CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses and results supporting the information presented in the direct final rule (DFR) for residential clothes dryers and room air conditioners. This TSD reports on the activities and analyses conducted in support of the DFR.

1.2 SUMMARY OF NATIONAL BENEFITS

DOE's analyses indicate that the standards for residential clothes dryers and room air conditioners would save a significant amount of energy over 30 years (2014–2043)—an estimated 0.39 quads of cumulative energy for clothes dryers and 0.31 quads of cumulative energy for room air conditioners. The combined total, 0.70 quads, is equivalent to three-fourths of the estimated amount of energy used in 2008 to dry clothes in all U.S. homes. In addition, DOE expects the energy savings from today's standards to eliminate the need for approximately 0.98 gigawatts (GW) of generating capacity by 2043.

The cumulative national net present value (NPV) of total consumer costs and savings of today's standards in 2009$ ranges from $1.08 billion (at a 7-percent discount rate) to $3.01 billion (at a 3-percent discount rate) for clothes dryers, and from $0.57 billion (at a 7-percent discount rate) to $1.47 billion (at a 3-percent discount rate) for room air conditioners. This NPV expresses the estimated total value of future operating-cost savings minus the estimated increased product costs for products purchased in 2014–2043, discounted to 2011.

In addition, the standards would have significant environmental benefits. The energy savings would result in cumulative greenhouse gas emission reductions of approximately 36.1 million metric tons (Mt) of carbon dioxide (CO2) from 2014 to 2043. During this period, the standards would also result in emissions reductions of approximately 29.3 thousand tons of nitrogen oxides (NOX) and 0.073 ton of mercury (Hg). DOE estimates that the net present monetary value of the CO2 emissions reductions is between $170 and $2,654 million, expressed in 2009$ and discounted to 2011. DOE also estimates that the net present monetary value of the NOX emissions reductions, expressed in 2009$ and discounted to 2011, is $4.3 to $43.8 million at a 7-percent discount rate, and $8.9 to $91.7 million at a 3-percent discount rate.

The benefits and costs of the standards can also be expressed in terms of annualized values over the 2014–2043 period. The annualized monetary values are the sum of (1) the annualized national economic value, expressed in 2009$, of the benefits from operating the product (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase costs, which is another way of representing consumer NPV), plus (2) the monetary value of the benefits of emission reductions, including CO_2 emission reductions.[a] The value of the CO_2 reductions is otherwise known as the Social Cost of Carbon (SCC), and is calculated using a range of values per metric ton of CO_2 developed by a recent interagency process. The monetary benefits of cumulative emissions reductions are reported in 2009$ so that they can be compared with the other costs and benefits in the same dollar units. The derivation of the SCC values is discussed in chapter 16.

Although adding the value of consumer savings to the values of emission reductions provides a valuable perspective, two issues should be considered. First, the national operating cost savings are domestic U.S. consumer monetary savings that occur as a result of market transactions, while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use quite different time frames for analysis. The national operating cost savings is measured for the lifetime of products shipped in 2014–2043. The SCC values, on the other hand, reflect the present value of future climate-related impacts resulting from the emission of one ton of carbon dioxide in each year. These impacts go well beyond 2100.

Table 1.2.1 shows the annualized values for the clothes dryer standards. Using a 7-percent discount rate and the SCC value of $22.1/ton in 2010 (in 2009$), the cost of the standards for clothes dryers in today's rule is $52.3 million per year in increased equipment costs, while the annualized benefits are $139.1 million per year in reduced equipment operating costs, $25.0 million in CO2 reductions, and $0.9 million in reduced NOX emissions. In this case, the net benefit amounts to $112.7 million per year. Using a 3-percent discount rate and the SCC value of $22.1/ton in 2010 (in 2009$), the cost of the standards for clothes dryers in today's rule is $55.4 million per year in increased equipment costs, while the benefits are $209.1 million per year in reduced operating costs, $25.0 million in CO2 reductions, and $1.4 million in reduced NOX emissions. In this case, the net benefit amounts to $180.1 million per year.

Table 1.2.2 shows the annualized values for the room air conditioner standards. Using a 7-percent discount rate and the SCC value of $22.1/ton in 2010 (in 2009$), the cost of the standards for room air conditioners in today's rule is $107.7 million per year in increased equipment costs, while the annualized benefits are $153.7 million per year in reduced equipment operating costs, $19.5 million in CO2 reductions, and $0.999 million in reduced NOX emissions. In this case, the net benefit amounts to $66.4 million per year. Using a 3-percent discount rate and the SCC value of $22.1/ton in 2010 (in 2009$), the cost of the standards for room air conditioners in today's rule is $111.0 million per year in increased equipment costs, while the benefits are $186.2 million per year in reduced operating costs, $19.5 million in CO2 reductions,

[a] DOE used a two-step calculation process to convert the time-series of costs and benefits into annualized values. First, DOE calculated a present value for the time-series of costs and benefits using a discount rate of either three or seven percent. From the present value, DOE then calculated the fixed annual payment over the analysis time period (2014 through 2043) that yielded the same present value. The fixed annual payment is the annualized value. Although DOE calculated annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined is a steady stream of payments.

and $1.20 million in reduced NOX emissions. In this case, the net benefit amounts to $95.9 million per year.

Table 1.2.1 Annualized Benefits and Costs of Amended Standards (TSL 4) for Clothes Dryers for 2014–2043 Period

	Discount Rate	Primary Estimate*	Low Estimate*	High Estimate*
		Monetized (million 2009$/year)		
Benefits				
Operating Cost Savings	7%	139.1	120.6	158.3
	3%	209.1	177.4	241.3
CO_2 Reduction at $4.9/t**	5%	6.0	6.0	6.0
CO_2 Reduction at $22.1/t**	3%	25.0	25.0	25.0
CO_2 Reduction at $36.3/t**	2.5%	39.8	39.8	39.8
CO_2 Reduction at $67.1/t**	3%	76.0	76.0	76.0
NO_X Reduction at $2,519/ton**	7%	0.9	0.9	0.9
	3%	1.4	1.4	1.4
Total†	7% plus CO_2 range	146.1 to 216.1	127.6 to 197.6	165.3 to 235.3
	7%	165.0	146.5	184.3
	3%	235.4	203.7	267.6
	3% plus CO_2 range	216.5 to 286.5	184.8 to 254.8	248.7 to 318.7
Costs				
Incremental Product Costs	7%	52.3	48.8	55.9
	3%	55.4	51.2	59.6
Net Benefits				
Total†	7% plus CO_2 range	93.7 to 163.7	78.7 to 148.7	109.4 to 179.4
	7%	112.7	97.7	128.3
	3%	180.1	152.5	208.1
	3% plus CO_2 range	161.1 to 231.1	133.6 to 203.6	189.1 to 259.1

* The Primary, Low, and High Estimates utilize forecasts of energy prices and housing starts from the AEO2010 Reference case, Low Economic Growth case, and Low Economic Growth case, respectively.

** The CO_2 values represent global values (in 2009$) of the social cost of CO_2 emissions in 2010 under several scenarios. The values of $4.9, $22.1, and $36.3per metric ton are the averages of SCC distributions calculated using 5-percent, 3-percent, and 2.5-percent discount rates, respectively. The value of $67.1 per ton represents the 95th percentile of the SCC distribution calculated using a 3-percent discount rate. The value for NO_X (in 2009$) is the average of the low and high values used in DOE's analysis.

† Total benefits for both the 3-percent and 7-percent cases are derived using the SCC value calculated at a 3-percent discount rate, which is $22.1/ton in 2010 (in 2007$). In the rows labeled as "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

Table 1.2.2 Annualized Benefits and Costs of Amended Standards (TSL 4) for Room Air Conditioners for 2014–2043 Period

	Discount Rate	Primary Estimate*	Low Estimate*	High Estimate*
		Monetized (million 2009$/year)		
Benefits				
Operating Cost Savings	7%	153.7	145.1	161.9
	3%	186.2	174.2	197.3
CO_2 Reduction at $4.9/t**	5%	5.0	5.0	5.0
CO_2 Reduction at $22.1/t**	3%	19.5	19.5	19.5
CO_2 Reduction at $36.3/t**	2.5%	30.7	30.7	30.7
CO_2 Reduction at $67.1/t**	3%	59.4	59.4	59.4
NO_X Reduction at $2,519/ton**	7%	0.999	0.999	0.999
	3%	1.197	1.197	1.197
Total†	7% plus CO_2 range	159.6 to 214.0	151.1 to 205.5	167.9 to 222.3
	7%	174.1	165.5	182.4
	3%	206.8	194.9	218.0
	3% plus CO_2 range	192.3 to 246.7	180.4 to 234.8	203.5 to 257.9
Costs				
Incremental Product Costs	7%	107.7	107.7	107.7
	3%	111.0	111.0	111.0
Net Benefits				
Total†	7% plus CO_2 range	51.9 to 106.3	43.4 to 97.8	60.2 to 114.6
	7%	66.4	57.8	74.7
	3%	95.9	83.9	107.0
	3% plus CO_2 range	81.4 to 135.8	69.4 to 123.8	92.5 to 146.9

* The Primary, Low, and High Estimates utilize forecasts of energy prices and housing starts from the AEO2010 Reference case, Low Economic Growth case, and Low Economic Growth case, respectively.

** The CO_2 values represent global values (in 2009$) of the social cost of CO_2 emissions in 2010 under several scenarios. The values of $4.9, $22.1, and $36.3 per metric ton are the averages of SCC distributions calculated using 5-percent, 3-percent, and 2.5-percent discount rates, respectively. The value of $67.1 per ton represents the 95th percentile of the SCC distribution calculated using a 3-percent discount rate. The value for NO_X (in 2009$) is the average of the low and high values used in DOE's analysis.
† Total benefits for both the 3-percent and 7-percent cases are derived using the SCC value calculated at a 3-percent discount rate, which is $22.1/ton in 2010 (in 2009$). In the rows labeled as "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

1.3 OVERVIEW OF STANDARDS FOR RESIDENTIAL CLOTHES DRYERS AND ROOM AIR CONDITIONERS

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[b] of Title III (42 U.S.C. 6311–6317), which established an energy conservation program for certain industrial equipment. Additional amendments to EPCA give DOE the authority to regulate the energy efficiency of several products, including residential clothes dryers and room air conditioners—the products that are the focus of this document. The amendments to EPCA in the National Appliance Energy Conservation Act of 1987 (NAECA), Pub. L. 100-12, established energy conservation standards for room air conditioners, as well as requirements for determining whether these standards should be amended. (42 U.S.C. 6295(c) and (g))

DOE published draft data sheets containing energy-savings potentials for all covered products in October 2005 as part of its fiscal year 2006 schedule-setting process. These data sheets summarized the following in table format: (1) the potential energy savings from regulatory action in cumulative quads from 2010 to 2035, (2) the potential economic benefits or burdens, (3) the potential environmental or energy security benefits, (4) the status of required changes to test procedures, (5) other regulatory actions, (6) recommendations by interested parties, (7) evidence of market-driven or voluntary efficiency improvements, (8) regulatory issues, and (9) the 2005 priority. However, DOE had completed the calculations for residential clothes dryers and room air conditioners in previous years. Therefore, the following sections cite the appropriate fiscal year's priority-setting activities for which DOE completed the energy savings calculations for each product.

NAECA established prescriptive standards for residential clothes dryers, requiring gas clothes dryers not to be equipped with constant burning pilots, and further required that DOE conduct two cycles of rulemakings to determine if more stringent standards are justified.[c] (42 U.S.C. 6295 (g)(3) and (4)) On May 14, 1991, DOE published a final rule in the *Federal Register* (FR) establishing the first set of performance standards for residential clothes dryers; the new standards became effective on May 14, 1994. 56 FR 22250. DOE initiated a second standards rulemaking for residential clothes dryers by publishing an advance notice of proposed rulemaking (ANOPR) in the *Federal Register* on November 14, 1994. 59 FR 56423. However, pursuant to the priority-setting process outlined in the July 15, 1996, "Procedures, Interpretations and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer

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

[c] DOE defines "electric clothes dryer" under EPCA as "a cabinet-like appliance designed to dry fabrics in a tumble-type drum with forced air circulation. The heat source is electricity and the drum and blower(s) are driven by an electric motor(s)." 10 CFR 430.2. Gas clothes dryers would have a similar definition, but the heat source would be gas.

Products"[d] (the "Process Rule"), DOE classified the standards rulemaking for residential clothes dryers as a low priority for its fiscal year 1998 priority-setting process. As a result, DOE suspended the standards rulemaking activities for them.

As reported, DOE's draft data sheets for the fiscal year 2006 schedule-setting process included an updated analysis suggesting that amended standards for residential clothes dryers would have an energy savings potential ranging from 1.6 to 4.8 quadrillion British thermal units (Btu), or "quads," for electric clothes dryers and an energy savings potential of 0.06 quads for gas clothes dryers.[e] DOE based the low- and high-potential energy savings estimates for electric clothes dryers on the use of microwave and heat pump technologies, respectively. DOE is unaware of any commercially available microwave dryers that are currently for sale in any country. There are at least four manufacturers of heat pump dryers in Europe and Japan[f], but DOE is unaware of any such models on the market in the United States.

NAECA established performance standards for room air conditioners that became effective on January 1, 1990, and directed DOE to conduct two cycles of rulemakings to determine if more stringent standards are justified.[g] (42 U.S.C. 6295 (c)(1) and (2)) On March 4, 1994, DOE published in the *Federal Register* a notice of proposed rulemaking (NOPR) for several products, including room air conditioners. 59 FR 10464. As a result of the Process Rule, DOE suspended activities to finalize standards for room air conditioners. DOE subsequently resumed rulemaking activities related to room air conditioners, and, on September 24, 1997, DOE published a final rule establishing an updated set of performance standards, with an effective date of October 1, 2000. 62 FR 50122.

As reported in DOE's draft data sheets for the fiscal year 2006 schedule-setting process, amended standards for room air conditioners would be expected to have an energy savings potential ranging from 0.8 to 1.5 quads.[h] The low- and high-potential energy savings estimates corresponded to efficiency increases of 10 and 20 percent, respectively.

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[d] 61 FR 36974 (July 15, 1996) (establishing 10 CFR part 430, subpart C, appendix A).

[e] DOE based these estimates on the 2003 prioritization analysis, with a small adjustment for the 2010–2035 timeframe.

[f] Paul Roggema, "Sustainability in Home Appliances," *Appliance Magazine European Edition*, May 2007, p. 5. Available online at: *http://www.appliancemagazine.com/editorial.php?article=1747&zone=208&first=1*.

[g] DOE defines "room air conditioner" under EPCA as a "consumer product, other than a 'packaged terminal air conditioner,' which is powered by a single phase electric current and which is an encased assembly designed as a unit for mounting in a window or through the wall for the purpose of providing delivery of conditioned air to an enclosed space. It includes a prime source of refrigeration and may include a means for ventilating and heating." 10 CFR 430.2.

[h] DOE based these energy savings estimates on an updated analysis of room air conditioners it conducted for its 2005 priority setting. The spreadsheet is available from the DOE Building Technologies Program, Appliances and Commercial Equipment Standards website at:
www.eere.energy.gov/buildings/appliance_standards/docs/2006_schedule_setting_spreadsheets.zip

1.4 PROCESS FOR SETTING ENERGY CONSERVATION STANDARDS

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

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

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

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

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

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

6) the need for national energy conservation; and

7) other factors the Secretary considers relevant.

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

DOE considers stakeholder participation to be a very important part of the process for setting energy conservation standards. Through formal public notifications (*i.e.*, *Federal Register* notices), DOE actively encourages the participation and interaction of all stakeholders during the comment period in each stage of the rulemaking. Beginning with the framework document and during subsequent comment periods, interactions among stakeholders provide a balanced discussion of the information that is required for the standards rulemaking.

Before DOE determines whether or not to adopt a proposed energy conservation standard, it must first solicit comments on the proposed standard. (42 U.S.C. 6313(a)(6)(B)(i)) 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. 6313(a)(6)(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 notice of proposed rulemaking (NOPR), which presents a discussion of comments received in response to the NOPM and the preliminary analyses and analytical tools; analyses of the impacts of potential amended energy conservation standards on consumers, manufacturers, and the Nation; DOE's weighting of these impacts of amended energy conservation standards; and the proposed energy conservation standards for each 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 each product; and the effective dates of the amended energy conservation standards.

In October 2007, DOE published a NOPM and announced the availability of the framework document. 10 CFR 430 (October 9, 2007) The framework document, *Rulemaking Framework Document for Residential Clothes Dryers and Room Air Conditioners*, 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://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/dryer_roomac_framework.pdf*.

Subsequently, DOE held a public meeting on October 24, 2007 ("October 2007 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.

During the October 2007 public meeting, interested parties commented about numerous issues relating to each one of the analyses listed in Table 1.4.1. 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.

Table 1.4.1 Analyses Under the Process Rule*

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

* In the current rulemaking DOE conducted the analyses listed under NOPR as part of the final rule analysis.

As part of the information gathering and sharing process, DOE organized and held interviews with manufacturers of the residential clothes dryers and room air conditioners considered in this rulemaking. 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, and national impact analyses 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 clothes dryers and the DOE website for room air conditioners: (http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_dryers.html, http://www1.eere.energy.gov/buildings/appliance_standards/residential/room_ac.html).

On February 23, 2010, DOE published the NOPM and availability of the preliminary TSD. 75 FR 7987. The preliminary TSD provides technical analyses and results that support the information presented in the preliminary NOPM and the executive summary for residential clothes dryers and room air conditioners. The preliminary TSD also provides a detailed description of all of the analyses discussed in the paragraphs above. The preliminary TSD is available on DOE's website at: *http://www1.eere.energy.gov/buildings/appliance_standards/residential/preliminary_analysis_tsd.html.*

Following publication of the NOPM and the preliminary TSD, DOE held a public meeting on March 16, 2010 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 April 26, 2010 to allow interested parties to provide new comments or elaborate on any comments made at the public meeting.

On September 27, 2010, AHAM and the American Council for an Energy-Efficient Economy (ACEEE) jointly submitted on behalf of themselves and 26 manufacturers and 8 energy efficiency advocates the "Joint Petition to Adopt Joint Stakeholder Agreement as it Relates to the Rulemaking on Energy Conservation Standards for Residential Clothes Dryers and Room Air Conditioners," which included recommendations for amended energy conservation standards for residential clothes dryers and room air conditioners. After receiving this Petition as well as comments on the preliminary analysis, DOE determined it would consider the clothes dryer and room air conditioner energy conservation standards provided in the Petition as part of a direct final rule that updated the preliminary analyses based on inputs from these interested parties. DOE organized and held a second round of interviews with manufacturers to gather additional feedback on the analyses and to provide input to the manufacturer impact analysis that was conducted for the final rule.

In addition to revising the various preliminary analyses, DOE also performed an LCC subgroup analysis, manufacturer impact analysis, utility impact analysis, employment impact analysis, and regulatory impact analysis for the final rule.

1.5 STRUCTURE OF THE DOCUMENT

This TSD outlines the analytical approaches used in this rulemaking. The TSD consists of 17 chapters and associated 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 costs to customer retail prices.
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.
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	Life-Cycle Cost Subgroup Analysis: discusses the effects of standards on different subgroups of consumers and compares the LCC and PBP of products with and without higher efficiency standards for these consumers.
Chapter 12	Manufacturer Impact Analysis: discusses the effects of standards on the finances and profitability of product manufacturers.

Chapter 13	Utility Impact Analysis: discusses the effects of standards on electric and gas utilities.
Chapter 14	Employment Impact Analysis: discusses the effects of standards on national employment.
Chapter 15	Environmental Assessment: discusses the effects of standards on emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), and mercury.
Chapter 16	Monetization of Emission Reductions Benefits: discusses the basis for the estimated monetary values used for the reduced emissions of CO_2 and other pollutants that are expected to result from each of the TSLs considered.
Chapter 17	Regulatory Impact Analysis: discusses the impact of non-regulatory alternatives to efficiency standards.
Appendix 5A	AHAM Data Request Sheets
Appendix 5B	Data Submissions
Appendix 5C	Engineering Questionnaires
Appendix 5D	Room Air Conditioner Engineering Data
Appendix 6A	Equipment Price Markup Data
Appendix 7A	RECS 2005 Variables and Values
Appendix 7B	CBECS 2003 Variables and Values
Appendix 7C	LCC Energy Use Calculations
Appendix 7D	Weather and Temperature Parameters
Appendix 8A	User Instructions for LCC and PBP Spreadsheets
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Appendix 8C	Lifetime Distributions
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CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Section 6295(o)(2)(A) of 42 U.S.C. requires the U.S. Department of Energy (DOE) to set forth energy conservation standards that are technologically feasible and economically justified and would result in significant additional energy conservation. This chapter provides a description of the general analytical framework that DOE uses in developing such standards, in particular, standards for residential clothes dryers and room air conditioners ("the considered products"). The analytical framework is a description of the methodology, the analytical tools, and relationships among the various analyses that are part of this rulemaking. For example, the methodology that addresses the statutory requirement for economic justification includes analyses of life-cycle cost (LCC); economic impact on manufacturers and users; national benefits; impacts, if any, on utility companies; and impacts, if any, from lessening competition among manufacturers.

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 stakeholders or persons with special knowledge. 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.

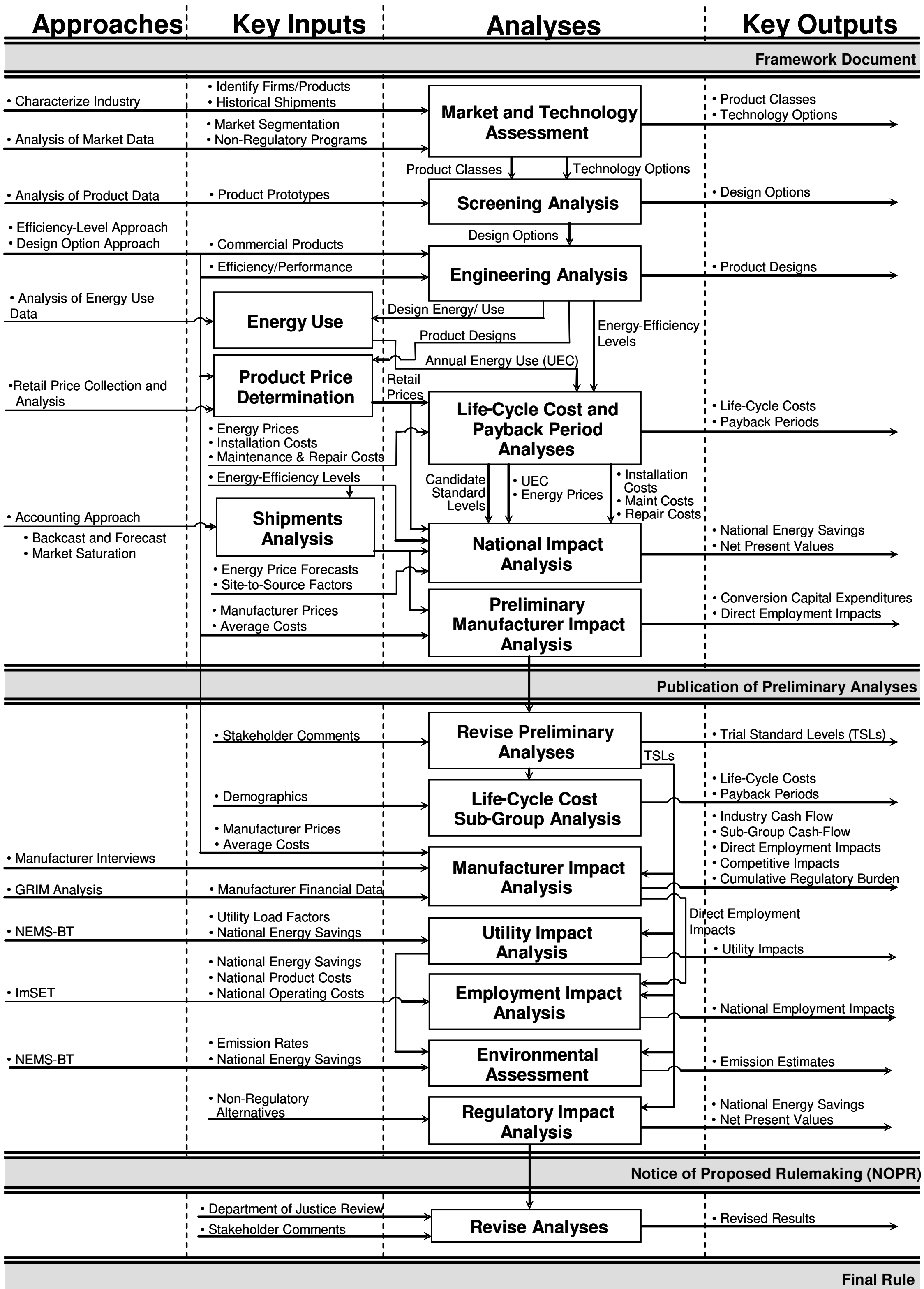

Figure 2.1.1 Flow Diagram of Analyses for the Rulemaking Process

The analyses performed as part of the preliminary analysis stage and reported in the preliminary technical support document (preliminary TSD) include:

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

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

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

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

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

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

- A shipments analysis to forecast shipments of residential clothes dryers and room air conditioners, which are then used to calculate the national impacts of standards on energy, net present value (NPV), and future manufacturer cash flows.

- A national impact analysis (NIA) to assess aggregate impacts at the national level of potential energy conservation standards for the considered products, as measured by the NPV of total consumer economic impacts and the national energy savings (NES).

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

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

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

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

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

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

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

- A regulatory impact analysis to examine major alternatives to 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 findings in the *Energy Conservation Standards Rulemaking Framework Document for Residential Clothes Dryers and Room Air Conditioners* (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 October 9, 2007. 72 FR 57254. DOE presented the analytical approach to interested parties during a public meeting held on October 24, 2007. The framework document is available at http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/dryer_roomac_framework.pdf

In response to the publication of the framework document and the framework public meeting, DOE received numerous comments from interested parties regarding DOE's analytical approach. DOE published the preliminary analysis on February 23, 2010 (75 FR 7987), addressing key comments received from interested parties. DOE subsequently held a public meeting on March 16, 2010, to present the preliminary analysis and to seek public comment. The preliminary analysis and preliminary TSD are available at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/preliminary_analysis.html.

This final rule TSD contains details of the final analyses conducted for residential clothes dryers and room air conditioners.

2.2 MARKET AND TECHNOLOGY ASSESSMENT

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

2.2.1 Market Assessment

When initiating a standards rulemaking, DOE develops information on the present and past industry structure and market characteristics for the products concerned. This activity assesses the industry and products, both quantitatively and qualitatively, based on publicly available information. As such, for the considered products, DOE addressed the following: (1) manufacturer market share and characteristics; (2) existing regulatory and non-regulatory product efficiency improvement initiatives; and (3) trends in product characteristics and retail markets. This information serves as resource material throughout the rulemaking.

DOE reviewed existing literature and interviewed manufacturers to get an overall picture of the markets for the considered products in the United States. Industry publications and trade journals, government agencies, and trade organizations provided the bulk of the information, including information on: (1) manufacturers and their market share; (2) shipments by capacity; and (3) market saturation. The appropriate sections of this TSD describe the resulting information as DOE used it in the analysis.

DOE has used the most reliable and accurate data available at the time of each analysis in this rulemaking. All data are available for public review.

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 stakeholders, DOE develops a list of technologies for consideration. Initially, these technologies encompass all those it believes are technologically feasible.

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

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. As described in section 2.3.2 above, DOE develops 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, reviews the list to determine if these options are practicable to manufacture, install, and service, would adversely affect product utility or availability, or would have adverse impacts on health and safety. In addition, DOE removed from the list technology options that lack energy consumption data as well as technology options whose energy consumption could not be adequately measured by existing DOE test procedures. In the engineering analysis, DOE further considers efficiency enhancement options that it did not screen out in the screening analysis.

2.4 ENGINEERING ANALYSIS

The engineering analysis (chapter 5 of the final rule TSD) establishes the relationship between the manufacturing production cost and the efficiency for each class of residential clothes dryers and room air conditioners. 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, the impact of efficiency improvements on the considered products, and the methodology DOE used to extend the analysis to low-shipment-volume product classes.

In the engineering analysis, DOE evaluates a range of product efficiency levels and their associated manufacturing costs. 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. The engineering analysis considers 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 considers the remaining technologies, designated as design options, in developing the cost-efficiency curves, which are subsequently used for the LCC and PBP analyses.

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

In the framework document, DOE proposed to use the design-option approach for residential clothes dryers and the efficiency-level approach room air conditioners, combining each with the cost-assessment approach to develop a cost for each efficiency level. This approach involved physically disassembling commercially available products, consulting with outside experts, reviewing publicly available cost and performance information, and modeling equipment cost. DOE determined in the preliminary analysis that the efficiency-level approach was more appropriate for clothes dryers, and used this approach for the clothes dryer engineering final rule analysis. The efficiency levels that DOE considered in the engineering analysis are attainable using technologies currently available on the market in residential clothes dryers and room air conditioners, or have been demonstrated in working prototypes. In addition, DOE associated each efficiency level with specific technologies that manufacturers might use to provide interested parties with additional transparency of assumptions and results and the ability to perform independent analyses for verification. Chapter 5 of this TSD describes the methodology and results of the efficiency level analysis used to derive the cost-efficiency relationships.

2.5 MARKUPS ANALYSIS

DOE used markups 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 calculates markups for baseline products (baseline markups) and for more efficient products (incremental markups). The incremental markup relates the change in the manufacturer sales price of higher-efficiency models (the incremental cost increase) to the change in the retailer or distributor sales price.

To develop markups, DOE identifies how the products are distributed from the manufacturer to the customer. After establishing appropriate distribution channels, DOE relied on economic data from the U.S. Census Bureau and other sources to define how prices are marked up as the products pass from the manufacturer to the customer. See chapter 6 of this TSD for details on the development of markups.

2.6 ENERGY USE ANALYSIS

The energy use analysis, which assesses the energy savings potential from higher efficiency levels, provides the basis for the energy savings values used in the LCC and subsequent analyses. The goal of the energy use analysis is to generate a range of energy use values that reflects actual product use in American homes. The analysis uses information on use of actual products in the field to estimate the energy that would be used by new products at various efficiency levels.

Measurements of field energy use often vary considerably from the rated usage as determined by the DOE test procedure. To determine the field energy use by products that would meet possible energy efficiency standards, DOE used data from the 2005 *RECS*.[1] *RECS* is a national sample survey of housing units that collects statistical information on the consumption of and expenditures for energy in housing units along with data on energy-related characteristics of the housing units and occupants. DOE developed separate samples for homes that used residential clothes dryers and room air conditioners, and then developed sub-samples for each considered product class. For room air conditioners, DOE used climate data specific to each sample household to apportion annual electricity use for room air conditioner operation among the months in the year. Chapter 7 of this TSD provides more detail about DOE's approach for characterizing energy use of clothes dryers and room air conditioners.

2.7 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

New energy conservation standards affect products' operating expenses—usually decreasing them—and consumer prices for the products—usually increasing them. DOE analyzes the effect of amended standards on consumers by evaluating changes in the LCC of owning and operating the product. To evaluate the change in LCC, DOE used the cost-efficiency relationship derived in the engineering analysis, along with the energy costs derived from the energy use characterization. Inputs to the LCC calculation include the installed cost of a product to the consumer (consumer purchase price plus installation cost), operating expenses (energy expenses and maintenance costs), the lifetime of the unit, and a discount rate.

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

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 in the inputs using Monte Carlo simulation and probability distributions. DOE developed LCC and PBP spreadsheet models incorporating both Monte Carlo simulation and probability distributions by using Microsoft Excel spreadsheets combined with Crystal Ball (a commercially available add-in program).

As described above in section **Error! Reference source not found.**, DOE developed samples of individual households or commercial enterprises that use residential clothes dryers and room air conditioners. By developing such samples, DOE was able to perform the LCC and PBP calculations for each household to account for the variability in energy consumption and electricity price associated with actual users of the considered products. DOE identified several other input values for estimating the LCC, including retail prices, discount rates, and product lifetime. DOE characterized discount rates and product lifetime with probability distributions.

DOE developed discount rates separately for residential consumers and commercial customers. Because some room air conditioners are used in commercial applications, DOE developed commercial discount rates for those commercial subsectors that purchase room air conditioners. DOE developed discount rates from estimates of the interest rate, or finance cost, applied to purchases of residential and commercial products. Following accepted principles of financial theory, the finance cost of raising funds to purchase such products can be interpreted as: (1) the financial cost of any debt incurred to purchase products, principally interest charges on debt; or (2) the opportunity cost of any equity used to purchase products, principally interest earnings on household equity.

DOE considered installation, maintenance and repair costs for the efficiency levels considered in this rulemaking. Typically, small incremental changes in energy efficiency produce no, or only minor, changes in repair and maintenance costs over baseline efficiency products. Products having efficiencies that are significantly greater than baseline models can incur increased repair and maintenance costs, as they are more likely to incorporate technologies that are new to the industry.

2.8 SHIPMENTS ANALYSIS

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

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

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

2.9 NATIONAL IMPACT ANALYSIS

The national impact analysis assesses the aggregate impacts at the national level of potential energy conservation standards for each of the considered products, as measured by the NPV of total consumer economic impacts and the NES. DOE determined the NPV and NES for the efficiency levels considered for each of the product classes analyzed. To make the analysis more accessible and transparent to all interested parties, DOE prepared a Microsoft Excel spreadsheet model to forecast NES and the national consumer economic costs and savings resulting from new standards. The spreadsheet model uses typical values as inputs (as opposed to probability distributions). To assess the effect of input uncertainty on NES and NPV results, DOE may conduct sensitivity analyses by running scenarios on specific input variables. Chapter 10 of this TSD provides additional details regarding the national impact analysis.

Several of the inputs for determining NES and NPV depend on the forecast trends in product energy efficiency. For the base case (which presumes no revised standards), DOE uses the efficiency distributions developed for the LCC analysis, and assumes some rate of change over the forecast period. In this analysis, DOE has used a roll-up scenario in developing its forecasts of efficiency trends after standards take effect. Under a roll-up scenario, all products that perform at levels below a prospective standard are moved, or rolled-up, to the minimum performance level allowed under the standard. Product efficiencies above the standard level under consideration would remain the same as before the revised standard takes effect.

2.9.1 National Energy Savings

The inputs for determining the NES for each product analyzed are: (1) annual energy consumption per unit; (2) shipments; (3) product stock; (4) national energy consumption; and (5) site-to-source conversion factors. DOE calculated the national energy consumption by multiplying the number of units, or stock, of each product (by vintage, or age) by the unit energy consumption (also by vintage). DOE calculated annual NES based on the difference in national energy consumption for the base case (without new efficiency standards) and for each higher efficiency standard. DOE estimated energy consumption and savings based on site energy, and converted the electricity consumption and savings to source primary) energy. Cumulative energy savings are the sum of the NES for each year.

2.9.2 Net Present Value of Consumer Benefit

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

DOE calculated increases in total installed costs as the product of 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 expressed savings in operating costs as decreases associated with the lower energy consumption of products bought in the standards case compared to the base efficiency case.

Total savings in operating costs are the product of savings per unit and the number of units of each vintage that survive in a given year.

2.10 CONSUMER SUBGROUP ANALYSIS

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

For this rulemaking, DOE analyzed as subgroups: (1) low-income households; (2) households solely occupied by senior citizens.

2.11 MANUFACTURER IMPACT ANALYSIS

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

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

2.12 EMPLOYMENT IMPACT ANALYSIS

New or amended energy conservation standards can impact employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the plants that produce the covered products, and at the affiliated distribution and service companies, resulting from the adoption of new standards. DOE evaluated direct employment impacts in the MIA. Indirect employment impacts may result from expenditures shifting between goods (the substitution effect) and changes in income and overall expenditure levels (the income effect) that occur due to the adoption of standards.

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

2.13 UTILITY IMPACT ANALYSIS

The utility impact analysis estimates the effects of amended energy conservation standards on installed electricity generation capacity and electricity generation. For this analysis, DOE adapted NEMS, which is a large multi-sectoral, partial-equilibrium model of the U.S. energy sector that the EIA has developed throughout the past decade, primarily for preparing EIA's *AEO*. In previous rulemakings, a variant of NEMS (currently termed NEMS-BT, BT referring to DOE's Building Technologies Program), was developed to better address the specific impacts of an energy conservation standard. NEMS, which is available in the public domain, produces a widely recognized baseline energy forecast for the United States. The typical NEMS outputs include forecasts of electricity and natural gas sales, prices, and electric generating capacity.

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

2.14 ENVIRONMENTAL ASSESSMENT

To comply with the National Environmental Policy Act and the requirements of 42 U.S.C. 6295(o)(2)(B)(i)(VI) and 6316(a), DOE intends to prepare an environmental assessment of the impacts of amended energy conservation standards for residential clothes dryers and room air conditioners on the human environment. The primary environmental effects of these standards would be reduced power plant emissions resulting from reduced consumption of electricity. DOE will assess these environmental effects by using NEMS-BT to provide key inputs to its analysis. The portion of the environmental assessment that will be produced by NEMS-BT considers carbon dioxide (CO_2), nitrogen oxides (NO_x), and mercury (Hg). The environmental assessment also considers impacts on SO_2 emissions and discusses particulate matter (PM) emissions. After a brief discussion of general methodology, this section will address each of the relevant emissions.

2.14.1 Carbon Dioxide

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

2.14.2 Sulfur Dioxide

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

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

2.14.3 Nitrogen Oxides

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

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

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

2.14.4 Mercury

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

2.14.5 Particulate Matter

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

2.15 MONETIZING CARBON DIOXIDE AND OTHER EMISSIONS REDUCTIONS

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

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

At the time of this analysis, the most recent interagency estimates of the potential global benefits resulting from reduced CO_2 emissions in 2010 were $4.7, $21.4, $35.1, and $64.9 per metric ton in 2007 dollars. These values are then adjusted to 2009$ using the standard GDP deflator value for 2008 and 2009. For emissions (or emission 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 will give preference to consideration of the global benefits of reducing CO_2 emissions. See appendix 16A of this TSD for the full range of annual SCC estimates from 2010 to 2050. To calculate a present value of the stream of monetary values, DOE will discount the values in each of the four cases using the discount rates that had been used to obtain the SCC values in each case.

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

DOE also intends to estimate the potential monetary benefit of reduced NO_X emissions resulting from the standard levels it considers. For NO_x emissions, available estimates suggest a very wide range of monetary values for NO_X emissions, ranging from $370 per ton to $3,800 per ton of NO_X from stationary sources, measured in 2001$ (equivalent to a range of $447 to $4,591 per ton in 2009$). Refer to the OMB, Office of Information and Regulatory Affairs, "2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities," for additional information. In accordance with U.S. Office of Management and Budget (OMB) guidance, DOE will conduct two calculations of the monetary benefits derived using each of the economic values used for NO_x, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.

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

2.16 REGULATORY IMPACT ANALYSIS

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

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

REFERENCES

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

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

3.2 PRODUCT DEFINITIONS

DOE defines "**electric clothes dryer**" under the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 United States Code (U.S.C.) 6291–6309) as "a cabinet-like appliance designed to dry fabrics in a tumble-type drum with forced air circulation. The heat source is electricity and the drum and blower(s) are driven by an electric motor(s)." Similarly, EPCA defines "**gas clothes dryer**" as "a cabinet-like appliance designed to dry fabrics in a tumble-type drum with forced air circulation. The heat source is gas and the drum and blower(s) are driven by an electric motor(s)." (10 Code of Federal Regulation (CFR) 430.2)

DOE defines "**room air conditioner**" under EPCA as "a consumer product, other than a "packaged terminal air conditioner", which is powered by a single phase electric current and which is an encased assembly designed as a unit for mounting in a window or through the wall for the purpose of providing delivery of conditioned air to an enclosed space. It includes a prime source of refrigeration and may include a means for ventilating and heating." (10 CFR 430.2)

3.3 PRODUCT CLASSES

DOE has established separate product classes for each product (residential clothes dryers and room air conditioners). DOE formulates a separate energy conservation standard for each product class. As required by EPCA, the criteria for separation into different classes are: (1) type of energy used, or (2) capacity or other performance-related features such as those that provide utility to the consumer or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 U.S.C. 6295 (q) and 6316(a))

For residential **clothes dryers**, DOE considered four product classes for vented and two product classes for ventless dryers, as shown in Table 3.3.1. This is a new analytical structure for clothes dryers, recognizing the unique utility that ventless clothes dryers offer to consumers.[a] Another new entry with unique utility is the combination washer/dryer (*i.e.*, a device which washes and then dries clothes in the same basket/cavity in a combined cycle). Combination washer/dryers are very popular in space-constrained environments (*e.g.*, apartments, recreational vehicles), and all products of this type appear to utilize ventless operation. Thus, like other ventless dryers, such combination washer/dryers can be installed in locations where venting dryers would be precluded due to venting restrictions. As discussed in section 0, DOE published a test procedure final rule amending the DOE test procedure for clothes dryers to include provisions for testing of ventless clothes dryers. Therefore, DOE included product classes for ventless clothes dryers in this rulemaking analysis.

Table 3.3.1 Residential Clothes Dryer Product Classes

Vented dryers
1. Electric, Standard (4.4 cubic feet (ft^3) or greater capacity)
2. Electric, Compact (120 volts (V)) (less than 4.4 ft^3 capacity)
3. Electric, Compact (240 V) (less than 4.4 ft^3 capacity)
4. Gas
Ventless dryers
5. Electric, Compact (240 V) (less than 4.4 ft^3 capacity)
6. Electric, Combination Washer/Dryer

For **room air conditioners**, amendments to EPCA in the National Appliance Energy Conservation Act of 1987 (NAECA), Pub. L. 100-12, initially specified 12 product classes which were applicable to units designed for single- or double-hung window installation or through-the-wall installation and based on the following criteria: (1) cooling capacity; (2) the presence of louvered sides (LS); and (3) the capability of reverse cycle (*i.e.*, the unit can function as a heat pump). (42 U.S.C. 6295(c)(1)) Capacity is measured in British Thermal Units (Btu) per hour (h). In the final rule published in the *Federal Register* on September 24, 1997, DOE established an updated set of performance standards (effective October 1, 2000) which included four additional product classes.[b]

[a] Previously, DOE has described ventless dryers as condensing dryers. The new designation reflects the actual consumer utility (*i.e.,* no external vent required) and the market availability of vented dryers that also condense.

[b] DOE divided the product class covering units with reverse cycle and with louvered sides into units of capacity less than 20,000 Btu/h and units 20,000 Btu/h or more. DOE split the product class covering units with reverse cycle and without louvered sides into units of capacity less than 14,000 Btu/h and units 14,000 Btu/h or more. In addition, DOE established two new product classes for units that are designed to be installed in casement-slider and casement-only windows. Due to the size constraints imposed by casement windows, casement units are small in size and typically deliver 5,000 to 10,000 Btu/h in cooling capacity.

