table 14B.6.2 202 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton $CO_2$)**

| Percentile | 1st | 5th | 10th | 25th | 50th | Avg | 75th | 90th | 95th | 99th |
|---|---|---|---|---|---|---|---|---|---|---|
| Scenario | PAGE | | | | | | | | | |
| IMAGE | 6 | 11 | 15 | 27 | 58 | 129 | 139 | 327 | 515 | 991 |
| MERGE | 4 | 6 | 9 | 16 | 34 | 78 | 82 | 196 | 317 | 649 |
| MESSAGE | 4 | 8 | 11 | 20 | 42 | 108 | 107 | 278 | 483 | 918 |
| MiniCAM Base | 5 | 9 | 12 | 22 | 47 | 107 | 113 | 266 | 431 | 872 |
| 5th Scenario | 2 | 4 | 6 | 11 | 25 | 85 | 68 | 200 | 387 | 955 |
| Scenario | DICE | | | | | | | | | |
| IMAGE | 25 | 31 | 37 | 47 | 64 | 72 | 92 | 123 | 139 | 161 |
| MERGE | 14 | 18 | 20 | 26 | 36 | 40 | 50 | 65 | 74 | 85 |
| MESSAGE | 20 | 24 | 28 | 37 | 51 | 58 | 71 | 95 | 109 | 221 |
| MiniCAM Base | 20 | 25 | 29 | 38 | 53 | 61 | 76 | 102 | 117 | 135 |
| 5th Scenario | 17 | 22 | 25 | 33 | 45 | 52 | 65 | 91 | 106 | 126 |
| Scenario | FUND | | | | | | | | | |
| IMAGE | -14 | -2 | 4 | 15 | 31 | 39 | 55 | 86 | 107 | 157 |
| MERGE | -6 | 1 | 6 | 14 | 27 | 35 | 46 | 70 | 87 | 141 |
| MESSAGE | -16 | -5 | 1 | 11 | 24 | 31 | 43 | 67 | 83 | 126 |
| MiniCAM Base | -7 | 2 | 7 | 16 | 32 | 39 | 55 | 83 | 103 | 158 |
| 5th Scenario | -29 | -13 | -6 | 4 | 16 | 21 | 32 | 53 | 69 | 103 |

**Table 14B.6.3 SCC Estimates at 3 Percent Discount Rate (2007$/ton CO2)**

| Percentile | 1st | 5th | 10th | 25th | 50th | Avg | 75th | 90th | 95th | 99th |
|---|---|---|---|---|---|---|---|---|---|---|
| Scenario | PAGE | | | | | | | | | |
| IMAGE | 4 | 7 | 10 | 18 | 38 | 91 | 95 | 238 | 385 | 727 |
| MERGE | 2 | 4 | 6 | 11 | 23 | 56 | 58 | 142 | 232 | 481 |
| MESSAGE | 3 | 5 | 7 | 13 | 29 | 75 | 74 | 197 | 330 | 641 |
| MiniCAM Base | 3 | 5 | 8 | 14 | 30 | 73 | 75 | 184 | 300 | 623 |
| 5th Scenario | 1 | 3 | 4 | 7 | 17 | 58 | 48 | 136 | 264 | 660 |
| Scenario | DICE | | | | | | | | | |
| IMAGE | 16 | 21 | 24 | 32 | 43 | 48 | 60 | 79 | 90 | 102 |
| MERGE | 10 | 13 | 15 | 19 | 25 | 28 | 35 | 44 | 50 | 58 |
| MESSAGE | 14 | 18 | 20 | 26 | 35 | 40 | 49 | 64 | 73 | 83 |
| MiniCAM Base | 13 | 17 | 20 | 26 | 35 | 39 | 49 | 65 | 73 | 85 |
| 5th Scenario | 12 | 15 | 17 | 22 | 30 | 34 | 43 | 58 | 67 | 79 |
| Scenario | FUND | | | | | | | | | |
| IMAGE | -13 | -4 | 0 | 8 | 18 | 23 | 33 | 51 | 65 | 99 |
| MERGE | -7 | -1 | 2 | 8 | 17 | 21 | 29 | 45 | 57 | 95 |
| MESSAGE | -14 | -6 | -2 | 5 | 14 | 18 | 26 | 41 | 52 | 82 |
| MiniCAM Base | -7 | -1 | 3 | 9 | 19 | 23 | 33 | 50 | 63 | 101 |
| 5th Scenario | -22 | -11 | -6 | 1 | 8 | 11 | 18 | 31 | 40 | 62 |

**Table 14B.6.4 2020 Global SCC Estimates at 5 Percent Discount Rate (2007$/ton $CO_2$)**

| Percentile | 1st | 5th | 10th | 25th | 50th | Avg | 75th | 90th | 95th | 99th |
|---|---|---|---|---|---|---|---|---|---|---|
| Scenario | | | | | PAGE | | | | | |
| IMAGE | 1 | 2 | 2 | 5 | 10 | 28 | 27 | 71 | 123 | 244 |
| MERGE | 1 | 1 | 2 | 3 | 7 | 17 | 17 | 45 | 75 | 153 |
| MESSAGE | 1 | 1 | 2 | 4 | 9 | 24 | 22 | 60 | 106 | 216 |
| MiniCAM Base | 1 | 1 | 2 | 3 | 8 | 21 | 21 | 54 | 94 | 190 |
| 5th Scenario | 0 | 1 | 1 | 2 | 5 | 18 | 14 | 41 | 78 | 208 |
| Scenario | | | | | DICE | | | | | |
| IMAGE | 6 | 8 | 9 | 11 | 14 | 15 | 18 | 22 | 25 | 27 |
| MERGE | 4 | 5 | 6 | 7 | 9 | 10 | 12 | 15 | 16 | 18 |
| MESSAGE | 6 | 7 | 8 | 10 | 12 | 13 | 16 | 20 | 22 | 25 |
| MiniCAM Base | 5 | 6 | 7 | 8 | 11 | 12 | 14 | 18 | 20 | 22 |
| 5th Scenario | 5 | 6 | 6 | 8 | 10 | 11 | 14 | 17 | 19 | 21 |
| Scenario | | | | | FUND | | | | | |
| IMAGE | -9 | -5 | -4 | -1 | 2 | 3 | 6 | 10 | 14 | 24 |
| MERGE | -6 | -4 | -2 | 0 | 3 | 4 | 6 | 11 | 15 | 26 |
| MESSAGE | -10 | -6 | -4 | -1 | 1 | 2 | 5 | 9 | 12 | 21 |
| MiniCAM Base | -7 | -4 | -2 | 0 | 3 | 4 | 6 | 11 | 14 | 25 |
| 5th Scenario | -11 | -7 | -5 | -3 | 0 | 0 | 3 | 5 | 7 | 13 |