For this final rule, DOE will split product classes 5 and 8 into two product classes each. Current product class 5 (louvered, non-reverse-cycle, capacity of 20,000 and higher) will be split into product class 5A (louvered, non-reverse-cycle, capacity of 20,000 to 27,999 Btu/h) and product class 5B (Louvered, non-reverse-cycle, capacity of 28,000 and higher). Product class 8 (non-louvered, non-reverse-cycle, capacity of 8,000 to 13,999 Btu/h) will be split into product class 8A (non-louvered, non-reverse-cycle, capacity of 8,000 to 10,999 Btu/h) and 8B (non-louvered, non-reverse-cycle, capacity of 11,000 to 13,999 Btu/h). These product class changes are discussed in greater detail in section 5.9.2.11 in chapter 5 of this technical support document (TSD). Table 3.3.2 lists the 18 product classes for room air conditioners.

Table 3.3.2 Room Air Conditioner Product Classes

Without reverse cycle and with louvered sides
1. Less than 6,000 Btu/h
2. 6,000 to 7,999 Btu/h
3. 8,000 to 13,999 Btu/h
4. 14,000 to 19,999 Btu/h
5A. 20,000 to 27,999 Btu/h
5B. 28,000 Btu/h or more
Without reverse cycle and without louvered sides
6. Less than 6,000 Btu/h
7. 6,000 to 7,999 Btu/h
8A. 8,000 to 10,999 Btu/h
8B. 11,000 to 13,999 Btu/h
9. 14,000 to 19,999 Btu/h
10. 20,000 Btu/h or more
With reverse cycle
11. With louvered sides and less than 20,000 Btu/h
12. Without louvered sides and less than 14,000 Btu/h
13. With louvered sides and 20,000 Btu/h or more
14. Without louvered sides and 14,000 Btu/h or more
Casement
15. Casement-Only
16. Casement-Slide

3.4 PRODUCT TEST PROCEDURES

Test procedures exist for both products covered by this rulemaking to determine energy efficiency and annual energy use as the basis for representation and determination of compliance with energy conservation standards. DOE established test procedures for residential clothes dryers and room air conditioners through the rulemaking process, in both cases over 25 years ago. The Energy Independence and Security Act of 2007 (EISA 2007), Pub. L. 110-140, amends EPCA to require DOE to review these test procedures at least every 7 years and to amend them if such amended test procedures would more accurately or fully comply with the requirements of producing test results which measure energy efficiency, energy use, or estimated annual operating cost during a representative average use cycle or period of use without being unduly burdensome to conduct. (42 U.S.C. 6293(b)(1))

DOE originally established its test procedure for residential **clothes dryers** in a final rule published in the *Federal Register* on September 14, 1977. (42 FR 46145; 10 CFR part 430, subpart B, appendix D) On May 19, 1981 DOE published a final rule to amend the test procedure by establishing a field-use factor for clothes dryers with automatic termination controls, clarifying the test cloth specifications and clothes dryer preconditioning, and making editorial and minor technical changes. 46 FR 27324. The clothes dryer test procedure cited two industry test standards: (1) the Association of Home Appliance Manufacturers (AHAM) Standard HLD-1-1974, *AHAM Performance Evaluation Procedure for Household Tumble Type Clothes Dryers* and (2) AHAM Standard HLD-2EC, *Test Method for Measuring Energy Consumption of Household Tumble Type Clothes Dryers*, December 1975.

DOE redesignated and amended its test procedure for **room air conditioners** on June 29, 1979. (44 FR 37938; 10 CFR part 430, subpart B, appendix F) The current room air conditioner test procedure cites two test standards that are each at least 25 years old: (1) American National Standards (since renamed American National Standards Institute (ANSI)) Z234.1-1972, Room *Air Conditioners* and (2) American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 16-69, *Method of Testing for Rating Room Air Conditioners*.

Standby power measurement is not currently incorporated into DOE test procedures for residential clothes dryers or room air conditioners. Section 310 of EISA 2007 amended Section 325 of EPCA to require that the test procedures for clothes dryers and room air conditioners be amended to include measurement of standby mode and off mode power, taking into consideration the most current version of International Electrotechnical Commission (IEC) Standard 62301 *Household electrical appliances – Measurement of standby power* (IEC Standard 62301).[c] EPCA, as amended by EISA 2007, also required that the final rule for this test procedure be published no later than March 31, 2009. (42 U.S.C. 6295(gg)) DOE initiated a separate test procedure rulemaking to modify the test procedures for clothes dryers and room air

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[c] DOE notes that EPCA as amended by EISA 2007, also requires DOE to consider IEC Standard 62087, which specifies methods of measurement for the power consumption of TV receivers, VCRs, set top boxes, audio equipment and multi-function equipment for consumer use. IEC Standard 62087 does not, however, include measurement for the power consumption of electrical appliances such as clothes dryers and room air conditioners. Therefore, DOE determined that IEC Standard 62087 was not suitable for amendments to the clothes dryer and room air conditioner test procedures.

conditioners to provide procedures for the measurement of standby and off modes. DOE published a NOPR for this rule on December 9, 2008 (December 2008 TP NOPR). 73 FR 74639.

DOE determined after the December 2008 TP NOPR was published that it would consider a revised version of IEC Standard 62301, *i.e.*, IEC Standard 62301 Second Edition, which at that time was expected to be published in July 2009. DOE anticipated, based on review of drafts of the updated IEC Standard 62301, that the revisions could include different mode definitions. Subsequently, DOE received information that IEC Standard 62301 Second Edition would not be published until late 2010. To allow for the consideration of standby and off mode power consumption in this energy conservation standards rulemaking, DOE published a SNOPR on June 29, 2010 (June 2010 TP SNOPR), proposing mode definitions based on the new mode definitions from the most recent draft version of IEC Standard 62301 Second Edition which, at that time, was designated as IEC Standard 62301 Second Edition Committee Draft for Vote (IEC Standard 62301 CDV). 75 FR 37594. The IEC circulated IEC Standard 62301 CDV on August 28, 2009. IEC Standard 62301 CDV contained the most recent proposed amendments to IEC Standard 62301, including new mode definitions, at the time the June 2010 TP SNOPR was issued. IEC Standard 62301 CDV revised the proposed mode definitions from previous draft versions of IEC Standard 62301 and addressed comments received by interested parties in response to those drafts. As a result, DOE stated in the June 2010 TP SNOPR that the mode definitions in IEC Standard 62301 CDV represent the best definitions available for the supporting analysis. Id.

DOE also determined after publication of the December 2008 TP NOPR to conduct a rulemaking to amend the active mode test procedure for clothes dryers and room air conditioners. DOE addressed the test procedure issues relating to active mode for clothes dryers and room air conditioners in the June 2010 TP SNOPR. In the June 2010 TP SNOPR, DOE proposed the following test procedure amendments for the measurement of active mode energy consumption for clothes dryers and room air conditioners: 1) procedures for more accurately measuring the effects of different automatic termination technologies in clothes dryers; (2) provisions for ventless clothes dryers, which are being considered under an amended energy conservation standard; (3) updated detergent specifications for clothes dryer test cloth preconditioning; (4) changes to better reflect current usage patterns and capabilities for the covered products; (5) updated references to external test procedures; and (6) clarifications to the test conditions for gas clothes dryers. 75 FR 37594 (June 29, 2010).

DOE recently published a final rule in the *Federal Register* on XX, 2011, (MONTH 2011 TP Final Rule) in which it adopted amendments to the clothes dryer and room air conditioner test procedures. CITE. In the MONTH 2011 TP Final Rule, DOE incorporated by reference into both the clothes dryer and room air conditioner test procedures specific clauses from IEC Standard 62301 First Edition 2005-06 regarding test conditions and test procedures for measuring standby and off mode power consumption. DOE also incorporated into each test procedure definitions of "active mode," "standby mode," and "off mode" that are based on the definitions provided in IEC Standard 62301 CDV. Further, DOE adopted language in each test procedure to clarify the application of clauses from IEC Standard 62301 First Edition and the mode definitions from IEC Standard 62301 CDV for measuring standby and off mode power consumption. CITE.

DOE also notes that EISA 2007 amended EPCA to require that standby mode and off mode energy consumption be integrated into the overall energy efficiency, energy consumption, or other energy descriptor unless the Secretary determines that – (i) the current test procedures for a covered product already fully account for and incorporate standby mode and off mode energy consumption of the covered product; or (ii) such an integrated test procedure is technically infeasible for a particular covered product, in which case the Secretary shall prescribe a separate standby mode and off mode energy use test procedure for the covered product, if technically feasible. (42 U.S.C. 6295(gg)(2)(A)) For both clothes dryers and room air conditioners, DOE determined in the MONTH 2011 TP Final Rule that it is technically feasible to incorporate standby mode and off mode energy consumption into overall energy consumption. As a result, DOE adopted new methods to calculate clothes dryer and room air conditioner standby and off mode energy use and a new measure of energy efficiency (Combined Energy Factor (CEF) and Combined Energy Efficiency Ratio (CEER), respectively) that integrates standby and off mode energy use with the active mode energy use for both products. CITE. Accordingly, DOE developed the amended energy conservation standards for residential clothes dryers and room air conditioners based on these integrated metrics.

Concerning the active mode, DOE adopted amendments in the MONTH 2011 TP Final Rule to the clothes dryer test procedure to include the provisions for testing ventless clothes dryers proposed in the June 2010 TP SNOPR. These amendments consisted of adding separate definitions for a "conventional clothes dryer" (vented) and a "ventless clothes dryer". Further, the alternate test procedure qualifies the requirement for an exhaust simulator so that it would only apply to conventional clothes dryers. DOE also adopted provisions to clarify the testing procedures for ventless clothes dryers, including requirements for clothes dryers equipped with a condensation box, requirements for the condenser heat exchanger, and specifications for ventless clothes dryer preconditioning. In addition to the amendments proposed in the TP SNOPR, DOE adopted clarifications in the TP Final Rule to provide explicit instructions as to the procedure for re-running the test cycle when the condensation box is full. DOE also revised the requirement for ventless clothes dryer preconditioning to remove the maximum time limit for achieving a steady-state temperature. DOE also included additional editorial clarifications to the testing procedures for ventless clothes dryers..CITE

In addition, DOE amended the clothes dryer test procedure to reflect current usage patterns and capabilities. These amendments were based on DOE's analysis of consumer usage patterns data. DOE revised the number of annual use cycles from 416 cycles per year to 283 cycles per year for all types (*i.e.*, product classes) of clothes dryers. This revision was based on DOE's analysis of data from the Energy Information Administration (EIA)'s 2005 *Residential*

Energy Consumption Survey (RECS)[d],[e] for the number of laundry loads (clothes washer cycles) washed per week and the frequency of clothes dryer use. In the June 2010 TP SNOPR, DOE proposed to revise the 70-percent initial remaining moisture content (RMC) required by the test procedure to 47 percent so as to accurately represent the condition of laundry loads after a wash cycle. This proposal was based on analysis of shipment-weighted RMC data for clothes washers submitted by the Association of Home Appliance Manufacturers (AHAM) and based on a distribution analysis of RMC values for clothes washer models listed in the December 22, 2008, California Energy Commission (CEC) directory. 75 FR 37594, 37599 (June 29, 2010). Based on comments from interested parties, DOE determined that an initial clothes dryer RMC of 57.5 percent more accurately represents the moisture content of laundry loads after a wash cycle for the purposes of clothes dryer testing. This RMC was derived from the 47-percent shipment-weighted RMC for clothes washers, but was derived without applying an RMC correction factor as required by the DOE clothes washer test procedure. For these reasons, DOE revised the initial clothes dryer RMC from 70 percent to 57.5 percent in the final rule. In addition, DOE changed the 7-pound (lb) clothes dryer test load size specified by the current test procedure for standard-size clothes dryers to 8.45 lb. This revision was based on the historical trends of clothes washer tub volumes and the corresponding percentage increase in clothes washer test load sizes (as specified by the DOE clothes washer test procedure). DOE assumed these historical trends proportionally impact dryer load sizes. CITE.

Based on the rinse temperature use factors in the DOE clothes washer test procedure and 2005 RECS data reporting the percentage of clothes washer cycles for which consumers use cold water for the rinse cycle, DOE amended the clothes dryer test procedure to change the water temperature for clothes dryer test load preparation from 100 degrees Fahrenheit (°F) ± 5°F to 60°F ± 5°F. This temperature is more representative of the clothes load temperature after a cold rinse cycle at the end of the wash cycle. CITE.

DOE also amended the clothes dryer test procedure to: (1) revise the detergent specifications for test cloth preconditioning due to obsolescence of the detergent specified in the test procedure, (2) update the reference to the industry test standard, (3) eliminate an unnecessary reference to an obsolete industry clothes dryer test standard, (4) amend the provisions in its test procedure which specify test conditions for gas clothes dryers to clarify the required gas supply pressure, (5) amend the provisions for measuring the drum capacity, (6) amend the provisions for the application of the field use factor for automatic cycle termination, and (7) add the calculations of energy factor (EF) and CEF to 10 CFR part 430, subpart B, appendix D1. CITE.

In the June 2010 TP SNOPR, DOE proposed amendments to more accurately measure automatic cycle termination by accounting for the amount over-drying energy consumption. 75

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[d] U.S. Department of Energy-Energy Information Administration. *Residential Energy Consumption Survey*, 2005 Public Use Data Files, 2005. Washington, DC. Available online at: http://www.eia.doe.gov/emeu/recs/

[e] EIA's 2005 RECS is the latest available version of this survey.

FR 37594, 37599 (June 29, 2010). However, DOE conducted testing of representative clothes dryers using the automatic cycle termination test procedure proposed in the June 2010 TP SNOPR. The test results showed that all of the dryers tested significantly over-dried the DOE test load to near bone dry. In addition, the measured EF values were significantly lower than EF values obtained using the existing DOE test procedure, and the test data indicated that clothes dryers equipped with automatic termination controls were less efficient than timer dryers. DOE stated in the TP Final Rule that the test procedure amendments for automatic cycle termination proposed in the June 2010 TP SNOPR do not adequately measure the energy consumption of clothes dryers equipped with such systems using the test load specified in the DOE test procedure. CITE. DOE believes that clothes dryers with automatic termination sensing control systems, which infer the RMC of the load from the properties of the exhaust air such as temprature and humidity, may be designed to stop the cycle when the consumer load has a higher RMC than the RMC obtained using the proposed automatic cycle termination test procedure in conjunction with the existing test load.[f] Manufacturers have indicated, however, that test load types and test cloth materials different than those specified in the DOE test procedure do not produce results as repeatable as those obtained using the test load as currenty specified. In addition, DOE presented data in the May 1981 TP Final Rule from a field use survey conducted by AHAM as well as an analysis conducted by the National Bureau of Standards (now known as the National Institute of Standards and Technology (NIST)) of field test data on automatic termination control dryers. Analysis of this data showed that clothes dryers equipped with an automatic cycle termination feature consume less energy than timer dryers by reducing over-drying. 46 FR 27324 (May 19, 1981). For these reasons, DOE stated in the MONTH 2011 TP Final Rule that the test procedure amendments for automatic cycle termination proposed in the June 2010 TP SNOPR do not adequately measure the energy consumption of clothes dryers equipped with such systems. As a result, DOE did not adopt the amendments for automatic cycle termination proposed in the June 2010 TP SNOPR. CITE.

As discussed above, DOE published the MONTH 2011 TP Final Rule amending the test procedures for clothes dryers and room air conditioners. As part of this final rule, DOE amended the room air conditioner test procedure to update the references to the industry test standards to reference, ANSI/AHAM RAC-1-2008, *Room Air Conditioners*, and ANSI/ASHRAE 16-1983 (RA2009), *Method of Testing for Rating Room Air Conditioners and Packaged Terminal Air Conditioners*, respectively. CITE.

[f] To investigate this, DOE conducted additional testing using a test load similar to that specified in AHAM Standard HLD-1-2009, which consists of cotton bed sheets, towels, and pillow cases. For tests using the same automatic cycle termination settings as were used in the testing described earlier (i.e., normal cycle setting and highest temperature setting, the alternate test load was dried to 1.7 to 2.2 percent final RMC, with an average RMC of 2.0 percent. In comparison, the same clothes dryer under the same cycle settings dried the DOE test load to 0.3 to 1.2 percent RMC, with an average RMC of 0.7 percent. Thus, DOE concluded that the proposed automatic cycle termination control test procedures may not stop at an appropriate RMC when used with the current test load.

In the October 24, 2007 Framework Document, DOE identified two other limitations of the room air conditioner test procedure: (1) the inability of the test procedure to measure the benefits of technologies that improve part-load performance, and (2) the assumed annual operational hours.

The current room air conditioner test procedure measures only the full-load performance at outdoor ambient conditions of 95 ºF dry-bulb and 75 ºF wet-bulb. Therefore, technologies that improve part-load performance, such as multiple-speed compressors and variable-opening expansion devices, will not improve the rated performance of a room air conditioner under the current test procedure. In contrast, central air conditioners and heat pumps are rated with a seasonal energy efficiency ratio (SEER) descriptor, but the test procedure consists of multiple rating points that add time and expense when rating the product.

DOE concluded in the June 2010 TP SNOPR that widespread use of part-load technology in room air conditioners would not likely be stimulated by the development of a part-load metric at this time, and therefore, the significant effort required to develop an accurate part-load metric is not likely to be warranted by the expected minimal energy savings. 75 FR 37594, 37633–34 (June 29, 2010). DOE also noted that the key design changes that improve full-load efficiency also improve part-load efficiency, so the existing EER metric is already a strong indication of product efficiency over a wide range of conditions. DOE concluded that development of an additional test for part load, or a change of the room air conditioner metric to a part-load test, is not supported by information available to DOE at this time. Therefore, DOE did not consider amendments to its room air conditioner test procedure to measure part-load performance in the June 2010 TP SNOPR. 75 FR 37594, 37634 (June 29, 2010).For these reasons, DOE did not amend its room air conditioner test procedure to measure part-load performance in the TP Final Rule. CITE.

DOE determined in the TP Final Rule that the 750 annual operating hours specified by the current DOE room air conditioner test procedure is representative of current usage patterns, based upon its analysis of data from the 2005 RECS. Therefore, DOE did not amend the annual usage hours specified by the current DOE test procedure for room air conditioners. CITE.

EPCA requires that DOE must determine to what extent, if any, the proposed test procedure would alter the measured energy efficiency of any covered product as determined under the existing test procedure. (42 U.S.C. 6293(e)(1)) If DOE determines that the amended test procedure would alter the measured efficiency of a covered product, DOE must amend the applicable energy conservation standard during the rulemaking carried out with respect to such test procedure. In determining the amended energy conservation standard, the Secretary shall measure, pursuant to the amended test procedure, the energy efficiency, energy use, or water use of a representative sample of covered products that minimally comply with the existing standard. (42 U.S.C. 6293(e)(2))

Under 42 U.S.C. 6295(gg)(2)(C), EPCA provides that amendments to the test procedures to include standby mode and off mode energy consumption will not determine compliance with previously established standards. (U.S.C. 6295(gg)(2)(C)) Because the amended test procedures for standby mode and off mode energy consumption would not alter existing measures of energy consumption or efficiency, these amendments would not affect a manufacturer's ability to demonstrate compliance with previously established standards.

As discussed in chapter 5 of this TSD, DOE investigated how the amendments to the active mode provisions in its clothes dryer and room air conditioner test procedures in the MONTH 2011 TP Final Rule affect the measured efficiency of products.

3.5 MANUFACTURER TRADE GROUPS

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

DOE identified several trade groups that support, or have an interest in, the residential clothes dryer and/or room air conditioner industries, including AHAM and the Air Conditioning and Refrigeration Institute.

3.5.1 Association of Home Appliance Manufacturers

AHAM[g], formed in 1967, aims to enhance the value of the home appliance industry through leadership, public education and advocacy. AHAM provides services to its members including government relations; certification programs for room air conditioners, dehumidifiers and room air cleaners; an active communications program; and technical services and research. In addition, AHAM conducts other market and consumer research studies and publishes a biennial *Major Appliance Fact Book*. AHAM also develops and maintains technical standards for various appliances to provide uniform, repeatable procedures for measuring specific product characteristics and performance features.

3.5.2 Air Conditioning, Heating, and Refrigeration Institute

The Air Conditioning, Heating, and Refrigeration Institute (AHRI)[h] is the trade organization that represents manufacturers of over 90 percent of the air conditioning and

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

[h] For more information, please visit http://www.ahrinet.org/

refrigeration equipment that is currently installed in the United States. AHRI develops and publishes technical standards, often in conjunction with ANSI, the IEC, and the International Organization for Standardization (ISO). AHRI maintains a certification program and certified product database, and supports legislation, regulations, and codes favorable to the HVACR industry. While AHRI does not certify room air conditioners, it represents a number of manufacturers which produce multiple types of air conditioning systems, including room air conditioners, and is involved with regulatory issues affecting all types of refrigeration-based systems.

3.6 MANUFACTURER INFORMATION

The following section details information regarding manufacturers of residential clothes dryers and room air conditioners for sale in the United States, including estimated market shares (section 3.6.1), industry mergers and acquisitions (section 3.6.2), potential small business impacts (section 3.6.3), and product distribution channels (section 3.6.4).

3.6.1 Manufacturers and Market Shares

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

For residential **clothes dryers**, DOE estimates that there are 14 manufacturers selling into the domestic market, of which several are foreign-owned companies with manufacturing facilities outside of the United States. The majority of market share is held by four major domestic manufacturers, including Whirlpool Corporation (Whirlpool), Maytag Corporation (Maytag), GE Consumer & Industrial (GE), and AB Electrolux (Frigidaire).[1] As will be discussed in section 3.6.2, Maytag and Whirlpool merged in 2006 but have continued to maintain both product lines to this date. The combined Maytag-Whirlpool entity accounts for 70 - 74 percent of the residential clothes dryer market. Other manufacturers include Alliance Laundry Systems LLC (Alliance), AM Appliance Group (formerly ASKO, Inc.), BSH Home Appliances Corporation (Bosch-Siemens), Fisher & Paykel Appliances Limited (Fisher & Paykel), Haier America Trading, LLC (Haier), Indesit Company (Indesit), LG Electronics, Inc. (LG), Miele, Inc. (Miele), Samsung Electronics America, Inc. (Samsung), and Felix Storch, Inc. (Summit). Table 3.6.1 lists these manufacturers. Figure 3.6.1 and Figure 3.6.2 illustrate the 2008 market shares for the domestic residential electric and gas clothes dryer markets, respectively.

Table 3.6.1 Major and Other Residential Clothes Dryer Manufacturers

Major Manufacturers	Other Manufacturers
Whirlpool	Alliance
Maytag	ASKO
GE	Bosch-Siemens
Frigidaire	Fisher & Paykel
	Haier
	Indesit
	LG
	Miele
	Samsung
	Summit

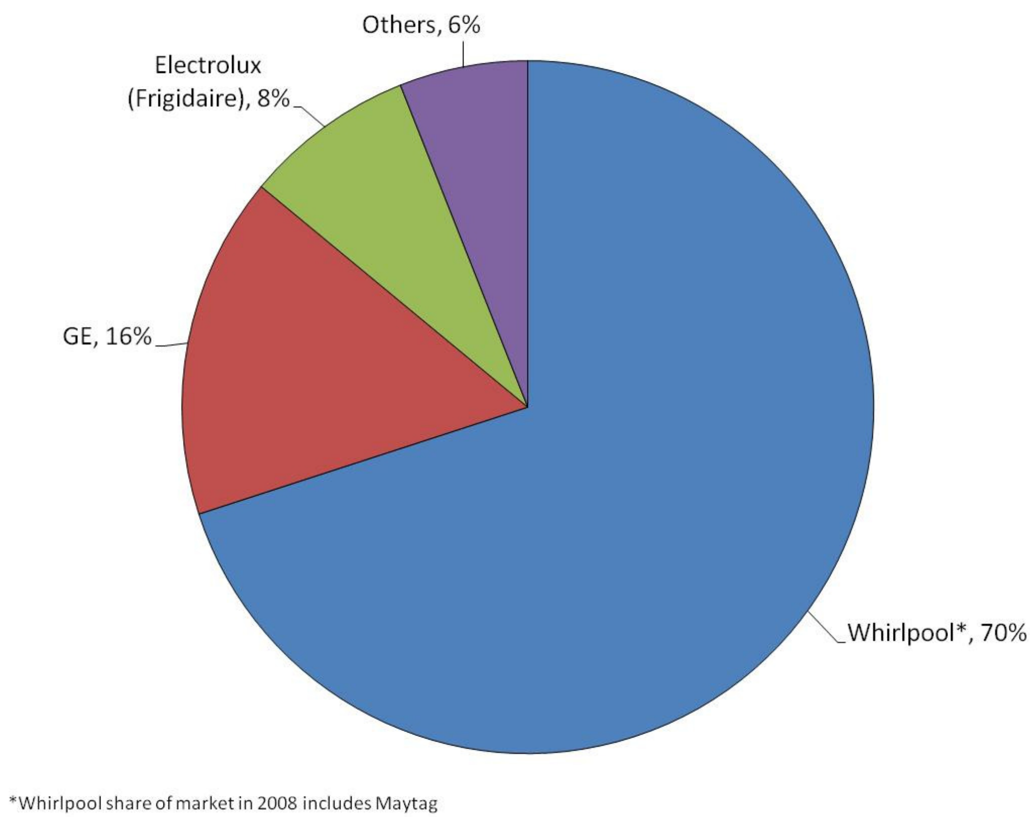

Figure 3.6.1 2008 Market Shares for the Domestic Electric Clothes Dryer Market[2]

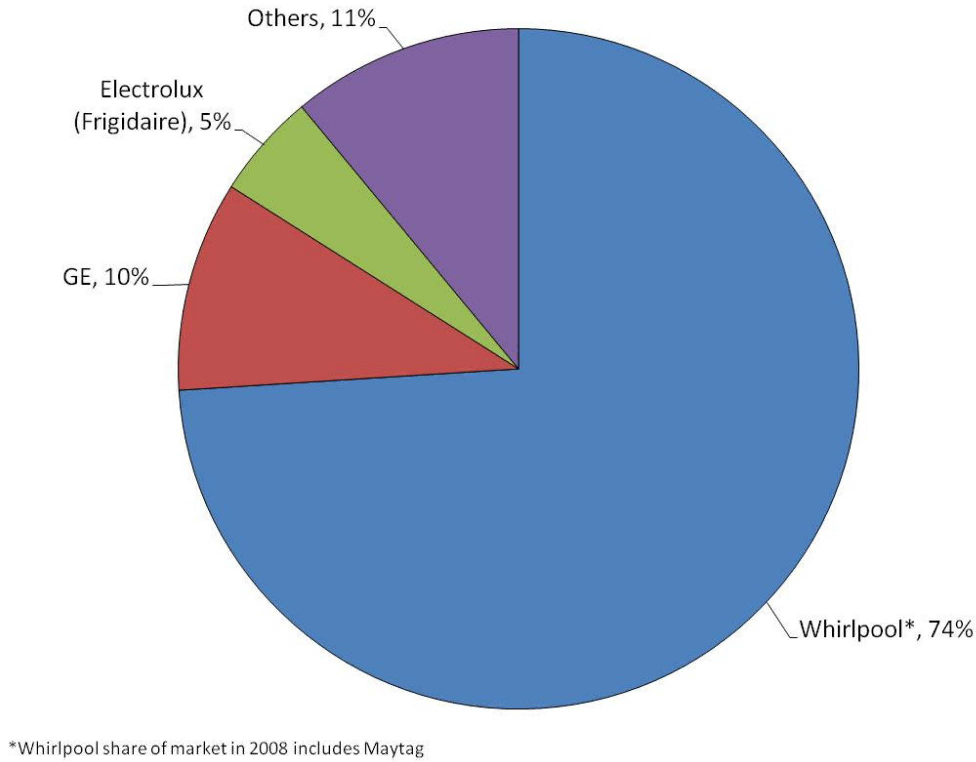

Figure 3.6.2 2008 Market Shares for the Domestic Gas Clothes Dryer Market[3]

Table 3.6.2 and Table 3.6.3 show the market share for electric and gas clothes dryer manufacturers, respectively, between 2000 and 2008. The market shares for the top three clothes dryer manufacturers have remained relatively stable since 2000; however, the market share for Electrolux gas dryers has decreased by 5 percent since 2000.

Table 3.6.2 2000-2008 Electric Clothes Dryer Manufacturer Market Share [4]

	Market Share *(%)*								
Company	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
Whirlpool	70*	56	56	56	56	56	55	54	54
Maytag	-	16	17	18	19	18	20	20	19
GE	16	15	15	14	14	15	17	18	16
Electrolux (Frigidaire)	8	8	9	10	10	11	8	8	8
Others	6	5	3	2	1	0	0	0	3

*Whirlpool share of market in 2008 includes Maytag.

Table 3.6.3 2000-2008 Gas Clothes Dryer Manufacturer Market Share [5]

Company	Market Share (%)								
	2008	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
Whirlpool	74	55	55	55	55	55	57	58	56
Maytag	-	22	23	25	25	26	23	23	21
GE	10	11	11	11	11	11	13	13	13
Electrolux (Frigidaire)	5	5	6	7	7	8	7	6	10
Others	11	7	5	3	2	0	0	0	0

*Whirlpool share of market in 2008 includes Maytag.

For **room air conditioners**, DOE estimates that there are less than 10 key manufacturers supplying the U.S. market. Based on data published by *Appliance Magazine*,[6] nearly three quarters of the domestic market, 70 percent, in 2008 was controlled by four manufacturers: LG, Fedders Corporation (Fedders), Frigidaire, and Whirlpool. The remaining market share was divided among companies including Haier, Samsung, Sharp Electronics Corporation (Sharp), Friedrich Air Conditioning Company (Friedrich) and others. Table 3.6.4 lists these manufacturers. Figure 3.6.3 illustrates the 2008 market shares for the domestic room air conditioner market.

Table 3.6.4 Major and Other Room Air Conditioner Manufacturers

Major Manufacturers	Other Manufacturers
LG	Haier
Fedders	Samsung
Frigidaire	Sharp
Whirlpool	Matsushita
	Friedrich
	Carrier

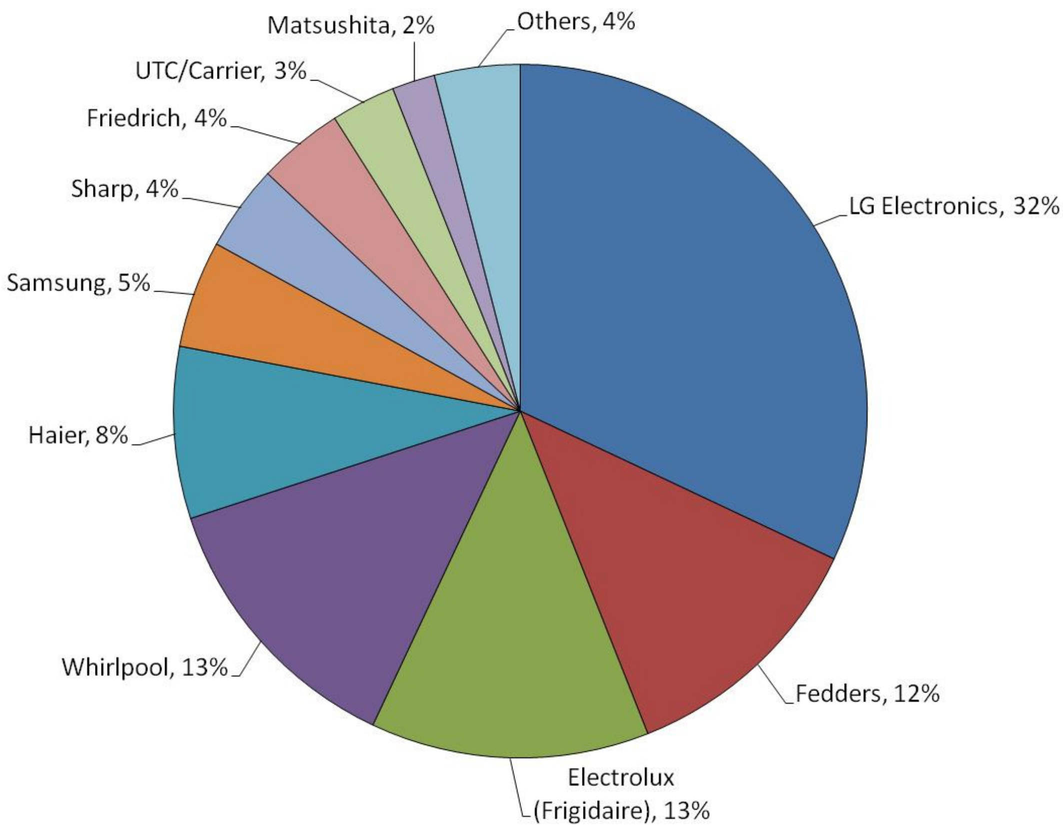

Figure 3.6.3 2008 Market Shares for the Domestic Room Air Conditioner Market[6]

Table 3.6.5 shows the market share for room air conditioner manufacturers between 2000 and 2008. The market share for LG increased 12 percent since 2000, whereas the market share for Fedders and Electrolux dropped by 10 and 4 percent, respectively, over the same period. Whirlpool's market share remained relatively stable between 2000 and 2008.

Table 3.6.5 2000-2008 Room Air Conditioner Manufacturer Market Share [7]

	Market Share *(%)*								
Company	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
LG Electronics	32	32	30	30	29	32	28	26	20
Fedders	12	12	14	14	22	21	22	20	22
Electrolux (Frigidaire)	13	13	14	14	11	13	11	13	17
Whirlpool	13	13	14	14	11	9	11	12	12
Haier	8	8	6	5	6	9	12	11	6
Samsung	5	5	5	5	6	5	2	1	3
Sharp	4	4	5	4	4	3	4	3	2
Friedrich	4	4	4	4	2	2	3	3	3
UTC/Carrier	3	3	3	0	0	2	2	3	2
Matsushita	2	2	1	2	2	3	2	2	3
Others	4	4	4	8	7	5	3	6	10

Since 2007 there have been significant changes to the market. Fedders and Whirlpool left the market in 2008, and the status of other manufacturers including Sharp and Matsushita is unclear. Also not reflected in the market share data is the distinction between brand share and manufacturer share. GE and Midea, for example, are active brands that are not listed in the *Appliance Magazine* data, while some of the brands listed do not currently manufacture their room air conditioners. The manufacture of room air conditioners has, in recent years, entirely moved offshore. There is some limited manufacturing still occurring in North America, but most of the production is currently in Asia, primarily in China.

3.6.2 Mergers and Acquisitions

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

According to the September 2009 issue of *Appliance Magazine*, four manufacturers comprise 85 percent of the core appliance market share. "Core appliances" include dishwashers, dryers, freezers, ranges, refrigerators, and clothes washers. Table 3.6.6 lists these core appliance manufacturers, and Figure 3.6.4 illustrates the breakdown of 2008 market shares in the core appliance category.

Table 3.6.6 Core Appliance Manufacturers

Core Appliance Manufacturers
Whirlpool
GE
Electrolux (Frigidaire)

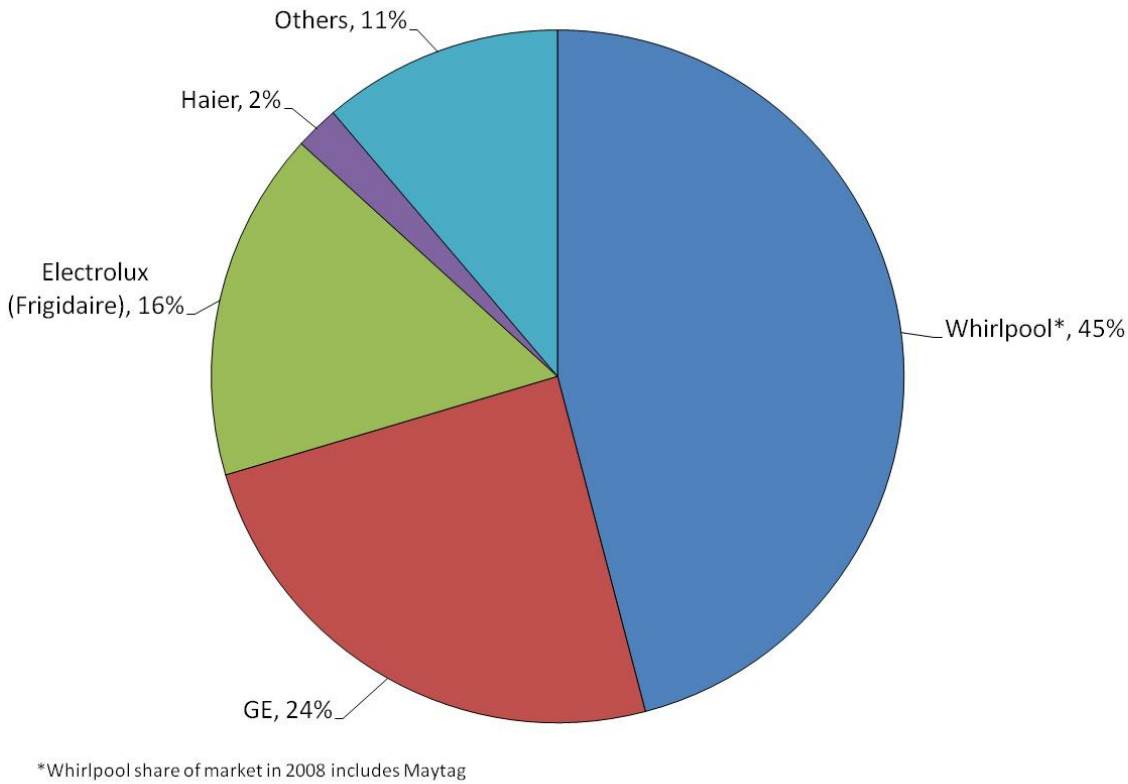

Figure 3.6.4 2008 Core Appliance Market Shares[8]

On August 22, 2005, Whirlpool, headquartered in Benton Harbor, Michigan, and Maytag, based in Newton, Iowa, announced plans to merge in a deal worth $2.7 billion.[9] Maytag shareholders approved the merger on December 22, 2005. Shortly after announcing the merger, Whirlpool submitted a pre-merger notification to the U.S. Department of Justice (DOJ). The DOJ Antitrust Division initiated an investigation, scheduled to end February 27, 2006, into the effects of the merger, including potential lessening of competition or the creation of a monopoly. Following this initial review, the DOJ asked for additional materials from each company and extended the review to March 30, 2006.

Opponents of the merger asserted that the combined companies would control as much as 70 percent of the residential laundry market and as much as 50 percent of the residential dishwasher market.[10] Whirlpool claimed that their large potential residential laundry market share was skewed because the company produces washing machines for Sears, which sells them under their Kenmore in-house brand. Whirlpool went on to say that they must periodically bid with other manufacturers to keep the Kenmore contract and that Sears controls the pricing of the Kenmore units.[11]

In early January 2006, U.S. Senator Tom Harkin and U.S. Representative Leonard Boswell, both of Iowa, called upon the DOJ to block the merger, claiming it would give Whirlpool an unfair advantage in the home appliance industry. The Congressmen wrote, that if the DOJ does not block the deal, the agency should at least "require that Whirlpool divest the washer and dryer portions of Maytag to a viable purchaser who will have the financial capability and desire to continue to operate that business."[12]

On March 29, 2006, DOJ closed its investigation and approved the merger. DOJ claims "that the proposed transaction is not likely to reduce competition substantially. The combination of strong rival suppliers with the ability to expand sales significantly and large cost savings and other efficiencies that Whirlpool appears likely to achieve indicates that this transaction is not likely to harm consumer welfare."[13]

The DOJ Antitrust Division focused its investigation on residential laundry, although it considered impacts across all products offered by the two companies. DOJ determined that the merger would not give Whirlpool excessive market power in the sale of its products and that any attempt to raise prices would likely be unsuccessful. In support of this claim, DOJ noted: (1) other U.S. brands, including Kenmore, GE, and Frigidaire, are well established; (2) foreign manufacturers, including LG and Samsung, are gaining market share; (3) existing U.S. manufacturers are below production capacity; (4) the large home appliance retailers have alternatives available to resist price increase attempts; and (5) Whirlpool and Maytag substantiated large cost savings and other efficiencies that would benefit consumers.[14]

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

3.6.3 Small Business Impacts

DOE considers the possibility of small businesses being impacted by the promulgation of energy conservation standards for residential clothes dryers and room air conditioners. The Small Business Association (SBA) considers an entity to be a small business if, together with its affiliates, it employs less than a threshold number of workers specified in 13 CFR part 121, which relies on size standards and codes established by the North American Industry Classification System (NAICS). The threshold number for NAICS classification for 335224, which applies to household laundry equipment manufacturers and includes clothes dryer manufacturers, is 1,000 employees. The threshold number for NAICS classification for 333415, which applies to air conditioning and warm air heating equipment and commercial and industrial refrigeration equipment manufacturers and includes room air conditioner manufacturers, is 750 employees. Searches of the SBA website[i] to identify manufacturers within these NAICS codes that manufacture clothes dryers and/or room air conditioners revealed only Staber Industries, Inc. (Staber) of Groveport, Ohio, as a producer of laundry equipment. However, DOE notes that the Staber website indicates that their clothes dryer is manufactured by Whirlpool and rebranded. Therefore, DOE believes that there are no clothes dryer manufacturers that are considered a small business. Further, DOE is not aware of any room air conditioner manufacturers that are considered a small business. For any small business manufacturers of the two appliance products that DOE identifies, DOE will study the potential impacts on the small businesses in greater detail during the manufacturer impact analysis (MIA), which it will conduct as a part of the NOPR analysis.

3.6.4 Distribution Channels

Understanding the distribution channels of products covered by this rulemaking is an important facet of the market assessment. DOE gathered information regarding the distribution channels for residential clothes dryers and room air conditioners from publicly available sources. This section contains distribution channel information for residential appliances.

For residential appliances, including room air conditioners and clothes dryers, the majority of consumers purchase their appliances directly from retailers. Table 3.6.7 identifies the types of retail stores through which major appliances, including residential clothes washers, are sold, based on data from the AHAM *Fact Book* 2005.[15]

Table 3.6.7 Major Appliance Sales by Channel (Purchased between 2001 and 2005)[16]

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

Home appliance retailers generally obtain products directly from manufacturers. The AHAM *Fact Book* 2003 shows that over 93 percent of residential appliances are distributed from the manufacturer directly to a retailer.[17] A 2000 Consortium for Energy Efficiency (CEE) report determined that 5–10 percent of major appliance sales were made to commercial consumers such as builders, contractors, government sales, and property managers through distributors/wholesalers.[18]

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[i] A searchable database of certified small businesses is available online at: *http://dsbs.sba.gov/dsbs/search/dsp_dsbs.cfm*.

3.7 REGULATORY PROGRAMS

The following section details current regulatory programs mandating energy conservation standards for residential clothes dryers and room air conditioners. Section 3.7.1 discusses current Federal energy conservation standards, while section 3.7.2 discusses the requirements of EISA 2007 and section 3.7.3 provides an overview of existing State standards. In addition, section 3.7.4 reviews standards in Canada that may impact the companies servicing the North American market.

3.7.1 Current Federal Energy Conservation Standards

Current Federal energy conservation standards exist for residential **clothes dryers**. NAECA amended EPCA to establish prescriptive standards for clothes dryers, requiring that gas dryers manufactured on or after January 1, 1988 not be equipped with a constant burning pilot and further requiring that DOE conduct two cycles of rulemakings to determine if more stringent standards are justified. (42 U.S.C. 6295 (g)(3) and (4)) On May 14, 1991, DOE published a final rule in the *Federal Register* (FR) establishing the first set of performance standards for residential clothes dryers (56 FR 22250); the new standards became effective on May 14, 1994. (10 CFR 430.32(h)) Table 3.7.1 presents these standards for residential clothes dryers, expressed as EF in terms of pounds (lb) of clothes washed per kilowatt-hour (kWh). DOE initiated a second standards rulemaking for residential clothes dryers by publishing an advance notice of proposed rulemaking (ANOPR) in the *Federal Register* on November 14, 1994 (hereafter "November 1994 ANOPR). 59 FR 56423. However, pursuant to the priority-setting process outlined in its *Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products* (the "Process Rule") (61 FR 36974 (July 15, 1996); establishing 10 CFR part 430, subpart C, appendix A), DOE classified the standards rulemaking for residential clothes dryers as a low priority for its fiscal year 1998 priority-setting process. As a result, DOE suspended the standards rulemaking activities for them.

Table 3.7.1 Federal Energy Conservation Standards for Residential Clothes Dryers

Clothes Dryer Classification	**Minimum EF** *(lb/kWh))*
Electric, Standard (4.4 ft^3 or greater capacity)	3.01
Electric, Compact (120 V) (less than 4.4 ft^3 capacity)	3.13
Electric, Compact (240 V) (less than 4.4 ft^3 capacity)	2.90
Gas	2.67

NAECA established performance standards for **room air conditioners** that became effective on January 1, 1990, and directed DOE to conduct two cycles of rulemakings to determine if more stringent standards are justified. (42 U.S.C. 6295 (c)(1) and (2)) On March 4, 1994, DOE published in the *Federal Register* a NOPR for several products, including room air conditioners. 59 FR 10464. As a result of the Process Rule, DOE suspended activities to finalize standards for room air conditioners. DOE subsequently resumed rulemaking activities related to room air conditioners, and, on September 24, 1997, DOE published a final rule establishing an updated set of performance standards, with an effective date of October 1, 2000. (62 FR 50122; 10 CFR 40.32(b)). Table 3.7.2 presents these standards for room air conditioners in terms of energy efficiency ratio (EER), which is expressed as cooling capacity in Btu/h per watt (W) of input power.

Table 3.7.2 Federal Energy Conservation Standards for Room Air Conditioners

Room Air Conditioner Classification	Minimum EER *(Btu/h-W)*, effective as of Jan. 1, 1990	Minimum EER *(Btu/h-W)*, effective as of Oct. 1, 2000
1. Without reverse cycle, with LS, and less than 6,000 Btu/h	8.0	9.7
2. Without reverse cycle, with LS and 6,000 to 7,999 Btu/h	8.5	9.7
3. Without reverse cycle, with LS and 8,000 to 13,999 Btu/h	9.0	9.8
4. Without reverse cycle, with LS and 14,000 to 19,999 Btu/h	8.8	9.7
5. Without reverse cycle, with LS and 20,000 Btu/h or more	8.2	8.5
6. Without reverse cycle, without LS, and less than 6,000 Btu/h	8.0	9.0
7. Without reverse cycle, without LS and 6,000 to 7,999 Btu/h	8.5	9.0
8. Without reverse cycle, without LS and 8,000 to 13,999 Btu/h	8.5	8.5
9. Without reverse cycle, without LS and 14,000 to 19,999 Btu/h	8.5	8.5
10. Without reverse cycle, without LS and 20,000 Btu/h or more	8.2	8.5
11. With reverse cycle, with LS, and less than 20,000 Btu/h	8.5	9.0
12. With reverse cycle, without LS, and less than 14,000 Btu/h	8.0	8.5
13. With reverse cycle, with LS, and 20,000 Btu/h or more	8.5	8.5
14. With reverse cycle, without LS, and 14,000 Btu/h or more	8.0	8.0
15. Casement-Only	*	8.7
16. Casement-Slider	*	9.5

* Casement-only and casement-slider room air conditioners were not separate product classes under standards effective January 1, 1990. These units were subject to the applicable standards in classes 1 through 14 based on unit capacity and the presence or absence of louvered sides and a reverse cycle.

3.7.2 Energy Independence and Security Act of 2007

There is currently no prescriptive Federal energy conservation standard for standby power consumption for either residential clothes washers or room air conditioners, nor is standby power incorporated into the efficiency metric prescribed by the existing DOE test procedure for either product. On December 19, 2007, the President signed into law EISA 2007, which contains numerous amendments to EPCA. Section 310 of EISA 2007 amends Section 325 of EPCA to require any final rule establishing or revising a standard for a covered product, adopted after July 10, 2010, to incorporate standby mode and off mode energy use into a single amended or new standard. (42 U.S.C. 6295(gg)(3)(A)) If not feasible, the Secretary shall prescribe within the final rule a separate standard for standby mode and off mode energy consumption, if justified. (42 U.S.C. 6295(gg)(3)(B))

Off mode is defined by EISA 2007 as "the condition in which an energy-using product – (I) is connected to a main power source; and (II) is not providing any standby or active mode function." (42 U.S.C. 6295(gg)(1)(A)(ii)) Active mode refers to the one or more main functions, while standby is defined by EISA 2007 as "the condition in which an energy-using product (I) is connected to a main power source; and (II) offers 1 or more of the following user-oriented or protective functions: (aa) To facilitate the activation or deactivation of other functions (including active mode) by remote switch (including remote control), internal sensor, or timer. (bb) Continuous functions, including information or status displays (including clocks) or sensor-based functions." (*Id.*; 42 U.S.C. 6295(gg)(1)(A)(iii))

The final rule for this rulemaking was scheduled to be published in the Federal Register by June 30, 2011. Thus, according to EISA 2007, energy conservation standards for residential clothes dryers and room air conditioners that would be put forth from this rulemaking are required to incorporate standby mode and off mode energy consumption.

As noted above in section 0, the test procedure rulemaking to incorporate standby mode and off mode energy consumption in the energy descriptors for residential clothes dryers and room air conditioners was initiated in parallel with the current rulemaking. For both clothes dryers and room air conditioners, DOE has determined that it is technically feasible to incorporate standby mode and off mode energy consumption into overall energy consumption. Therefore, DOE adopted in the MONTH 2011 TP Final Rule amendments which integrate standby mode and off mode energy use with the existing energy use metrics, creating new overall energy use descriptors, CEF and CEER for clothes dryers and room air conditioners, respectively. Accordingly, DOE is adopting the amended energy conservation standards for residential clothes dryers and room air conditioners based on these integrated metrics.

3.7.3 State Energy Conservation Standards

For those States which currently regulate residential clothes dryers and/or room air conditioners, no State energy conservation standards differ from Federal standards.

3.7.4 Canadian Energy Conservation Standards

Canada's Energy Efficiency Regulations (hereafter Regulations) mandate minimum energy conservation standards for residential clothes dryers and room air conditioners.

Canadian Regulations stipulate minimum efficiency levels and definitions for electric residential **clothes dryers** which are identical to current U.S. Federal standards, mandating an EF of at least 3.01 for standard clothes dryers, an EF of at least 3.13 for compact (120 V) clothes dryers, and an EF of at least 2.90 for compact (240 V) clothes dryers. There are no Canadian Regulations covering gas clothes dryers.

For **room air conditioners**, Canada's Regulations are currently identical to U.S. Federal standards for all product classes. Canada's Regulations, however, provide a stipulation in the definition of covered products that limits cooling capacity to 36,000 Btu/h. U.S. Federal standards do not specify a maximum cooling capacity.

Canada has proposed increasing the required efficiency levels of room air conditioners, with an effective date of January 1, 2011. For many of the product classes, the proposed standards are the same as the current ENERGY STAR efficiency levels, which are roughly 10 percent higher than the minimum standard levels. The current and proposed efficiency levels are summarized in Table 3.7.3 below. The proposal also calls for measurement and reporting of standby and off mode energy use, anticipating future regulation of the energy use of these modes.

Table 3.7.3: Canada's Proposed Efficiency Requirements for Room Air Conditioners

Room Air Conditioner Classification	Minimum EER *(Btu/h-W)*	
	Current Standard	**Proposed**
1. Without reverse cycle, with LS, and less than 6,000 Btu/h	9.7	10.7
2. Without reverse cycle, with LS and 6,000 to 7,999 Btu/h	9.7	10.7
3. Without reverse cycle, with LS and 8,000 to 13,999 Btu/h	9.8	10.8
4. Without reverse cycle, with LS and 14,000 to 19,999 Btu/h	9.7	10.7
5. Without reverse cycle, with LS and 20,000 Btu/h or more	8.5	9.4
6. Without reverse cycle, without LS, and less than 6,000 Btu/h	9.0	9.9
7. Without reverse cycle, without LS and 6,000 to 7,999 Btu/h	9.0	9.9
8. Without reverse cycle, without LS and 8,000 to 13,999 Btu/h	8.5	9.4
9. Without reverse cycle, without LS and 14,000 to 19,999 Btu/h	8.5	9.4
10. Without reverse cycle, without LS and 20,000 Btu/h or more	8.5	8.5
11. With reverse cycle, with LS, and less than 20,000 Btu/h	9.0	9.9
12. With reverse cycle, without LS, and less than 14,000 Btu/h	8.5	9.2
13. With reverse cycle, with LS, and 20,000 Btu/h or more	8.5	9.5
14. With reverse cycle, without LS, and 14,000 Btu/h or more	8.0	8.8
15. Casement-Only	8.7	9.5
16. Casement-Slider	9.5	9.5

3.7.5 International Standby Power Regulatory Programs

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

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

Australia has announced plans to implement a mandatory horizontal 1 W requirement for all consumer electrical products by 2012, including room air conditioners and clothes dryers.[19]

The European Union (EU) enacted the Commission Regulation (EC) No. 1275/2008 of December 17, 2008, implementing design requirements for standby and off mode power for electrical and electronic household and office equipment, including clothes dryers. Annex II of the regulation specifies the following maximum power requirements:

> 1. One year after this Regulation has come into force:
>
> (a) Power consumption in 'off mode':
>
> Power consumption of equipment in any off-mode condition shall not exceed [1.00] W.
>
> (b) Power consumption in 'standby mode(s)':
>
> The power consumption of equipment in any condition providing only a reactivation function, or providing only a reactivation function and a mere indication of enabled reactivation function, shall not exceed [1.00] W.
>
> The power consumption of equipment in any condition providing only information or status display, or providing only a combination of reactivation function and information or status display, shall not exceed [2.00] W.
>
> (c) Availability of off mode and/or standby mode
>
> Equipment shall, except where this is inappropriate for the intended use, provide off mode and/or standby mode and/or another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source.
>
> 2. Four years after this Regulation has come into force:
>
> (a) Power consumption in 'off mode':
>
> Power consumption of equipment in any off-mode condition shall not exceed [0.50] W.
>
> (b) Power consumption in 'standby mode(s)':

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

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

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

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

(d) Power management

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

— standby mode, or

— off mode, or

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

3.8 VOLUNTARY PROGRAMS

DOE reviewed several voluntary programs promoting energy-efficient residential appliances in the United States. Many programs, including the CEE, ENERGY STAR, and the Federal Energy Management Program (FEMP), establish voluntary energy conservation standards for these products.

3.8.1 Consortium for Energy Efficiency

The CEE[k] develops initiatives for its North American members to promote the manufacture and purchase of energy efficient products and services. The goal of the organization is to induce lasting structural and behavioral changes in the marketplace, resulting in the increased adoption of energy-efficient technologies.

CEE issues voluntary specifications for **room air conditioners**. Qualifying units must use at least 15 percent less electricity, based on EER, than the Federal standard. Table 3.8.1 presents the room air conditioner efficiency specifications, effective January 2003, under its Super-Efficient Home Appliance Initiative (SEHA). Unlike for Federal standards, no distinction is made among the features present on a qualifying unit (*i.e.,* louvered sides, reverse cycle, etc.). The classes are differentiated only by cooling capacity.

Table 3.8.1 CEE Criteria for Room Air Conditioners

Product Class *(Btu/h)*	**Tier 1 (EER,** *Btu/h-W*)	**Tier 2 (EER,** *Btu/h-W*)
< 8,000	11.2	11.6
8,000 to 13,999	11.3	11.8
14,000 to 19,999	11.2	11.6
≥ 20,000	9.8	10.2

3.8.2 ENERGY STAR

ENERGY STAR, a voluntary labeling program jointly administered by the U.S. Environmental Protection Agency (EPA) and DOE, identifies energy efficient products through a qualification process[l]. 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 the models on the market at the time the qualifying criteria are specified meet or exceed the ENERGY STAR levels. ENERGY STAR specifications exist for several products, including room air conditioners.

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[k] For more information, please visit *www.cee1.org*.

[l] For more information, please visit *www.energystar.gov*.

Prior to November, 2005, ENERGY STAR **room air conditioner** criteria existed for only cooling-only units; *i.e.*, those without a reverse cycle or electric resistance heating. New criteria which became effective November 16, 2005 added ENERGY STAR specifications for room air conditioners with reverse cycle operation. The current ENERGY STAR criteria for room air conditioners are listed in Table 3.8.2. According to the ENERGY STAR program, 54 percent of room air conditioners sold in 2006 were ENERGY STAR-qualified.

Table 3.8.2 ENERGY STAR Criteria for Room Air Conditioners

Without reverse cycle and with louvered sides	**Required EER** *(Btu/h-W)*
1. Less than 6,000 Btu/h	≥ 10.7
2. 6,000 to 7,999 Btu/h	≥ 10.7
3. 8,000 to 13,999 Btu/h	≥ 10.8
4. 14,000 to 19,999 Btu/h	≥ 10.7
5. 20,000 Btu/h or more	≥ 9.4
Without reverse cycle and without louvered sides	
6. Less than 6,000 Btu/h	≥ 9.9
7. 6,000 to 7,999 Btu/h	≥ 9.9
8. 8,000 to 13,999 Btu/h	≥ 9.4
9. 14,000 to 19,999 Btu/h	≥ 9.4
10. 20,000 Btu/h or more	≥ 9.4
With reverse cycle and with louvered sides	
11. Less than 20,000 Btu/h	≥ 9.9
12. 20,000 Btu/h or more	≥ 9.4
With reverse cycle and without louvered sides	
13. Less than 14,000 Btu/h	≥ 9.4
14. 14,000 Btu/h or more	≥ 8.8
Casement	
15. Casement-Only	≥ 9.6
16. Casement-Slider	≥ 10.5

3.8.3 Federal Energy Management Program

DOE's Federal Energy Management Program[m] (FEMP) works to reduce the cost and environmental impact of the Federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at Federal sites. FEMP helps Federal buyers identify and purchase energy efficient equipment, including certain residential appliances.

[m] For more information, please visit www.eere.energy.gov/femp.

FEMP issues energy efficiency recommendations for **room air conditioners**. Table 3.8.3 presents the room air conditioner recommendations.

Table 3.8.3 FEMP Recommendations for Room Air Conditioners

Air Conditioner Type and Capacity	**Required EER** *(Btu/h-W)*
With louvered sides, < 20,000 Btu/h	≥ 10.7
With louvered sides, ≥ 20,000 Btu/h	≥ 9.4
Without louvered sides, < 8,000 Btu/h	≥ 9.9*
Without louvered sides, ≥ 8,000 Btu/h	≥ 9.4
* FEMP states that currently there are no models that can meet this recommendation, and suggests purchasing a unit with the best available EER.	

FEMP estimates that a typical household using a louvered-side model room air conditioner with a cooling capacity of 10,000 Btu/h and 750 operating hours per year with an EER of 9.8 (DOE minimum standard) can save $40 in energy costs over the lifetime of the unit (assuming Federal average energy prices) by upgrading to a unit with an EER of 10.7 (FEMP recommendation). The lifetime energy savings increase to $80 by purchasing a unit with an EER of 11.5.

Executive Order 13221 Energy Efficient Standby Power Devices, signed July 31, 2001, requires that Federal agencies purchase commercially available products with low standby power. In addition, Executive Order 13221 of July 31, 2001, directs Federal agencies, when purchasing a product that contains an internal standby power function or that uses an external standby power device, to purchase such a product that consumes no more than 1 W in standby power mode or, if such a product is not available, to select a product with the lowest available standby power consumption. These requirements shall apply only if the lower-wattage eligible product is lifecycle cost effective and practicable, and the utility and performance of the product is not compromised by the lower wattage requirement. 66 FR 40571.

3.8.4 Rebates for Highly Energy-Efficient Products

Electric utilities and other organizations promote the purchase of highly energy efficient residential clothes washers through consumer rebates. Typically, these programs offer rebates for products meeting existing ENERGY STAR efficiency levels. Table 3.8.4 lists some rebates that were offered in 2008. Some utilities also offer incentives to retire old and inefficient appliances.

Table 3.8.4 Rebates Offered for Highly Energy Efficient Room Air Conditioners in 2008[20]

Utility/Organization*	**Rebate Level** *($)*
Alliant Energy (Iowa and Minnesota)	50 (ENERGY STAR)
Efficiency Vermont	25 (ENERGY STAR) 40 (CEE Tier 1)
Los Angeles Department of Water and Power (CA)	50 (ENERGY STAR)
Pacific Gas and Electric Company (Northern California)	50 (ENERGY STAR)
Sacramento Municipal Utility District (CA)	50 (ENERGY STAR)
San Diego Gas & Electric (CA)	50 (ENERGY STAR)

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

3.9 HISTORICAL SHIPMENTS

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

3.9.1 New Home Starts

Trends in new home starts may directly affect shipments of certain home appliances. While there is certainly both a replacement and remodeling market for some appliances including residential clothes dryers, these products are also fixtures in many new homes. Room air conditioner shipments are not as greatly impacted by new home starts, as they are often purchased for use in existing construction.

Figure 3.9.1 presents the number of new single-family and multi-family housing units started in the United States from 1998–2009. Over the 5-year period from 2000–2005, single-family home starts increased 39.4 percent, to 1,716,000 units annually. However, between 2005 and 2009, single-family home starts decreased 74.1 percent, to 445,100 units annually. Multi-family unit starts remained relatively flat between 1998 and 2005, hovering around 350,000 units annually. However, between 2005 and 2009, multi-family unit starts decreased by 69.1 percent, to around 108,900 units annually.[21]

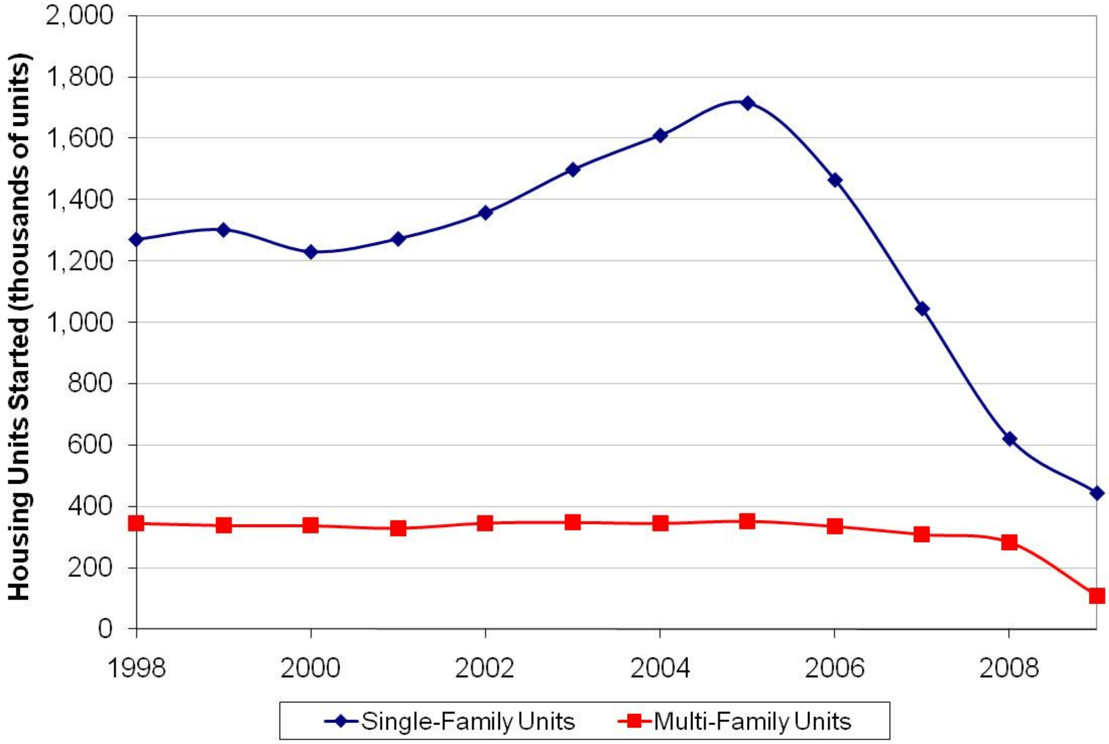

Figure 3.9.1 New Privately Owned Single-Family and Multi-Family Housing Unit Starts in the United States from 1998–2009 [22]

3.9.2 Unit Shipments

AHAM submitted data for the annual unit shipments for residential **clothes dryers**, and DOE obtained additional shipments data from *Appliance Magazine*. Table 3.9.1 presents the annual shipments of clothes dryers for the 15-year period from 1993 to 2008. The shipments of electric clothes dryers increased 73 percent from 1993 to 2006, to about 6.4 million units in 2006. However, between 2006 and 2008, shipments of electric clothes dryers decreased by 11.6 percent, to 5.6 million units in 2008. The shipments of gas dryers increased 40 percent from 1993 to 2006, to about 1.6 million units in 2006. Again, between 2006 and 2008, shipments of gas clothes dryers decreased by about 16 percent, to about 1.4 million in 2008.

Table 3.9.1 Industry Shipments of Residential Clothes Dryers (Domestic and Import, in Thousands of Units)[23]

Year	Clothes Dryers *(Thousands)*				
	Electric	**Standard Electric**	**Compact Electric**	**Gas**	**Total**
2008**	5,620			1,353	6,973
2007**	6,035			1,530	7,565
2006	6,360	6,246	114	1,614	7,974
2005	6,408	6,330	78	1,707	8,115
2004	6,262	6,159	103	1,660	7,922
2003	5,718	5,622	96	1,616	7,334
2002	5,402			1,490	6,892
2001	5,117			1,384	6,501
2000	5,095			1,480	6,575
1999	4,865			1,444	6,309
1998	4,482			1,307	5,789
1997	4,115			1,195	5,310
1996	3,947			1,193	5,140
1995	3,823			1,169	4,992
1994	3,838			1,239	5,077
1993	3,674			1,156	4,830

*AHAM did not provide data for standard and compact electric clothes dryers prior to 2003, nor any clothes dryer shipments data for 2007 and 2008.
**Source: September 2008 and 2009 *Appliance Magazine* "Share-of-Market Picture".

AHAM's *Fact Book* 2003 and 2005, as well as *Appliance Magazine*, provide annual unit shipments for room air conditioners. Table 3.9.2 presents the annual shipments of **room air conditioners** for the 14-year period from 1994 to 2008. Shipments of room air conditioners increased sharply in 1999 and again in 2003 and 2006.

Table 3.9.2 Industry Shipments of Room Air Conditioners (Domestic and Import, in Thousands of Units)[24]

Year	Room Air Conditioners *(Thousands)*
2008*	9,086
2007*	9,550
2006*	10,055
2005	8,032
2004	8,082
2003	8,216
2002	6,153
2001	5,575
2000	6,496
1999	6,114
1998	4,403
1997	4,123
1996	4,825

1995	4,300
1994	3,853

*Shipments data for 2006 through 2008 were obtained from the September 2007-2009 *Appliance Magazine* "Share-of-Market Picture".

ENERGY STAR market share data are an indicator of the demand for energy efficient products. Table 3.9.3 shows the ENERGY STAR-qualified **room air conditioner** shipments and market share from 1997 to 2006 provided in the ENERGY STAR *Room Air Conditioner 2007 Product Snapshot*. Sales of ENERGY STAR qualified room air conditioners have grown faster than the overall total sales of clothes washers over the 10-year period, with market share increasing more than 40 percent.

Table 3.9.3 ENERGY STAR Shipments for Room Air Conditioners (Domestic and Import)

Year	Shipments			% ENERGY STAR of Total[25]
	ENERGY STAR-Qualified	Other	Total[26]	
2006	5,429,862	4,625,438	10,055,300*	54
2005	4,176,640	3,855,360	8,032,000	52
2004	2,828,700	5,253,300	8,082,000	35
2003	2,382,640	5,833,360	8,216,000	29
2002	2,215,080	3,937,920	6,153,000	36
2001	669,000	4,906,000	5,575,000	12
2000	1,234,240	5,261,760	6,496,000	19
1999	794,820	5,319,180	6,114,000	13
1998	572,390	3,830,610	4,403,000	13
1997	494,760	3,628,240	4,123,000	12

*Total shipments data for 2006 from the September 2007 *Appliance Magazine* "Share-of-Market Picture for 2006".

3.9.3 Value of Shipments

Table 3.9.4 provides the value of household laundry equipment shipments, which includes residential **clothes dryer** and clothes washer shipments, from 1994 to 2008 based upon data from the U.S. Census Bureau's *Annual Survey of Manufacturers* (ASM)[n]. The ASM expresses all dollar values in nominal dollars; *i.e.*, 2008 data are expressed in 2008 dollars, and 2005 data are expressed in 2005 dollars. Using the Gross Domestic Product Implicit Price Deflator, DOE converted each year's value of shipments to 2008 dollars. In constant dollars, the value of household laundry shipments increased 14 percent from 1994 to 2005, but then decreased 25 percent between 2005 and 2008. During the same period, unit shipments of residential clothes dryers increased about 37 percent, suggesting that the U.S. laundry appliance industry is very competitive.

[n] Available online at *www.census.gov/manufacturing/asm/index.html*.

Table 3.9.4 Household Laundry Equipment Value of Shipments by Year[27]

Year	Value of Shipments in Nominal Dollars *($ million)*	Value of Shipments in 2008 Dollars *($ million)*
2008	4,232	4,232
2007	4,678	4,780
2006	5,129	5,395
2005	5,222	5,672
2004	4,987	5,598
2003	4,658	5,377
2002	4,352	5,132
2001	4,549	5,451
2000	4,420	5,416
1999	4,365	5,464
1998	4,249	5,397
1997	3,710	4,766
1996	3,699	4,836
1995	3,541	4,717
1994	3,671	4,992

Table 3.9.5 provides the value of shipments for the NAICS product class which includes **room air conditioners** and dehumidifiers, other than portable dehumidifiers (NAICS product class code 3334156). The value of shipments for these products has decreased 72 percent from 1994 to 2008 while unit shipments of room air conditioners have increased about 136 percent during the same time period, indicating significant industry competition.

Table 3.9.5 "Room Air-Conditioners and Dehumidifiers, Except Portable Dehumidifiers" Product Class Value of Shipments by Year[28]

Year	Value of Shipments in Nominal Dollars *($ million)*	Value of Shipments in 2008 Dollars *($ million)*
2008	452	452
2007	646	660
2006	542	570
2005	572	621
2004	598	671
2003	820	947
2002	839	989
2001	944	1,131
2000	984	1,206
1999	1,177	1,473
1998	1,034	1,313
1997	979	1,258
1996	1,367	1,787
1995	1,300	1,732
1994	1,183	1,609

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 appliances.

Table 3.9.6 Disposition of Previous Appliance (Percentage)[29]

Product	**Kept It** *(%)*	**Left with Previous Home** *(%)*	**Sold / Gave Away** *(%)*	**Recycling Facility** *(%)*	**Left at Curb for Disposal** *(%)*	**Retailer Took Away** *(%)*
Clothes Dryers	5	19	25	18	10	23
Room Air Conditioners	16	21	40	9	9	4

3.9.4 Imports and Exports

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

Table 3.9.7 shows selected import data from AHAM's *Import/Export Trade Report – December 2009.*[30] For non-coin-operated clothes dryers with a capacity less than 10 kilograms (kg) (*i.e.*, residential clothes dryers), the number of units imported decreased by 19.4 percent from 2008 to 2009, while the value of units imported decreased by 13.7 percent over that same period. For room air conditioners with a capacity less than 2.93 kW (10,000 Btu/h), both the number and value of units imported decreased by more than 18 percent from 2008 to 2009. For room air conditioners with a capacity between 2.93 to 4.98 kW (10,000 to 17,000 Btu/h) both the number and value of units imported decreased by more than 7.5 percent. For room air conditioners with a capacity greater than 4.98 kW (17,000 Btu/h) both the number and value of units imported decreased by more than 27 percent

Table 3.9.7 2008-2009 Imports of Appliances Covered by this Rulemaking[31]

Appliance Description	Jan. – Dec. 2009	Jan. – Dec. 2008	% Change	Jan. – Dec. 2009	Jan. – Dec. 2008	% Change
	Units			*$ Mil (Nominal)*		
Drying machines, except coin-operated, capacity ≤ 10 kg	935,249	1,159,852	-19.4	209.598	242.892	-13.7
Air conditioners, window/wall, capacity < 2.93 kW (<10,000 Btu/h)	3,869,851	4,965,619	-22.1	424.696	519.801	-18.3
Air conditioners, window/wall, self-contained, capacity 2.93-4.98 kW (10,000 to 17,000 Btu/h)	1,751,125	2,109,678	-17.0	349.816	378.262	-7.5
Air conditioners, window/wall, self-contained, capacity ≥4.98 kW (≥17,000 Btu/h)	432,145	636,289	-32.1	130.253	178.319	-27.0

Table 3.9.8 shows selected export data from AHAM's *Import/Export Trade Report – December 2009*.[32] For the 1-year period from 2008 to 2009, the number and value of unit exports of non-coin-operated clothes dryers and all room air conditioners decreased significantly.

Table 3.9.8 2007-2008 Exports of Appliances Covered by this Rulemaking[33]

Appliance Description	Jan. – Dec. 2009	Jan. – Dec. 2008	% Change	Jan. – Dec. 2009	Jan. – Dec. 2008	% Change
	Units			*$ Mil (Nominal)*		
Drying machines, except coin-operated, capacity ≤ 10 kg	129,186	158,492	-18.5	27.817	34.725	-19.9
Air conditioners, window/wall, capacity < 2.93 kW/h (<10,000 Btu/h)	72,358	103,999	-30.4	23.662	33.536	-29.4
Air conditioners, window/wall, self-contained, capacity 2.93-4.98 kW/h (10,000 to 17,000 Btu/h)	48,483	73,737	-34.2	21.270	30.555	-30.4
Air conditioners, window/wall, self-contained, capacity ≥4.98 kW/h (≥17,000 Btu/h)	39,453	51.673	-23.6	26.915	36.386	-26.0

3.10 HISTORICAL EFFICIENCIES

Table 3.10.1 shows the historical efficiency trends and the percentage of domestic shipments by EER classification for **room air conditioners** from 1980 to 2004, as provided in the AHAM *Fact Book* 2005. New coil designs, increased motor and compressor efficiencies, and better air circulation systems have all contributed to the 11-percent efficiency increase from 1990 through 2004. The percentage of domestic shipments by EER classification also shows a trend towards high efficiency room air conditioners. The increases in EER and percent of shipments of higher efficiency room air conditioners in 2000 and 2001 were a result of the new energy conservation standards which became effective in October 1, 2000.

Table 3.10.1 Room Air Conditioner Energy Efficiency and Consumption Trends (Shipment Weighted Averages)[34]

Year	EER *(Btu/h)*	Percentage of Domestic Shipments *(%)*		
		Less than 8.5 EER	**8.5 - 9.4 EER**	**9.5 EER and Higher**
2004	9.71	0.04	11.2	88.8
2003	9.75	0.03	9.0	91.0
2002	9.75	0.02	12.4	87.6
2001	9.63	0.1	13.8	86.0
2000	9.3	14.2	34.2	51.5
1999	9.07	26.9	41.4	31.7
1998				
1997	9.09	16.7	47.3	36.0
1996	9.08	16.0	49.3	34.7
1995	9.03	19.3	51.9	28.8
1994	8.97	24.1	50.9	25.0
1993	9.05	24.8	55.3	19.9
1992	8.88	24.6	58.1	17.3
1991	8.8	27.5	57.2	15.3
1990	8.73	28.9	58.3	12.8
1980	7.02	88.6	9.3	2.1

3.11 MARKET SATURATION

AHAM's *Fact Book* 2005 presents the market saturation for residential clothes dryers and room air conditioners. Table 3.11.1 presents the appliance saturation and percentage of U.S. households with each product as reported in the AHAM *Fact Book* 2005. The number of U.S. households with each product is based on U.S. Census Bureau projections of occupied units in the relevant year. The saturation of gas dryers as a percentage of households has remained constant since 2001, while the saturation of electric dryers has increased. Conversely, the saturation of room air conditioners as a percentage of households has decreased somewhat since 1990.

Table 3.11.1 Appliance Saturation (Number in Millions and Percentage of U.S. Households with Product) [35]

Product	1970		1982		1990		2001		2005	
	#	%	#	%	#	%	#	%	#	%
Dryers, Electric	18.6	29.3	42.3	50.6	56.1	60.1	61.8	59.3	67.6	62.1
Dryers, Gas	7.8	12.3	12.3	14.7	19.1	20.5	19.8	19	20.7	19
Room Air Conditioners	16.9	25	22.6	27	30.2	32.4	26.9	25.8	27.4	25.2

3.12 PRODUCT RETAIL PRICES

Table 3.12.1 presents the average retail prices of residential clothes dryers and room air conditioners for select years between 1980 and 2002. The retail prices presented in nominal dollars are obtained from the AHAM *Fact Book* 2003. To adjust these prices to constant 2002 dollars, the values are scaled by the annual U.S. city average Consumer Price Index (CPI), published by the U.S. Department of Labor's Bureau of Labor Statistics (BLS). Although retail prices in nominal dollars for electric and gas **clothes dryers** have increased since 1980, the increase has been at a slower rate than the CPI, so that in constant 2002 dollars the retail prices have decreased. Prices of **room air conditioners** in both nominal and 2002 dollars have decreased in the same time period.

Table 3.12.1 Residential Appliance Retail Prices[36]

Product	Average Retail Prices *(Nominal $)*			Average Retail Prices *(2002$)*		
	1980	1994	2002	1980	1994	2002
Electric Clothes Dryers	286	327	396	624	397	396
Gas Clothes Dryers	315	325	467	688	395	467
Room Air Conditioners	372	351	322	812	426	322

DOE used the consolidated room air conditioner database developed for the energy efficiency analysis in section 3.15.3.2 to produce a more recent overview of the retail prices. The prices shown represent retail prices offered by a wide variety of retailers and internet distributors. The prices reflected information collected in August 2008.

Figure 3.12.1 and Figure 3.12.2 show the retail price versus cooling capacity of each **room air conditioner** listed in the databases, shown separately for product class groups 1-5 and 6-10. There is a definite positive trend in cost for both of the graphs, however, the range of prices at a given capacity is much wider for product classes 1 through 5. The second graph shows that there are a limited number of products in the product class 6 through 10 group with capacities higher than 15,000 Btu/h. This represents primarily product classes 9 and 10.

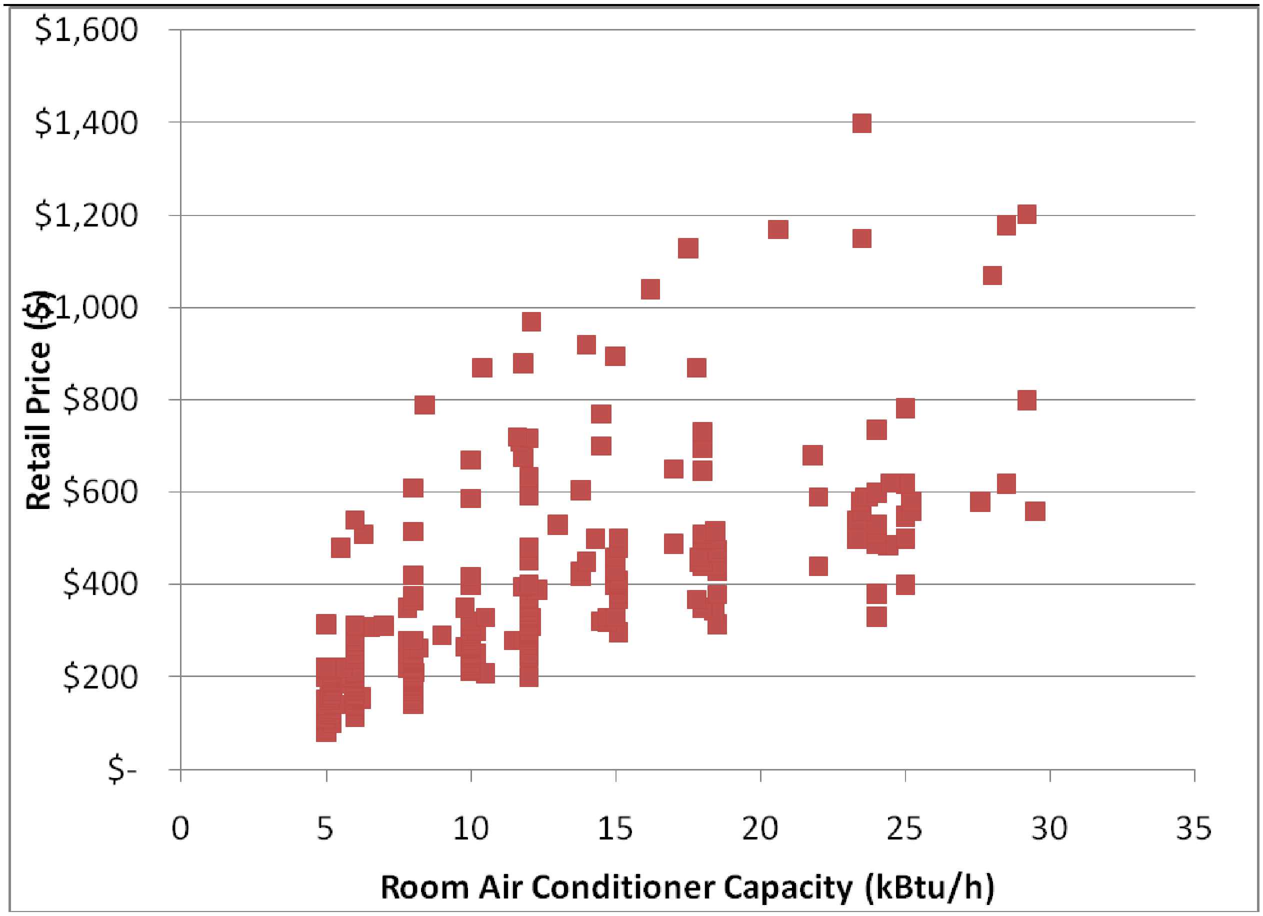

Figure 3.12.1 Retail Prices for Room Air Conditioners, Product Classes 1 through 5

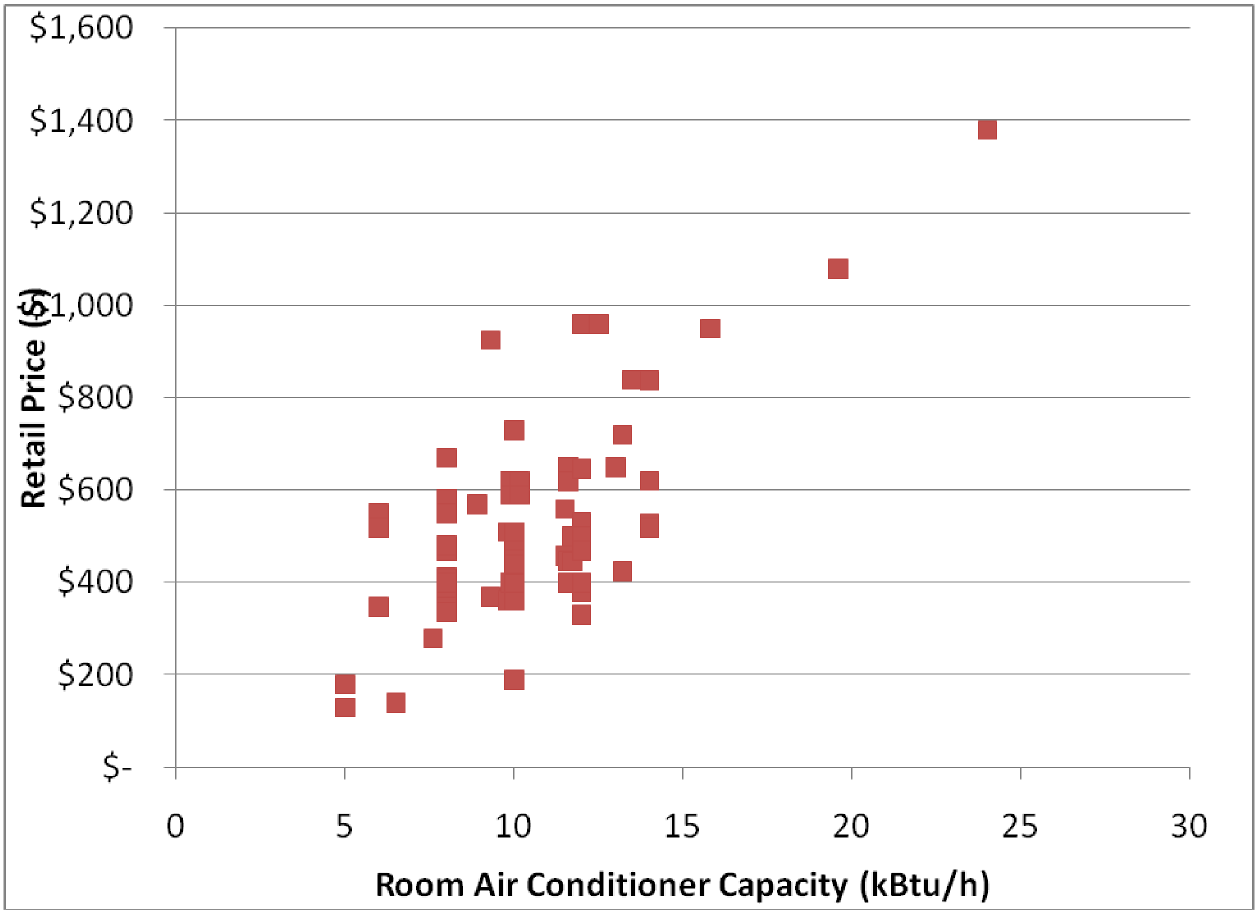

Figure 3.12.2 Retail Prices for Room Air Conditioners, Product Classes 6 through 10

Figure 3.12.3 through Figure 3.12.8 show the retail price as a function of EER for the room air conditioners in the consolidated database, specifically for the product classes analyzed in detail in the engineering analysis (product classes 1, 3, 5, and 8). The figures show concentrations of products at the baseline and ENERGY STAR efficiency levels. Figure 3.12.3 shows an approximate $50 price increment for those units in product class 1 with an ENERGY STAR rating. However, there are not strong trends of price as a function of EER observed for product classes 3, 5, and 8.