# APPENDIX 17A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

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# APPENDIX 17A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

## 17A.1 INTRODUCTION

This appendix contains sections discussing the following topics:

- Projections of annual market share increases for the alternative policies;
- NIA-RIA Integrated Model;
- Market penetration curves used to analyze consumer rebates and voluntary energy efficiency targets, including:
    - Background material on XENERGY's approach,
    - DOE's adjustment of these curves for this analysis, and
    - The method DOE used to derive interpolated, customized curves;
- Detailed table of rebates offered for the considered product, as well as DOE's approach to estimate a market representative rebate value for this RIA; and
- Background material on Federal and State tax credits for appliances.

## 17A.2 MARKET SHARE ANNUAL INCREASES BY POLICY

Table 17A.2.1 through Table 17A.2.5 show the annual increases in market shares of dehumidifiers meeting the target efficiency levels for the proposed TSL (TSL 3). DOE used these market share increases as inputs to the NIA-RIA spreadsheet model.

**Table 17A.2.1 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Portable Dehumidifiers ≤30.00 Pints/Day (TSL 3)**

| Year | Consumer Rebates | Consumer Tax Credits | Manufacturer Tax Credits | Vol Energy Eff Targets | Bulk Govt Purchases |
|---|---|---|---|---|---|
| 2019 | 4.8% | 2.9% | 1.5% | 1.2% | 0.02% |
| 2020 | 4.8% | 2.9% | 1.5% | 2.5% | 0.03% |
| 2021 | 4.8% | 2.9% | 1.5% | 3.7% | 0.05% |
| 2022 | 4.8% | 2.9% | 1.5% | 4.8% | 0.06% |
| 2023 | 4.8% | 2.9% | 1.5% | 6.0% | 0.08% |
| 2024 | 4.8% | 2.9% | 1.5% | 7.0% | 0.10% |
| 2025 | 4.8% | 2.9% | 1.5% | 8.1% | 0.11% |
| 2026 | 4.8% | 2.9% | 1.5% | 9.2% | 0.13% |
| 2027 | 4.8% | 2.9% | 1.5% | 10.2% | 0.15% |
| 2028 | 4.8% | 2.9% | 1.5% | 11.2% | 0.16% |
| 2029 | 4.8% | 2.9% | 1.5% | 11.3% | 0.16% |
| 2030 | 4.8% | 2.9% | 1.5% | 11.3% | 0.16% |
| 2031 | 4.8% | 2.9% | 1.5% | 11.4% | 0.16% |
| 2032 | 4.8% | 2.9% | 1.5% | 11.4% | 0.16% |
| 2033 | 4.8% | 2.9% | 1.5% | 11.5% | 0.16% |
| 2034 | 4.8% | 2.9% | 1.5% | 11.5% | 0.16% |
| 2035 | 4.8% | 2.9% | 1.5% | 11.6% | 0.16% |
| 2036 | 4.8% | 2.9% | 1.5% | 11.6% | 0.16% |
| 2037 | 4.8% | 2.9% | 1.5% | 11.7% | 0.16% |
| 2038 | 4.8% | 2.9% | 1.5% | 11.7% | 0.16% |
| 2039 | 4.8% | 2.9% | 1.5% | 11.8% | 0.16% |
| 2040 | 4.8% | 2.9% | 1.5% | 11.8% | 0.16% |
| 2041 | 4.8% | 2.9% | 1.5% | 11.9% | 0.16% |
| 2042 | 3.0% | 1.8% | 0.9% | 10.1% | 0.14% |
| 2043 | 0.0% | 0.0% | 0.0% | 6.9% | 0.10% |
| 2044 | 0.0% | 0.0% | 0.0% | 3.8% | 0.06% |
| 2045 | 0.0% | 0.0% | 0.0% | 0.6% | 0.03% |
| 2046 | 0.0% | 0.0% | 0.0% | 0.0% | 0.00% |
| 2047 | 0.0% | 0.0% | 0.0% | 0.0% | 0.00% |
| 2048 | 0.0% | 0.0% | 0.0% | 0.0% | 0.00% |

**Table 17A.2.2 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Portable Dehumidifiers 30.01-45.00 Pints/Day (TSL 3)**