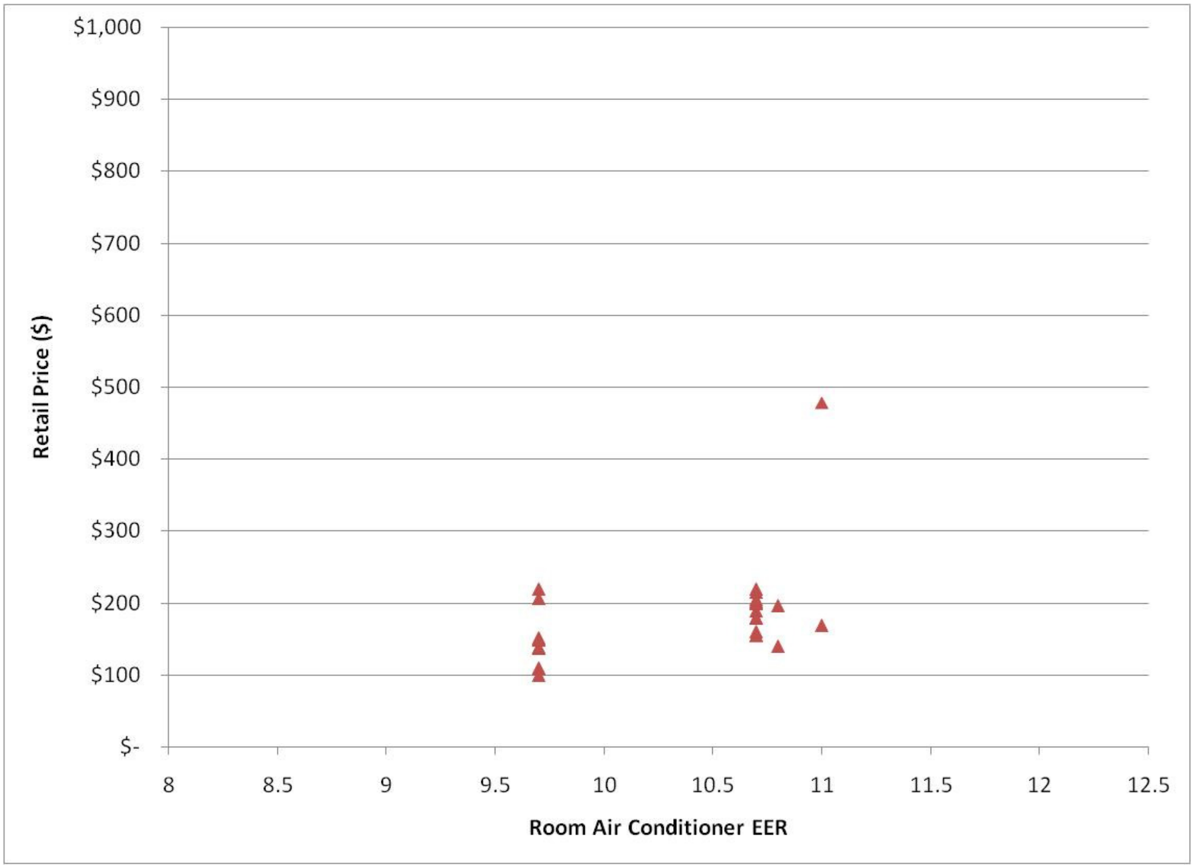

Figure 3.12.3 Retail Price versus EER for Product Class 1

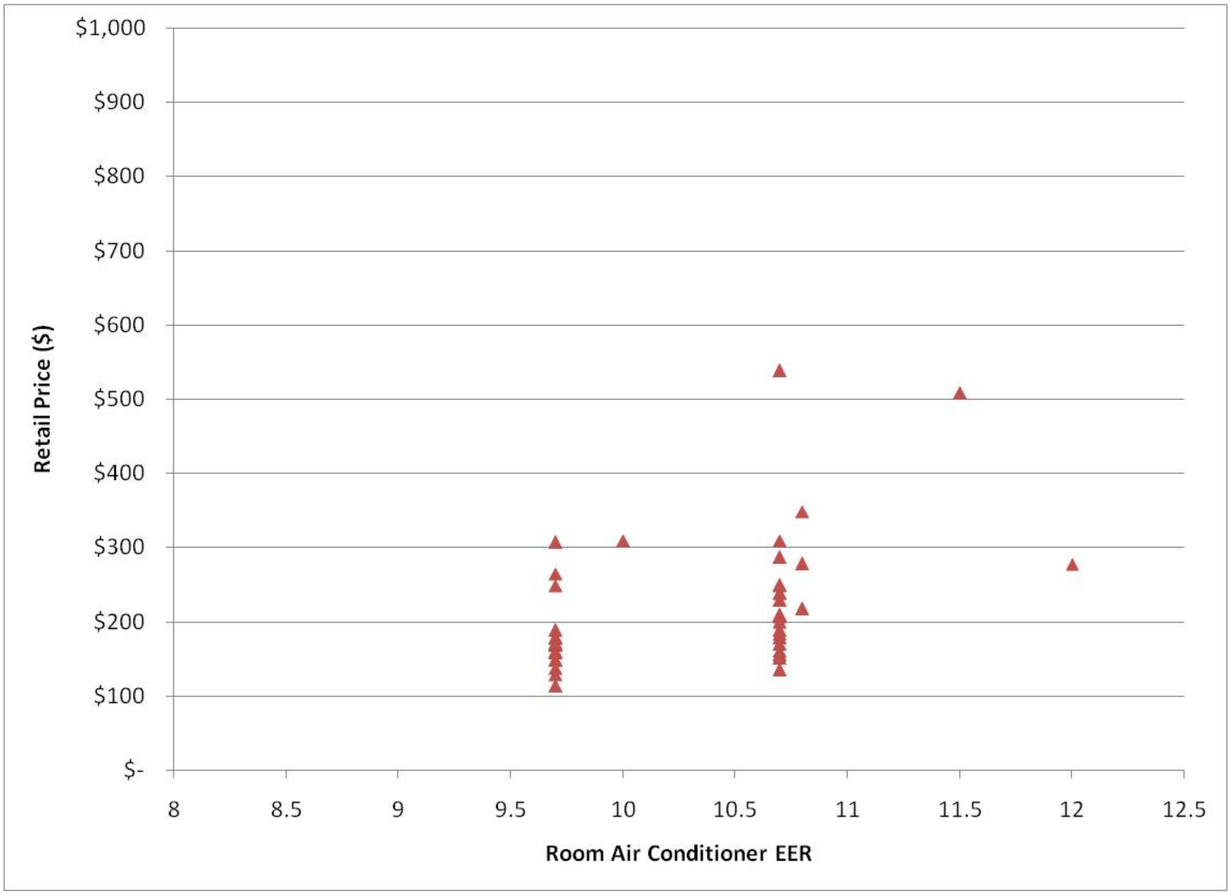

Figure 3.12.4 Retail Price versus EER for Product Class 2

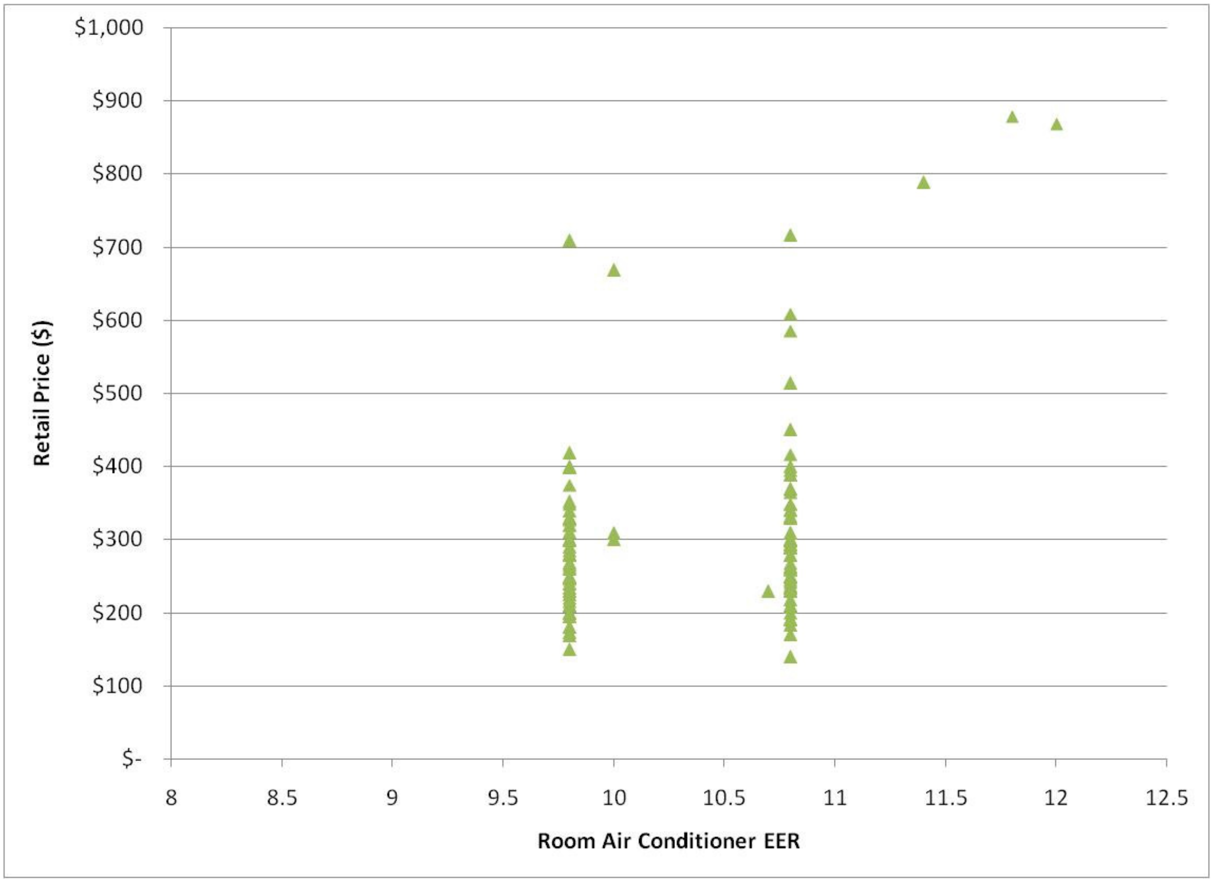

Figure 3.12.5 Retail Price versus EER for Product Class 3

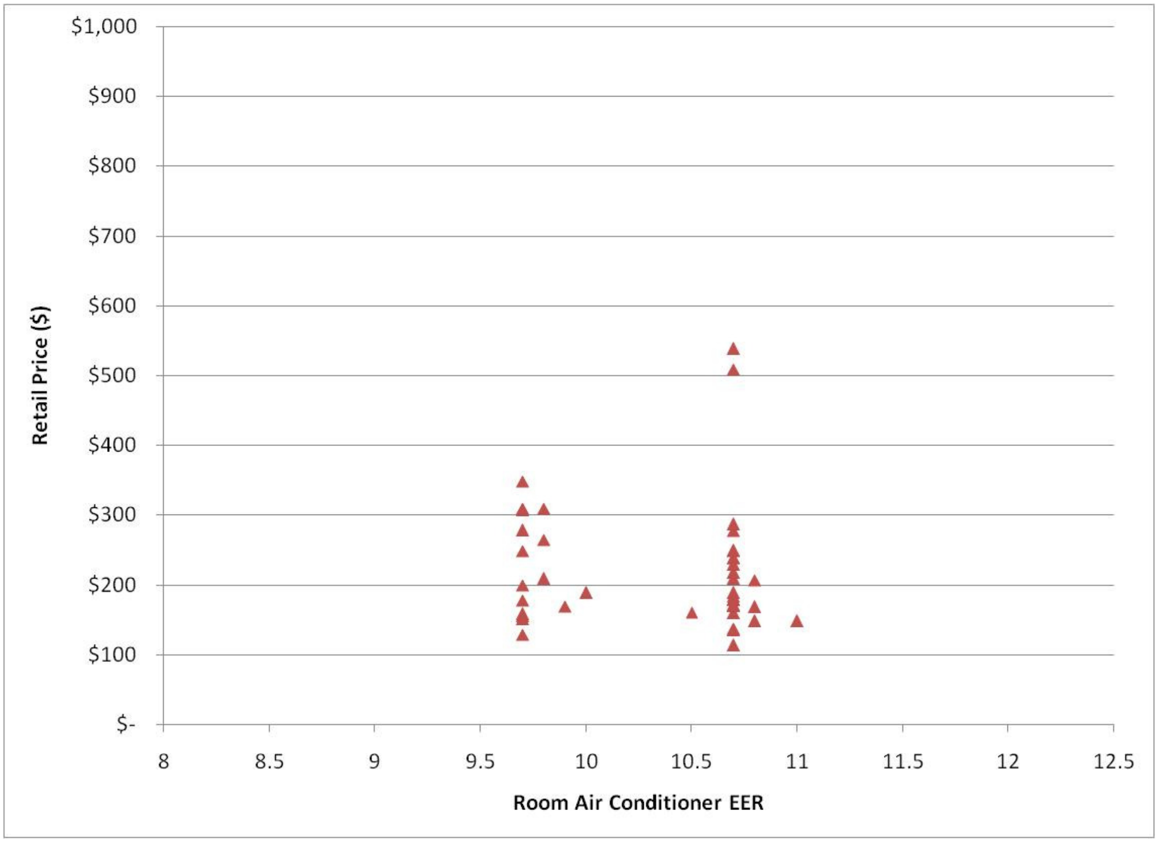

Figure 3.12.6 Retail Price versus EER for Product Class 4

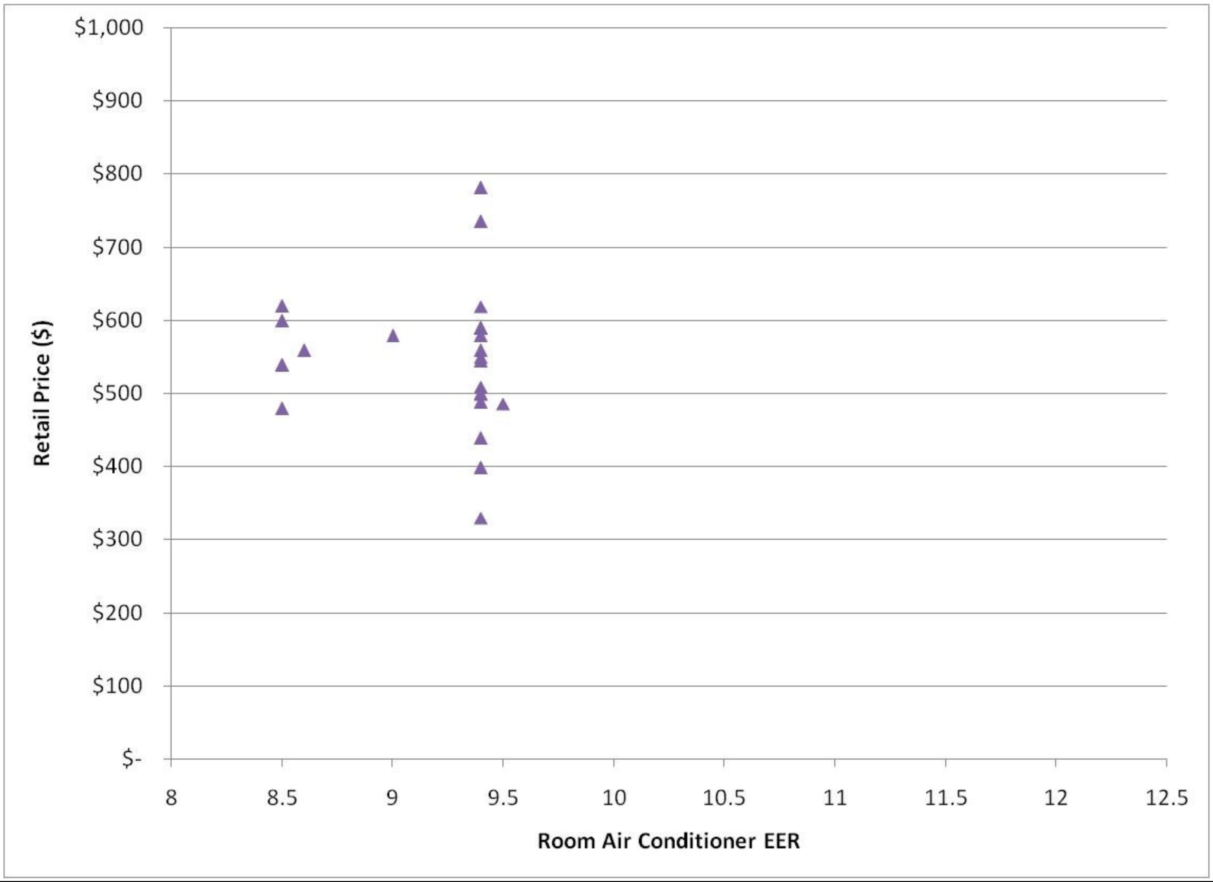

Figure 3.12.7 Retail Price versus EER for Product Class 5

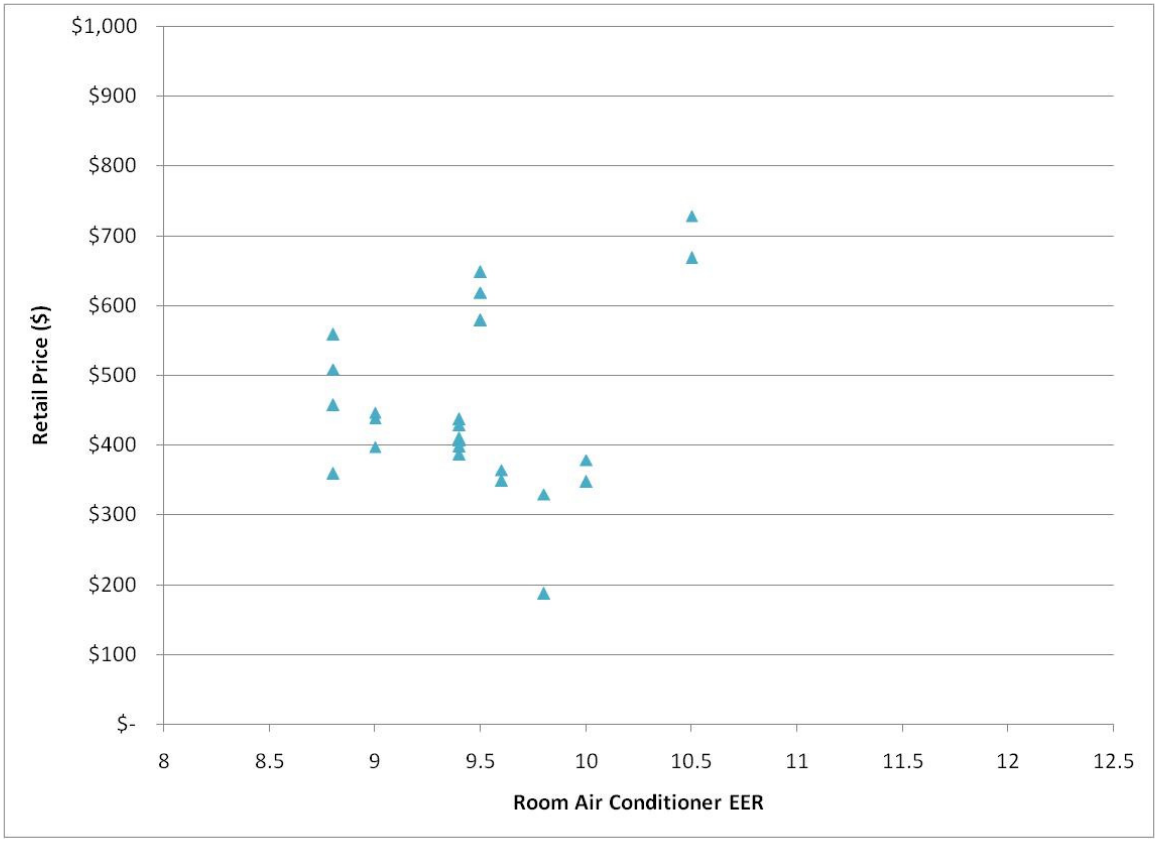

Figure 3.12.8 Retail Price versus EER for Product Class 8

3.13 INDUSTRY COST STRUCTURE

DOE developed the household appliance, household laundry, and air-conditioning and warm air heating and commercial/industrial refrigeration equipment industries cost structures from publicly available information from the ASM (Table 3.13.1 through Table 3.13.6) and from the Securities and Exchange Commission (SEC) 10-K reports filed by publicly owned manufacturers (summarized in Table 3.13.7). Table 3.13.1 presents the home appliance industry employment levels and earnings from 1994–2008. The statistics illustrate a steady decline in the number of production and non-production workers in the industry.

Because the ASM expresses all dollar values in constant 2008 dollars, the following table shows that as industry employment levels decline, the industry payroll is also decreasing. The percent decrease in total industry employees tracks closely with the percent decrease in payroll for all employees.

Table 3.13.1 Household Appliance Industry Employment and Earnings [37]

Year	Production Workers *('000)*	All Employees *('000)*	Payroll for All Employees *(2008$ Mil)*
2008	49.1	57.5	2,296.0
2007	56.2	65.5	2,537.9
2006	60.0	69.7	2,777.8
2005	64.3	76.9	2,928.2
2004	69.4	83.7	3,244.1
2003	71.0	85.3	3,326.1
2002	73.5	88.8	3,525.2
2001	76.6	92.6	3.693.5
2000	82.7	99.5	4,023.4
1999	82.3	97.9	3,892.2
1998	82.4	99.5	3,919.5
1997	79.8	97.2	3,742.3
1996	87.1	108.1	4,010.7
1995	88.9	110.8	4,077.0
1994	90.4	110.4	4,063.1

Table 3.13.2 presents the employments levels and earnings for just the household laundry portion of the appliance industry from 1994-2007[o]. Statistics for both employment levels and payroll show a steady fluctuation over the past 14 years, with payroll and employment levels again showing a positive correlation.

Table 3.13.2 Household Laundry Industry Employment and Earnings [38]

Year	Production Workers *('000)*	All Employees *('000)*	Payroll for All Employees *(2007$ Mil)*
2007	10.3	11.1	415.1
2006	12.4	14.1	587.8
2005	12.6	14.5	549.2
2004	12.9	15.1	606.9
2003	13.1	15.5	645.8
2002	13.5	15.9	711.8
2001	12.8	14.9	633.9
2000	13.3	15.5	681.6
1999	14.0	15.9	678.3
1998	14.3	16.7	702.0
1997	12.9	14.8	603.0
1996	12.9	15.7	640.4
1995	12.9	16.3	678.7
1994	12.9	16.2	714.4

Table 3.13.3 shows the employment levels and payroll for the air conditioning and warm air heating and commercial/industrial refrigeration equipment industry. Industry statistics show a

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[o] Data for 2008 was withheld from the U.S. Census Bureau ASM to avoid disclosing data for individual companies.

steady decrease in the levels of employment and payroll, and the same correlation between these parameters as seen in the appliance industry.

Table 3.13.3 Air-Conditioning & Warm Air Heating & Commercial/Industrial Refrigeration Equipment Industry Employment and Earnings [39]

Year	**Production Workers** *('000)*	**All Employees** *('000)*	**Payroll for All Employees** *(2008$ Mil)*
2008	70.8	96.5	4,010.0
2007	74.7	101.5	4,120.2
2006	74.9	98.1	4,224.6
2005	75.9	102.2	4,271.7
2004	73.1	99.0	4,137.8
2003	77.5	104.7	4,353.6
2002	80.4	108.3	4,493.6
2001	89.0	118.9	4,727.6
2000	98.0	127.4	5,222.9
1999	95.9	124.0	5,054.9
1998	92.0	120.0	4,877.5
1997	91.0	119.4	4,720.1
1996	104.0	134.9	5,849.8
1995	103.2	134.8	5,723.0
1994	99.1	130.6	5,572.9

Table 3.13.4 presents the costs of materials and industry payroll as a percentage of value of shipments from 1994–2008. The cost of materials as a percentage of value of shipments has fluctuated slightly over the 15-year period. DOE notes that fluctuations in raw material costs are common from year to year. The cost of payroll for production workers as a percentage of value of shipments has declined since 2000. Similarly, the cost of total payroll as a percentage of value of shipments has declined since 2000.

Table 3.13.4 Household Appliance Industry Census Data[40]

Year	Cost of Materials as a Percentage of Value of Shipments *(%)*	Cost of Payroll for Production Workers as a Percentage of Value of Shipments *(%)*	Cost of Total Payroll (Production + Admin.) as a Percentage of Value of Shipments *(%)*
2008	58.5	7.7	10.5
2007	57.8	8.0	10.5
2006	57.9	8.4	10.9
2005	56.9	8.3	11.0
2004	57.2	9.0	12.1
2003	55.9	9.2	12.5
2002	54.9	9.7	13.4
2001	56.8	10.1	13.8
2000	55.8	10.2	14.0
1999	54.7	10.2	13.9
1998	56.0	10.0	13.7
1997	52.8	9.9	13.6
1996	56.8	9.9	13.9
1995	57.7	9.4	13.7
1994	55.5	9.2	13.1

Table 3.13.5 shows the cost of materials and industry payroll as a percentage of value of shipments for the household laundry industry from 1994-2007[p]. DOE observed a decline in both the cost of materials and payroll as a percentage of value of shipments from 1996–2005. However, from 2005-2007, the cost of materials and payroll for production workers as a percentage of value of shipments has increased. Table 3.13.6 shows the trends for the air conditioning and warm air heating and commercial/industrial refrigeration equipment industry, which showed decreases in percentages of both cost of material and payroll from 1996-2005. However, from 2005-2008, the cost of materials as a percentage of value of shipments has increased, whereas the cost of payroll as a percentage of value of shipments has remained relatively constant.

[p] Data for 2008 was withheld from the U.S. Census Bureau ASM to avoid disclosing data for individual companies.

Table 3.13.5 Household Laundry Industry Census Data [41]

Year	Cost of Materials as a Percentage of Value of Shipments *(%)*	Cost of Payroll for Production Workers as a Percentage of Value of Shipments *(%)*	Cost of Total Payroll (Production + Admin.) as a Percentage of Value of Shipments *(%)*
2007	60.1	8.2	9.4
2006	61.2	9.0	11.1
2005	52.5	7.8	9.9
2004	52.5	8.5	11.1
2003	56.0	9.4	12.3
2002	56.6	10.4	14.2
2001	56.2	9.2	11.9
2000	54.2	9.7	12.9
1999	51.4	10.0	12.7
1998	54.5	10.3	13.3
1997	56.1	10.6	12.9
1996	64.4	10.6	13.5
1995	62.3	10.5	14.7
1994	63.4	10.4	14.6

Table 3.13.6 Air Conditioning & Warm Air Heating & Commercial/Industrial Refrigeration Equipment Industry Census Data[42]

Year	Cost of Materials as a Percentage of Value of Shipments *(%)*	Cost of Payroll for Production Workers as a Percentage of Value of Shipments *(%)*	Cost of Total Payroll (Production + Admin.) as a Percentage of Value of Shipments *(%)*
2008	56.7	8.4	13.9
2007	57.7	8.5	13.9
2006	53.2	8.9	13.8
2005	55.3	8.7	14.1
2004	53.3	9.2	14.8
2003	52.5	9.9	16.0
2002	51.3	10.2	16.5
2001	54.8	10.3	16.5
2000	56.3	10.7	17.0
1999	55.9	10.2	16.1
1998	58.1	10.5	16.3
1997	56.7	10.6	16.8
1996	62.0	12.0	17.6
1995	62.7	12.3	18.1
1994	59.5	12.4	18.3

Table 3.13.7 presents the industry cost structure derived from SEC 10-K reports of publicly-owned home appliance manufacturers which produce residential clothes dryers and room air conditioners. DOE averaged the financial data from 2002–2007 of several companies to obtain an industry average. Each financial statement entry is presented as a percentage of total revenues.

Table 3.13.7 Industry Cost Structure Using SEC Data

Financial Statement Entry	**Percent of Revenues** *(%)*
Cost of sales	81.3
Net income	1.7
Selling, general and administrative	12.8
Capital expenditure	3.3
Research and development	2.3
Depreciation and amortization	3.3
Net plant, property and equipment	18.7
Working capital	1.6

Figure 3.13.1 presents the industry-average gross margin over the period from 2002–2007 for the same manufacturers from which the industry cost structure is derived. The slope of the curve indicates the downward cost pressure facing manufacturers.

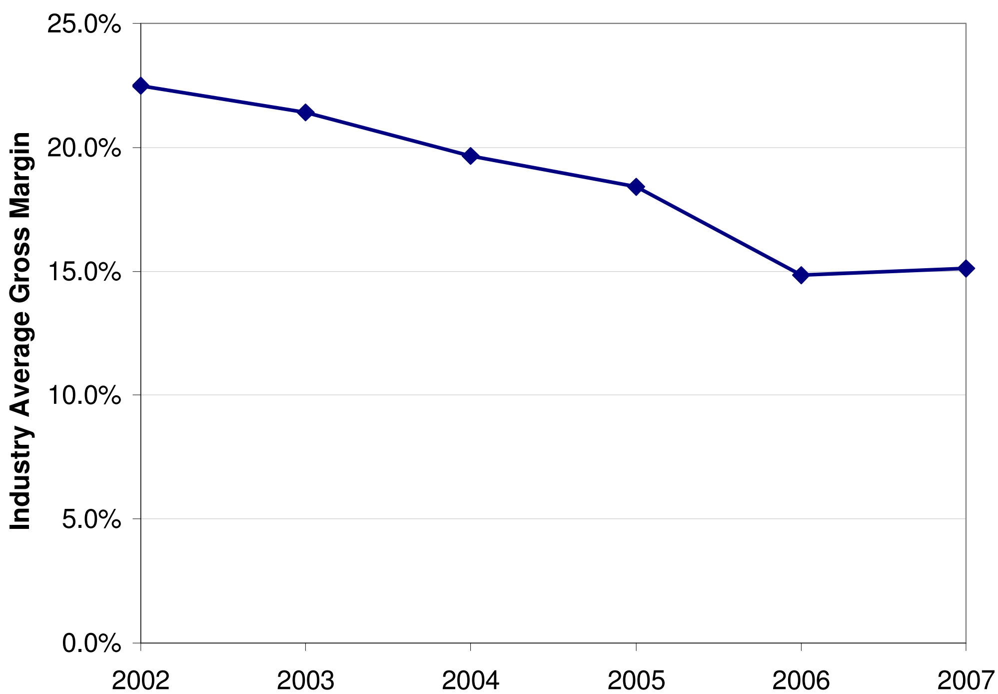


Figure 3.13.1 Industry Gross Margin Derived from SEC Data

3.14 INVENTORY LEVELS AND CAPACITY UTILIZATION RATES

Table 3.14.1 through Table 3.14.3 shows the year-end inventory for the household appliance, household laundry, and air conditioning and warm air heating and commercial/industrial refrigeration equipment industries, according to the ASM. Both in dollars and as a percentage of value of shipments, the end-of-year inventory for these industries has steadily declined since 1995. This data illustrates that domestic manufacturers are retaining less of their inventories each consecutive year.

Table 3.14.1 Household Appliance Industry Census Data[43]

Year	**End-of-Year Inventory** *(2008$ Mil)*	**End-of-Year Inventory as a Percentage of Value of Shipments** *(%)*
2008	1,918.2	8.7
2007	2,040.0	8.4
2006	1,774.0	7.0
2005	1,772.0	6.6
2004	1,959.3	7.3
2003	1,964.0	7.4
2002	2,111.8	8.1
2001	2,347.6	8.8
2000	2,649.0	9.2
1999	2,639.6	9.4
1998	2,845.9	10.0
1997	2,735.3	10.0
1996	3,001.8	10.4
1995	3,315.5	11.1
1994	3,436.4	11.1

Table 3.14.2 Household Laundry Industry Census Data[44]

Year	End-of-Year Inventory *(2007$ Mil)*	End-of-Year Inventory as a Percentage of Value of Shipments *(%)*
2007	258.4	5.8
2006	313.7	5.9
2005	230.5	4.2
2004	211.3	3.9
2003	237.5	4.5
2002	267.2	5.3
2001	310.6	5.8
2000	288.6	5.4
1999	440.9	8.3
1998	449.7	8.5
1997	462.4	9.9
1996	443.5	9.4
1995	423.9	9.2
1994	454.3	9.3

Table 3.14.3 Air Conditioning & Warm Air Heating & Commercial/Industrial Refrigeration Equipment Industry Census Data[45]

Year	End-of-Year Inventory *(2008$ Mil)*	End-of-Year Inventory as a Percentage of Value of Shipments *(%)*
2008	2,888.0	10.0
2007	3,101.5	10.5
2006	3,033.9	9.9
2005	2,903.7	9.6
2004	2,777.3	10.0
2003	2,734.5	10.0
2002	2,711.2	9.9
2001	3,092.3	10.8
2000	3,670.5	11.9
1999	3,687.6	11.8
1998	3,346.5	11.2
1997	3,309.3	11.8
1996	4,007.4	12.0
1995	4,035.8	12.8
1994	3,832.2	12.6

DOE obtained full production capacity utilization rates from the U.S. Census Bureau, *Survey of Plant Capacity* from 1994 to 2006. Table 3.14.4 presents utilization rates for various sectors of the household appliance industry. Full production capacity is defined as the maximum level of production an establishment could attain under normal operating conditions. In the *Survey of Plant Capacity* report, the full production utilization rate is a ratio of the actual level of operations to the full production level. The full production capacity utilization rate for household appliances in aggregate, along with the rates for household laundry appliances, show a decrease in utilization from 1994 to 2006, although trends in subsets of that time period have fluctuated. Full production capacity utilization rates for air conditioning and warm air heating and commercial/industrial refrigeration equipment have remained relatively steady over the period from 1996 to 2006. Prior to 1996, reported data did not disaggregate these types of equipment from more general heating and refrigeration equipment.

Table 3.14.4 Full Production Capacity Utilization Rates[46]

Year	Rates *(%)*		
	Household Appliances	**Household Laundry**	**Air Conditioning & Warm Air Heating & Commercial/Industrial Refrig. Equip.**
2006	77	80	63
2005	74	79	66
2004	76	77	60
2003	78	85	62
2002	72	87	60
2001	70	90	59
2000	70	88	66
1999	75	87	67
1998	73	75	67
1997	73	80	66
1996	76	81	NA*
1995	79	83	NA*
1994	82	89	NA*
* Data not available at this level of disaggregation			

3.15 TECHNOLOGY ASSESSMENT

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

3.15.1 Product Operations and Component

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

3.15.1.1 Residential Clothes Dryers

Residential **clothes dryers** are appliances designed to dry clothes by tumbling the load in a heated drum to remove moisture by means of evaporation. Because a horizontal axis of rotation is required to create the tumble action, residential clothes dryers are generally front-loading. Front-loading clothes dryers have an opening on the front of the unit, covered by a door, which gives access to an inner cylindrical drum where the load to be dried is placed. The inner drum is perforated and is surrounded by a larger outer housing which collects the moisture-laden air. The clothes dryer uses electricity to power an electric motor that rotates the drum within the housing, which is contained inside a cabinet. Vanes and/or surface textures may be incorporated into the inner surface of the drum to facilitate separation of the clothing to expose surface areas for drying.

Air is drawn through the drum by means of an electrically driven blower. This air stream is heated prior to entering the drum in order to evaporate the moisture in the clothing with which the air comes in contact. Heating may be provided by an electrically energized resistive element. Alternatively, hot air in the drum may be supplied by means of a gas burner system whose combustion products are directed into the drum by the electrically powered blower.

In the case of vented clothes dryers, the moisture-laden air is exhausted from the drum through a length of ducting, and as it exits, freshly heated room air is drawn in. The exhaust air is typically vented to an exterior location due to its high temperature and relative humidity. In installations where exterior venting is not possible, a ventless system may be used in which the moist air in the drum is routed through an air- or water-cooled heat exchanger. The water vapor condenses on the heat exchanger surface where it is either collected in a removable container for disposal by the user or discharged into a drain line. Ventless systems may either open-loop, in which the relatively dry air from the drum is exhausted into the room, or closed-loop, in which the dry air is recirculated back to the heater and subsequently to the drum inlet. With an air-to-air heat exchanger, the ambient air that was used to provide cooling is also discharged back into the room at a slightly higher temperature due to the heat transfer from the condensing water. Because the exhaust products from gas combustion systems contain a significant amount of moisture and varying levels of hazardous emissions such as carbon monoxide, ventless clothes dryers are all electrically heated. Tradeoffs associated with ventless versus vented dryers include greater flexibility in installation but longer drying times. In addition, for air-to-air systems, space conditioning loads may be increased due to the discharge of warm dry air to ambient. This may be offset, however, by the fact that conditioned ambient air is not being discharged to the exterior, as would be the case for a vented unit.

Combination washer/dryers combine clothes washing and drying functions in the same front-loading tub. The wash and dry cycles are performed in sequence. Since the washing function requires a drain hookup, and because these units are often installed where space is at a premium and outside access might not be available, all combination washer/dryers currently on the market utilize condensation drying. In addition, a water-cooled heat exchanger is made possible due to the water hookup already in place for the washing.

3.15.1.2 Room Air Conditioners

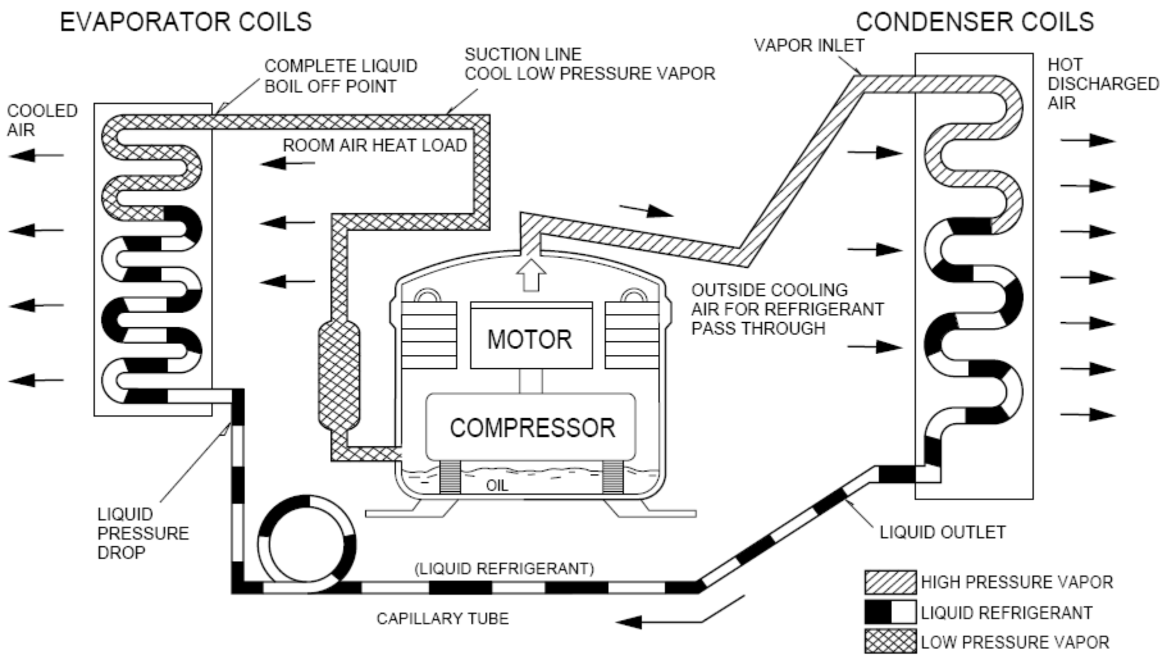
Room air conditioners are portable, refrigeration-based appliances that enable users to cool or warm an enclosed space, room, or zone. In addition to the primary cooling or warming function, room air conditioners also reduce the relative humidity (RH) of the conditioned space. RH is defined as the amount of water vapor present in the air compared to the maximum amount of water vapor the air can hold at that temperature, these amounts being expressed as partial pressures of the water vapor. Although they are portable, room air conditioners are designed for semi-permanent installation in a window opening or opening in an exterior wall. Room air conditioners are classified according to the amount of heat that can be removed from the room air during a given time period, called the capacity, expressed in Btu/h.

Room air conditioners contain refrigeration systems that remove both sensible and latent heat (*i.e.*, thermal load associated with water vapor in the air), from room air. The refrigerant-side and air-side components are all contained within one cabinet. The refrigerant-side components include the evaporator (indoor conditioning coil), the compressor, the condenser (outdoor coil), and the capillary tube. These components are all connected with refrigerant tubing. The air-side components consist of the fan motor, the evaporator blower, and the condenser fan. The cabinet containing both refrigerant-side and air-side components is split into an indoor and outdoor side. An insulated divider wall separates the two sides and reduces the heat transfer between sides. The indoor components are the evaporator and evaporator blower. The outdoor components are the compressor, condenser, capillary tube, fan motor, and condenser fan. A single fan motor with a shaft which extends out both ends is generally used to power both the evaporator blower and the condenser fan. The motor is located on the outdoor side to isolate motor losses from the indoor side. The evaporator blower shaft penetrates the insulated dividing wall.