| Year | Consumer Rebates | Consumer Tax Credits | Manufacturer Tax Credits | Vol Energy Eff Targets | Bulk Govt Purchases |
|---|---|---|---|---|---|
| 2019 | 48.0% | 28.8% | 14.4% | 32.2% | 0.1% |
| 2020 | 46.2% | 27.7% | 13.9% | 33.4% | 0.2% |
| 2021 | 44.5% | 26.7% | 13.3% | 34.2% | 0.2% |
| 2022 | 42.7% | 25.6% | 12.8% | 34.7% | 0.3% |
| 2023 | 40.9% | 24.5% | 12.3% | 34.9% | 0.4% |
| 2024 | 39.1% | 23.5% | 11.7% | 35.0% | 0.4% |
| 2025 | 37.3% | 22.4% | 11.2% | 34.9% | 0.5% |
| 2026 | 35.5% | 21.3% | 10.7% | 34.7% | 0.6% |
| 2027 | 33.7% | 20.2% | 10.1% | 34.4% | 0.7% |
| 2028 | 31.9% | 19.1% | 9.6% | 34.0% | 0.7% |
| 2029 | 30.1% | 18.0% | 9.0% | 32.5% | 0.7% |
| 2030 | 28.3% | 17.0% | 8.5% | 30.9% | 0.7% |
| 2031 | 26.4% | 15.9% | 7.9% | 29.3% | 0.7% |
| 2032 | 24.6% | 14.8% | 7.4% | 27.7% | 0.6% |
| 2033 | 22.8% | 13.7% | 6.8% | 26.0% | 0.6% |
| 2034 | 20.9% | 12.6% | 6.3% | 24.4% | 0.6% |
| 2035 | 19.1% | 11.5% | 5.7% | 22.8% | 0.6% |
| 2036 | 17.3% | 10.4% | 5.2% | 21.1% | 0.6% |
| 2037 | 15.4% | 9.2% | 4.6% | 19.5% | 0.5% |
| 2038 | 13.5% | 8.1% | 4.1% | 17.8% | 0.5% |
| 2039 | 11.7% | 7.0% | 3.5% | 16.1% | 0.5% |
| 2040 | 9.8% | 5.9% | 2.9% | 14.5% | 0.5% |
| 2041 | 8.0% | 4.8% | 2.4% | 12.8% | 0.5% |
| 2042 | 6.8% | 4.1% | 2.1% | 11.0% | 0.4% |
| 2043 | 5.8% | 3.5% | 1.7% | 9.3% | 0.4% |
| 2044 | 4.9% | 2.9% | 1.5% | 7.6% | 0.4% |
| 2045 | 4.1% | 2.5% | 1.2% | 5.8% | 0.4% |
| 2046 | 3.5% | 2.1% | 1.1% | 4.1% | 0.3% |
| 2047 | 3.0% | 1.8% | 0.9% | 2.3% | 0.3% |
| 2048 | 2.6% | 1.6% | 0.8% | 0.6% | 0.3% |

**Table 17A.2.3 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Portable Dehumidifiers >45.00 Pints/Day (TSL3)**

| Year | Consumer Rebates | Consumer Tax Credits | Manufacturer Tax Credits | Vol Energy Eff Targets | Bulk Govt Purchases |
|---|---|---|---|---|---|
| 2019 | 7.3% | 4.4% | 2.2% | 3.7% | 0.1% |
| 2020 | 7.3% | 4.4% | 2.2% | 7.4% | 0.1% |
| 2021 | 7.3% | 4.4% | 2.2% | 10.7% | 0.2% |
| 2022 | 7.3% | 4.4% | 2.2% | 13.5% | 0.3% |
| 2023 | 7.3% | 4.4% | 2.2% | 16.1% | 0.3% |

| Year | Consumer Rebates | Consumer Tax Credits | Manufacturer Tax Credits | Vol Energy Eff Targets | Bulk Govt Purchases |
|---|---|---|---|---|---|
| 2024 | 7.3% | 4.4% | 2.2% | 18.6% | 0.4% |
| 2025 | 7.3% | 4.4% | 2.2% | 20.8% | 0.5% |
| 2026 | 7.3% | 4.4% | 2.2% | 23.0% | 0.5% |
| 2027 | 7.3% | 4.4% | 2.2% | 25.1% | 0.6% |
| 2028 | 7.3% | 4.4% | 2.2% | 27.1% | 0.7% |
| 2029 | 7.3% | 4.4% | 2.2% | 27.6% | 0.7% |
| 2030 | 7.3% | 4.4% | 2.2% | 28.1% | 0.7% |
| 2031 | 7.3% | 4.4% | 2.2% | 28.6% | 0.7% |
| 2032 | 7.3% | 4.4% | 2.2% | 29.1% | 0.7% |
| 2033 | 7.3% | 4.4% | 2.2% | 29.6% | 0.7% |
| 2034 | 7.3% | 4.4% | 2.2% | 30.2% | 0.7% |
| 2035 | 7.3% | 4.4% | 2.2% | 30.7% | 0.7% |
| 2036 | 7.3% | 4.4% | 2.2% | 31.2% | 0.7% |
| 2037 | 7.3% | 4.4% | 2.2% | 31.7% | 0.7% |
| 2038 | 7.3% | 4.4% | 2.2% | 32.2% | 0.7% |
| 2039 | 7.3% | 4.4% | 2.2% | 32.7% | 0.7% |
| 2040 | 7.3% | 4.4% | 2.2% | 33.2% | 0.7% |
| 2041 | 7.3% | 4.4% | 2.2% | 33.7% | 0.7% |
| 2042 | 7.3% | 4.4% | 2.2% | 34.1% | 0.7% |
| 2043 | 7.3% | 4.4% | 2.2% | 34.6% | 0.7% |
| 2044 | 7.3% | 4.4% | 2.2% | 35.0% | 0.7% |
| 2045 | 7.3% | 4.4% | 2.2% | 35.5% | 0.7% |
| 2046 | 7.3% | 4.4% | 2.2% | 35.9% | 0.7% |
| 2047 | 7.3% | 4.4% | 2.2% | 36.4% | 0.7% |
| 2048 | 7.3% | 4.4% | 2.2% | 36.8% | 0.7% |

**Table 17A.2.4 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Whole-Home Dehumidifiers for ≤8.0 $ft^3$ Case Volume (TSL 3)**

| Year | Consumer Rebates | Consumer Tax Credits | Manufacturer Tax Credits | Vol Energy Eff Targets | Bulk Govt Purchases |
|---|---|---|---|---|---|
| 2019 | 35.8% | 21.5% | 10.7% | 0.7% | 0.1% |
| 2020 | 34.4% | 20.6% | 10.3% | 0.7% | 0.1% |
| 2021 | 34.5% | 20.7% | 10.3% | 0.7% | 0.2% |
| 2022 | 34.5% | 20.7% | 10.4% | 0.6% | 0.2% |
| 2023 | 34.5% | 20.7% | 10.4% | 0.5% | 0.3% |
| 2024 | 34.5% | 20.7% | 10.4% | 0.3% | 0.3% |
| 2025 | 34.4% | 20.6% | 10.3% | 0.1% | 0.4% |
| 2026 | 33.4% | 20.1% | 10.0% | 0.0% | 0.4% |
| 2027 | 32.5% | 19.5% | 9.7% | 0.0% | 0.4% |
| 2028 | 31.6% | 19.0% | 9.5% | 0.0% | 0.5% |
| 2029 | 30.3% | 18.2% | 9.1% | 0.0% | 0.5% |