Refrigeration-based room air conditioners operate as follows, illustrated in Figure 3.15.1:

1. The fan motor drives the evaporator blower and condenser fan simultaneously;
2. Warm air from the room or space is drawn into the indoor side of the unit across the evaporator coil, where latent and sensible heat is removed, and the cooled, conditioned air is circulated back into the room by the evaporator fan;
3. The heat from the air vaporizes the refrigerant in the evaporator coil. The evaporated refrigerant is compressed by means of the compressor;
4. The heated refrigerant is circulated through the condenser coil on the outdoor side of the unit, wherein the vapor is cooled by outdoor air being drawn across the coil by means of the condenser fan. This cools the vapor to saturation conditions and then condenses the refrigerant.
5. The cooled liquid passes through the capillary tube, reducing its pressure. The refrigerant flashes to a liquid/vapor mixture, and the temperature drops, consistent

with the pressure/temperature curve of saturated refrigerant. The two-phase refrigerant re-enters the evaporator and the cycle is repeated.



Source: Friedrich CP10E10 Service and Parts Manual[47]
Figure 3.15.1 Room Air Conditioner Operation Schematic

3.15.2 Technology Options

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

3.15.2.1 Residential Clothes Dryers

For **clothes dryers**, DOE will consider technologies identified in the November 1994 ANOPR (59 FR 56423), supplemented by technologies described in recent trade publications, research reports, and manufacturer product offerings. DOE took the technologies listed below (Table 3.15.1)—with exceptions noted below—from the November 1994 ANOPR. DOE took the modulating gas dryer technology from an April 2005 report by TIAX LLC (TIAX).[48] Additionally, DOE's preliminary market research indicated the availability of hydronically heated clothes dryers, so DOE has decided to include them in the clothes dryer heat generation technologies, but notes that significant revisions to the clothes dryer test procedure would be required to accommodate them. Specifically, DOE would have to incorporate a number of assumptions about the efficiency of the heat generation source used with these dryers. Improved air circulation, motor efficiency, and fan efficiency were added as technology options based on comments received during the Framework Document public meeting for this rulemaking held October 24, 2007 as well as submitted written comments in response to the framework document. DOE also added technology options for reducing standby power, including switching power supplies and transformerless power supplies with auto-powerdown, based on its reverse engineering analyses.

Table 3.15.1 Technology Options for Residential Clothes Dryers

Dryer Control or Drum Upgrades
1. Improved termination
2. Increased insulation
3. Modified operating conditions
4. Improved air circulation
5. Reverse tumble
6. Improved drum design
Methods of Exhaust Heat Recovery (Vented Models Only)
7. Recycle exhaust heat
8. Inlet air preheat
9. Inlet air preheat, condensing mode
Heat Generation Options
10. Heat pump, electric only
11. Microwave, electric only
12. Modulating Heat
13. Water-cooling, ventless electric only
14. Indirect heating
Component Improvements
15. Improved motor efficiency
16. Improved fan efficiency
Standby Power Improvements
17. Switching Power Supply
18. Transformerless Power Supply with Auto-Powerdown

The technology options for residential clothes dryers can be broadly grouped into five main categories: dryer control or drum upgrades, methods of exhaust heat recovery (for vented models only), heat generation options, improvements to components, and options to reduce standby power.

Improved termination

The standard dryer is assumed to use a timed drying cycle, which automatically turns off the dryer after a user-specified time interval. With automatic termination by temperature sensing, an exhaust air temperature sensor controls the length of the drying cycle. With automatic termination by moisture sensing, the moisture content of the clothes in the dryer is determined by sensors that measure conductivity along with an exhaust air temperature sensor. When the moisture content is reduced to a level at which these sensors cannot measure accurately (generally around 15 percent RMC) a countdown timer is started. After a pre-specified time period that is set by the manufacturer, the cycle terminates. Manufacturers indicated in discussions with DOE that moisture sensing with electromechanical controls increase the accuracy above automatic termination using only temperature sensors. Manufacturers stated that moisture sensing with electronic controls further improves the accuracy of automatic termination.

One method to improve automatic termination via moisture sensing is to improve the accuracy of the conductivity sensors at low levels of RMC. This can be done by increasing the contact area between the sensor and the clothing, as achieved by one manufacturer by including slip rings in the drum design. An adjustable gain control can also be used in the electronics to improve the sensitivity; however, this adds significant cost and reliability issues. A second method to improve automatic termination is to improve the accuracy of end-of-cycle detection. One manufacturer has indicated preliminary energy savings of up to 17 percent through timer controls based on new dryer process modeling.[49]

The test procedure for dryers allows an energy credit of 12 percent for either temperature or moisture sensing relative to time control to terminate drying. There has been some controversy as to whether the use of moisture sensors reduces energy consumption relative to temperature sensors. A number of sources claim that temperature sensing controls provide 10 percent real-world energy savings, whereas moisture sensing controls provide 15 percent energy savings.[50] Based on field measurements conducted by one manufacturer for the previous rulemaking, it appears that the test procedure credits are appropriate.

Increased insulation

During the drying cycle some parts of the dryer are warmer than the ambient air. Insulating the dryer drum reduces the heat lost through conduction, convection, and radiation to the surrounding air. During the previous rulemaking, two dryer manufacturers reported an energy savings of about 2 percent from the addition of 1 inch of fiberglass insulation around the dryer drum. Computer simulations performed by other researchers with a thermal model showed a 6 percent energy savings.[51] However, in recent discussions with DOE, manufacturers indicated that there is little to no efficiency improvement associated with adding insulation.

There is concern that the insulation would eventually degrade, resulting in fiberglass particles being drawn into the drum and onto the clothes because dryer air circulation systems operate with a negative air pressure in the drum relative to the outside. These particles can cause skin irritation. Potential material substitutions for fiberglass include polystyrene, polyethylene, or polyurethane foam insulation. They have similar or lower thermal conductivities and do not cause skin irritation.

Modified operating conditions

Reducing air flow and/or heat input rate changes the efficiency of the drying process. Manufacturers may select operating points which match the dryer cycle time to the washer cycle time. From an efficiency standpoint, these settings do not necessarily lead to optimum dryer operation. By decreasing the air flow rate, the air temperature in the drum, and thus the evaporating rate, increases and results in better energy efficiency. Energy savings of as much as 8 percent have been shown for tests with reduced air flow rates and electric heater inputs, but the drying time increased from about 40 to 55 minutes. Tests by the same researchers with only reduced heater input (3.3 kW instead of 4.55 kW) yielded no energy savings and increased the drying time from 40 to 56 minutes. For a very low heater input (1.25 kW), energy savings of around 5 percent were achieved, but the drying times were very long (112 minutes).[52]

Improved air circulation

One manufacturer of commercial clothes dryers has claimed that designing the drum to improve airflow (*i.e.,* directing and maintaining heat more efficiently) decreases the energy use while maintaining the drying performance.[q] However, DOE is unaware of any data quantifying the energy savings associated with improved air circulation.

DOE noted that air flow through the drum in conventional dryers is generally directed from the rear to the front of the drum. Based on discussions with a number of manufacturers, a small efficiency improvement, between 1 and 2 percent, can be achieved by changing the air flow in the drum such that the air flows in through one side on the rear of the drum, and exits on the other side of the rear of the drum.

Dryer booster fans can be installed to increase the airflow in clothes dryers, which conceivably increases the rate of forced convection. In cases of long exhaust ducting where the static pressure that must be overcome by the dryer fan is increased, incorporating a dryer booster can increase the airflow and thus increase drying capacity and reduce energy consumption of the clothes dryer. However, the current DOE clothes dryer test procedure uses an exhaust simulator with a standard length and geometry and does not account for alternate installation conditions. DOE is unaware of any data quantifying the energy savings associated with dryer booster fans.

Reverse tumble

Reverse tumble drying spins the drum in both the clockwise and counter-clockwise directions. This action is typically carried out at the end of the cycle in order to reduce the amount of wrinkling and tangling of the clothes. However, it is possible to reverse rotational direction earlier in the cycle to increase the separation of clothing and thus dry the clothes load more quickly and evenly. In the description of a patented reverse tumbling method, it is claimed that a 10 percent reduction in drying time, and thus energy consumption, could be achieved.[53] In addition, reversing the drum rotation can prevent “balling” of large items such as sheets, which restricts air flow to the center of the item and requires longer drying times. No manufacturer indicated they use, or would consider, reverse tumble for increasing efficiency. Tests conducted

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[q] For more information visit *www.amdry.com/resources/products/450264%20Solaris%206_06_final.pdf*

by one manufacturer, however, found that the small size of the test cloths in the DOE test procedure prevents balling and thus no energy efficiency benefit can be measured.[54] Manufacturers also noted in discussions with DOE that reverse tumble does not improve efficiency, and in some cases can reduce efficiency when the drum is not rotating while it is changing directions.

Improved drum design

The intrinsic energy efficiency of a clothes dryer can be affected by the design of the drum, including the internal vane design.[55] Optimized vane design promotes clothing separation during tumbling, which can reduce drying times. According to some manufacturers, the surface texture of the drum can also enhance clothing separation. Manufacturers noted that such designs are performance related features to ensure gentle handling of delicate clothing, but conceivably the improvements in clothes separation and aeration could shorten drying times as well. However, DOE is unaware of any data quantifying potential energy efficiency improvements associated with improved drum design.

Recycle exhaust heat

It is estimated that about 20–25 percent of total heat input energy is lost through the dryer vent. For the recycle exhaust heat technology option, a portion of the exhaust air stream is reintroduced at the dryer air inlet. This recovers a portion of the energy in the exhaust air stream and reduces the energy needed to raise the inlet air to drying temperatures. The exhaust air suitable for direct recovery would be available only late in the drying cycle when most of the moisture is evaporated and the air temperature rises. Therefore, the realizable energy savings are significantly less than the theoretical maximum of about 20 percent. The estimated energy use reduction for this technology option is 6 percent.

Recycling of exhaust air late in the dryer cycle can be accomplished using extra duct work and mechanical air diverters; however, it presents several technical problems. There is the potential for lint accumulation in the duct work and on the clothes. Recycling of exhaust air could present a potential fire hazard since some large pieces of lint could enter the heated area. For a gas dryer, there is also a potential inability to promote satisfactory combustion.

Experiments performed with a 230 V electric dryer (with a baseline energy use of over 3.0 kWh/cycle) showed that energy savings ranged from 10 to 18 percent, depending on the fraction of exhaust air recirculated.[56] A fine nylon-mesh filter was installed to minimize the amount of recirculated lint. These energy savings are greater than one would expect given the large quantity of moisture in the exhaust early in the cycle. Additionally, the National Institute of Standards and Technology (NIST) testing indicated savings ranged from 3 to 6 percent for this option.[57]

Inlet air preheat

For this technology option, a heat exchanger is used to recover exhaust heat energy and to preheat inlet air. This system should be feasible for both gas and electric dryers since none of the exhaust air re-enters the dryer. Energy savings are achieved either by a faster drying time or by reducing the required heater input power. A number of researchers have investigated this technology option for clothes dryers. One manufacturer has estimated 2 to 3 percent energy savings, while NIST estimated 3 to 6 percent.[58] Both of the above experiments were carried out in the non-condensing mode. That is, moisture in the exhaust air was not condensed, which limited the maximum heat recovery.

A limitation of this technology option is that a large surface area is required to achieve sufficient heat transfer, and that lint may accumulate on these heat transfer surfaces. Although every dryer is equipped with a lint filter, considerable lint is still contained in the exhaust air. This lint can foul the heat exchanger, decreasing its effectiveness. Additionally, to overcome the increased resistance to air flow, an extra blower is needed at the fresh air inlet or a stronger blower in the exhaust air duct is required.

Manufacturers have also expressed concern that any decrease in exhaust temperature will lead to moisture condensation in the exhaust duct, which could result in damage to the exhaust duct and dryer, as well as water leakage into the home. Water leakage into the home could lead to the health risks from the development of mildew and/or mold.

Inlet air preheat, condensing mode

Dryers have been manufactured both in the United States and Europe that utilize a condenser to capture some of the sensible and latent heat in the exhaust air stream. For this technology option, heat energy from the exiting air is transferred, using a heat exchanger, to the cooler incoming air. If the effectiveness of the heat exchanger is high enough, the water vapor in the exhaust air will condense. Therefore, more heat energy is transferred than in a sensible heat exchanger system as described above. In Europe, condenser dryers have been used in an open system to supply space heat during the winter. In the United States, they have been used to avoid the need for vents in apartments. Research has shown that compared to a conventional air vented dryer, an open-cycle condensing dryer is about 14 percent more efficient and a closed-cycle condensing dryer is 7 percent more efficient.[59] Manufacturers have indicated that only minimal (1 to 3 percent) efficiency improvement can be achieved with inlet air preheat.

Manufacturers have identified several problems with this technology option: 1) a drain for the moisture is required; 2) lint accumulation on the heat exchanger reduces the heat transfer efficiency; and 3) lint can accumulate and clog the drain. Because a drain is required to be installed, and humid operating conditions require extensive use of stainless steel or glass in the heat exchanger to avoid corrosion, manufacturer cost for this technology option will be greater than for the inlet air preheat with a sensible heat exchanger.

An alternative approach to capture heat from the exhaust air stream is to mechanically compress the exhaust air to extract water vapor and transfer the latent heat to the remaining gaseous steam. The extracted water is drained from the compression chamber, and the pressurized gaseous steam is allowed to expand and be superheated before being injected back into the drum to help preheat the inlet air. Researchers have claimed that such a compression condenser dryer is as energy efficient as a heat pump dryer, but has almost half the cycle time and requires fewer specialized components.[60]

Heat pump, electric only

Heat pump dryers function by recirculating the exhaust air back to the dryer while moisture is removed by a refrigeration-dehumidification system. A heat pump dryer is essentially a dryer and an air conditioner packaged as one appliance. No heating element is needed. The warm and damp exhaust air of the dryer enters the evaporation coil of the dehumidifier where it cools down below the dew point, and sensible and latent heat are extracted. The heat is transferred to the condenser coil by the refrigerant and reabsorbed by the air, which is moving in a closed air cycle. A drain is required to remove the condensate; however, one is usually available since clothes washers and dryers are typically located side by side. Heat pump dryers have been unable to penetrate the market despite showing significant energy savings (in some cases over 50 percent compared to electric resistance dryers), even in Europe, where they have been in existence for years. Based on a recent study, heat pump dryers had a market share of only 0.3 percent in Western Europe in 2005.[61] The major issue for heat pump dryers has been cost and performance. Heat pump dryer dry times are typically significantly longer than those associated with standard U.S. electric dryers.

A heat pump dryer has been developed by a U.S. company which has successfully tested several prototypes and found energy savings of 68 percent as compared to energy use by a conventional electric clothes dryer. The estimated retail cost is approximately twice that of a conventional electric dryer. Drying times were essentially the same as for the conventional dryer, and the dryer operates on standard 120 V line power. The prototype uses a disposable filter to reduce lint in the air system. One inch of polyisocyanurate insulation was used to avoid condensation of water vapor in the recirculated air. In addition, the extension on the back of the prototype dryer to accommodate the added refrigeration components was estimated to be about the same depth as a vent duct, so the cabinet may fit in the same space as a conventional dryer.

More maintenance will probably be required for a heat pump dryer than for a conventional dryer. The heater is replaced by equipment found in a small room air conditioner—a condenser, evaporator, compressor, expansion valve, etc. Installation costs, though, may be less than for a conventional electric dryer because the heat pump dryer does not require an exhaust vent as does a conventional dryer (although some heat pump dryers may still use a vent). However, heat pump dryers require access to a drain for removal of condensate.

Research conducted on both heat pump dryers and conventional vented dryers on the European market showed that heat pump dryers consumed about 50 percent less energy than conventional dryers. The heat pump dryers tested had energy efficiency values between 0.32 and 0.40 kWh/kg laundry (with 70 percent initial moisture, measured according to test standard EN 61121) whereas conventional dryers had values between 0.6 and 0.8 kWh/kg laundry. Another benefit noted by this research was that the leakage of water vapor into the room was around 20 percent, which is significantly lower than conventional dryers. This research performed a cost comparison of heat pump dryers versus conventional dryers, which showed that the combined sale price and electricity costs over 15 years was about 1900 and 2300 Euros, respectively.[62]

Research sponsored by TIAX and Whirlpool developed a high efficiency, high-performance heat pump clothes dryer for the U.S. market. This different approach to the heat pump system maximized the output capacity and temperature from the heat pump. This design has shown 40 to 50 percent energy savings on large loads along with 35 degree Fahrenheit (°F) lower fabric temperatures and similar dry times. For delicate loads, the design reduced fabric temperature by 10–30 °F and provide up to 50 percent energy savings and 30–40 percent drying time savings. The heat pump dryer designed by TIAX also exhibited improved fabric temperature uniformity as well as robust performance across a range of vent restrictions in a partially open-loop design described below.[63]

In order to maximize the air inlet temperature and airflow into the dryer's drum, TIAX replaced the standard refrigerant, R-22, with R-134a in an R-22 air conditioner/heat pump compressor, shifting evaporating and condensing temperatures by 30 °F while maintaining similar operating pressures and power input. TIAX was also able to maximize the capacity of the heat pump system by redesigning the heat exchanger components to optimize space utilization and increasing the airflow in the system as compared to typical dryers.[64]

A key issue in the TIAX design was the venting options of the heat pump dryer. The moisture in the air exiting the drum is removed by the evaporator. This air can then be recirculated back into the drum, which removes the need for a vent. However, some form of heat rejection is required since the heat pump generates more heat than cooling in steady state operation. TIAX used a partially open-loop design in which a portion of the process air is vented outdoors to remove excess heat. In this design, all of the process air is recirculated through the dryer until the system has fully warmed, at which point the exhaust is opened and a portion of the total flow is vented to the outside.[65]

Microwave, electric only

Microwave energy can be absorbed by water, thereby heating the water enough to cause evaporation. This would be a direct and efficient manner to remove moisture from clothes. Prototype microwave dryers have been built and tested. The previous rulemaking determined that energy savings from the use of a microwave dryer would be approximately 26 percent compared to a conventional dryers. The data was provided by a company developing a prototype microwave dryer, and the developers claimed that the system could safely dry clothes with metal buttons and zippers, although clothes with metallic threads could be damaged. Uniform drying is also a problem since the microwaves may not reach the interior of the clothing container. The prototype dryer described above utilized two magnetrons for delivering the microwave energy to the drum.

Instead of the conventional method of passing warm air over the clothes, microwave energy can be directly absorbed by water retained in the clothing, thereby heating the water enough to cause evaporation. Microwave drying uses the principle of dielectric heating, in which electromagnetic energy is radiated into the dryer drum where it is absorbed by water molecules which have a higher dielectric loss factor than most common fabric materials. Most fabric materials are also relatively transparent to microwave energy, so that the microwaves can penetrate the fabric's interior to heat the water molecules directly. This allows the fabric in a microwave dryer to stay cooler—below 115 °F—as compared to conventional dryers which heat air to approximately 350 °F, with fabric surfaces reaching 150 °F. Microwave dryer prototypes have been shown to consume about 17 to 25 percent less energy as well as to dry clothes about 25 percent faster than conventional electric dryers.[66]

Early conceptualization of this technology began in the mid-1960s; however, product development was not pursued because of high manufacturing costs and difficulties in overcoming hazards relating to arcing and overheating of clothing. In 1997, the Electric Power Research Institute (EPRI) focused on developing a compact countertop dryer based on economic feasibility and market surveys. EPRI market studies and the development of prototypes for in-house evaluation have led to negotiations for technology licensing and indications of serious product development for a residential microwave clothes dryer.[67]

Because of the interaction between the metallic sensor contacts and the electromagnetic field, microwave dryers are incapable of using contact moisture sensors as in conventional dryers. EPRI investigated using sensors to detect the microwave electric field strength and the fabric temperature, which both correlate well with the moisture content. As evaporation nears completion, both measured signal slopes begin to rise in a predictable manner, so that the dryer can be shut off automatically and avoid wasted energy in over-drying clothes.[68]

Microwave drying also introduces a safety concern related to arcing. Arcing is caused by an electric field which induces a voltage differential between metal objects, allowing current to flow within them. The resultant heating and sparking of the metal objects may ignite a fire in the load. EPRI has developed a rapid-response gas sensor to detect small amounts of gaseous by-products of combustion in the exhaust stream. Upon detection, the drying cycle can be shut down immediately, preventing safety hazards and damage. Another technique to avoid arcing is to switch to electric resistance heaters when the clothes are almost dry.[69]

Modulating Heat

Most gas dryers on the market operate with a single burner at a fixed input rate and a fixed airflow rate in an on/off mode based on the cycle chosen and the temperature of the exhaust flow. Based on a modulating gas dryer design jointly developed by TIAX and Whirlpool, a reduction of energy consumption of up to 25 percent for small and medium loads has been shown. For large loads, a reduction in energy consumption of 10–15 percent has been shown as well as up to 35 percent drying time savings, with no adverse effect on cloth temperature. For delicate loads, modulating gas dryers are able to reduce fabric temperatures as well as dry times, achieving an 18 percent reduction of energy consumption. Along with these performance characteristics, modulating gas dryers would provide robust performance across a range of vent restrictions.[70]

A key consideration in the design of a modulating gas dryer is matching the heat input rate to the moisture level of the load. The design developed by TIAX used a maximum gas input rate of 40,000 Btu/h using two inshot burners firing into a combustion chamber that was larger than in a conventional gas dryer. The gas input rate was able to be modulated to three different levels: (1) high (40,000 Btu/h), (2) medium (rate similar to conventional gas dryers), and (3) low (rate less than half of a conventional gas dryer). The burners were positioned so that they fired into an oval-shaped combustion funnel before turning upwards into the rear duct and entering the drum. A downstream blower was used to induce airflow into the drum. A new funnel/collar/rear duct was designed to deliver evenly distributed and improved air flow to increase efficiency, while being able to be manufactured with minimal modifications to existing plant tooling.[71]

TIAX utilized a variable speed blower to deliver varying airflow rates to match the following general dryer cycles: (1) heavy duty, (2) normal, and (3) delicate. In order to account for airflow changes and resultant pressure drops associated with installation variations, the system used a pressure switch in the exhaust flow stream from the dryer. The blower speed would be increased at the beginning of the dry cycle until the pressure switch was tripped, providing an indication of the level of exhaust restriction.[72]

Control of this system was achieved via a temperature and humidity sensor in the exhaust. Since the flow rate would be known, the temperature in the exhaust would be used to infer the amount of moisture inside the drum. The temperature signal would thus be used to determine when to perform the first and second modulation steps. In addition, this temperature signal, combined with the output from a humidity sensor in the exhaust, could be used to determine the end of the cycle.[73]

Modulating heat can also be implemented in an electric clothes dryer. The electric resistance heater could be accurately controlled by an electronic controller that incorporates a bidirectional triode thyristors (Triacs) or similar solid-state approaches to control the heat output.

Water-cooling, ventless electric only

For this technology option, an internal water-cooled condenser heat exchanger system condenses the water vapor in the air exiting the drum. This design is similar to conventional condenser heat exchanger systems used in clothes dryers in which the exhaust heat is recirculated back to the dryer, except that the cooling fluid is water, not air. On the market in Australia, water-cooled condensers are generally used in combination washer/dryers whereas air-cooled condensers are used in stand-alone dryers. According to a report prepared for the Department of the Environment and Water Resources in Australia, for combination washer/dryers using water-cooled condensers, the amount of water required for condenser cooling can be as much or more than as is used for the wash cycle.[74] In addition, this technology option would require a drain for the removal of condensate as well as plumbing to the supply water. DOE is unaware of any data quantifying potential energy efficiency improvements associated with improved drum design.

Indirect heating

For indirect heating, the clothes dryer heat energy is derived from the home's heating system. This technology option uses a residence's hydronic heater system to heat water which then flows through a heat exchanger in the dryer, heating the air entering the drum. Significant plumbing would be required to circulate heated water through the heat exchanger in the dryer. DOE is unaware of any data quantifying potential energy efficiency improvements associated with indirect heating.

It is possible that a stand-alone hydronic heater could be implemented as a clothes dryers heat source. One source claims that water or other heat transfer fluids could be heated using an immersion element similar to a water heater. The heated fluid passes through a heat exchanger, where the heat is transferred to the air entering the drum, and is then pumped back to the hydronic heater. The source claims that a hydronic heating clothes dryer uses 50 percent less energy and dries the clothing load up to 41 percent faster than conventional clothes dryers.[75]

Improved motor efficiency

Clothes dryers generally use a single motor which functions to turn the drum as well as to power the blower in order to draw air through the drum and out the exhaust vent. The typical clothes dryer uses a 1/3 horsepower four-pole induction motor. Based on DOE testing, about 5 percent of the total electrical energy consumed by a typical clothes dryer is used by the electric motor to drive the drum and the blower. Manufacturers stated that improving the efficiency of the motor can increase overall efficiency by 1 to 5 percent. Manufacturers also indicated that using an electronically-commutated motor (ECM) is very expensive and provides minimal efficiency improvement.

A number of manufacturers indicated that they use separate motors to drive the drum and the blower fan with a permanent split capacitor motor or brushless permanent magnet motor in some models in order to adjust air flow rates based on different exhaust vent installations to improve performance. However, they indicated that because the DOE test procedure uses a standard exhaust simulator (as indicated above), there would be no benefit to efficiency. DOE believes that such a split motor design which can adjust air flow rates implemented designs such as a modulating heater could conceivably improve efficiency.

Improved fan efficiency

Clothes dryers generally use an electrically driven fan blower to draw air through the drum. Increasing the efficiency of this blower could reduce the clothes dryer energy consumption. A blower fan with rear curved blades (as opposed to conventional forward curved blades) could conceivably provide more consistent air flow and improve efficiency. However, DOE is unaware of any data quantifying the potential energy efficiency improvements associated with an improved blower fan, distinct from improvements in its drive motor.

Switching Power Supply

A potential area for standby power improvement is the power supplies on the control board. A typical clothes dryer may use an unregulated plus regulated control board power supply (also referred to as a linear power supply). The unregulated portion consists of a small transformer, a bridge rectifier, and an electrolytic capacitor. Voltage regulators then step down the voltage(s) to the level(s) required by the control logic, display, and cooking sensor. This approach results in a rugged power supply which is reliable, but typically has an efficiency of about 55 percent.

Switching power supplies offer the highest conversion efficiencies (up to 75 percent) and lowest no-load standby losses (0.2 W or less), though at a higher cost, higher part count, and greater complexity. Switching power supplies convert power differently than conventional linear power supplies. Switching power supplies first rectify the alternating current (AC) mains voltage to direct current (DC), converting it back to AC by switching the current on and off at high frequency. The high-frequency AC current passes through the primary winding of a transformer while the output from the secondary winding of the transformer is rectified, resulting in a low-voltage DC output. Because the AC current passing through the transformer is at high frequency, the transformer is smaller and has lower standby losses. Switching power supplies greater complexity may also result in lower overall reliability and take greater care to implement. For example, among other issues, a switching power supply can be prone to causing electromagnetic interference. However, DOE noted in its reverse engineering teardown analysis that there are a large number of clothes dryers on the U.S. market that incorporate switching power supplies.

Transformerless Power Supply for Auto-Powerdown

DOE's reverse engineering teardown analysis suggests that very low standby levels can be achieved by implementing a transformerless power supply for the microprocessor logic, along with a conventional power supply that is activated when the unit goes into active mode. Such a power supply design, incorporated with a "soft" power pushbutton and triac to control power through the transformer, would provide just enough power through the transformerless power supply to maintain the microcontroller chip while the clothes dryer is not powered on. When the power button is pressed, current would then be allowed to pass through the transformer of the conventional power supply to power the remainder of the control board. DOE is unaware of any data indicating the reliability of such a design.

3.15.2.2 Room Air Conditioners

For **room air conditioners**, DOE considered technologies identified in its last standards rulemaking that culminated in the September 24, 1997, final rule. 62 FR 50122. With the exception of microchannel heat exchangers and hydrophilic-film coating on fins, DOE has determined that the technologies listed in Table 3.15.2 have not changed appreciably since DOE's TSD was published in September 2007. With regard to microchannel heat exchangers, research conducted at the University of Illinois has demonstrated that this technology can be applied to room air conditioner applications.[76] Hydrophilic-film coating on fins was identified in an analysis of energy efficiency in Chinese room air conditioners conducted jointly by Lawrence Berkeley National Laboratory, the China National Institute of Standardization (CNIS), and the Beijing Energy Efficiency Center (BECon).[77]

Table 3.15.2 Technology Options for Room Air Conditioners

Increased Heat Transfer Surface Area	**Technology Passed to Screening Analysis?**
1. Increased frontal coil area	Yes
2. Increased depth of coil (add tube rows)	Yes
3. Increased fin density	Yes
4. Add subcooler to condenser coil	Yes
Increased Heat Transfer Coefficients	
5. Improved fin design	Yes
6. Improved tube design	Yes
7. Hydrophilic-film coating on fins	Yes
8. Spray condensate onto condenser coil	Yes
9. Microchannel heat exchangers	Yes
Component Improvements	
10. Improved indoor blower and outdoor fan efficiency	Yes
11. Improved blower/fan motor efficiency	Yes
12. Improved compressor efficiency	Yes
Part-Load Technology Improvements	
13. Two-speed, variable-speed, or modulating-capacity compressors	Yes
14. Thermostatic or electronic expansion valves	Yes
15. Thermostatic cyclic controls	Yes
Standby Power Improvements	
16. Switching Power Supply	Yes
Refrigeration System Options	
17. Alternative Refrigerants (R-407C)	No
18. Suction-Line Heat Exchanger	No

As shown in Table 3.15.2, design improvements to improve energy efficiency can be categorized according the following six methods: increasing heat transfer performance by either increasing heat transfer surface area or the heat transfer coefficients, improvements upon individual components, part-load technology improvements, standby power improvements, and refrigeration system options.

Technology options that are intended to improve efficiency under cycling or part-load conditions cannot be evaluated under the current DOE test procedure which specifies steady-state test conditions. Technology options such as variable speed compressors, electronic expansion valves, and cyclic controls improve efficiency in central air-conditioning (CAC) systems. CAC products are rated using a seasonal efficiency metric (the seasonal energy efficiency ratio, SEER), which takes into account the efficiency of the product while operating under part-load conditions. However, CAC operating conditions are different than those experienced by room units. CAC units typically are generally active during the entire cooling season, ready to be turned on by the thermostat when there is a call for cooling. In contrast, room air conditioners are generally turned on when the room temperature is high, thus reducing the amount of cycling as compared to CAC systems. Manufacturers have commented that room air conditioners have become a commodity item that is typically undersized for the room in which it is installed, and thus increasing their tendency to operate mostly in on/off mode. Measurement of part load efficiency has not been integrated into the room air conditioner efficiency metric, because of the low probability that greater use of part-load technologies will be used and/or will save energy. Hence, the potential for energy-savings benefits from technology options that reduce energy consumption during part load conditions cannot be evaluated using the new efficiency metric, CEER, on which the engineering analysis is based.

DOE added technology options 17: R-407C as a refrigerant, and 18: Suction-Line Heat Exchanger (SLHX) in response to stakeholder comments during the preliminary phase of the rulemaking.

Table 3.15.2 indicates which technologies DOE considered suitable for further analysis. These are the technologies that DOE passed to the screening analysis for further review. The reasons that certain technologies were not passed to the screening analysis are provided in the individual technology descriptions below.

Technologies Passed to the Screening Analysis

Increased frontal coil area

One of the most common ways of increasing heat transfer surface area is by using a coil with a larger frontal area. With a greater amount of coil face area, the heat transfer performance of the coil is increased. For the condenser, the required heat can be rejected from the refrigerant to the outside air stream at a lower condensing temperature. For the evaporator, the specified cooling capacity can be delivered to the room at a higher evaporator temperature. These changes reduce the pressure difference between the low pressure and high pressure sides of the system which the compressor must overcome, thus reducing compressor power input. However, a trade-off associated with increased evaporating temperature is that the evaporator’s ability to dehumidify the air may be compromised.

Increase of coil frontal area is limited in many situations by the size constraints for the room air conditioner, particularly for large-capacity and through-the-wall products (*i.e.*, products without louvered sides).

Increased depth of coil (add tube rows)

Heat transfer surface area may also be increased by adding rows of tubes to the coil. In the previous rulemaking, manufacturers asserted that each room air conditioner chassis is designed for a maximum-depth evaporator and condenser. Vertical tube rows may be added up to that maximum depth, however adding more rows would require an increase in the size of the chassis, which incurs significant costs beyond just the costs of the larger heat exchanger.

Other issues associated with increase of heat exchanger depth include the need to minimize weight, the added refrigerant charge, decreasing improvement associated which each additional tube row, and the airside pressure drop. With regard to weight, manufacturers claimed that there is a practical limit to the depth of a room air conditioner which is related to weight, appearance, and strength of the mounting. The increase in refrigerant charge combined with the increased effectiveness of the heat exchangers can lead to risk of compressor failure. The room air conditioner may require a smaller-capacity compressor to meet the specified cooling load. Smaller compressors have lower refrigerant charge limitations to avoid problems such as oil frothing during startup, so the changes could impact the reliability of the compressor. Manufacturers asserted in the previous rulemaking that each successive row in a coil is only about 70 percent as effective as the preceding row, thus adding rows to a three- or four-row heat exchanger has a small effect on system efficiency. Finally, increasing heat exchanger depth can reduce air flow, which can negate any benefit associated with the additional heat exchanger surface area.

Increased fin density

Another method of increasing the heat transfer surface area is to increase the fin density. Increased fin density improves the heat transfer; however, its effect on air flow, fan power, water drainage, and dirt build-up places a limit on how much the density can be increased.

Fin density has a direct effect on the fan power required to draw or blow air over the coil. Increasing the fin density increases the air-side pressure drop over the coil, resulting in more power being used by the fan motor. Any reduction in air flow can negate the improvement in heat transfer associated with increased fin density. Increased fin density also can increase water retention in the evaporator. The condensate that forms on the evaporator must flow down to the drain pan by the effect of gravity. Increased fin density can limit the condensate flow, which can restrict air flow and lead to entrainment of water droplets in the discharge air flow. The build-up of dirt on heat exchanger surfaces is accelerated by an increase in fin density. Smaller air passageways through the coils are more likely to retain dirt which, if allowed to accumulate over a unit's life, decrease the system performance. Taking these factors into consideration the maximum fin density is a function of the type of coil (*i.e.*, evaporator or condenser), the fin type (*i.e.*, wavy, louvered, or enhanced), the number of tube rows, and the tube diameter.

Add subcooler to condenser coil

Subcoolers are added between the condenser coil outlet and the capillary tube inlet and are submerged near the condenser in the condensate produced by the evaporator. Adding a subcooler effectively increases the size of the condenser coil as it further cools the refrigerant coming out of the condenser. However, finding the space to incorporate a subcooler into a room air conditioner can be difficult..They are used much more frequently in larger-capacity units, which have more space for them.

In the previous rulemaking, manufacturers supplied data for evaluating subcoolers as a design option. The data from the 1997 TSD analysis is recreated in Table 3.15.3, which shows the manufacturer test results on the performance improvements due to adding a subcooler. Using a representative baseline for each product class, specifications were given on how large a subcooler could be to be incorporated into the existing baseline design. In addition, manufacturers provided test data detailing the effect on capacity, power consumption, and efficiency due to the addition of a subcooler. For each product class, the percentage change in efficiency was used to establish the efficiency gain due to adding a subcooler. Test data was not provided for classes with reverse cycle.

Table 3.15.3 Manufacturer Test Results from 1997 TSD Analysis: Performance Improvements due to Subcoolers

Product Class	Before Subcooler Added		Percent Change with Subcooler Added (%)		
	Capacity *(Btu/h)*	**EER *(Btu/W-h)***	**Capacity *(Btu/h)***	**Power *(kWh)***	**EER *(Btu/W-h)***
Louvered side w/o reverse cycle less than 6,000 Btu/h	6,338	9.19	1.0	-2.0	2.9
Louvered side w/o reverse cycle 6,000 to 7,999 Btu/h	7,461	8.50	1.7	-1.3	3.0
Louvered side w/o reverse cycle 8,000 to 13,999 Btu/h	9,984	9.20	-0.8	-1.1	1.0
	11,668	9.00	0.8	-0.9	1.8
Average Change for Product Class:			0.0	-1.0	1.4
Louvered side w/o reverse cycle 14,000 to 19,999 Btu/h	18,351	9.70	2.0	0.0	2.1
	18,984	9.70	1.5	-0.2	1.6
	17,954	9.71	1.1	-0.3	1.4
Average Change for Product Class:			1.5	-0.2	1.7
Louvered side w/o reverse cycle greater than 20,000 Btu/h	24,319	8.00	0.9	-1.0	1.9
	34,947	8.00	0.3	-0.6	1.0
Average Change for Product Class:			0.6	-0.8	1.5
No louvered side w/o reverse cycle 6,000 to 7,999 Btu/h	6,204	8.91	0.5	-1.3	1.8
No louvered side w/o reverse cycle 8,000 to 13,999 Btu/h	11,300	8.51	0.2	-2.6	2.8

A study for the Directorate-General for Energy (DGXVII) of the Commission of the European Communities used a simulation model to calculate the impact of individual technology options on a room air conditioner's performance. The results of the simulation showed that the addition of a subcooler to the condenser coil resulted in a 1 percent average increase in EER.[78]

Improved Fin Design

Improvements to the fin design may have the effect of improving the coil's air-side heat-transfer coefficient, and thus improving the overall heat-transfer capability of the coil. This improvement can be due to the increase in air turbulence over the coil caused by the enhanced fin design. Manufacturers commented in the previous rulemaking that most room air conditioners use some form of fin enhancement in their coil designs already. This fin improvement is generally achieved by using louvered, lanced, or slit-type fin surfaces.

Specific attention to evaporator design regarding condensate runoff and fin patterns may increase room air conditioner energy efficiency. It is useful for the evaporator to be designed such that condensate runs off effectively and does not adhere to the surface. In addition to allowing less entrainment of liquid droplets into the air stream, effective condensate runoff results in higher heat transfer between the evaporator and the air and allows higher air flow, thus increasing evaporator performance.

Improved Tube Design

Improvement of the refrigerant-side heat-transfer coefficient is accomplished by augmenting the inside surface of the refrigerant tubes with spiral grooves. This type of refrigerant tubing is known as rifled or grooved tubing. Research has shown that the refrigerant-side heat-transfer coefficient for grooved tubing is significantly greater than that of conventional smooth tubing. As seen with fin enhancements, manufacturers of refrigerant tubing have developed various types of grooved tubing to improve the heat-transfer capability of air conditioning coils. Improvement to the refrigerant-side heat-transfer coefficient is a function of width, height, and spacing of the grooves as well as the concentration of lubricant oil being circulated within the refrigerant. As discussed in the 1997 TSD, statistical equations have been developed which can predict the benefits of rifling.[79]

Hydrophilic-film coating on fins

The condensate water that forms on heat exchanger fins may adhere to the surface as droplets and cause bridging of the fin spacing, resulting in decreased heat transfer performance and increased air pressure drop. Adding a hydrophilic coating to heat exchanger fins gives them an affinity for water, which reduces the condensate layer thickness. This helps the water to flow down the fins and fall off the evaporator quickly, resulting in reduced air-side pressure drops and increased airflow rates across the heat exchanger.[80] Hydrophilic-film coating on heat exchanger fins have been shown to reduce air-side pressure drop 20 to 50 percent when operating with high-humidity room-side air. DOE is unaware of any publicly available data quantifying the energy efficiency improvements associated with hydrophilic-film coating on fins under normal room air conditioner operating conditions.

Spray condensate onto condenser coil

The condensate that forms on and drips off of the evaporator coil is collected in a condensate pan. Part of the pan is positioned near the condenser and is placed directly underneath the condenser fan. The condenser fan is equipped with a slinger ring, which is located at the fan blade tips and is able to collect and spray the condensate onto the condenser coil as the fan rotates. The spray provides evaporative cooling to enhance the performance of the condenser.

Microchannel heat exchangers

Unlike a conventional coil tube with an attached plate fin, microchannel heat exchangers have a rectangular aluminum cross-section containing several small channels (typically less than 1 millimeter across) through which refrigerant passes. Aluminum fins are brazed between the rectangular tubes. Microchannel can increase heat transfer while reducing pressure drop as compared with conventional coils. Microchannel heat exchangers generally weigh less and hold significantly less refrigerant than conventional heat exchangers.

Currently there are several manufacturers of microchannel heat exchangers. The technology was first used in automobile air conditioning systems, where it is used almost exclusively for condensers. Other air-conditioning applications are adopting the technology, particularly in applications requiring reduced size and weight. These include military environmental control units (ECUs), air-cooled chillers for commercial buildings, and some residential central air conditioning systems. However, microchannel heat exchangers have not yet been adopted by room air conditioner manufacturers. A key issue for use in room air conditioner applications is the much higher investment cost required for the equipment needed to fabricate these heat exchangers (*i.e.*, brazing ovens) as compared with equipment used for fabrication of conventional heat exchangers.

Microchannel heat exchangers have traditionally had difficulty in evaporator applications, because their geometry is less amenable to condensate removal than conventional heat exchangers. When installed with the headers oriented vertically, the horizontal flat fins between fin sections block gravity flow of condensate. Also, even distribution of expanded two-phase refrigerant into the many parallel flow paths through the tubes is challenging. While these issues can be alleviated by orienting the evaporator with the headers horizontal, such an orientation is undesirable for many applications.

Research has compared the performance of a window-mounted room air conditioner with microchannel condensers to a baseline system with a conventional finned-tube condenser. The results showed the heat transfer rates per unit core volume of the microchannel heat exchangers were 14 to 331 percent higher than the conventional finned-tube heat exchangers. However, the overall efficiencies of two systems using the microchannel condenser heat exchanger were 1 to 3 percent lower than the baseline system. The lower efficiencies attained by this work were believed to be due in part to the un-optimized condensate slinger ring and smaller subcooling of the microchannel systems. The results did show reductions in refrigerant charge, condenser core volume, and weight of 35, 55, and 35 percent, respectively, using microchannel condensers.[81]

Improved indoor blower and outdoor fan efficiency

The air delivery system of a room air conditioner consists of one motor driving two fans, the indoor blower (evaporator), and outdoor (condenser) fans. The evaporator blower is typically a centrifugal blower, while the condenser fan is a propeller-type fan with a slinger ring attached to it. As mentioned earlier, the slinger ring sprays condensate onto the condenser coil. Improvements to the fan designs to improve air flow characteristics could increase the overall efficiency by decreasing the power demands for the fan motor.

Fans and blowers are generally molded plastic parts with fairly advanced geometries as compared with stamped sheet metal designs of the past. The condenser fan is mounted with reasonable clearance to the fan orifice, which is typically sheet metal which may have a formed bell mouth in the region of the fan blade tips. The evaporator blower is generally housed inside a Styrofoam enclosure which is shaped to provide smooth flow of air into and out of the blower. The Styrofoam doubles as thermal isolation between the indoor and outdoor sides of the unit.

Air system efficiency could possibly be improved through more advanced fan and blower design. It could also be improved by reducing the restrictions to air flow. However, the space limitations within room air conditioners make reduction of flow resistance difficult. Adjustments to the designs of the heat exchangers can affect air flow, as discussed in the sections addressing heat exchangers above.

Improved blower/fan motor efficiency

Room air conditioners primarily use permanent split capacitor (PSC) fan/blower motors. These motors range in efficiency from 45 to 70 percent. While larger motors are generally more efficient, there is a range of efficiency for any given power level.

Electric motors operate based on the interaction between a field magnet and a magnetic rotor. However, single-phase motors only produce a rotating magnetic field when the rotor is rotating, and simply powering the electromagnet is therefore not sufficient to start such a motor. One of the most significant differences between different types of single-phase motors is the way in which they handle start-up. In a PSC motor, a small start-up winding is present which is energized out of phase with the main winding. 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. PSC motors are produced in large quantities and are relatively inexpensive.[82]

Permanent magnet motors have higher efficiencies than PSC motors. For the purposes of this report, they will be called brushless DC (BLDC) motors. They are also known as ECMs, brushless permanent magnet (BPM) motors, and electronically-commutated permanent magnet (ECPM) motors. BLDC motors are more efficient than PSC motors. BLDC motors convert single-phase AC input power into DC power and achieve the commutation required for operation of DC motors by electronic switching rather than through use of a conventional mechanical commutator. The commutation is coordinated through use of sensor technology that determines when the motor is at the proper angle for switching the power. BLDC motors have efficiencies approaching 80 percent.[83] However, BLDC motors can weigh more than PSC motors of the same shaft power, potentially necessitating a redesign of the room air conditioner chassis to accommodate the increased weight. In addition, BLDC motors are more expensive than PSC motors.

Improved compressor efficiency

Most room air conditioners are now made with hermetic rotary compressors. Rotary compressors have displaced reciprocating compressors, because they are smaller, weigh less, and have reduced noise and vibration. Compressors for room air conditioners traditionally used a hydrochlorofluorocarbon (HCFC) refrigerant, designated HCFC-22. Maximum rotary compressor efficiencies for HCFC-22 refrigerant range from 10.7 to 11.2 EER. However, due to the phaseout of HCFC-22 for new products that took place starting in 2010, room air conditioners have switched to R-410A refrigerant, which is a blend of hydrofluorocarbon (HFC) refrigerants that do not contain chlorine. The room air conditioner market has lagged central air conditioners in the transition to R-410A. Compressor manufacturers have developed rotary compressors for the new refrigerant, but the product lines initially available did not span the applicable capacities and efficiency levels for room air conditioners fully. Hence, while room air conditioner manufacturers may have had multiple compressor options of varying EER to consider in the design of a unit using HCFC-22, there may initially have been only one option with appropriate capacity for the design of a unit using R-410A. This compressor availability issue improved as 2010 arrived, and is expected to improve further. Also, the thermodynamic efficiency of R-410A is not as high as that of HCFC-22 at operating conditions typical for rating of room air conditioner performance.

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 orbiting. Scroll compressors EERs for HCFC-22 refrigerant range from 10.8 to 11.2 for the capacities of interest for larger room air conditioners. Scroll compressors are generally 1 to 2 inches taller than rotary compressors, and therefore are better suited for larger units.[84] Scroll compressors can be larger and heavier than their rotary counterparts. Thus, incorporating these compressors may require larger chassis sizes and bracing to accommodate the increased size and weight.

Switching Power Supplies

A potential area for standby power improvement for room air conditioners is the power supply on the control board. As with clothes dryers, a typical room air conditioner may use an unregulated plus regulated control board power supply, with voltage regulators stepping down the unregulated voltage(s) to the level(s) required by the control logic, display, and remote control sensor. As noted previously for clothes dryers, this approach results in a rugged power supply which is reliable, but typically has an efficiency of about 55 percent. The power supply accounts for the majority of the energy consumed by the control board in inactive mode. DOE's room air conditioner reverse engineering showed that the majority of the inspected units used this type of power supply.

Power supply efficiency may be improved, at higher cost and complexity, with the use of switching power supplies. For a complete discussion of switching power supply function and efficiency, see section 3.15.2.1 for the comparable clothes dryer technology option. Based on DOE's reverse engineering, described in chapter 5 of this TSD, DOE determined that room air conditioners with switching power supplies consume approximately 0.7 W in standby mode, a roughly 50 percent power savings as compared with standby power consumption with linear power supplies.

Two-speed, variable-speed, or modulating-capacity compressors

Most conventional single speed compressors run at a constant speed and vary their capacity by cycling on and off in response to the thermostat. The efficiency of systems using these compressors is typically lower than full-capacity efficiency at part load, due to off-cycle losses. 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 capacity, allowing the air conditioner to match the cooling load. This can improve efficiency by eliminating off-cycle losses and because, when operating with the lower mass flow at part load, the heat exchangers are more effective. There are non-energy advantages to variable-speed control, including quieter operation at low speeds, enhanced comfort by eliminating temperature fluctuations in the room, and potential for improved dehumidification.

The control of variable-speed compressors is accomplished through the use of electronic adjustable-speed drives (ASDs) at the motor. Because electronic ASDs require no drive-train in order to be coupled to the motor, they can be used with the sealed refrigeration systems used in room air conditioners. ASDs can be designed for use with induction motors or with permanent-magnet brushless motors. There are two inverter types that are applicable to induction motors typically used in room air conditioner compressors: voltage source (VSI) and pulse-width modulated voltage source (PWM) inverters. In either case, the input AC power supply is first converted to DC by using a solid-state rectifier. This DC signal is then converted to a variable-frequency AC waveform by the inverter and supplied to the motor. The speed of the motor is roughly proportional to the frequency.[85]

A recently developed method for modulating capacity in scroll compressors is intermittent discharge. This technology utilizes a pressure control system in which a solenoid valve opens, relieving the pressure on the back side of a piston. This spring-loaded piston is connected to the rotating scroll, and the scroll-piston system is then displaced once the backpressure is removed. This displacement disengages the scrolls, leaving the driveshaft free to rotate without any compression taking place. Modulating the time in which the scrolls are engaged allows capacity to be varied from 10 to 100 percent of maximum. Intermittent discharge technology, however, is only applicable to scroll compressors, and is a proprietary approach.[r]

There are no obvious technical barriers to use of variable-speed compressors in room air conditioners. ASDs have been demonstrated to perform well with both rotary and scroll compressors. The heat pump market in Japan is now dominated by split systems equipped with variable-speed rotary compressors. Based on an initial US market survey, a number of manufacturers offer split system air conditioners equipped with inverter systems using variable speed compressors. The most common motor used in this application is an induction motor. But the HVAC industry is now showing a strong interest in brushless permanent magnet motors due to their high efficiency.

As stated earlier, technology options that primarily improve efficiency on a seasonal basis will not demonstrate any efficiency improvements according to the current DOE test procedure which specified steady-state conditions. The greatest benefit of variable speed systems is to save energy on a seasonal basis. Because tests have not been performed to determine the amount of cycling in room air-conditioners, the potential magnitude of seasonal energy savings in room air units is not well understood. Research has demonstrated that energy savings from 15 to 40 percent are attainable in central air conditioning systems.[86,87,88] In the previous rulemaking, DOE estimated that the implementation of variable-speed compressors in room air-conditioners could achieve an energy savings of approximately 10 percent.[89] However, comments received from manufacturers subsequent to the Framework Document public meeting of this current rulemaking indicate that room air conditioners are typically purchased oversized relative to the conditioned space, indicating that they would operate in on/off mode and thus preclude the energy savings associated with variable-speed systems.

Thermostatic or electronic expansion valves

Manufacturer interviews and DOE's reverse engineering indicate that the capillary tube is the flow control device that is currently used by all room air conditioners. The capillary tube is a pressure-reducing device that consists of a small-diameter tube that connects the outlet of the condenser to the inlet of the evaporator. The very high pressure drop as refrigerant flows through the capillary allows the high and low pressures in the system to be maintained. Since it is a fixed device, the capillary tube provides optimum system operating parameters over a narrow range of operating conditions.

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

[r] For more information, please visit *www.digitalscroll.com/digitalweb/english/howitworks.htm*

due to variations in ambient temperature, which affect the condensing temperature. As a result, TXVs can control for optimum system operating parameters over a wider range of operating conditions, and can thus improve seasonal efficiency.

Electronic expansion valves (EEVs) are similar to TXVs, but they operate using electronic (microprocessor) control. The EEV uses a pulse motor, which rotates based on an electronic signal from a microcomputer determining the desired valve position from measured system parameters. While a TXV is limited due to its thermo-mechanical design, there is greater flexibility for operation of an EEV. Research has demonstrated that, when incorporated into air-conditioning systems using inverter-driven variable-speed compressors, EEVs improve seasonal energy efficiency beyond that of systems using conventional TXVs. As with variable speed compressors, the main benefit of electronic expansion valves is to improve efficiency on a seasonal basis. DOE is aware of a patent describing a room air conditioner using an electronic expansion valve[90] but is not aware of any publications describing prototype testing to evaluate the efficiency improvement potential of this technology.

Thermostatic cyclic controls

Remote thermostatic cyclic controls more accurately monitor room temperature than typical built-in thermostats. Research has been conducted to investigate the use of fuzzy logic controllers for HVAC applications. These controller types have been shown to improve the performance of HVAC systems over that of conventional controllers. Thermostatic controls could offer seasonal energy savings.

As with variable speed compressors and expansion valves, the DOE test procedure can only measure energy efficiency improvements based on steady-state conditions. In addition, no data were found or presented that indicated how the performance of room air conditioners could be enhanced with thermostatic cyclic controls.

Technologies Not Passed to the Screening Analysis

DOE identified the following technologies as potentially providing opportunity for energy savings. However, as described individually for each of the technologies, DOE determined that these technologies were not suitable for consideration for the engineering analysis because sufficient data are not available to demonstrate that the technologies save energy as compared to current products.

R-407C Refrigerant

R-407C is a blend of HFC refrigerants that could be considered for use in room air conditioners instead of R-410A. In response to stakeholder comments during the preliminary analysis phase, DOE conducted preliminary modeling of R-407C room air conditioner systems, using the MarkN analysis tool used for energy modeling.[s]

DOE conducted this R-407C assessment using five room air conditioner energy models developed as part of the engineering analysis. These energy models represent product classes 1, 3, and 5, all product classes with louvered sides and without reverse cycle, with varying capacities (5,000 Btu/h, 8,000 Btu/h, 12,000 Btu/h, 24,000 Btu/h, and 28,000 Btu/h). The development of energy models for these products is described in section 5.9.2.4 in chapter 5 of the TSD. DOE compared identical designs for these products, operating with both R-410A and R-407C. These designs represent drop-in of R-410A and/or R-407C in a product designed for HCFC-22. Figure 3.15.2 shows the modeling results of R-410A and R-407C with the MarkN model. In each product class, the efficiency of the R-407C system was notably lower than the respective R-410A system. These analyses don't definitively indicate that R-407C could not provide any efficiency benefit as compared to R-410A, because the systems were optimized for neither of these refrigerants for this analysis. However, they do provide an indication that R-407C does not provide clear improvement.

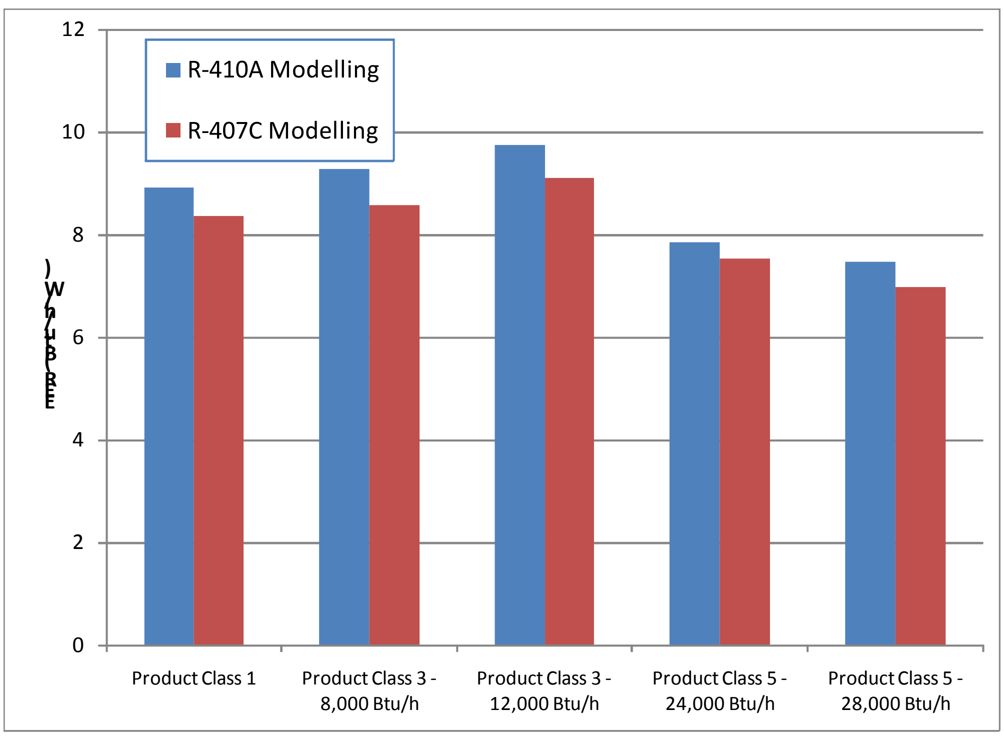

Figure 3.15.2. Modeling of R-407C compared to R-410A

[s] The MarkN energy model is discussed in chapter 5, "Engineering Analysis", of the TSD, in section 5.9.2.4.

The room air conditioning industry has switched to R-410A in response to EPA requirements banning use of HCFC-22 starting in 2010. 74 FR 66412, 66418 (December 15, 2009). Based on discussions with manufacturers during both preliminary analysis and final rule phase interviews, there was no indication that any manufacturers would instead consider use of R-407C refrigerant as a potentially more efficient option. DOE concluded that it is not realistic to expect the industry to transition away from R-410A in response to more stringent efficiency standards. Hence, DOE's analysis was based on industry's continued use of R-410A, and alternatives such as R-407C were not considered as design options.

Liquid-Line to Suction-Line Heat Exchangers

In response to stakeholder comments during the preliminary analysis phase, DOE investigated the use of suction-line heat exchangers (SLHX). These heat exchangers cool the refrigerant leaving the condenser (or leaving the subcooler, if the refrigeration circuit has a subcooler) by simultaneously warming the refrigerant vapor leaving the evaporator. This increases capacity, but also increases compressor power input, since the warmer refrigerant vapor returning to the compressor has greater volume. However, for some refrigerants, the technology can improve efficiency.

The preliminary phase comments of the California Investor-Owned Utilities (IOUs) cited a study conducted by the National Institute of Standards and Technology (NIST) investigating the use of LSHX.[t] This study reports an EER improvement using a SLHX of 1.0 percent for an outdoor temperature of 95 °F, which is used in the DOE energy test. These results were obtained in a modeling study using the NIST vapor-compression model CYCLE 11. There is no indication in the paper that the simulations address room air conditioners, since it does not mention outdoor air moisture content, which would be an important parameter affecting performance of room air conditioners. While the simulations show a potential for slight performance improvement, questions about the applicability of the assessment remain, because it is not clear that the simulations are applicable for room air conditioners and the because the results were not validated experimentally.

DOE notes that use of SLHX raises the temperatures of the incoming vapor to the compressor, which raises the temperature of the compressor. Warmer compressor temperature will generally reduce compressor lifetime, since heat-sensitive compressor components are designed for specified life when operating under specific conditions. Compressor suction temperatures are typically close to 65 ˚F in room air conditioners operating under DOE test conditions. This is also typically the highest allowable steady-operating suction temperature for R-410A rotary compressors, based on compressor specifications obtained from compressor vendors. A SLHX operating at close to 50% effectiveness (as analyzed in the NIST study) would raise suction temperature roughly 20 ˚F, thus significantly exceeding the specified limit.

[t] "Performance of R-22 and its Alternatives Working at High Outdoor Temperatures." Eighth International Refrigeration Conference at Purdue University, West Lafayette, IN – July 25-28, 2000 pp. 47-54

During interviews conducted during the preliminary and final rule analysis, manufacturers did not indicate that SLHX could be used to improve system performance.

Because of concerns regarding impacts on product life and reliability, and the fact that manufacturers did not indicate that this technology can be used to improve efficiency, DOE did not consider SLHX as a design option in its engineering analysis.

3.15.3 Energy Efficiency

In preparation for the screening and engineering analyses, DOE gathered data on the energy efficiency of residential clothes dryers and room air conditioners currently available in the marketplace. This data is taken from databases maintained by a variety of regulatory agencies. While this section is not intended to provide a complete characterization of the energy efficiency of all appliances currently available and in use, it does provide an overview of the energy efficiency of each product covered by this rulemaking.

3.15.3.1 Residential Clothes Dryers

The CEC publishes a list of "certified" residential clothes dryers. Figure 3.15.3 through Figure 3.15.5 display the distribution of clothes dryers in the CEC database that are currently available on the market as a function of EF for electric standard and compact dryers, gas dryers. Each graph also shows the current federal energy conservation standard. All of the dryer models listed in the CEC database meet or are above the current standard level, if one exists for the product class. There are also no ventless clothes dryer models listed in the CEC database since there is no accepted way of rating the performance of such dryers.

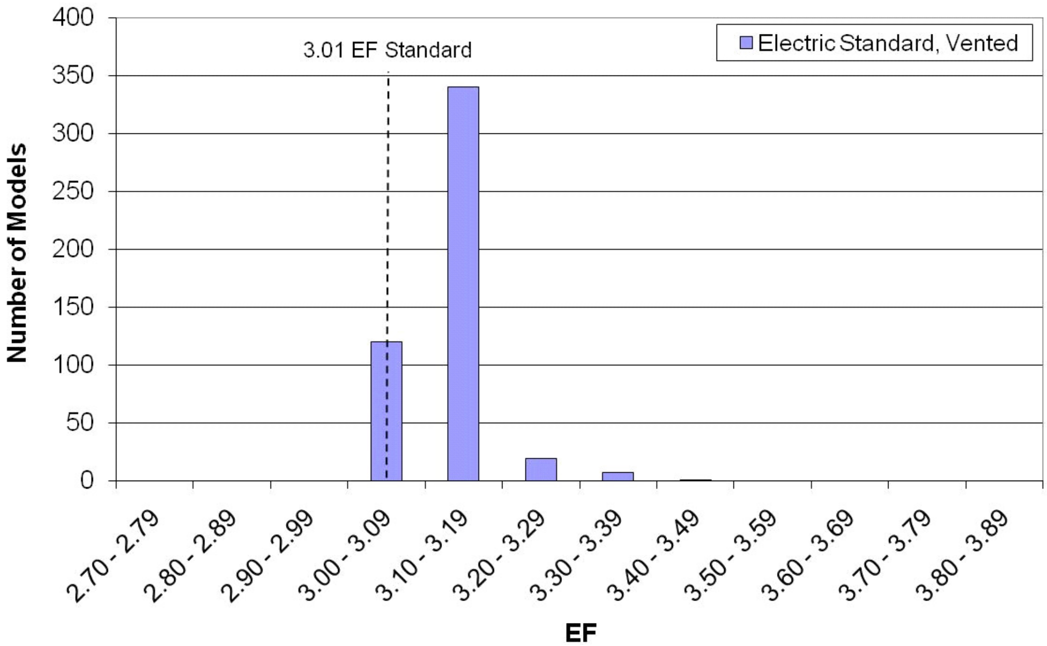

Figure 3.15.3 Electric Standard Capacity Clothes Dryers in the CEC Directory[91]

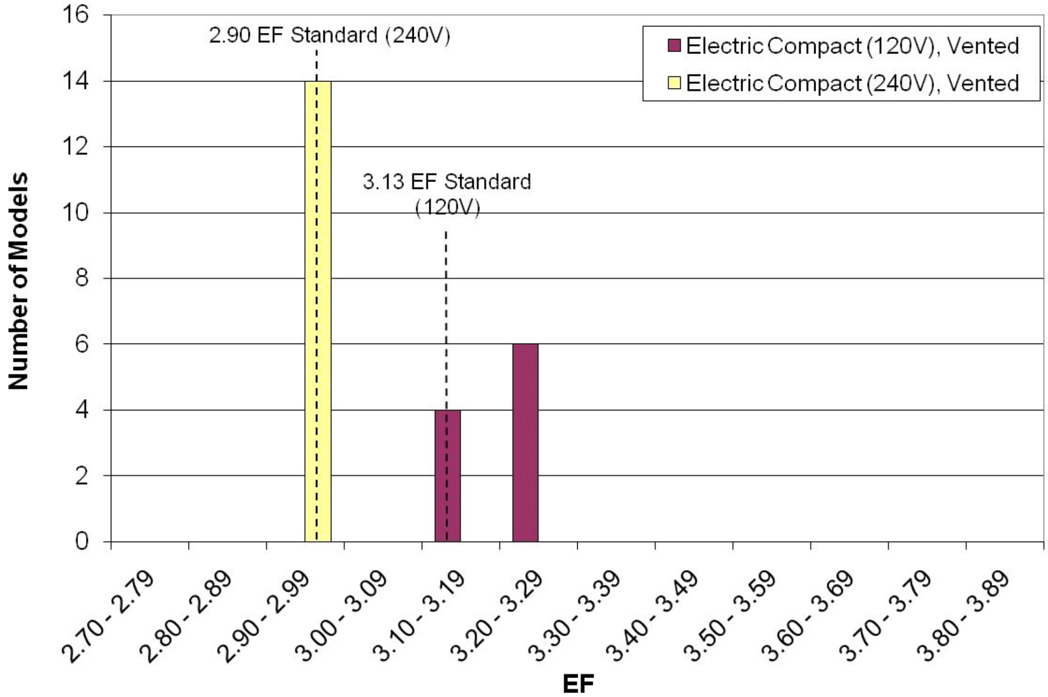

Figure 3.15.4 Electric Compact Capacity Clothes Dryers in the CEC Directory[92]

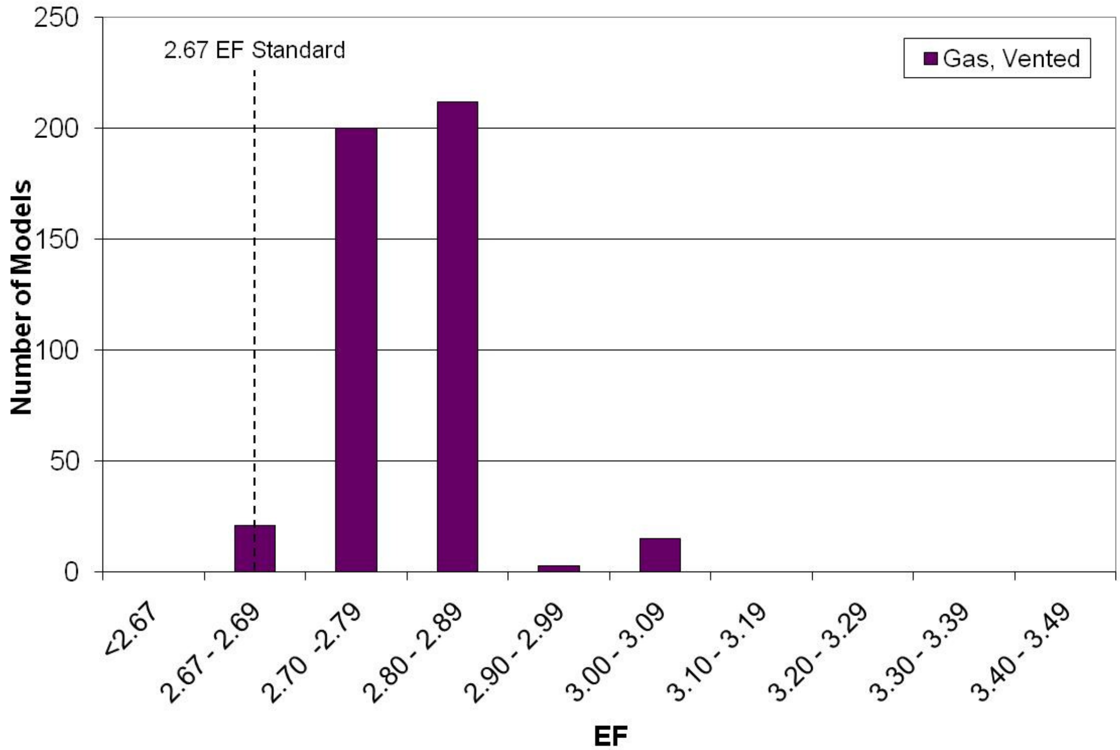

Figure 3.15.5 Gas Clothes Dryers in the CEC Directory[93]

AHAM submitted market share efficiency data for residential clothes dryers. Table 3.15.4 and Table 3.15.5 present the market share efficiency data for electric standard and gas dryers, respectively. AHAM noted that, in order to maintain confidentiality, market share for electric standard dryers between EF of 3.20 and 3.29 were incorporated into the EF range between 3.10 and 3.19. Similarly, market share for gas clothes dryers with an EF > 2.94 was incorporated into the EF > 2.85 efficiency bin.

Table 3.15.4 Residential Clothes Dryer Market Share Efficiency Data for Electric Standard Dryers[94]

EF	Market Share *(%)*	
	2005	**2006**
3.01 – 3.09	26	33
3.10 – 3.29	74	67

Table 3.15.5 Residential Clothes Dryer Market Share Efficiency Data for Gas Dryers[95]

EF	Market Share *(%)*	
	2005	**2006**
2.67 – 2.74	25	28
2.75 – 2.84	42	44
> 2.85	32	27

3.15.3.2 Room Air Conditioners

Although not completely representative of the entire current room air conditioner market, CEC, ENERGY STAR[u] and AHAM publish lists of "certified" room air conditioners. The AHAM Room Air Conditioner Certification Program verifies the cooling and heating capacity rating, amperes, and EER of each listed room air conditioner as tested by an independent laboratory.[v] DOE consolidated the three databases and reviewed all of the listed room air conditioners, searching websites of the manufacturers and retailers to verify whether the products are still active. DOE conducted this investigation in August 2008.

Figure 3.15.6 through Figure 3.15.9 show the EER versus the capacity of each room air conditioner listed in the consolidated database. Each graph illustrates the current federal energy conservation standard, which became effective on October 1, 2000. The screening of products which are no longer available removed many old products, but some of the products still had reported EER below the current federal standards. These may have erroneous EER listings, or have model numbers identical to updated products. In any case the exhaustive screening of the products in the databases clearly was not sufficiently thorough to eliminate all outdated entries.

[u] For more information, please visit *www.energystar.gov*.

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

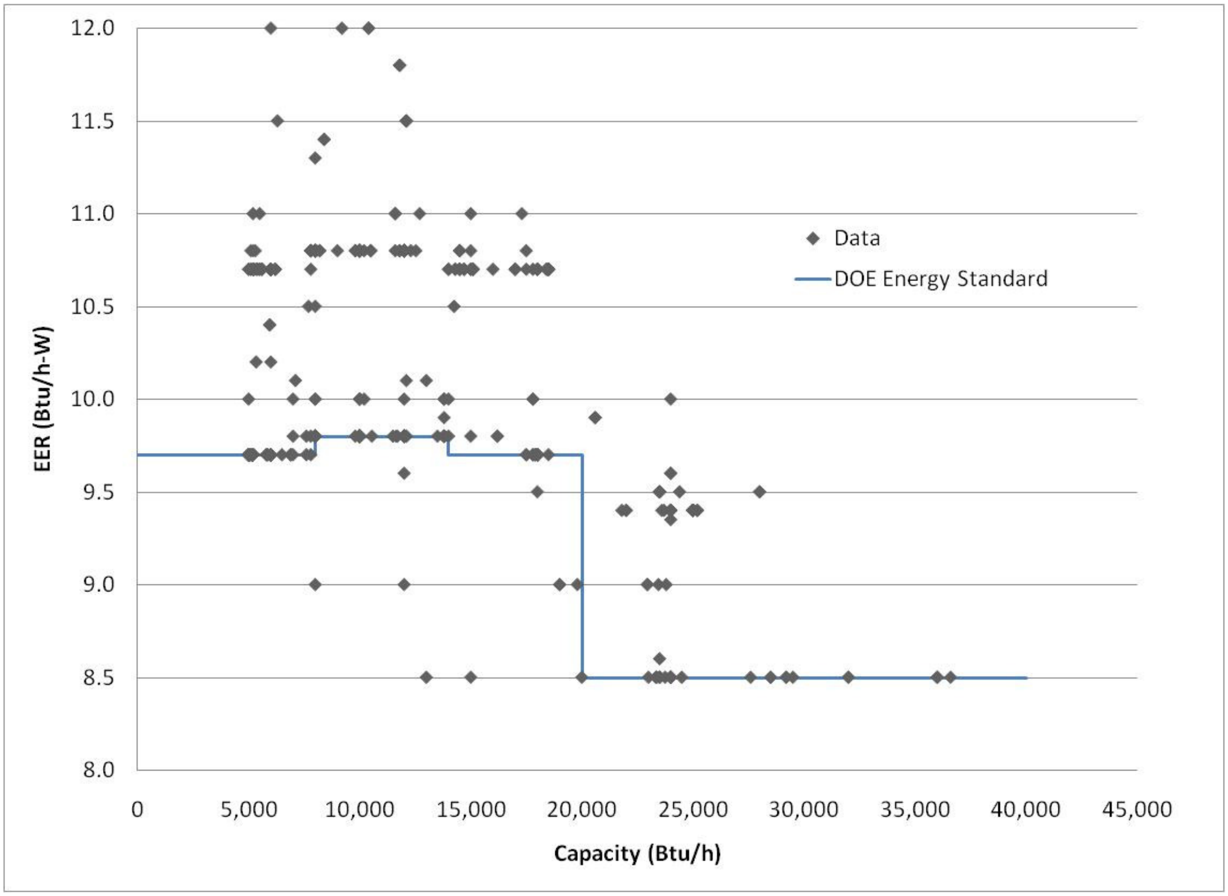

Figure 3.15.6 CEC, AHAM, and ENERGY STAR Certified Room Air Conditioners without Reverse Cycle and with Louvered Sides (Product Classes 1–5) [96, 97, 98]

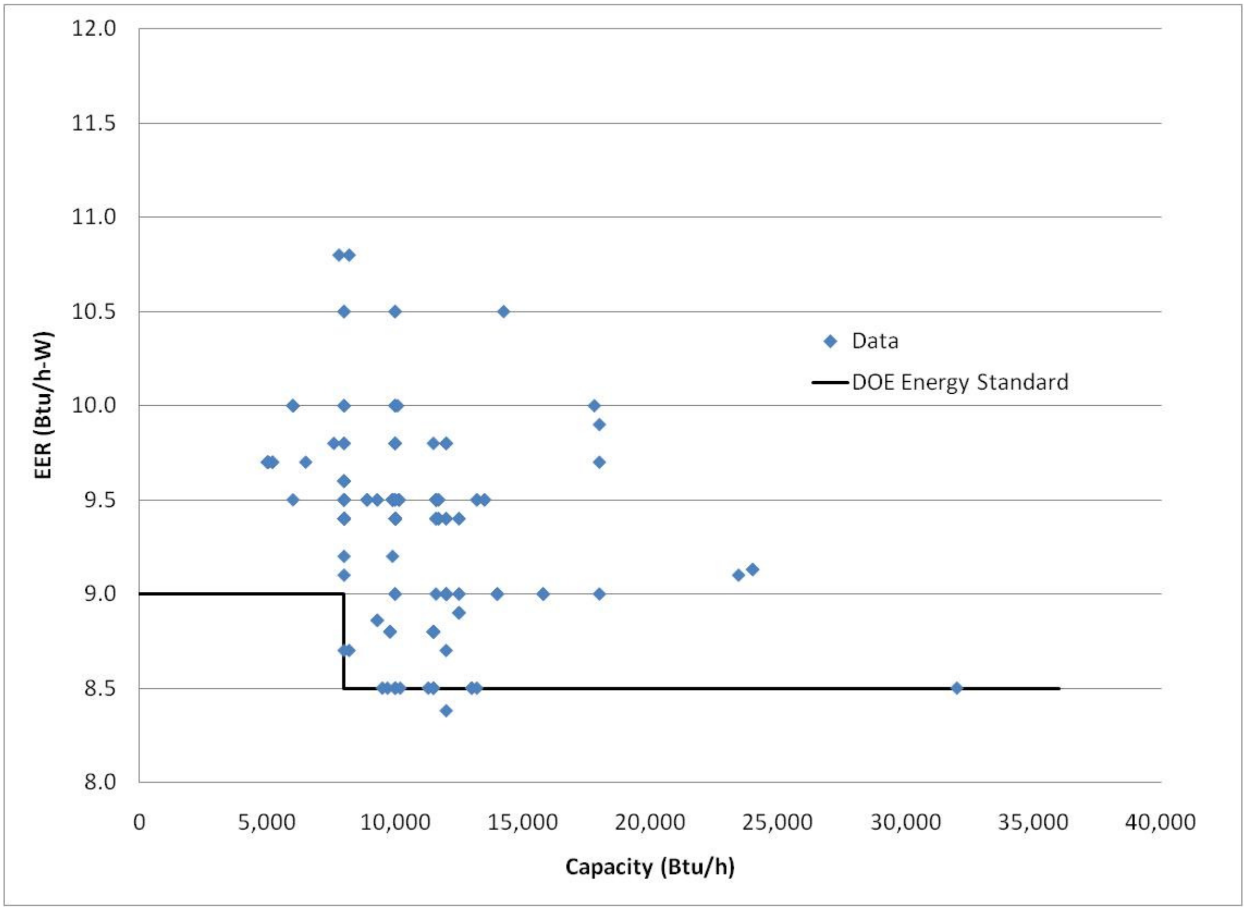

Figure 3.15.7 CEC, AHAM, and ENERGY STAR Certified Room Air Conditioners without Reverse Cycle and without Louvered Sides (Product Classes 6–10)[99, 100, 101]

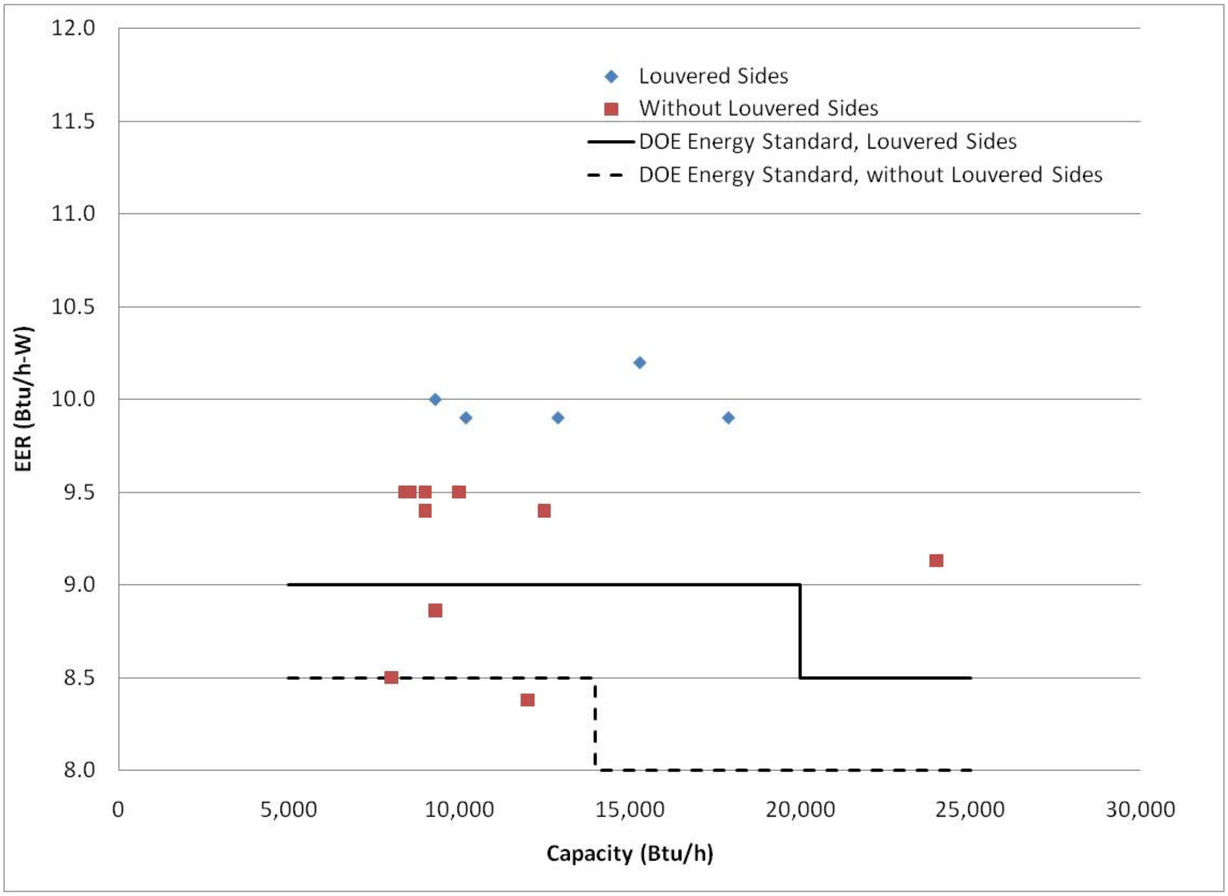

Figure 3.15.8 CEC, AHAM, and ENERGY STAR Certified Room Air Conditioners with Reverse Cycle (Product Classes 11–14)[102, 103, 104]

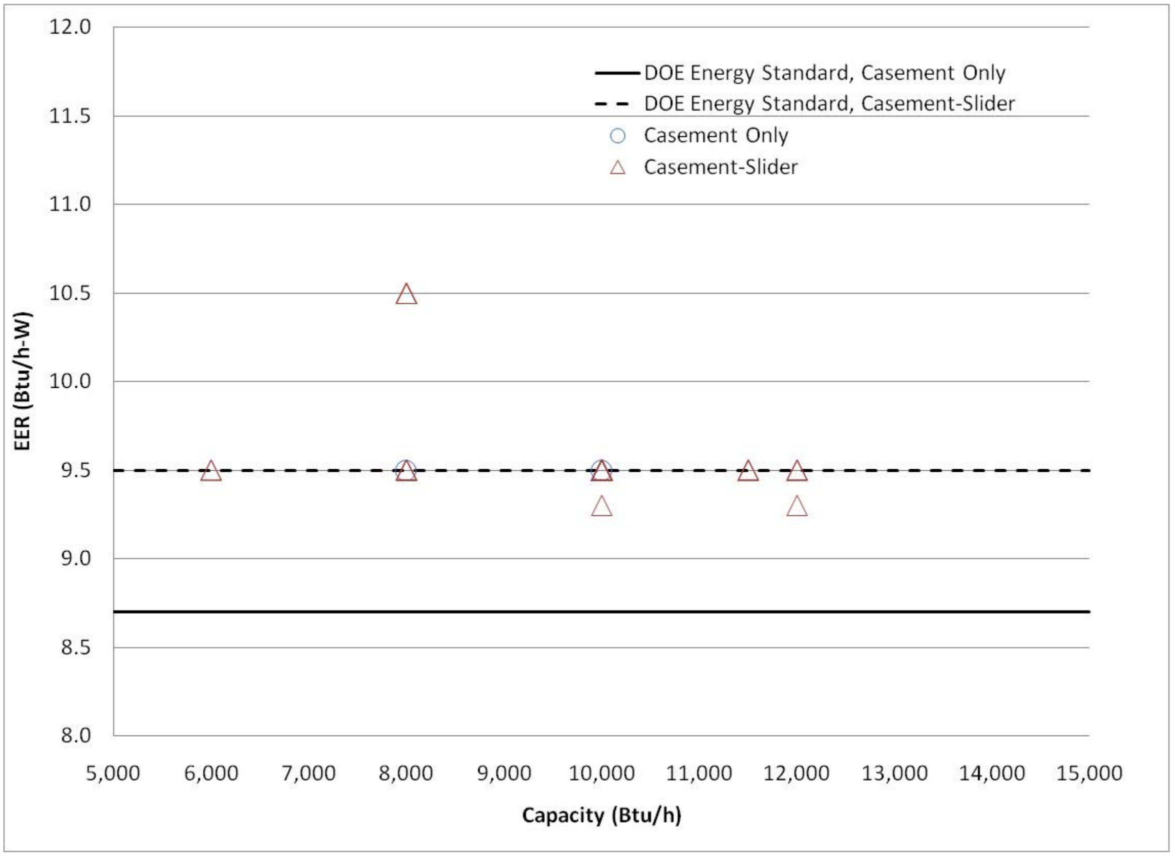

Figure 3.15.9 CEC, AHAM, and ENERGY STAR Certified Room Air Conditioners Casement-Only and Casement-Slider (Product Classes 15, 16) [105, 106, 107]

Figure 3.15.10 shows the distribution of the models listed in the screened database for each product class. Nearly 70 percent of the products are room air conditioner models without reverse cycle and with louvered sides (product classes 1 through 5). In addition, there are a high number of models in product class 8, room air conditioners without reverse cycle, without louvered sides, and a capacity between 8,000 and 13,999 Btu/h. Also of note, there are no models in product class 13 (with reverse cycle, with louvered sides, capacity greater than 120,000 Btu/h). During individual manufacturer interviews, manufacturers confirmed that product classes 1, 2, 3, 4, 5, and 8 make up the vast majority of room air conditioner shipments.