| Year | Consumer Rebates | Consumer Tax Credits | Manufacturer Tax Credits | Vol Energy Eff Targets | Bulk Govt Purchases |
|---|---|---|---|---|---|
| 2030 | 29.0% | 17.4% | 8.7% | 0.0% | 0.5% |
| 2031 | 27.6% | 16.6% | 8.3% | 0.0% | 0.4% |
| 2032 | 26.2% | 15.7% | 7.9% | 0.0% | 0.4% |
| 2033 | 24.9% | 14.9% | 7.5% | 0.0% | 0.4% |
| 2034 | 23.6% | 14.1% | 7.1% | 0.0% | 0.4% |
| 2035 | 22.3% | 13.4% | 6.7% | 0.0% | 0.4% |
| 2036 | 21.0% | 12.6% | 6.3% | 0.0% | 0.4% |
| 2037 | 19.8% | 11.9% | 5.9% | 0.0% | 0.3% |
| 2038 | 18.6% | 11.2% | 5.6% | 0.0% | 0.3% |
| 2039 | 17.5% | 10.5% | 5.2% | 0.0% | 0.3% |
| 2040 | 16.4% | 9.8% | 4.9% | 0.0% | 0.3% |
| 2041 | 15.3% | 9.2% | 4.6% | 0.0% | 0.3% |
| 2042 | 14.4% | 8.6% | 4.3% | 0.0% | 0.2% |
| 2043 | 13.5% | 8.1% | 4.0% | 0.0% | 0.2% |
| 2044 | 12.6% | 7.5% | 3.8% | 0.0% | 0.2% |
| 2045 | 11.8% | 7.1% | 3.5% | 0.0% | 0.2% |
| 2046 | 11.0% | 6.6% | 3.3% | 0.0% | 0.2% |
| 2047 | 10.2% | 6.1% | 3.1% | 0.0% | 0.2% |
| 2048 | 9.6% | 5.7% | 2.9% | 0.0% | 0.1% |

**Table 17A.2.5 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Whole-Home Dehumidifiers >8.0$^3$ Case Volume (TSL 3)**

| Year | Consumer Rebates | Consumer Tax Credits | Manufacturer Tax Credits | Vol Energy Eff Targets | Bulk Govt Purchases |
|---|---|---|---|---|---|
| 2019 | 10.9% | 6.5% | 3.3% | 0.8% | 0.1% |
| 2020 | 10.9% | 6.5% | 3.3% | 2.4% | 0.1% |
| 2021 | 10.9% | 6.5% | 3.3% | 4.0% | 0.2% |
| 2022 | 10.9% | 6.5% | 3.3% | 5.4% | 0.3% |
| 2023 | 10.9% | 6.5% | 3.3% | 6.9% | 0.3% |
| 2024 | 10.9% | 6.5% | 3.3% | 8.3% | 0.4% |
| 2025 | 10.9% | 6.5% | 3.3% | 9.7% | 0.5% |
| 2026 | 10.9% | 6.5% | 3.3% | 11.0% | 0.5% |
| 2027 | 10.9% | 6.5% | 3.3% | 12.3% | 0.6% |
| 2028 | 10.9% | 6.5% | 3.3% | 13.6% | 0.7% |
| 2029 | 10.9% | 6.5% | 3.3% | 14.3% | 0.7% |
| 2030 | 10.9% | 6.5% | 3.3% | 15.0% | 0.7% |
| 2031 | 10.9% | 6.5% | 3.3% | 15.7% | 0.7% |
| 2032 | 10.5% | 6.3% | 3.2% | 16.1% | 0.7% |
| 2033 | 9.7% | 5.8% | 2.9% | 15.9% | 0.7% |
| 2034 | 8.8% | 5.3% | 2.6% | 15.7% | 0.7% |
| 2035 | 7.9% | 4.7% | 2.4% | 15.6% | 0.6% |

| Year | Consumer Rebates | Consumer Tax Credits | Manufacturer Tax Credits | Vol Energy Eff Targets | Bulk Govt Purchases |
|---|---|---|---|---|---|
| 2036 | 7.0% | 4.2% | 2.1% | 15.4% | 0.6% |
| 2037 | 6.1% | 3.7% | 1.8% | 15.2% | 0.6% |
| 2038 | 5.2% | 3.1% | 1.6% | 15.0% | 0.6% |
| 2039 | 4.3% | 2.6% | 1.3% | 14.7% | 0.6% |
| 2040 | 3.4% | 2.1% | 1.0% | 14.5% | 0.6% |
| 2041 | 2.5% | 1.5% | 0.8% | 14.2% | 0.6% |
| 2042 | 1.6% | 1.0% | 0.5% | 13.9% | 0.6% |
| 2043 | 0.7% | 0.4% | 0.2% | 13.6% | 0.6% |
| 2044 | 0.0% | 0.0% | 0.0% | 13.3% | 0.5% |
| 2045 | 0.0% | 0.0% | 0.0% | 13.0% | 0.5% |
| 2046 | 0.0% | 0.0% | 0.0% | 12.7% | 0.5% |
| 2047 | 0.0% | 0.0% | 0.0% | 12.3% | 0.5% |
| 2048 | 0.0% | 0.0% | 0.0% | 11.9% | 0.5% |

## 17A.3 NIA-RIA INTEGRATED MODEL

For this analysis, DOE used its integrated NIA-RIA[a] model approach that the Department built on the NIA model discussed in Chapter 10 and documented in Appendix 10-A.The resulting integrated NIA-RIA model features both the NIA and RIA inputs, analyses and results. It has the capability to generate results, by product class and TSL, for the mandatory standards and each of the RIA policies. Separate modules estimate increases in market penetration of more efficient equipment for consumer rebates, voluntary energy efficiency targets and bulk government purchases.[b] The consumer rebates module calculates benefit-cost (B/C) ratios and market barriers, and generates customized market penetration curves for each product class; the voluntary energy efficiency targets module relies on the market barriers calculated in the consumer rebates module to project a reduction in those barriers over the first ten years of the forecast period and estimate the market effects of such a reduction; and the bulk government purchases module scales down the market for dehumidifiers to housing units in public housing authority. A separate module summarizes the market impacts from mandatory standards and all policy alternatives, and an additional module produces all tables and figures presented in Chapter 17 as well as the tables of market share increases for each policy reported in Section 17A.2 of this Appendix.

## 17A.4 MARKET PENETRATION CURVES

This section first discusses the theoretical basis for the market penetration curves that DOE used to analyze the Consumer Rebates and Voluntary Energy Efficiency Targets policies. Next it discusses the adjustments it made to the maximum penetration rates. It then refers to the method it used to develop interpolated penetration curves for dehumidifiers that meet the target efficiency levels at each TSL. The resulting curves are presented in Chapter 17.

### 17A.4.1 Introduction

XENERGY, Inc.[c], developed a re-parameterized, mixed-source information diffusion model to estimate market impacts induced by financial incentives for purchasing energy efficient appliances.[1] The basic premise of the mixed-source model is that information diffusion drives the adoption of technology.

Extensive economic literature describes the diffusion of new products as technologies evolve. Some research focuses primarily on developing analytical models of diffusion patterns applicable to individual consumers or to technologies from competing firms.[2, 3, 4] One study records researchers' attempts to investigate the factors that drive diffusion processes.[5] Because a new product generally has its own distinct characteristics, few studies have been able to

[a] NIA = National Impact Analysis; RIA = Regulatory Impact Analysis
[b] As mentioned in Chapter 17, the increase in market penetrations for consumer tax credits and manufacturer tax credits are estimated as a fraction of the increase in market penetration of consumer rebates.
[c] XENERGY is now owned by KEMA, Inc. (www.kema.com)

conclusively develop a universally applicable model. Some key findings, however, generally are accepted in academia and industry.

One accepted finding is that, regardless of their economic benefits and technological merits, new technologies are unlikely to be adopted by all potential users. For many products, a ceiling must be placed on the adoption rate. A second conclusion is that not all adopters purchase new products at the same time: some act quickly after a new product is introduced; others wait for the product to mature. Third, diffusion processes can be characterized approximately by asymmetric S-curves that depict three stages of diffusion: starting, accelerating, and decreasing (as the adoption ceiling is approached).

A so-called epidemic model of diffusion is used widely in marketing and social studies. The epidemic model assumes that (1) all consumers place identical value on the benefits of a new product, and (2) the cost of a new product is constant or declines monotonically over time. What induces a consumer to purchase a new product is information about the availability and benefits of the product. In other words, information diffusion drives consumers' adoption of a new product.[3] The model incorporates information diffusion from both internal sources (spread by word of mouth from early adopters to prospective adopters) and external sources (the "announcement effect" produced by government agencies, institutions, or commercial advertising). The model incorporates both internal and external sources by combining a logistic function with an exponential function.[4,5]

The relative degree of influence from the internal and external sources determines the general shape of the diffusion curve for a specific product.[4,5] If adoption of a product is influenced primarily by external sources of information (the announcement effect), for instance, a high rate of diffusion occurs at the beginning of the process. In this scenario, external sources provide immediate information exposure to a significant number of prospective adopters. In contrast, internal sources (such as a network of prospective adopters) are relatively small in size and reach, producing a more gradual exposure to prospective adopters. Graphically speaking, information diffusion dominated by external sources is represented by a concave curve (the exponential curve in Figure 17A.4.1). If adoption of a new product is influenced most strongly by internal sources of information, the number of adopters increases gradually, forming a convex curve (the logistic curve in Figure 17A.4.1).