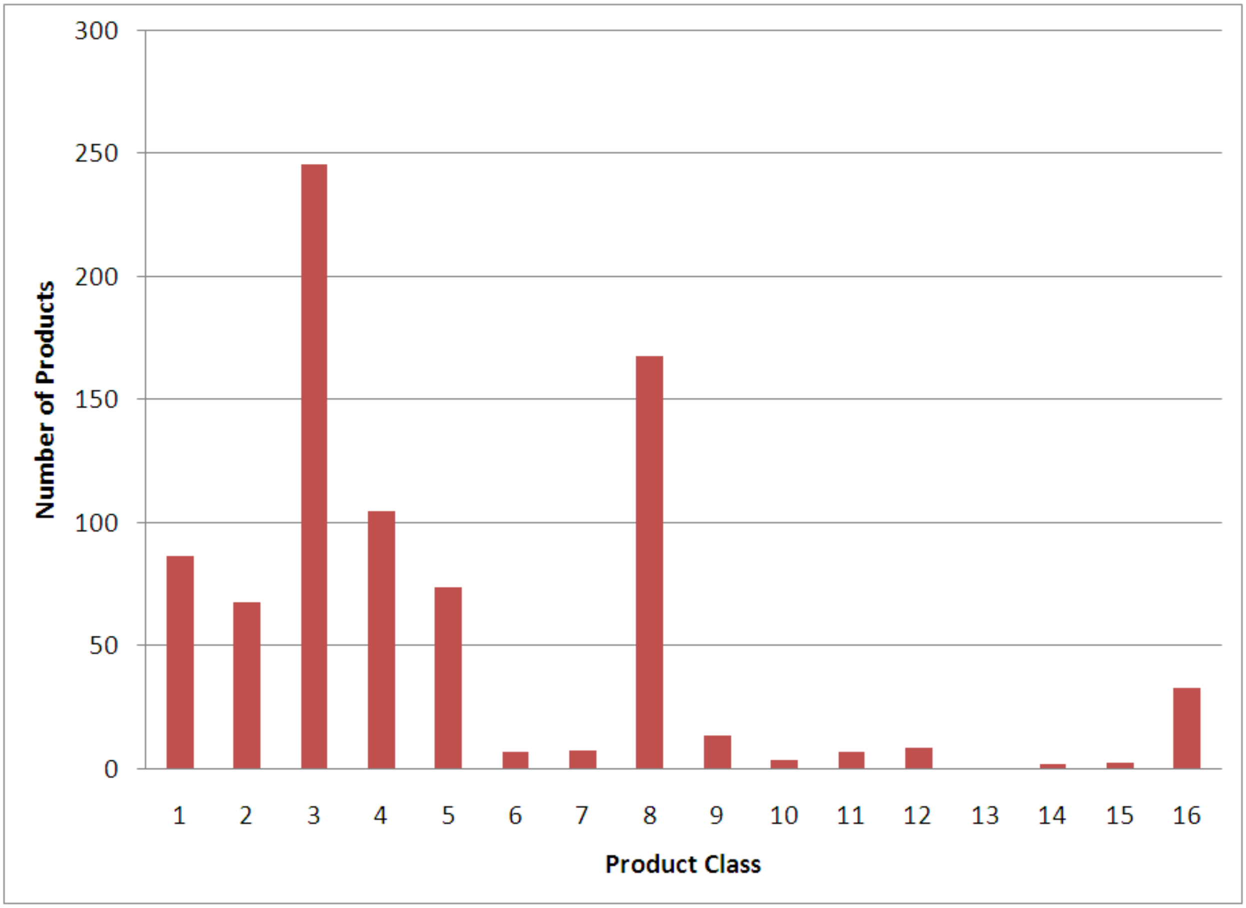

Figure 3.15.10 Distribution of Room Air Conditioner Models in the CEC, AHAM, and ENERGY STAR Databases[108, 109, 110]

DOE during the final rule phase conducted another investigation of the ENERGY-STAR Database, manufacturer websites, and vendor websites to assemble information on newly available R-410A units. Figure 3.15.11 through Figure 3.15.12 show the EER versus the capacity of each room air conditioner found in this investigation. Each graph illustrates the current federal energy conservation standard, which became effective on October 1, 2000. Some of the products still had reported EER below the current federal standards. These may have erroneous EER listings, are mislabeled, or have model numbers identical to updated products. DOE completed this investigation in May 2010.

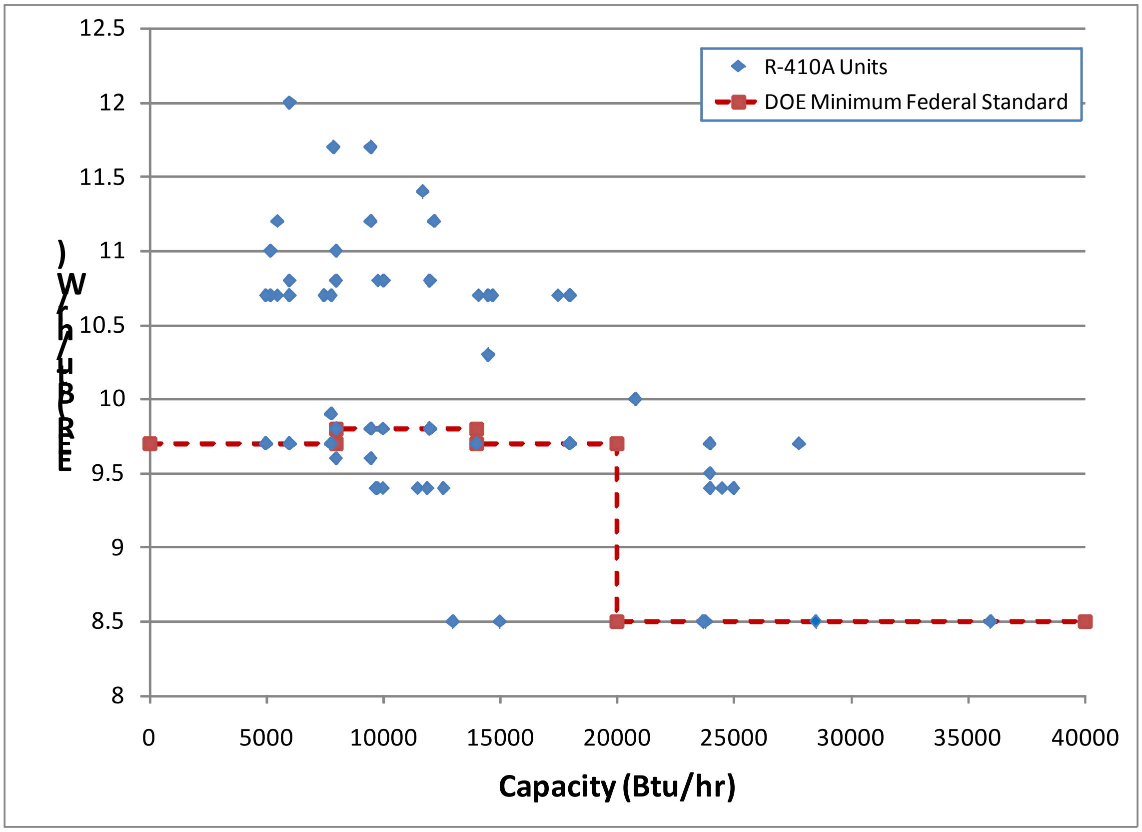

Figure 3.15.11. R-410A Room Air Conditioners without Reverse Cycle and with Louvered Sides (Product Classes 1–5)

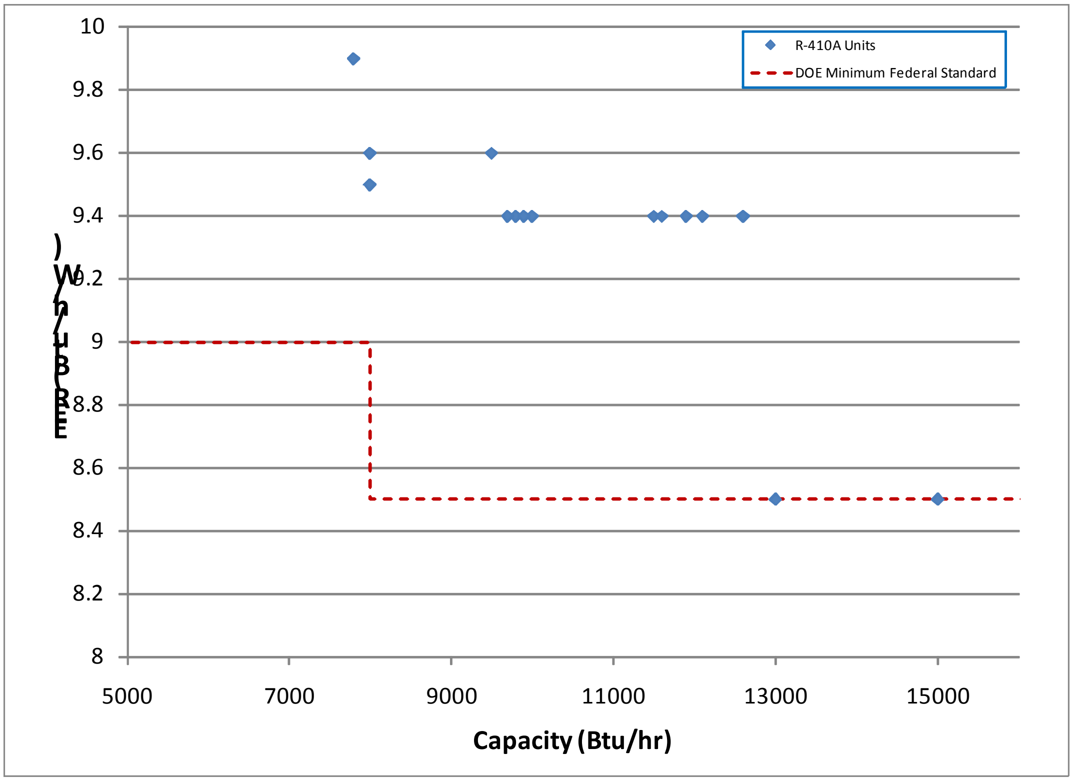

Figure 3.15.12. R-410A Room Air Conditioners without Reverse Cycle and with Louvered Sides (Product Classes 1–5)

Investigation of Max-Tech Units

During the preliminary analysis public meeting, DOE requested comment on the efficiency levels chosen by DOE. DOE identified products with an EER of 12.0 as the highest efficiency products available on the market. Several stakeholders commented that DOE should update its analysis to include all current ENERGY STAR and max-tech units on the market. In particular, stakeholders indicated that the CEC and the ENERY-STAR databases listed products with higher efficiency levels than those considered by DOE.

DOE is aware that the ENERGY STAR and CEC databases have listed products that exceed the max-tech EER of 12.0 that DOE identified in the preliminary analysis. Table 3.15.6 below, shows products listed at 12.0 EER or higher in one or both of these databases. Some of these products were noted specifically in stakeholder comments.

Table 3.15.6 RAC Models of Interest for Max-Tech Analysis, as Listed in the ENERGY-STAR and CEC Listings

Brand	Model	Listed EER	Source	
			CEC	ENERGY STAR
Climette	CH1826A	13.8	➼	
Comfort-Aire	REC-183	13.8	➼	
Fedders	AED18E7DG	13.8	➼	
Maytag	MED18E7A	13.8	➼	
Fedders	A7Q06F2A	13.4	➼	
Turbo Air	TAS-09EH	13.5		➼
Turbo Air	TAS-12EH	13.0		➼
Turbo Air	TAS-18EH	13.0		➼
Friedrich	SS10M10	12.0	➼	➼
Friedrich	YS09L10	12.0	➼	➼
Friedrich	SS10L10	12.0	➼	➼
Friedrich	XQ06M10	12.0	➼	➼
Friedrich	SS12M10	12.0	➼	
Haier	ESAD4066	12.0		➼

DOE investigation of these products indicates that none of the products listed with EER higher than 12.0 represent valid RAC ratings, and that some of the products rated at an EER of 12.0 are also invalid representations. The first five products in the table are listed with much lower EER ratings in Natural Resources Canada (NRCan) database[w]. Table 3.15.7 below contains the NRCan ratings of these products.

Table 3.15.7 Selected Product Ratings in NRCan Directory

Brand	Model No.	Listed EER in NRCan Database
Climette	CH1826A	9.7
Comfort-Aire	REC-183	9.7
Fedders	AED18E7DG	9.8
Maytag	MED18E7A	9.8
Fedders	A7Q06F2A	10.7

[w] (1) "EnerGuide for Equipment – EnerGuide Room Air Conditioner Directory 2002". Natural Resources Canada, Office of Energy Efficiency.2002; (2) Room Air Conditioner Model Listing. "EnerGuide Room Air Conditioner Directory 2004" http://oee.nrcan.gc.ca/.

The three Turbo-Air products are ductless mini-split products (as identified by the manufacturer's website[x]), not room air conditioners. The Friedrich SS12M10 has been rerated at lower than 12.0 EER[y], and the validity of the 12.0 rating of the Haier ESAD4066 is also in question.

In particular, Consumer Reports published an article in October 2008[z] in which it reported on test results indicating that the Haier ESAD4066's efficiency was not 12 EER. DOE's analysis of this unit using the Mark N energy model (discussed in chapter 5 of this TSD), showed that matching this performance level with the energy model required making some input assumptions that DOE considers unlikely, particularly for the condenser air flow rate.

Consequently, DOE concludes that its identification of a ma- tech available level no higher than 12.0 EER is valid, given the information available.

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[y] Friedrich product specifications. Specifications for SS12M10. Please see more information at *http://kuhl.friedrich.com/model-specifications/*

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CHAPTER 4. SCREENING ANALYSIS

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4.1 INTRODUCTION

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

For each product, the corresponding candidate technology options are assessed based on DOE analysis as well as inputs from stakeholders including manufacturers, trade organizations, and energy efficiency advocates. Technology options which are judged to be viable approaches for improving energy efficiency are retained as inputs to the subsequent engineering analysis. Technologies that pass through the screening analysis are referred to as "design options" in the engineering analysis. Technology options which 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 technology option is detailed in the following sections.

4.2 DISCUSSION OF TECHNOLOGY OPTIONS

For residential clothes dryers and room air conditioners, the screening criteria specified in section 4.1 were applied to the technology options to either retain or eliminate each technology from the engineering analysis.

4.2.1 Screened-Out Technologies

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

The technologies identified in the market and technology assessment were evaluated pursuant to the criteria set out in 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 and economically justified. (42 U.S.C.

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

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

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

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

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

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

4.2.1.1 Residential Clothes Dryers

For residential **clothes dryers**, DOE screened out microwave, water-cooling, and indirect heating, for the reasons that follow

Microwave, electric only

Due to the large energy savings associated with microwave drying, this technology was the subject of a multiyear development effort at the Electric Power Research Institute (EPRI) in the mid-1990s[1]; and at least one major manufacturer, Whirlpool Corporation (Whirlpool), developed a countertop-scale version of such a product as recently as 2002[2], but to date this technology has not been successfully commercialized.

Significant technical and safety issues are introduced by the potential arcing from metallic objects in the fabric load, including zippers, buttons, or "stray" items such as coins. While efforts have been made to mitigate the conditions that are favorable to arcing, or to detect incipient arcing and terminate the cycle, the possibility of fabric damage cannot be completely eliminated.[3] In addition to consumer utility impacts, these conditions can also pose a safety hazard. For these reasons, microwave drying was not considered further for analysis.

Water-cooling, vent-less electric only

Water-cooling for vent-less electric dryers, which uses water as a cooling fluid to condense the moisture in the air exiting the drum, would require significant plumbing in order to circulate water through a heat exchanger in the dryer. In addition, this technology option would add to the complexity of maintenance. Therefore, the water-cooling for vent-less electric dryers technology option does not meet the criterion of practicability to install and service on a scale necessary to serve the relevant market at the time of the effective date of a new standard and will be screened out of the analysis.

Indirect heating

Indirect heating would only be viable in residences which use a hydronic heating system. Also, in order to derive dryer heat energy from the home's heating system, significant plumbing work would be required to circulate heated water through a heat exchanger in the dryer. Therefore, this technology option does not meet the criterion of practicability to install on a scale necessary to serve the relevant market at the time of the effective date of a new standard and will not be considered for further analysis.

4.2.1.2 Room Air Conditioners

For **room air conditioners**, DOE did not screen out any technologies.

4.2.2 Remaining Design Options

The following sections list the design options for both products covered by this rulemaking that were retained by DOE. Each of these technologies will be evaluated further in the subsequent engineering analysis.

4.2.2.1 Residential Clothes Dryers

For residential **clothes dryers**, DOE considered the following design options for further analysis.

Table 4.2.1 Retained Design Options for Residential Clothes Dryers

Dryer Control or Drum Upgrades
Improved termination
Increased insulation
Modified operating conditions
Improved air circulation
Reverse tumble
Improved drum design
Methods of Exhaust Heat Recovery (vented models only)
Recycle exhaust heat
Inlet air preheat
Inlet air preheat, condensing mode
Heat Generation Options
Heat pump, electric only
Modulating, gas only
Component Improvements
Improved motor efficiency
Improved fan efficiency
Standby Power Improvements
Switching Power Supply
Transformerless Power Supply with Auto-Powerdown

4.2.2.2 Room Air Conditioners

For **room air conditioners**, DOE considered the following design options for further analysis.

Table 4.2.2 Retained Design Options for Room Air Conditioners

Increased Heat Transfer Surface Area
Increased frontal coil area
Increased depth of coil (add tube rows)
Increased fin density
Add subcooler to condenser coil
Increased Heat Transfer Coefficients
Improved fin design
Improved tube design
Hydrophilic film coating on fins
Spray condensate onto condenser coil
Microchannel heat exchangers
Component Improvements
Improved indoor blower and outdoor fan efficiency
Improved blower/fan motor efficiency
Improved compressor efficiency
Part-Load Technology Improvements
Two-speed, variable-speed, or modulating-capacity compressors
Thermostatic or electronic expansion valves
Thermostatic cyclic controls
Standby Power Improvements
Switching Power Supply

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CHAPTER 5. ENGINEERING ANALYSIS

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CHAPTER 5. ENGINEERING ANALYSIS

5.1 INTRODUCTION

After conducting the screening analysis, the Department of Energy (DOE) performed an engineering analysis based on the remaining design options. The engineering analysis consists of estimating the energy consumption and costs of products at various levels of increased efficiency. This section provides an overview of the engineering analysis (section 5.1), considers technologies which are unable to be analyzed for this rulemaking (section 5.2), discusses established product classes (section 5.3), defines baseline unit specifications (section 5.4.1), discusses incremental efficiency levels (section 0), explains the methodology used during data gathering (5.4.2.3) and discusses the analysis and results (section 5.6). DOE completed separate engineering analysis for residential clothes dryers and room air conditioners.

The primary inputs to the engineering analysis are baseline product information from the market and technology assessment (chapter 3 of the technical support document (TSD)) and technology options that are not eliminated in the screening analysis (chapter 4). Additional inputs include cost and energy efficiency data, which DOE received from the Association of Home Appliance Manufacturers (AHAM) and qualified and supplemented through tear-down analysis, energy modeling, and manufacturer interviews. The primary output of the engineering analysis is a set of cost-efficiency curves. In the subsequent markups analysis (chapter 7), DOE determined customer (*i.e.*, product purchaser) prices by applying distribution markups, sales tax and contractor markups. After applying these markups, they serve as the input to the building energy-use and end-use load characterization (chapter 6) and the life-cycle cost (LCC) and payback period (PBP) analysis (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 derived from teardowns of the product being analyzed. Deciding which methodology to use for the engineering analysis depends on the product, the design options under study, and any historical data that DOE can draw on.

5.2 TECHNOLOGIES UNABLE TO BE INCLUDED IN THE ANALYSIS

In performing the engineering analysis, DOE did not consider for analysis certain technologies that met the screening criteria but were unable to be evaluated for one or more of the following reasons: (1) data are not available to evaluate the energy efficiency characteristics of the technology; (2) available data suggest that the efficiency benefits of the technology are negligible; and (3) certain technologies cannot be measured according to the conditions and methods specified in the existing test procedure. In the first case, DOE is unable to adequately assess how these technologies impact annual energy consumption. In other cases, available data suggested that some of the design options resulted in such small energy savings as to be negligible. Because DOE intends to focus on the technologies with measurable impact on efficiency, design options with negligible energy savings have been eliminated from further consideration.

5.2.1 Clothes Dryers

5.2.1.1 Reverse tumble

Manufacturers interviewed as part of the preliminary manufacturer interview analysis indicated that such a feature is used primarily for fabric care. The benefits of reverse tumbling include prevention of balling and wrinkling of the clothes load. No manufacturer indicated they use, or would consider, reverse tumble for increasing efficiency. Tests conducted by one manufacturer, in fact, found that the small size of the test cloths in the DOE test procedure prevents balling and thus no energy efficiency benefit can be measured[1]. At least one manufacturer stated that reverse tumble could actually reduce efficiency by stopping the drum rotation while it is changing directions. For reasons of no demonstrable energy savings and uncertainty as to whether its impacts can be measured by the existing test procedure, DOE will not further analyze reverse tumble.

5.2.1.2 Improved termination

Improved cycle termination is potentially possible by means of more accurate moisture sensors or by incorporating temperature and moisture sensors together. Alternatively, algorithms may be developed to more accurately detect end-of-cycle conditions. While each of these approaches may produce real-world energy savings by preventing consumers from over-drying the clothes load, the DOE test procedure requires that the test be terminated as soon as a certain level of dryness is achieved. A fixed field use factor is then applied to the measured energy consumption depending on whether timed or automatic cycle termination is present. Therefore, improved cycle termination cannot be measured by the test procedure. As discussed in chapter 3 of this TSD, DOE proposed amendments to the clothes dryer test procedure to more accurately account for automatic cycle termination. However, DOE determined that the proposed amendments for automatic cycle termination do not adequately measure the energy consumption of clothes dryers equipped with such systems using the test load specified in the DOE test procedure. As a result, in the test procedure final rule published in the *Federal Register* on XX, 2011 (hereafter the MONTH 2011 TP Final Rule), DOE did not adopt the proposed amendments for automatic cycle termination (see chapter 3 of this TSD for more details). As a result, for this analysis, DOE did not further analyze improved termination.

5.2.2 Room Air Conditioners

5.2.2.1 Improved Fin Design

The louvered, raised-lance, or slit-fin fin designs currently used in nearly all room air conditioners are the most effective technologies for heat transfer to air. These designs work by repeatedly interrupting the surface in the flow direction, which prevents thermal boundary layers from growing. The air near the fin remixes with the bulk flow at the end of each louver, and a new boundary layer forms on the next louver. A similar approach is used in high performance heat exchangers in nearly all applications for which high heat transfer is required without incurring high penalties for air-side pressure drop. DOE is not aware of any other improved fin technology that can make further improvements in heat exchanger performance for room air conditioners. Hence, DOE did not further analyze this technology.

5.2.2.2 Improved Tube Design

Rifled tubes are currently used in nearly all room air conditioners. Variants of conventional spiral rifling have been developed, but they have not been shown to be more effective than the rifling which has become standard for tubes used in all air conditioning applications. DOE is not aware of any other improved tube technology that can make further improvements in heat exchanger performance for room air conditioners. Hence, DOE did not further analyze this technology.

DOE did consider use of smaller diameter tubes in the engineering analysis, especially for use with R-410A refrigerant.

5.2.2.3 Hydrophilic-film coating on fins

During interviews conducted during the preliminary analysis phase, manufacturers indicated that hydrophilic film coatings do improve room air conditioner efficiency. However, they indicated that use of these coatings is standard practice for room air conditioners. Hence, DOE did not further analyze this technology.

5.2.2.4 Spray condensate onto condenser coil

Spraying of condensate onto the condenser coil is currently used in all room air conditioners. DOE questioned manufacturers during interviews about more effective approaches for use of the condensate, but no viable alternatives were identified. DOE measured the condenser fan power impact of the slinger ring on a typical room air conditioner and determined that filling the condensate pan with water and thus initiating slinging action made no noticeable impact on fan power input. The engineering analysis incorporated use of condensate spraying into the energy use analysis. However, in no case was this technology used as the basis for estimates of possible efficiency improvement, since all baseline products were analyzed assuming they already have this feature. The effect of condensate spray on room air conditioner performance was based upon research to determine the effect that water spray had on heat exchanger performance.[2] Hence, DOE did not further analyze this technology.

5.2.2.5 Improved indoor blower and outdoor fan efficiency

The indoor blowers and outdoor fans of current room air conditioners are molded plastic parts with complex geometries. The performance of these blowers and fans has improved as compared to stamped sheet metal fan blades used in the past. DOE expects that there may be potential for incremental improvement in air moving efficiency for some room air conditioners. However, there are no data available which can be used to predict this improvement. During manufacturer interviews, improvement in air moving efficiency through use of better fan blades or blower impellers was not identified as a viable option for improvement in room air conditioner efficiency. Hence, DOE did not further analyze these technologies.

5.2.2.6 Two-speed, Variable-speed, or Modulating-capacity Compressors

Two-speed, variable-speed, or modulating-capacity compressors can increase efficiency over a broad operating range, but they do not inherently increase the efficiency at the room air conditioner rating point. Because the DOE energy test procedure specifies steady-state maximum-capacity conditions for evaluation of active mode efficiency, the speed of a variable-speed compressor would remain at a constant maximum capacity (*e.g.* highest speed) during the test. As a result, there is no opportunity to measure the energy savings that such compressors can provide during part-load conditions, when, instead of cycling at high speed, they operate a reduced capacity to satisfy the load. In fact, the losses associated with the inverter board of a variable-speed compressor would decrease the maximum-capacity energy efficiency ratio (EER). Therefore, DOE did not further analyze this technology in the engineering analysis.

5.2.2.7 Thermostatic or Electronic Expansion Valves

Thermostatic or electronic expansion valves have the capability of maintaining optimum room air conditioner operating parameters over a broad range of operating conditions (outdoor and room temperature levels, during startup transients, and in case of high or low refrigerant charge). However, because the DOE energy test procedure for room air conditioners specifies steady state operating conditions, the benefit of these technologies will not be measured by the test. The design of a capillary expansion device can be adjusted to provide optimum operating conditions for the steady-state test. Therefore, DOE did not consider these technologies further in the engineering analysis.

5.2.2.8 Thermostatic Cyclic Controls

Advanced thermostatic cyclic controls would be designed to control room air conditioner operation if the load is less than the room air conditioner capacity. The DOE energy test procedure, however, measures room air conditioner efficiency at full-capacity steady conditions. Hence, the test procedure cannot measure the efficiency benefits of alternative thermostatic controls which might improve control of the cycling (or modulation for variable capacity units) of the room air conditioner. Therefore, DOE did not further consider this technology in the engineering analysis.

5.3 PRODUCT CLASSES ANALYZED

DOE separated residential clothes dryers and room air conditioners into product classes. Because DOE formulated a separate energy conservation standard for each product class, the criteria for separation into different classes are: (1) type of energy used (natural gas or electricity), and (2) capacity or other performance-related features such as those that provide utility to the consumer, or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 United States Code (U.S.C.) 6295 (q))

For residential **clothes dryers**, DOE considered four product classes for vented and two product classes for ventless clothes dryers, as shown in Table 5.3.1. This is a new analytical structure for clothes dryers, recognizing the unique utility that ventless clothes dryers offer to consumers. (Previously, DOE has described ventless clothes dryers as condensing clothes dryers. The new designation reflects the actual consumer utility (*i.e.,* no external vent required) and the potential market availability of vented clothes dryers that also condense). Another new entry with unique utility is the combination washer/dryer (*i.e.*, a device which washes and then dries clothes in the same basket/cavity in a combined cycle). Combination washer/dryers are suitable for space-constrained environments (*e.g.*, apartments, recreational vehicles), and all products of this type appear to utilize ventless operation. Thus, like other ventless clothes dryers, such combination washer/dryers can be installed in locations where venting dryers would be precluded due to venting restrictions. As discussed in chapter 3 of this TSD, DOE recently adopted amendments to the clothes dryer test procedure in the MONTH 2011 TP Final Rule to include provisions for testing ventless clothes dryers, thus allowing the consideration of ventless product classes. The amendments for ventless clothes dryers are discussed in more detail in chapter 3 of this TSD.

Table 5.3.1 Residential Clothes Dryer Product Classes

Vented dryers	
1.	Electric, Standard (4.4 cubic feet (ft^3) or greater capacity)
2.	Electric, Compact (120 volts (v)) (less than 4.4 ft^3 capacity)
3.	Electric, Compact (240 v) (less than 4.4 ft^3 capacity)
4.	Gas
Ventless dryers	
5.	Electric, Compact (240 v) (less than 4.4 ft^3 capacity)
6.	Electric, Combination Washer/Dryer

For **room air conditioners**, amendments to the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 U.S.C. 6291–6309) in the National Appliance Energy Conservation Act of 1987 (NAECA), Pub. L. 100-12, initially specified 12 product classes for products designed for single- or double-hung window installation or through-the-wall installation and based on the following criteria: (1) cooling capacity; (2) the presence of louvered sides (LS); and (3) the capability of reverse cycle (*i.e.*, the unit can function as a heat pump). (42 U.S.C. 6295(c)(1)) Capacity is measured in British Thermal Units (Btu) per hour (h) (Btu/h). In the final rule published in the *Federal Register* on September 24, 1997, DOE established an updated set of performance standards (effective October 1, 2000) which included four additional product classes.[a]

As detailed in chapter 3 of this TSD, DOE is establishing in this final rule four new product classes by splitting existing product classes 5 and 8 into two product classes each. Table 5.3.2 lists the 18 resulting product classes for room air conditioners. See chapter 3 for additional discussion of the creation of these new product classes.

Based on DOE's estimate that higher-capacity units may be constrained by space limitations in their ability to incorporate design options that could raise energy efficiency, and the assumption that the increments in energy efficiency among the other product classes are well-defined by the increments in their associated minimum efficiency standards, DOE conducted a full analysis of product classes 1, 3, 5, and 8 during the preliminary analysis. For this final rule, DOE conducted full analyses of product classes 1, 3, 5A, 5B, 8A, and 8B. Product classes 1, 3, 5A, and 5B span the range of capacities of room air conditioners without reverse cycle and with louvered sides. Product classes 8A and 8B are intermediate-capacity product classes for room air-conditioners without reverse cycle and without louvered sides. These two product classes represent the

[a] DOE divided the product class covering units with reverse cycle and with louvered sides into units of capacity less than 20,000 Btu/h and units 20,000 Btu/h or more. DOE split the product class covering units with reverse cycle and without louvered sides into units of capacity less than 14,000 Btu/h and units 14,000 Btu/h or more. In addition, DOE established two new product classes for units that are designed to be installed in casement-slider and casement-only windows. Due to the size constraints imposed by casement windows, casement units are small in size and typically deliver 5,000 to 10,000 Btu/h in cooling capacity.

majority of shipments of products without reverse cycle without louvered sides (see Figure 3.15.10 in chapter 3). DOE then grouped each of the remaining 12 product classes with an analyzed product class that provided the best representation of cost effectiveness for improving its efficiency. This grouping is discussed in greater detail in section **Error! Reference source not found.**.

Table 5.3.2 Room Air Conditioner Product Classes

Without reverse cycle and with louvered sides
1. Less than 6,000 Btu/h
2. 6,000 to 7,999 Btu/h
3. 8,000 to 13,999 Btu/h
4. 14,000 to 19,999 Btu/h
5A. 20,000 to 27,999 Btu/h
5B. 28,000 Btu/h or more
Without reverse cycle and without louvered sides
6. Less than 6,000 Btu/h
7. 6,000 to 7,999 Btu/h
8A. 8,000 to 10,999 Btu/h
8B. 11,000 to 13,999 Btu/h
9. 14,000 to 19,999 Btu/h
10. 20,000 Btu/h or more
With reverse cycle
11. With louvered sides and less than 20,000 Btu/h
12. Without louvered sides and less than 14,000 Btu/h
13. With louvered sides and 20,000 Btu/h or more
14. Without louvered sides and 14,000 Btu/h or more
Casement
15. Casement-Only
16. Casement-Slider

5.4 EFFICIENCY LEVELS

5.4.1 Baseline Units

DOE selected baseline units as reference points for each product class, against which DOE measured changes resulting from energy conservation standards. The baseline unit in each product class represents the basic characteristics of equipment in that class. Typically, a baseline unit is a unit that just meets current required energy conservation standards and provides basic consumer utility.

DOE used the baseline units in the engineering analysis and the LCC and PBP analysis. To determine energy savings and changes in price, DOE compared each higher-energy-efficiency or lower-energy-efficiency design option with the baseline unit.

As discussed in chapter 3 of this TSD, EPCA requires that the test procedures for clothes dryers and room air conditioners be amended to include measurement of standby mode and off mode power, except where current test procedures fully address such energy consumption or such a procedure is technically infeasible. EPCA also requires 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)) As discussed in chapter 3 of this TSD, DOE published the MONTH 2011 TP Final Rule in which it amended the test procedures to include testing methods for measuring standby and off mode energy use for clothes dryers and room air conditioners. As part of the MONTH 2011 TP Final Rule, DOE adopted new methods to calculate clothes dryer and room air conditioner standby and off mode energy use and new measures of energy efficiency (Combined Energy Factor (CEF) and Combined Energy Efficiency Ratio (CEER), respectively) that integrate standby and off mode energy use with the active mode energy use for both products. As a result, the engineering analysis and the energy conservation standards for clothes dryers and room air conditioners are based on these integrated metrics (CEF and CEER). The CEER is identical to the Integrated Energy Efficiency Ratio (IEER) metric used in the preliminary analysis documents, but renamed to avoid confusion with an existing industry standard. The "inactive" mode of this metric is now referred to simply as the standby mode. The CEF differs from the IEF metric previously used, in that it is based on a different number of annual cycles for the active mode analysis.

Test data based on CEF and CEER, as defined in the MONTH 2011 TP Final Rule, are not available for any products. As a result, baseline units for these metrics are defined using the baseline efficiency characteristics of products using current efficiency metrics and an understanding of the typical energy use of the products in standby and off modes. The following sections discuss active mode, standby/off mode(s), and integrated metric characteristics for baseline products.

5.4.1.1 Active Modes

The current minimum energy conservation standards for residential **clothes dryers**, as measured by energy factor (EF) in pounds (lb) per kilowatt-hour (kWh) under the previous DOE clothes dryer test procedure (found at 10 Code of Federal Regulations (CFR) part 430, subpart B, appendix D), became effective on May 14, 1994. Table 5.4.1 sets forth the standards for the four vented clothes dryer product classes. (10 CFR part 430.32(h)(2)) DOE used these existing energy conservation standards to characterize the baseline active mode unit efficiency for each of the vented product classes. DOE estimated baseline efficiencies for ventless dryers based upon testing it conducted on representative units, using the previous DOE clothes dryer test procedure without the exhaust simulator.

Table 5.4.1 Clothes Dryer Baseline Active Mode Unit Efficiencies

Product Class	EF *(lb/kWh)*
Vented dryers	
1. Electric, Standard (4.4 ft^3 or greater capacity)	3.01
2. Electric, Compact (120 v) (less than 4.4 ft^3 capacity)	3.13
3. Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	2.90
4. Gas	2.67
Ventless dryers	
5. Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	2.37
6. Electric, Combination Washer/Dryer	1.95

In addition to adopting provisions for the measurement of standby mode and off mode power use, as discussed above, DOE also adopted amendments to the clothes dryer test procedure in the MONTH 2011 TP Final Rule concerning the active mode. In particular, DOE adopted amendments to include provisions for the testing of ventless products. The amendments also included the following changes to reflect the current usage and capabilities of products to: (1) change the clothes dryer use cycles per year from 416 to 283, (2) change the initial remaining moisture content (RMC) of clothes dryer loads from 70 ± 3.5 percent to 57.5 ± 3.5 percent, and (3) change the clothes dryer test load size from 7.00 ± .07 pounds (lbs) to 8.45 ± .085 lbs for standard-size clothes dryers. In addition, the MONTH 2011 TP Final Rule also amends the DOE clothes dryer test procedure to: (1) revise the detergent specifications for test cloth preconditioning due to obsolescence of the detergent specified in the test procedure, (2) revise the water temperature for test load preparation from 100 degrees Fahrenheit (°F) ± 5 °F to 60 °F ± 5 °F, (3) update references to industry test standards, (4) eliminate an unnecessary reference to an obsolete industry test standard, (5) clarify the required gas supply conditions for testing gas clothes dryers (6) amend the provisions for measuring the drum capacity, (7) amend the provisions for the application of the field use factor for automatic cycle termination, (8),add the calculations of EF and CEF to 10 CFR part 430, subpart B, appendix D1. CITE.

EPCA requires that DOE must determine to what extent, if any, the proposed test procedure would alter the measured energy efficiency of any covered product as determined under the existing test procedure. (42 U.S.C. 6293(e)(1)) If DOE determines that the amended test procedure would alter the measured efficiency of a covered product, DOE must amend the applicable energy conservation standard accordingly. In determining the amended energy conservation standard, DOE shall measure, pursuant to the amended test procedure, the energy efficiency, energy use, or water use of a representative sample of covered products that minimally comply with the existing standard. The average of such energy efficiency, energy use, or water use levels determined under the amended test procedure shall constitute the amended energy conservation standard for the applicable covered products. (42 U.S.C. 6293(e)(2)) EPCA also states that models of covered products in use before the date on which the amended energy conservation standard becomes effective (or revisions of such models that come into use after such date and have the same energy efficiency, energy use, or water use characteristics) that comply with the energy conservation standard applicable to such covered products on the day before such date shall be deemed to comply with the amended energy conservation standard. (42 U.S.C. 6293(e)(3)) DOE notes that these EPCA requirements apply only when there is no concurrent energy conservation standards rulemaking. However, DOE has adjusted the measured efficiency values as part of this rulemaking, consistent with these requirements.

As part of the MONTH 2011 TP Final Rule, DOE conducted testing on a sample of 17 representative clothes dryers to evaluate the effects of the amendments to the clothes dryer test procedure on the measured EF. CITE. DOE tested these units according to the amended clothes dryer test procedure in the MONTH 2011 TP Final Rule, conducting up to three tests for each test unit and averaging the results. The results from this testing are shown below in Table 5.4.2. DOE noted in its testing that the amendments to the initial RMC, water temperature for test load preparation, and load size had an effect on the measured EF as compared to the existing test procedure. For vented electric standard-size clothes dryres, the measured EF increases by an average of about 20.1 percent as a result of the amendments to the test procedure. For vented gas clothes dryers, the measured EF increased by an average of about 19.8 percent. For vented electric compact-size 120V and 240V clothes dryers, the measured EF increased by an average of about 15.6 and 12.8 percent, respectively. For ventless electric compact 240V clothes dryers and ventless electric combination washer-dryers, the measured EF increased by an average of about 13.6 and 11.4 percent, respectively, as compared to the measured EF using the existing test procedure with only the amendments for ventless clothes dryers (without the changes to the initial RMC, water temperature for test load preparation, etc.). DOE noted that the increase in measured EF is greater for the standard-size products (*i.e.*, vented electric standard-size and vented gas dryers) than for compact-size products due to the additional amendments to increase the test load size for standard-size products. CITE.

Table 5.4.2 DOE Test Results to Evaluate the Effects of the Test Procedure Amendments on Measured EF

Test Unit		Average EF (lb/kWh) Previous Test Procedure (Appendix D)	Average EF (lb/kWh) Amended Test Procedure (Appendix D1)	% Change
Vented Electric Standard	Unit 1	3.07	3.69	20.4%
	Unit 2	3.14	3.77	19.5%
	Unit 3	3.20	3.83	19.6%
	Unit 4	3.28	3.92	19.4%
	Unit 5	3.24	3.96	22.5%
	Unit 6	3.12	3.72	19.1%
Vented Gas	Unit 7	2.78	3.36	20.6%
	Unit 8	2.83	3.40	19.9%
	Unit 9	2.85	3.42	20.2%
	Unit 10	2.80	3.37	20.5%
	Unit 11	2.98	3.50	17.6%
Vented Electric Compact (240V)	Unit 12	3.19	3.56	11.4%
	Unit 13	2.93	3.35	14.2%
Vented Electric Compact (120V)	Unit 14	3.23	3.74	15.6%
Ventless Electric Compact (240V)	Unit 15	2.37	2.69	13.6%
Ventless Electric Combo Washer-Dryer	Unit 16	2.01	2.27	12.5%
	Unit 17	2.50	2.76	10.3%

DOE applied these separate average percentage increases in the measured EF based on the test procedure amendments discussed above for each product class to the efficiency levels presented above in Table 5.4.1. Table 5.4.3 shows the revised baseline efficiency levels values for each product class.

Table 5.4.3 Clothes Dryer Baseline Active Mode Unit Efficiencies Revised for Test Procedure Amendments

	EF *(lb/kWh)*	
Product Class	**Previous Test Procedure**	**Amended Test Procedure**
Vented dryers		
7. Electric, Standard (4.4 ft^3 or greater capacity)	3.01	3.62
8. Electric, Compact (120 v) (less than 4.4 ft^3 capacity)	3.13	3.62
9. Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	2.90	3.27
10. Gas	2.67	3.20
Ventless dryers		
11. Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	2.37	2.69
12. Electric, Combination Washer/Dryer	1.95	2.17

The minimum energy conservation standards for **room air conditioners**, as measured by EER in Btu/h per watt (W), became effective on October 1, 2000. Table 5.4.4 sets forth the current minimum energy conservation standards for the 16 room air conditioner product classes. (10 CFR Part 430.32(b)) DOE used the existing energy conservation standards to characterize the baseline active mode unit efficiency for each product class, including using the existing standards of the currently still combined product classes for classes that DOE split in this rulemaking. As mentioned in section 5.3, DOE fully analyzed only product classes 1, 3, 5A, and 5B (room air conditioners without reverse cycle and with louvered sides, with capacities of less than 6,000 Btu/h; 8,000 to 13,999 Btu/h; 20,000 to 27,999 Btu/h; and 28,000 Btu/h or more, respectively), and product classes 8A and 8B (room air conditioners without reverse cycle and without louvered sides, with capacities of 8,000 to 10,999 Btu/h; and 11,000 to 13,999 Btu/h, respectively) and subsequently extended the analyses to the other product classes.

Table 5.4.4 Room Air Conditioner Baseline Active Mode Unit Efficiencies

Product Class	**EER** *(Btu/h-W)*
Without reverse cycle and with louvered sides	
1. Less than 6,000 Btu/h	9.7
2. 6,000 to 7,999 Btu/h	9.7
3. 8,000 to 13,999 Btu/h	9.8
4. 14,000 to 19,999 Btu/h	9.7
5A. 20,000 to 27,999 Btu/h	8.5*
5B. 28,000 Btu/h or more	8.5*
Without reverse cycle and without louvered sides	
6. Less than 6,000 Btu/h	9.0
7. 6,000 to 7,999 Btu/h	9.0
8A. 8,000 to 10,999 Btu/h	8.5*
8B. 11,000 to 13,999 Btu/h	8.5*
9. 14,000 to 19,999 Btu/h	8.5
10. 20,000 Btu/h or more	8.5
With reverse cycle and with louvered sides	
11. Less than 20,000 Btu/h	9.0
12. 20,000 Btu/h or more	8.5
With reverse cycle and without louvered sides	
13. Less than 14,000 Btu/h	8.5
14. 14,000 Btu/h or more	8.0
Casement	
15. Casement-Only	8.7
16. Casement-Slider	9.5

* Products of these two pairs of classes are covered in the current energy conservation standards under their "combined" classes of the current standards.

5.4.1.2 Standby Mode and Off Mode

In the MONTH 2011 TP Final Rule, DOE adopted clothes dryer and room air conditioner test procedure amendments to measure standby and off mode energy use. Among other provisions, "active mode," "standby mode," and "off mode" are defined based on the definitions in IEC Standard 62301 Second Edition, Committee Draft for Vote (CDV).