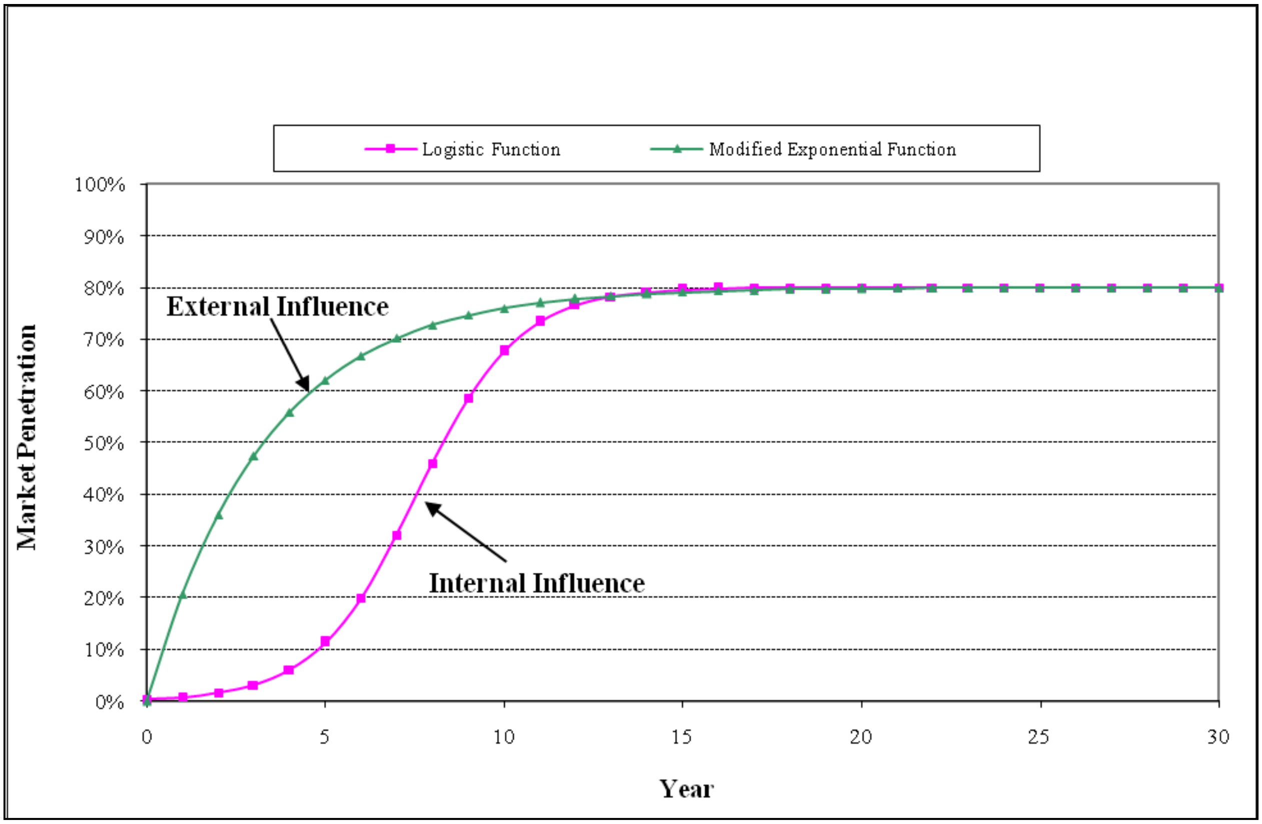


**Figure 17A.4.1 S-Curves Showing Effects of External and Internal Sources on Adoption of New Technologies**

### 17A.4.2 Adjustment of XENERGY Penetration Curves

In consultation with the primary authors of the 2002 XENERGY study who later conducted similar California studies, DOE made some adjustments to XENERGY's original implementation (penetration) curves.[6] The experiences with utility programs since the XENERGY study indicate that incentive programs have difficulty achieving penetration rates as high as 80 percent. Consumer response is limited by barriers created by consumer utility issues and other non-economic factors. DOE therefore adjusted the maximum penetration parameters for some of the curves from 80 percent to the following levels:

| | |
|---|---|
| Moderate Barriers: | 70% |
| High Barriers: | 60% |
| Extremely High Barriers: | 50% |

The *low barriers* and *no barriers* curves (the latter used only when a product has a very high base-case-market share) remained, respectively, with 80 percent and 100 percent as their maximum penetration rates. For the interpolated penetration curves (discussed below), DOE set the *no barriers* and *extremely high barriers* curves as the upper and lower bounds, respectively, for any benefit/cost ratio points higher or lower than the curves. It set another constraint such that the policy case market share cannot be great than 100 percent, as might occur for products with high base case market shares of the target-level technology.

### 17A.4.3 Interpolation of Penetration Curves

As discussed above, the XENERGY penetration (implementation) curves followed a functional form to estimate the market implementation rate caused by energy efficiency measures such as consumer rebates.[d] The XENERGY report presents five reference market implementation curves that vary according to the level of market barriers to technology penetration.[1] Such curves have been used by DOE in the Regulatory Impact Analyses for rulemakings for appliance energy efficiency standards to estimate market share increases in response to rebate programs.[e] They provide a framework for evaluating technology penetration, yet require matching the studied market to the curve that best represents it. This approximate matching can introduce some inaccuracy to the analysis.

Blum et al (2011, Appendix A)[7] presents an alternative approach to such evaluation: a method to estimate market implementation rates more accurately by performing interpolations of the reference curves. The referred report describes the market implementation rate function and the reference curves, the method to calibrate the function to a given market, and the limitations of the method.

DOE used the above referred method to interpolate market implementation curves, to generate customized curves that were used to estimate the effects of consumer rebates and voluntary energy efficiency targets for each product class covered by this RIA. For consumer rebates, DOE derived such curves based on an algorithm that finds the market implementation curve that best fits, for the first year of the analysis period, the B/C ratio of the target efficiency level and the market penetration of equipment with that level of energy efficiency in the base case. For the analysis of voluntary energy efficiency targets, DOE departs from the market barriers level corresponding to the market implementation curve it derived for consumer rebates, to linearly decrease it over the ten initial years of the analysis period. For each year, as market barriers decline, the corresponding market implementation curve leads – for the same B/C ratio – to higher market penetrations.

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[d] The RIA chapter refers to these curves as *penetration curves*. This section, in references to the original source, uses the term *implementation curve*.

[e] DOE has also used this method to estimate market share increases resulting from consumer tax credit and manufacturer tax credit programs, since the effects of tax credits on markets are considered in this RIA proportional to the impacts from rebates.

## 17A.5 CONSUMER REBATE PROGRAMS

DOE performed a search for rebate programs that offered incentives for dehumidifiers. Some organizations nationwide, comprising electric utilities and regional agencies, offer rebate programs for this. Table 17A.5.3 provides the organizations' names, states, rebate amounts, and program websites (as they were available in September, 2014. If there is more than one entry for an organization, it offers different rebates in different states. When an organization offers rebates through several utilities, it is represented only once in that table.

DOE relied on the data it gathered from the 34 rebate programs offered by the 29 organizations listed in Table 17A.5.3 to calculate a market representative rebate amount for dehumidifiers. DOE calculated the market representative rebate amount for dehumidifiers as the simple average of the rebate values offered by the programs listed in Table 17A.5.3. The representative rebate is $24.05 (in 2013$).[f]

[f] The former $24.41, average value expressed in 2014$ was deflated to 2013$ based on the ratio of the average 2013 CPI and the average 2014 CPI (January through September).

**Table 17A.5.1 Rebates Programs for Dehumidifiers**[g]

| Organization | State | Rebate* | Website |
|---|---|---|---|
| Empire | AR | $50 | https://www.empiredistrict.com/EnergySolutions/Electric.aspx |
| Bright Energy Solutions (Offered by 16 Utilities) | IA | $10 | http://www.brightenergysolutions.com/municipalities/?category=home&state=ia |
| Cedar Falls Utilities | IA | $25 | http://www.cfu.net/save-energy/residential-rebates.aspx |
| Central Iowa Power Cooperative (offered by 11 utilities) | IA | $25 | http://www.cipco.net/members.cfm |
| NIPSCO | IN | $40 | http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=IN54F |
| Cape Light Compact | MA | $30 | http://www.capelightcompact.org/rebates-applications/resrebates/ |
| Mansfield Municipal Electric Department | MA | $50 | http://www.mansfieldelectric.com |
| MuniHELPS (offered by 3 utilities through the MMWEC ) | MA | $25 | http://www.munihelps.org/energy-rebate-programs.html |
| MuniHELPS (offered by 8 utilities through the MMWEC ) | MA | $20 | http://www.munihelps.org/energy-rebate-programs.html |
| Reading Municipal Light Department (RMLD) | MA | $25 | http://www.rmld.com/sites/rmld/files/file/file/rebate.pdf |
| Baltimore Gas & Electric Company (BGE) SmartEnergy Savers Program | MD | $25 | http://www.bgesmartenergy.com/residential/lighting-appliances/dehumidifiers |
| Be SMART Home Efficiency Rebate Program | MD | $25 | http://www.mdhousing.org/website/programs/BeSmart/rebate.aspx |
| Delmarva Power | MD | $25 | http://homeenergysavings.delmarva.com/appliance-rebate-program/overview/dehumidifiers |
| PotomacEdison | MD | $25 | http://energysavemd-home.com/appliance/energy-appliance-rebates/ |
| Coldwater Board of Public Utilities (Efficiency Smart) | MI | $20 | http://www.efficiencysmart.org/for-your-home/efficient-product-rebates |

[g] This table is based on rebate programs DOE found to be available through an extensive internet search during September, 2014. Some of the programs referenced—and consequently their websites—may no longer be available by the time this document is published.

| Organization | State | Rebate* | Website |
|---|---|---|---|
| DTE Energy | MI | $25 | https://www2.dteenergy.com/wps/portal/dte/residential/saveEnergy/details/rebates%20and%20offers/dehumidifier%20rebate%20application/!ut/p/b1 |
| Energy Optimization (offered by 11 utilities) | MI | $25 | http://www.michigan-energy.org |
| Energy Smart Program - Bay City, Michigan | MI | $25 | http://www.baycityenergysmart.org/apply-now---home-rebates.html |
| Energy Smart Program (offered by 15 utilities) | MI | $15 | http://www.mienergysmart.com/zeeland.html |
| Lansing Board of Water & Light | MI | $25 | http://www.lbwl.com/energysavers/ |
| Alexandria Light and Power | MN | $10 | http://www.alputilities.com/residential/rebates.php |
| Bright Energy Solutions (Offered by 22 Utilities) | MN | $10 | http://www.brightenergysolutions.com/municipalities/?category=home&state=mn |
| Duluth Energy Efficiency Program (DEEP) | MN | $10 | http://duluthenergy.org/resources/financial |
| Southern Minnesota Municipal Power Agency (Offered by 13 utilities) | MN | $65 | http://smmpa.org/members/wells-public-utilities/home-services/energy-star%C2%AE-for-your-home-(1).aspx |
| Bright Energy Solutions (Offered by 5 Utilities) | ND | $10 | http://www.brightenergysolutions.com/municipalities/?category=home&state=nd |
| Orange & Rockland | NY | $10 | http://www.oru.com/programsandservices/incentivesandrebates/greenteam/residentialprograms/electricappliancerebate.html |
| American Municipal Power (Public Electric Utilities) - Efficiency Smart Residential Program | OH | $20 | http://www.efficiencysmart.org/for-your-home/efficient-product-rebates |
| First Energy Ohio - Residential Efficiency Rebates | OH | $25 | https://www.firstenergycorp.com/content/customer/save_energy/save_energy_ohio.html |
| FirstEnergy (MetEdison, Penelec, Penn Power, West Penn Power) | PA | $25 | https://www.firstenergycorp.com/save_energy/save_energy_pennsylvania.html |
| Bright Energy Solutions (Offered by 11 Utilities) | SD | $10 | http://www.brightenergysolutions.com/municipalities/?category=home&state=sd |
| Efficiency Vermont | VT | $25 | https://www.efficiencyvermont.com/For-My-Home/ways-to-save-and-rebates/Appliances/Dehumidifiers/General-Info |
| Eau Claire Energy | WI | $25 | http://documents.ecec.com/documents/incentive |

| Organization | State | Rebate* | Website |
|---|---|---|---|
| Cooperative | | | s/appliances/Incentive_Appliances.pdf |
| Riverland Energy Cooperative | WI | $25 | http://riverlandenergy.com/content/rebates |
| Appalachian Power | WV | $25 | https://www.appalachianpower.com/save/programs/SmartLightingProgram.aspx |

* In 2014$.

## 17A.6 FEDERAL AND STATE TAX CREDITS

This section summarizes the Federal and State tax credits available to consumers who purchase energy efficient appliances. This section also describes tax credits available to manufacturers who produce certain energy efficient appliances.

### 17A.1.1 Federal Tax Credits for Consumers

EPACT 2005 included Federal tax credits for consumers who installed efficient air conditioners or heat pumps; gas, oil and propane furnaces and boilers; furnace fans; and/or gas, oil, or electric heat pump water heaters in new or existing homes.[8, 9] These tax credits were in effect in 2006 and 2007, expired in 2008, and were reinstated for 2009–2010 by the American Recovery and Reinvestment Act (ARRA).[10] There was a $1,500 cap on the credit per home, including the amount received for insulation, windows, and air and duct sealing. Congress extended this provision for 2011, with some modifications to eligibility requirements, and reductions in the cap to $500 per home. The American Taxpayer Relief Act of 2012 extended, with some modifications, residential tax credits for air conditioners, heat pumps, furnaces, and water heaters placed in service between January 1, 2012 and December 31, 2013.[8, 11]
The tax credit for furnace fans was $50 in 2011, after which it expired.

The importance of the Federal tax credits has been emphasized in research in the residential heating industry on the impacts of the relatively large credits that were available for HVAC (heating, ventilating, and air conditioning) equipment. In a survey of HVAC distributors conducted by Vermont Energy Investment Corporation, respondents indicated that the ample credit had had a notable impact on sales of higher-efficiency heating and cooling equipment. Some distributors combined the Federal tax credits with manufacturer rebates and utility program rebates for a greater consumer incentive. However, when the amount of the Federal tax credit was reduced, smaller utility rebate incentives had not induced the same levels of equipment sales increases. The decrease in incentive size from a $1,500 cap in 2009-2010 to a $500 cap in 2011, during a period when the economy continued to be sluggish, resulted in a decline in total sales of residential HVAC products. Distributors stated that an incentive needed to cover 25 to 75 percent of the incremental cost of the efficient equipment to influence consumer choice. The industry publication "2011 HVAC Review and Outlook" noted a decline in sales of air conditioning units with >14 SEER in 2011 and a return in sales of units with >16 SEER to 2009 levels (after an increase in 2010). The large majority of distributors observed no impacts from the utility programs with their lower rebate amounts available in 2011. Distributors also commented on the advantages of the Federal tax credit being nationwide in contrast to utility rebate programs that target regional markets.[12, 13]

In an effort to evaluate the potential impact of a Federal appliance tax credit program, DOE reviewed Internal Revenue Service (IRS) data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. It estimated the percentage of taxpayers who filed Form 5695, *Residential Energy Credits.*[14] It also estimated the percentage of taxpayers with entries under Form 5695's section 3, *Residential energy property costs*, line 3b, *qualified natural gas, propane, or oil furnace or hot water boiler*. DOE reasoned that the percentage of taxpayers with an entry on Line 3b could serve as a rough indication of the potential of taxpayer participation in a Federal tax credit program for furnaces during the initial program years. DOE found that of all residential taxpayers filing tax returns, 0.8 percent in 2006 and 0.6 percent in 2007, claimed a credit for a furnace or boiler. DOE further found that the percentages of those filing Form 5695 for <u>any</u> qualifying energy property expenditure (which also included installation of efficient windows, doors and roofs) were 3.1 and 3.2 percent in 2006 and 2007 respectively.

DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. While this tax credit was available from 1979 through 1985, DOE located data for only the first three years of the program.[15, 16, 17] For those three years - 1979, 1980, and 1981 - the percentages of taxpayers filing Form 5695 were 6.4 percent, 5.2 percent, and 4.9 percent. Given that the data from this earlier tax credit program were not disaggregated by type of energy property, this data series served only to indicate a possible trend of greater participation in the initial program year, followed by slightly smaller participation in subsequent years. However, DOE did not find detailed analysis of this program to indicate the possible reasons for such a trend. Also, this trend varies from the more stable trend shown in the EPAct 2005 energy tax credit program data for its first two program years.

As discussed in Chapter 17, DOE analyzed the percentage of participation in consumer tax credit programs using its estimates of consumer participation in rebate programs that was based on benefit/cost data specific to each product class of dehumidifiers covered by this RIA. Hence it was difficult to compare these detailed estimates to the more general data analysis described above from the existing Federal tax credit program, or to use the IRS data analysis in its consumer tax credit analysis.

### 17A.6.1 Federal Tax Credits for Manufacturers

EPACT 2005 provided Federal Energy Efficient Appliance Credits to manufacturers that produced high-efficiency refrigerators, clothes washers, and dishwashers in 2006 and 2007.[18] The Emergency Economic Stabilization Act of 2008[19] amended the credits and extended them through 2010. The credits were extended again to 2011 with modifications in the eligibility requirements. Manufacturer tax credits were extended again, by the American Taxpayer Relief Act of 2012, for clothes washers, refrigerators, and dishwashers manufactured between January 1, 2012 and December 31, 2013.

Manufacturers who produce these appliances receive the credits for increasing their production of qualifying appliances. These credits had several efficiency tiers in 2011. For 2012-2013, credits for the higher tiers remain but were eliminated for the lowest (least efficient) tiers for clothes washers and dishwashers.[11] The credit amounts applied to each unit manufactured. The credit to manufacturers of qualifying clothes washers, refrigerators and dishwashers was capped at $75 million for the period of 2008-2010. However, the most efficient refrigerator (30%) and clothes washer (2.2 MEF/4.5 wcf) models was not subject to the cap. The credit to manufacturers was capped at $25 million for 2011, with the most efficient refrigerators (35%) and clothes washers (2.8 MEF/3.5 WCF) exempted from this cap.[20]

### 17A.6.2 State Tax Credits

The States of Oregon and Montana have offered consumer tax credits for efficient appliances for several years, and the States of Kentucky, Michigan and Indiana began offering such credits in 2009. The Oregon Department of Energy (ODOE) has disaggregated data on taxpayer participation in credits for eligible products. (See the discussion in Chapter 17, Section 17.3.3, on tax credit data for clothes washers.) Montana's Department of Revenue does not disaggregate participation data by appliance, although DOE reviewed Montana's overall participation trends and found them congruent with its analysis of Oregon's clothes washer tax credits.

Oregon's Residential Energy Tax Credit (RETC) was created in 1977. The Oregon legislature expanded the RETC program in 1997 to include residential refrigerators, clothes washers, and dishwashers, which significantly increased participation in the program. The program subsequently added credits for high-efficiency heat pump systems, air conditioners, and water heaters (2001); furnaces and boilers (2002); and duct/air sealing, fuel cells, heat recovery, and renewable energy equipment. Beginning in 2012 a Tax Credit Extension Bill (HB3672) eliminated refrigerators, clothes washers, dishwashers, air conditioners, and boilers from the RETC program, leaving credits for water heaters, furnaces, heat pumps, tankless water heaters, and heat pump water heaters.[21, 22] Those technologies recognized by the Oregon Department of Energy as "premium efficiency" are eligible for tax credit of $0.60 per kWh saved in the first year (up to $1,500).[21, 23]

Montana has had an Energy Conservation Tax Credit for residential measures since 1998.[24] The tax credit covers various residential energy and water efficient products, including split system central air conditioning; package system central air conditioning; split system air source heat pumps; package system heat pumps; natural gas, propane, or oil furnaces; hot water boilers; advanced main air circulating fans; heat recovery ventilators; gas, oil, or propane water heaters; electric heat pump water heaters; low-flow showerheads and faucets; light fixtures; and controls. In 2002 the amount of the credit was increased from 5 percent of product costs (up to $150) to 25 percent (up to $500) per taxpayer. The credit can be used for products installed in new construction or remodeling projects. The tax credit covers only that part of the cost and materials that exceed established standards of construction.

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