> "Active mode" is defined as a mode which "includes product modes where the energy using product is connected to a mains power source, has been activated and provides one or more main functions."
>
> "Standby mode" is defined as a mode category which "includes any product modes where the energy using product is connected to a mains power source and offers one or more of the following user oriented or protective functions which may persist for an indefinite time:
>
> - To facilitate the activation of other modes (including activation or deactivation of

active mode) by remote switch (including remote control), internal sensor, timer;

- Continuous function: information or status displays including clocks;
- Continuous function: sensor-based functions."

With the additional clarification that "a timer is a continuous clock function (which may or may not be associated with a display) that provides regular scheduled tasks (*e.g.*, switching) and that operates on a continuous basis."

"Off mode" is defined as a mode which "includes any product modes where the energy using product is connected to a mains power source and is not providing any standby mode or active mode function and where the mode may persist for an indefinite time. An indicator that only shows the user that the product is in the off position is included within the clasification of off mode." CITE.

In addition, the amendments provide that if power consumption drops from a higher-power state to a lower-power state in a given mode, as discussed in Section 5, Paragraph 5.1, note 1 of IEC Standard 62301, to allow sufficient time for the product to reach the lower power state before proceeding with the test measurement. CITE.

DOE measured standby and off mode energy use of residential **clothes dryers** in its sample of reverse-engineered units. (See section 5.6.1.3 for a discussion of the reverse engineering test sample, methodology, and results.) The results of the standby and off mode measurements are shown in Table 5.4.5 below. The compact (240 V) ventless and one electric standard vented clothes dryer in the test sample were unable be measured for standby/off mode power consumption because components energized in standby and off mode were powered off 240 V line power, which could not be accommodated by the power meter used by DOE. Additionally, DOE was unable to obtain any test units for electric compact (120 V) vented clothes dryers, so no data is presented for this product class.

Standby and off modes were determined for clothes dryers by observing unit function and power consumption for various operating states other than when the dryer was actively drying or tumbling the clothing. The operating conditions identified for the clothes dryers which are potential standby and off modes included (1) the unit plugged in, but the power switch turned off; (2) the unit plugged in and powered on, but no drying cycle setting selected; (3) the unit plugged in and powered on, with a "normal" setting selected but the drying cycle not started; and (4) the active cycle completed. DOE did not measure power consumption during a delay start condition because none of the clothes dryers in DOE's test sample were equipped with such a feature. For some clothes dryers in the test sample with electronic controls, DOE observed that at the completion of the active cycle, power consumption initially was measured at a higher level, then after a period of inactivity of typically several tens of seconds, would drop to a lower level. After another period of inactivity of typically several minutes, these dryers then changed to a state with even lower power consumption, in which all displays were turned off and the on/off "soft" power switch reset to the "off" condition. In this state, power consumption was the same as when the unit was initially plugged in but not powered on. In other cases, at the completion of the active cycle, the power consumption initially was measured at a higher level, then after a period of inactivity of typically tens of seconds, would drop to a lower level for which only a single light emitting diode (LED) was illuminated to indicate that the cycle was complete. This mode persisted until the dryer door was opened, at which point the LED turned off and the dryer reverted to an even lower power state in which all displays were turned off and the on/off "soft" power switch reset to the "off" condition. As for the previously discussed case, in this state, the power consumption was the same as for when the unit was initially plugged in but not powered on. Since, for the clothes dryers equipped with electronic controls, the unit would only be powered on in anticipation of starting a drying cycle and would revert to the lowest power consumption state after a period of several minutes after the cycle completed or after the clothes have been removed from the drum, DOE believes that the lowest power state represents standby/off mode energy use. Further, since DOE observed that all clothes dryers with displays deactivate them in this lowest power state but include a soft switch for initiating active mode, such units would be operating in a standby mode rather than in off mode. In contrast, clothes dryers with electromechanical controls do not consume any power when the unit is plugged in and not in active mode or once the active cycle has completed, and can thus be considered to operate in off mode. DOE also noted that for operating conditions (2) and (3) defined above, after a period of user inactivity (generally between 5 and 10 minutes), the display turns off and the on/off "soft" power switch resets to the "off' condition, reverting the clothes dryer to the lower power consumption state.

Table 5.4.5 summarizes the power consumption measurements in standby/off mode for each of the clothes dryers in the DOE test sample for which standby power could be measured. Review of this data, along with information on design options obtained during reverse-engineering activities, resulted in DOE proposing a level of 2.0 W for baseline power consumption in standby/off mode. This value is based on a maximum measured input power of 1.51 W for a unit with electronic controls, and thus which provides the consumer utility of a display. The model in the DOE test sample with this standby power consumption, however, was observed to incorporate a switching power supply, which DOE identified as a design option to reduce standby power consumption. In order to define the baseline level for an assumed clothes dryer that uses a conventional power supply, DOE increased the 1.51 W by the estimated change in standby power associated with changing from a conventional to switching power supply. DOE also measured standby power of approximately 0.7 W for other clothes dryers equipped with electronic controls and displays that were observed to differ only by having fewer available cycle settings. Because DOE does not intend to restrict consumer utility associated with the number of different cycles, the baseline was chosen to allow the maximum number of settings.

Table 5.4.5 Clothes Dryer Standby and Off Mode Power Input Measurements

Product Class	Test Unit	EF *(lb/kWh)*	Control Type	Power Input *(W)*	Mode
Vented Electric, Standard	1	3.06	Electromechanical	0.00	Off
	2	3.10	Electromechanical	0.00	Off
	3	3.15	Electronic	0.69	Standby
	4	3.20	Electromechanical	0.00	Off
	5	3.40	Electromechanical		Standby
Vented Electric, Compact (120 V)	6	2.98	Electromechanical	0.00	Off
Vented Gas	7	2.67	Electromechanical	0.00	Off
	8	2.76	Electronic	0.69	Standby
	9	2.8	Electronic	1.51	Standby
	10	3.00	Electronic	0.08	Standby
Ventless Combination Washer/Dryer	11	-	Electronic	0.83	Standby

DOE measured standby/off mode energy use of **room air conditioners** in order to determine the appropriate energy use baseline for these modes. The results of these measurements are shown in Table 5.4.6 below. Note that products with electronic controls were capable of operation in standby mode, as defined in the MONTH YEAR TP Final Rule, while products with electromechanical controls were capable of operation in off mode. For simplicity, DOE defined baseline characteristics for room air conditioners assuming use of electronic controls. Based on the test data, DOE established a baseline standby/off mode power consumption level of 1.4 W. This power input level was higher than all but four of the electronic-control products tested, and the highest power measurement was only 13.5 percent higher than this level.

Table 5.4.6 Room Air Conditioner Standby and Off Mode Power Input Measurements

Product Class	Capacity *(Btu/h)*	EER *(Btu/h-W)*	Control Type	Power Input *(W)* Standby Mode	Power Input *(W)* Off Mode
1	5,000	9.7	Electronic	1.59	
1	5,200	9.7	Electromechanical		0.20
1	5,200	10.7	Electronic	1.28	
1	5,200	11	Electronic	1.46	
3	11,800	11.8	Electronic	1.30	
3	11,800	10.8	Electronic	0.68	
3	12,000	9.8	Electronic	1.36	
3	8,400	11.4	Electronic	1.34	
3	8,000	9.8	Electronic	0.91	
3	8,000	10.8	Electronic	1.40	
3	12,000	9.5*	Electronic	1.21	
5	24,500	8.5	Electronic	0.74	
5	24,000	9.4	Electronic	1.404	
8	8,000	10.5	Electronic	1.27	
8	8,000	9.4	Electronic	1.44	
8	8,000	9.6	Electronic	1.52	
8	11,600	9.5	Electromechanical		0.03
8	11,500	8.5	Electromechanical		0.03
11	11,600	9.5	Electromechanical		0.03
16	8,000	9.5	Electronic	1.41	

*This product was advertised as being through-the-wall (*i.e.* product class 8), but it has louvered sides and no way to allow air flow into the condenser fan intake if the louvers were blocked off by a wall sleeve.

5.4.1.3 Integrated Efficiency

For the preliminary analysis, DOE based its analysis for **residential clothes dryers** on the Integrated Energy Factor (IEF) metric proposed as an alternative option in the December 2008 TP NOPR. Baseline IEF levels were determined from the baseline EF and standby energy use as discussed in sections 5.4.1.1 and 0. The IEF is calculated as the clothes dryer test load weight in lb divided by the sum of "active mode" per-cycle energy use and "standby mode" per-cycle energy use in kWh. As noted above, inactive mode was defined in the December 2008 NOPR as a standby mode other than delay start mode or cycle finished mode that facilitates the activation of active mode by remote switch (including remote control), internal sensor, or timer, or that provides continuous status display. This is the standby mode measured under the discussion in section 0 above. The per-cycle energy consumption associated with this standby mode for residential clothes dryers is calculated assuming 416 clothes dryer cycles in a year and 8,620 hours associated with standby mode. Table 5.4.7 shows the baseline IEF for each residential clothes dryer product class.

Table 5.4.7 Baseline Clothes Dryer IEF

Product Class	EF (Previous Test Procedure) *(lb/kWh)*	Standby Power *(W)*	IEF *(lb/kWh)*
Vented dryers			
1. Electric, Standard (4.4 ft^3 or greater capacity)	3.01	2.0	2.96
2. Electric, Compact (120 v) (less than 4.4 ft^3 capacity)	3.13	2.0	3.00
3. Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	2.90	2.0	2.79
4. Gas	2.67	2.0	2.63
Ventless dryers			
5. Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	2.37	2.0	2.29
6. Electric, Combination Washer/Dryer	1.95	2.0	1.90

As discussed above, DOE recently published the MONTH 2011 TP Final Rule in which it adopted clothes dryer test procedure amendments to measure standby and off mode energy use. Therefore, DOE based its analysis for this final rule for residential clothes dryers on the CEF metric adopted in the MONTH 2011 TP Final Rule. Baseline CEF levels were determined from the baseline EF under the amended test procedure (as discussed above in section 5.4.1.1) and the same standby power levels analyzed for the preliminary analysis, as discussed above in section 5.4.2.2. The per-cycle energy consumption associated with standby mode for residential clothes dryers is calculated assuming 283 clothes dryer cycles in a year[b] and 8,620 hours associated with standby mode. Table 5.4.8 shows the baseline CEF for each residential clothes dryer product class.

Table 5.4.8 Baseline Clothes Dryer CEF

Product Class	EF (Amended Test Procedure) *(lb/kWh)*	Standby Power *(W)*	CEF *(lb/kWh)*
Vented dryers			
7. Electric, Standard (4.4 ft^3 or greater capacity)	3.62	2.0	3.55
8. Electric, Compact (120 v) (less than 4.4 ft^3 capacity)	3.62	2.0	3.43
9. Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	3.27	2.0	3.12
10. Gas	3.20	2.0	3.14
Ventless dryers			
11. Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	2.69	2.0	2.55
12. Electric, Combination Washer/Dryer	2.17	2.0	2.08

For the preliminary analysis, DOE based its analysis for **room air conditioners** on the IEER metric proposed as an alternative option in the December 2008 NOPR. As discussed above, DOE recently published the MONTH 2011 TP Final Rule, in which it modified the name of the integrated metric to CEER to avoid conflict with another pre-existing use of the term

[b] DOE revised the number of active mode cycles per year in the MONTH 2011 TP Final Rule from 416 to 283 cycles per year based on analysis of more recent consumer usage data.

IEER. DOE determined baseline CEER levels from the baseline EER and standby energy use as discussed in sections 5.4.1.1 and 0. CEER is equal to capacity times active mode hours (equal to 750) divided by the sum of active mode annual energy use and standby mode annual energy use, as defined above. This is the standby mode measured under the discussion in section 0 above. The number of hours associated with this standby mode for room air conditioners is 5,115 hours per year.

Because CEER depends on capacity, calculating its baseline value for a product class requires specification of that capacity. For the four product classes and the capacities analyzed in detail for the preliminary analysis, the baseline CEERs are as indicated in Table 5.4.9 below.

Table 5.4.9 Baseline Room Air Conditioner CEER for Analyzed Product Classes

Product Class	**Capacity** *(Btu/h)*	**EER** *(Btu/h-W)*	**Standby Power** *(W)*	**CEER** *(Btu/h-W)*
1	5,000	9.7	1.4	9.52
3	8,000	9.8	1.4	9.69
3	12,000	9.8	1.4	9.72
5A	24,000	8.5	1.4	8.47
5B	28,000	8.5	1.4	8.48
8A	8,000	8.5	1.4	8.41
8B	12,000	8.5	1.4	8.44

5.4.2 Incremental Efficiency and Standby Levels

5.4.2.1 Active Mode

For the majority of the product classes presented in section 5.3, DOE analyzed several efficiency levels and obtained incremental cost data at each of these levels. Table 5.4.10 through Table 5.4.16 provide efficiency levels and the reference source of each level for each of the products under consideration. For most of the product classes, the highest efficiency level was identified based on a review of available product literature for products commercially available (this applied for gas vented clothes dryers and all room air conditioner product classes). For electric vented and ventless clothes dryers, the maximum levels identified in Table 5.4.10 and Table 5.4.11 are based on available research and product literature on heat pump clothes dryers as well as discussions with manufacturers.

As part of the preliminary analysis for **residential clothes dryers**, DOE considered four efficiency levels beyond the baseline efficiency level for electric standard vented clothes dryers and electric compact (120V and 240V) vented clothes dryers, and three efficiency levels for the gas vented product class, as listed in Table 5.4.10. These levels were derived primarily from data contained within the California Energy Commission (CEC) and Natural Resources Canada (NRCan) product databases. For gas clothes dryers, the highest efficiency level (which is the maximum technologically feasible (max-tech) level) is based on the value proposed in the framework document that was based on data contained in the CEC product database. AHAM submitted aggregated incremental manufacturing cost data in support of this max-tech efficiency level for vented gas clothes dryers. As discussed in section 5.6.1.5, multiple manufacturers stated during interviews that the current maximum efficiency that is listed for vented gas clothes dryers in the CEC product database is not achievable. Also, as discussed in section 0, DOE testing of the "maximum-available" gas clothes dryer determined that this unit did not achieve the rated efficiency. For these reasons, DOE proposed for the preliminary analysis to use the vented gas clothes dryer max-tech value for which AHAM submitted aggregated incremental manufacturing costs. This max-tech level was supported by multiple manufacturers during interviews. DOE also added two levels to fill the gap between the baseline and the max-tech for this product class. Since no data was available from either database for electric compact (120 V) clothes dryers, efficiency levels above the baseline for this product class were obtained by scaling the efficiency levels for electric standard units by the ratio of the baseline efficiencies. For electric standard and electric compact (240V) clothes dryers, the max-tech level corresponds to the efficiency improvement associated with incorporating heat pump technology, which was based upon manufacturer interviews and available research on heat pump dryers, while the three gap fill levels are derived from certification data. Some of these efficiency levels were changed from those proposed in the framework document, based on comments from interested parties, manufacturer interviews, and more recent certification data. Because DOE only recently amended the clothes dryer test procedure, the efficiency levels developed for the preliminary analysis were based on EF using the previous DOE clothes dryer test procedure. Table 5.4.10 below shows the efficiency level values for each vented clothes dryer product class proposed in the preliminary analysis.

Table 5.4.10 Vented Clothes Dryer Active Mode Efficiency Levels – Preliminary Analysis

Level	Efficiency Level Description	Efficiency Level (EF) *(lb/kWh)*			
		Electric Standard	Electric Compact (120V)	Electric Compact (240V)	Gas
Baseline	DOE Standard	3.01	3.13	2.90	2.67
1	Gap Fill	3.10	3.22*	2.98	2.75
2	Gap Fill	3.16	3.29*	3.09	2.85
3	Gap Fill/Maximum Available	3.40	3.54*	3.20	3.02 (max-tech)
4	Max-Tech	4.51	4.70*	4.35	

* Estimated by scaling from electric standard clothes dryer efficiency levels.

For ventless clothes dryers, DOE considered three efficiency levels above the baseline for both electric compact (240 V) and electric combination washer/dryer product classes for the preliminary analysis. For ventless electric compact (240 V) clothes dryers, DOE estimated efficiency level (EL) 1 using methodology based on a waiver DOE provided to Miele, Inc. (Miele) for its condenser clothes dryer. In that waiver, Miele voluntarily agreed to maintain the performance of its condenser clothes dryer to within 82.5 percent of the existing energy conservation standard for electric standard clothes dryers. 60 FR 9332 (Feb. 17, 1995). That same percentage was applied to the existing energy conservation standard for electric compact

(240 V) vented clothes dryers (EF = 2.90) to obtain an EF of 2.39 for electric compact (240 V) ventless clothes dryers. A gap-fill level for EL 2 was derived based upon test data from the National Institute of Standards and Technology (NIST). For ventless electric combination washer/dryers, EL 1 was based upon the efficiency improvement credit for incorporating automatic termination control per the DOE test procedure. A gap-fill level for EL 2 was derived using the efficiency improvement from design changes to reach EL 3[c] for electric standard dryers, scaled based upon the inherently lower efficiency of combination washer/dryers. The max-tech for both ventless electric compact (240 V) and combination washer/dryers was derived from the efficiency improvements associated with heat pump technology, as described above for electric standard dryers. DOE recognizes there is some uncertainty associated with the values based upon data from product databases, as it is unclear what test procedure was used to measure EF. As discussed above, because DOE only recently amended the clothes dryer test procedure, the efficiency levels developed for the preliminary analysis were based on EF using the previous DOE clothes dryer test procedure without the exhaust simulator, as discussed above in section 5.4.1.1. Table 5.4.11 below shows the efficiency level values for each ventless clothes dryer product class proposed in the preliminary analysis.

Table 5.4.11 Ventless Clothes Dryer Active Mode Efficiency Levels – Preliminary Analysis

Level	Efficiency Level Description	**Efficiency Level (EF)** *(lb/kWh)*	
		Electric Compact (240 V)	**Electric Combination Washer/Dryer**
Baseline	DOE Test Data	2.37	1.95
1	Gap Fill	2.39*	2.21
2	Gap Fill	2.59†	2.42
3	Max Tech	3.55	3.32

*Determined by scaling the existing Federal standard for vented electric compact (240V) clothes dryers based on Miele's voluntary plan to maintain its condenser clothes dryer EF within 82.5 percent of the existing non-condenser clothes dryer standard. 60 FR 9332.
† Based on NIST test data.[3]

As discussed above in section 5.4.1.1, DOE conducted product testing in order to convert the EF values for each vented clothes dryer product class measured under the previous DOE clothes dryer test procedure to EF values measured under the amended test procedure. As presented above in section 5.4.1.1, DOE test results showed that the measured EF according to the amended test procedure resulted in an average increase of about 20.1 percent for vented electric standard clothes dryers. For vented gas clothes dryers, the measured EF increased by an average of about 19.8 percent. For vented electric compact-size 120V and 240V clothes dryers, the measured EF increased by an average of about 15.6 and 12.8 percent, respectively. DOE applied these results for each product class to adjust the active mode efficiency levels to account for the amendments to the DOE clothes dryer test procedure in the MONTH 2011 TP Final Rule. In addition, DOE revised the active mode efficiency level 1 for vented electric standard clothes

[c] The design changes associated with EL 2 for electric standard clothes dryers are not technologically feasible for combination washer/dryers.

dryers and vented gas clothes dryers from 3.10 EF to 3.11 EF and from 2.75 to 2.76 EF, respectively, based on discussions with manufacturers and the efficiency improvement associated with the design options modeled by DOE, presented in section 5.6.1.3. Table 5.4.12 and Table 5.4.13 below show the revised active mode efficiency level values for each vented clothes dryer product class.

Table 5.4.12 Vented Clothes Dryer Active Mode Efficiency Levels (Vented Electric Standard and Vented Electric Compact (120V))

Level	Efficiency Level Description	Efficiency Level (EF) *(lb/kWh)*			
		Electric Standard		Electric Compact (120V)	
		Previous Test Procedure	Amended Test Procedure	Previous Test Procedure	Amended Test Procedure
Baseline	DOE Standard	3.01	3.62	3.13	3.62
1	Gap Fill	3.11	3.74	3.22	3.72
2	Gap Fill	3.17	3.81	3.29	3.80
3	Gap Fill/Maximum Available	3.40	4.08	3.54	4.09
4	Max-Tech	4.52	5.43	4.70	5.44

Table 5.4.13 Vented Clothes Dryer Active Mode Efficiency Levels (Vented Electric Compact (240V) and Vented Gas)

Level	Efficiency Level Description	Efficiency Level (EF) *(lb/kWh)*			
		Electric Compact (240V)		Gas	
		Previous Test Procedure	Amended Test Procedure	Previous Test Procedure	Amended Test Procedure
Baseline	DOE Standard	2.90	3.27	2.67	3.20
1	Gap Fill	2.98	3.36	2.76	3.31
2	Gap Fill	3.09	3.49	2.86	3.41
3	Gap Fill/Maximum Available	3.20	3.61	3.02 (max-tech)	3.62
4	Max-Tech	4.35	4.91		

For ventless clothes dryers, the preliminary analyses were based on the DOE test procedure with only the proposed amendments for ventless clothes dryers. As discussed above in section 5.4.1.1, DOE also conducted testing according to the final amended test procedure, including changes to the initial RMC, water temperature for test load preparation, etc., which showed that for ventless electric compact 240V clothes dryers and ventless electric combination washer/dryers, the measured EF increased by an average of about 13.6 and 11.4 percent, respectively. DOE similarly applied the percentage increases in the measured EF, developed based on product testing, to the EF values proposed for the preliminary analysis to account for the amendments to the DOE clothes dryer test procedure in the MONTH 2011 TP Final Rule, as discussed above in section 5.4.1.1. Based on discussions with manufacturers and based on the efficiency improvement associated with the design options modeled by DOE (discussed in detail below in section 5.6.1.4), active mode efficiency level 2 for ventless electric combination washer-dryers was revised from 2.59 to 2.47 EF.[d] Table 5.4.14 below shows the revised efficiency level values for each ventless clothes dryer product class.

Table 5.4.14 Ventless Clothes Dryer Active Mode Efficiency Levels

Level	Efficiency Level Description	Efficiency Level (EF) *(lb/kWh)*			
		Electric Compact (240 V)		Electric Combination Washer/Dryer	
		Previous Test Procedure	Amended Test Procedure	Previous Test Procedure	Amended Test Procedure
Baseline	DOE Test Data	2.37	2.69	1.95	2.17
1	Gap Fill	2.39	2.72	2.21	2.46
2	Gap Fill	2.47	2.81	2.30	2.56
3	Max Tech	3.56	4.04	3.32	3.70

For **room air conditioners**, during the preliminary analysis, DOE considered varying numbers of efficiency levels, depending on the product class, as indicated in Table 5.4.15 and Table 5.4.16 below. DOE determined these levels based on the range of efficiency levels associated with products as listed in the CEC, ENERGY STAR, and AHAM product databases and verified to be on sale by a listing on either a manufacturer's website or a retailer's website. DOE added a gap fill efficiency level between the current DOE standard and the ENERGY STAR efficiency level. The maximum available level exceeds the CEE Tier 2 level for product class 1, and matches the CEE Tier 2 level for product class 3. For product classes 5 and 8, the CEE Tier 2 levels are higher than the maximum available product EER, and thus are not included as efficiency levels.

Table 5.4.15 Room Air Conditioner Active Mode Efficiency Levels--Product Classes 1 and 3 – Preliminary Analysis

Level	Efficiency Level Description	EER *(Btu/h-W)*	
		<u>Product Class 1:</u> Without Reverse Cycle, With Louvered Sides, < 6,000 Btu/h	<u>Product Class 3:</u> Without Reverse Cycle, With Louvered Sides, 8,000 - 13,999 Btu/h
Baseline	DOE Standard	9.7	9.8
1	Gap Fill	10.2	10.3
2	Energy Star	10.7	10.8
3	CEE Tier 1	11.2	11.3
4	CEE Tier 2	11.6	11.8
5	Maximum Available*	12.0	

* Based on ENERGY STAR-qualified room air conditioners as of July, 2008 and verification of availability through retailer website searches.

[d] EL 2 was derived using the efficiency improvement from design changes to reach EL 3 for electric standard dryers, scaled based upon the inherently lower efficiency of combination washer/dryers.

Table 5.4.16 Room Air Conditioner Active Mode Efficiency Levels--Product Classes 5 and 8 – Preliminary Analysis

Level	Efficiency Level Description	EER *(Btu/h-W)*	
		Product Class 5: Without Reverse Cycle, With Louvered Sides, ≥ 20,000 Btu/h	**Product Class 8: Without Reverse Cycle, Without Louvered Sides, 8,000 – 13,999 Btu/h**
Baseline	DOE Standard	8.5	8.5
1	Gap Fill	9.0	9.0
2	Energy Star	9.4	9.4
3	CEE Tier 1	9.8	9.8
4	Maximum Available*	10.0	10.8 (8,000 Btu/h) 9.8 (12,000 Btu/h)

* Based on ENERGY STAR-qualified room air conditioners as of July, 2008 and verification of availability through retailer website searches. CEE Tier 2 level is higher than the maximum available EER for these product classes.

For the final rule analysis, DOE again considered varying numbers of efficiency levels, depending on the product class, as indicated in Table 5.4.17 to Table 5.4.18 below. DOE based the max-tech levels on the analysis, rather than the maximum available units. DOE also adjusted the gap-fill levels to provide reasonable increments between successive levels. When possible, DOE selected efficiency levels equivalent to CEE Tier 1 and Tier 2. For example the level following the ENERGY-STAR level matches CEE Tier 1 for product classes 1, 5A, and 5B.

Table 5.4.17 Room Air Conditioner Active Mode Efficiency Levels--Product Classes 1 and 3

Level	Efficiency Level Description	EER *(Btu/h-W)*	
		Product Class 1: Without Reverse Cycle, With Louvered Sides, < 6,000 Btu/h	**Product Class 3: Without Reverse Cycle, With Louvered Sides, 8,000 - 13,999 Btu/h**
Baseline	DOE Standard	9.7	9.8
1	Gap Fill	10.2	10.3
2	Energy Star	10.7	10.8
3	Gap Fill 2	11.2	11.0
4	Gap Fill 3	11.5	11.6
5	Max-Tech	11.8**	12.0

** This level is lower than the max-available efficiency of 12.0 identified by DOE. This reflects the 50 lb product weight limit discussed in section 5.6.2.6.

Table 5.4.18 Room Air Conditioner Active Mode Efficiency Levels--Product Classes 5A and 5B

Level	Efficiency Level Description	EER *(Btu/h-W)*	
		Product Class 5A: Without Reverse Cycle, With Louvered Sides, 20,000-27,999 Btu/h	**Product Class 5B: Without Reverse Cycle, With Louvered Sides, ≥ 28,000 Btu/h**
Baseline	DOE Standard	8.5	8.5
1	Gap Fill 1	9.0	9.0
2	Energy Star	9.4	9.4
3	Gap Fill 2	9.8	9.8
4	Max-Tech	10.2	

Table 5.4.19 Room Air Conditioner Active Mode Efficiency Levels--Product Classes 8A and 8B

Level	Efficiency Level Description	EER *(Btu/h-W)*	
		Product Class 8A: Without Reverse Cycle, Without Louvered Sides, 8,000-10,999 Btu/h	**Product Class 8B: Without Reverse Cycle, Without Louvered Sides, 11,000 - 13,999 Btu/h**
Baseline	DOE Standard	8.5	8.5
1	Energy Star	9.4	9.4
2	Gap Fill 1	9.7	9.6
3	Gap Fill 2	10.1	9.8
4	Max-Tech	10.4	10.1

5.4.2.2 Standby Mode and Off Mode

For **clothes dryers** DOE observed through testing and teardowns that several different features could be associated with successively lower standby power levels (SLs). Therefore, DOE was able to define several standby power levels for analysis. Only standby power is addressed because no power consumption was observed in the off mode for test units capable of such a mode. At the baseline standby power level of 2.0 W, the clothes dryer is estimated to be equipped with a full complement of cycle settings, a linear regulated control board power supply, and a display which powers down after a period of user inactivity. The automatic deactivation of electronic displays was observed in all tested units so equipped and was therefore considered a baseline feature.

SL 1 is associated with changing from a conventional power supply to a switch-mode power supply. For SL 2, a transformerless power supply enables a microcontroller to remain on at all times while disabling the main power supply whenever the clothes dryer is “asleep”. The control logic monitors the clothes dryer for key-presses, door openings, etc., and when user activity is detected, the logic activates the main power supply. These standby power levels, shown in Table 5.4.20, are believed to be the same for all clothes dryer product classes.

Table 5.4.20 Clothes Dryer Standby Power Levels

Level	Standby Power Source	Power Input *(W)*
Baseline	DOE Test Data and Analysis	2.0
1	DOE Test Data	1.5
2	DOE Test Data (Max-Tech)	0.08

For **room air conditioners**, DOE selected a single incremental standby power level for standby mode, based on the data presented in Table 5.4.6 above. The standby mode power input at SL 1 is 0.7 W, which was observed in one of the room air conditioners in the test sample and nearly achieved by a second unit.

Baseline room air conditioners with electronic controllers featured a linear regulated power supply and an infrared detector for the remote control. All sampled units with electronic controllers featured a remote control. SL 1 was met by one of the room air conditioners in the test sample and was nearly achieved by a second unit. DOE research suggests that SL1 can be achieved through the substitution of a switch-mode power supply, since both units that met or nearly met SL1 used such power supplies. All other electronic-controlled units used conventional linear regulated power supplies. The selected standby power levels are summarized in Table 5.4.21 below.

Table 5.4.21 Room Air Conditioner Standby Power Levels

Level	Standby Power Source	Power Input *(W)*
Baseline	DOE Test Data	1.4
1	DOE Test Data	0.7

5.4.2.3 Integrated Efficiency

As part of the preliminary analysis for **clothes dryers**, incremental IEF efficiency levels were determined by assuming that a clothes dryer with baseline energy efficiency (EF) performance would incorporate baseline standby power consumption (*i.e.*, 2.0 W). DOE recognizes that many clothes dryers that just meet the current Federal energy conservation standards for EF utilize electromechanical controls, which consume no standby power. There are, however, a significant number of models rated at baseline energy efficiency performance that incorporate electronic controls. Thus, DOE assumed that the baseline IEF level for a minimally-compliant unit should include the 2.0 W of standby power. At higher IEF levels, DOE estimated for the preliminary analysis that standby power would remain at 2.0 W for those levels that do not strictly require electronic controls to achieve. For those higher levels that do require electronic controls, DOE added in the design options for standby power improvements in order of cost effectiveness. This resulted in the incremental IEF efficiency levels proposed for the preliminary analysis shown in Table 5.4.22 through Table 5.4.24.

Table 5.4.22 Preliminary Analysis Clothes Dryer Integrated Efficiency Levels (IEF) – Vented Product Classes

Level	Efficiency Level Description	Integrated Efficiency Level (IEF) *(lb/kWh)*			
		Electric Standard	Electric Compact (120V)	Electric Compact (240V)	Gas
Baseline	DOE Standard + 2.0 W Standby	2.96	3.00	2.79	2.63
1	Gap Fill + 2.0 W Standby	3.04	3.08	2.86	2.71
2	Gap Fill + 2.0 W Standby	3.10	3.15	2.96	2.80
3	Gap Fill/Maximum Available + 2.0 W Standby	3.33	3.37	3.06	2.97
4	Maximum Available + 1.5 W Standby	3.35	3.41	3.10	2.98
5	Maximum Available + 0.08 W Standby	3.40	3.53	3.19	3.02
6	Heat Pump (Max Tech) + 0.08 W Standby	4.52	4.69	4.34	

Table 5.4.23 Preliminary Analysis Clothes Dryer Integrated Efficiency Levels (IEF) – Ventless Electric Compact (240V)

Level	Efficiency Level Description	Integrated Efficiency Level (IEF) *(lb/kWh)*
		Electric Compact (240 V)
Baseline	Baseline + 2.0 W Standby	2.29
1	Baseline + 1.5 W Standby	2.31
2	Baseline + 0.08 W Standby	2.37
3	Gap Fill + 0.08 W Standby	2.39
4	Gap Fill + 0.08 W Standby	2.59
5	Heat Pump (Max-Tech) + 0.08 W Standby	3.54

Table 5.4.24 Preliminary Analysis Clothes Dryer Integrated Efficiency Levels (IEF) – Ventless Electric Combination Washer/Dryers

Level	Efficiency Level Description	Integrated Efficiency Level (IEF) *(lb/kWh)*
		Electric Combination Washer/Dryer
Baseline	Baseline + 2.0 W Standby	1.90
1	Gap Fill + 2.0 W Standby	2.15
2	Gap Fill + 2.0 W Standby	2.34
3	Gap Fill + 1.5 W Standby	2.36
4	Gap Fill + 0.08 W Standby	2.42
5	Heat Pump (Max-Tech) + 0.08 W Standby	3.31

Based on the revised active mode efficiency levels for the final rule analyses presented above in section 5.4.2.1 and the standby power levels presented in section 5.4.2.2, DOE revised the incremental CEF efficiency levels. As discussed above, for the preliminary analysis, DOE only incorporated incremental standby power levels into IEF efficiency levels above which electronic controls would be required as part of the active mode design option changes. At that point, DOE then incorporated the incremental standby power levels where it determined them to be most cost effective. However, DOE believes that the low cost of the standby power design options should result in these technologies being layered in at the efficiency levels where these design options are most cost-effective (regardless of whether electronic controls are required for the active mode design options). As a result, for the final rule, DOE revised the order of the design options and efficiency levels presented in the preliminary analysis such that the standby power levels are applied immediately above the baseline level. DOE also noted that for the integrated efficiency levels where electronic controls are not required for the design changes, the standby power level changes would impact only those clothes dryers that consume standby power (*i.e.*, those products with electronic controls). DOE analyzed baseline efficiency products available on the U.S. market, and weighted the efficiency improvement and incremental manufacturing cost associated with standby power based on the percentage of baseline efficiency products that have electronic controls. DOE's review of currently available models with baseline efficiency showed that roughly 74 percent of models have electronic controls. For the integrated efficiency levels for which electronic controls are required as part of the active mode design changes, DOE assumed that the standby power levels and incremental manufacturing costs (presented below in section 5.6.1.4) affected 100 percent of clothes dryer models. The incremental CEF efficiency levels are shown in Table 5.4.25 through Table 5.4.27.

Table 5.4.25 Clothes Dryer Integrated Efficiency Levels (CEF) – Vented Product Classes

Level	Efficiency Level Description	Integrated Efficiency Level (CEF) *(lb/kWh)*			
		Electric Standard	**Electric Compact (120V)**	**Electric Compact (240V)**	**Gas**
Baseline	DOE Standard + 2.0 W Standby	3.55	3.43	3.12	3.14
1	DOE Standard + 1.5 W Standby	3.56	3.48	3.16	3.16
2	DOE Standard + 0.08 W Standby	3.61	3.61	3.27	3.20
3	Gap Fill + 0.08 W Standby	3.73	3.72	3.36	3.30
4	Gap Fill + 0.08 W Standby	3.81	3.80	3.48	3.41
5	Gap Fill/Maximum Available + 0.08 W Standby	4.08	4.08	3.60	3.61
6	Heat Pump (Max-Tech) + 0.08 W Standby	5.42	5.41	4.89	

Table 5.4.26 Clothes Dryer Integrated Efficiency Levels (CEF) – Ventless Electric Compact (240V)

Level	Efficiency Level Description	Integrated Efficiency Level (CEF) *(lb/kWh)*
		Electric Compact (240 V)
Baseline	Baseline + 2.0 W Standby	2.55
1	Baseline + 1.5 W Standby	2.59
2	Baseline + 0.08 W Standby	2.69
3	Gap Fill + 0.08 W Standby	2.71
4	Gap Fill + 0.08 W Standby	2.80
5	Heat Pump (Max-Tech) + 0.08 W Standby	4.03

Table 5.4.27 Clothes Dryer Integrated Efficiency Levels (CEF) – Ventless Electric Combination Washer/Dryers

Level	Efficiency Level Description	Integrated Efficiency Level (CEF) *(lb/kWh)*
		Electric Combination Washer/Dryer
Baseline	Baseline + 2.0 W Standby	2.08
1	Gap Fill + 2.0 W Standby	2.35
2	Gap Fill + 1.5 W Standby	2.38
3	Gap Fill + 0.08 W Standby	2.46
4	Gap Fill + 0.08 W Standby	2.56
5	Heat Pump (Max-Tech) + 0.08 W Standby	3.69

During the preliminary analysis, incremental IEER efficiency levels for **room air conditioners** were established at values rounded to the nearest tenth, except for the baseline levels described in section 5.4.1.3. The levels were chosen to correspond to the EER efficiency levels in the preliminary analysis discussed in section 5.4.2.1 as closely as was feasible. The selected levels are summarized in Table 5.4.28 and Table 5.4.29 below.

Table 5.4.28 Preliminary Analysis Room Air Conditioner Integrated Efficiency Levels (IEER)--Product Classes 1 and 3

Level	IEER *(Btu/h-W)*	
	1: Without Reverse Cycle, With Louvered Sides, < 6,000 Btu/h	**3:Without Reverse Cycle, With Louvered Sides, 8,000 - 13,999 Btu/h**
Baseline	9.52	9.71
1	10.1	10.3
2	10.6	10.8
3	11.1	11.3
4	11.6	11.5
5	12.0	

Table 5.4.29 Preliminary Analysis Room Air Conditioner Integrated Efficiency Levels (IEER)--Product Classes 5 and 8

Level	IEER *(Btu/h-W)*	
	5:Without Reverse Cycle, With Louvered Sides, ≥ 20,000 Btu/h	**8:Without Reverse Cycle, Without Louvered Sides, 8,000 – 13,999 Btu/h**
Baseline	8.47	8.43
1	9.0	8.9
2	9.4	9.3
3	9.8	9.8
4	10.0	-

As detailed in the section above, DOE modified its active mode efficiency levels for the final rule analysis, and renamed the integrated metric. Based on these changes, incremental CEER efficiency levels for **room air conditioners** were established at values rounded to the nearest tenth, except for the baseline levels described in section 5.4.1.3. The levels were chosen to correspond to the extent feasible with the EER efficiency levels selected for the active mode efficiency , which are discussed in section 5.4.2.1. The selected integrated efficiency levels are summarized in Table 5.4.30 to Table 5.4.32 below.

Table 5.4.30 Room Air Conditioner Integrated Efficiency Levels (CEER)--Product Classes 1 and 3

Level	CEER *(Btu/h-W)*	
	1: Without Reverse Cycle, With Louvered Sides, < 6,000 Btu/h	**3:Without Reverse Cycle, With Louvered Sides, 8,000 - 13,999 Btu/h**
Baseline	9.52	9.71
1	10.1	10.2
2	10.6	10.7
3	11.1	10.9
4	11.4	11.5
5	11.7	12.0

Table 5.4.31 Room Air Conditioner Integrated Efficiency Levels (CEER)--Product Classes 5A and 5B

Level	CEER *(Btu/h-W)*	
	5A:Without Reverse Cycle, With Louvered Sides, 20,000-27,999 Btu/h	**5B:Without Reverse Cycle, With Louvered Sides, ≥ 28,000 Btu/h**
Baseline	8.47	8.48
1	9.0	8.9
2	9.4	9.4
3	9.8	9.8
4	10.15	-

Table 5.4.32 Room Air Conditioner Integrated Efficiency Levels (CEER)--Product Classes 8A and 8B

Level	CEER *(Btu/h-W)*	
	8A:Without Reverse Cycle, Without Louvered Sides, 8,000 – 10,999 Btu/h	**8B:Without Reverse Cycle, Without Louvered Sides, 11,000 – 13,999 Btu/h**
Baseline	8.41	8.44
1	9.3	9.3
2	9.6	9.5
3	10.0	9.8
4	10.4	10.0

5.5 METHODOLOGY OVERVIEW

DOE typically uses data submitted by AHAM as the primary source of cost information for the engineering analysis. AHAM provided DOE with aggregated incremental manufacturing cost data from its member companies for several product classes of vented clothes dryers. However, AHAM did not receive enough responses from members to allow aggregation and reporting of data for the remaining clothes dryer product classes and all room air conditioner product classes.

For **clothes dryers**, DOE conducted an independent review of the AHAM data using several methods and data sources. To gain a better understanding of the data submitted by member companies and to be able to relate the costs of improving efficiency to discrete (or system) technologies, DOE reviewed the TSD from the previous rulemaking and conducted interviews with clothes dryer manufacturers. DOE also performed detailed product teardowns and cost modeling on several clothes dryer models spanning a range of efficiencies to generate cost-efficiency curves. These cost-efficiency relationships were compared to the AHAM data for validation. Finally, DOE conducted standby power testing, as well as detailed energy performance testing at an independent laboratory to gain insights into energy performance in active, standby, and off modes, and disaggregated energy use of components and subsystems.

For **room air conditioners**, in the absence of industry-supplied data, DOE conducted energy modeling analysis of the products obtained for reverse engineering analysis, product designs for R-410A refrigerant based on the reverse engineering products, and product designs using R-410A that incorporate energy-saving design options. The manufacturing cost model developed in conjunction with the reverse-engineering work was used to determine the incremental costs associated with the high-efficiency product designs evaluated in the energy modeling in order to allow development of cost-efficiency relationships for products using R-410A refrigerant. DOE supplemented these analysis with a review of the TSD from the previous rulemaking, product testing at an independent laboratory, and manufacturer interviews. Table 5.5.1 below shows which methods DOE used for each product.

Table 5.5.1 Engineering Analysis Methods

Method	Product	
	Clothes Dryers	Room Air Conditioners
AHAM Data	√	
Review of Previous TSD	√	√
Product Teardown and Manufacturing Cost Modeling	√	√
Product Testing	√	√
Manufacturer Interviews	√	√
Energy Modeling		√

5.5.1 AHAM Data Request

In support of this rulemaking effort, DOE requested incremental cost data from AHAM for both of the product categories. (See appendix 5A of this TSD for the data request sheets.) The data represent the average incremental production cost to improve a baseline unit to a specified efficiency level. This methodology constitutes an efficiency-level approach to the engineering analysis because DOE examined aggregated incremental increases in manufacturer selling price at specified levels of energy efficiency. In addition, DOE requested shipments, shipment-weighted average efficiency, and market share efficiency data. As noted in section 5.4.2.3, AHAM did not receive enough responses from members in order to allow aggregation and reporting of incremental cost data for room air conditioners. Tables of aggregated data for clothes dryers provided to DOE by AHAM are contained in appendix 5B of this TSD.

5.5.2 Manufacturer Interviews

AHAM provided to DOE shipment-weighted average manufacturer costs and capital expenditures. To better understand the manufacturer costs, DOE supplemented these data with information obtained through follow-up manufacturer interviews. These confidential interviews provided a deeper understanding of the various combinations of technologies used to increase product efficiency, and their associated manufacturing costs. Sample questions asked during interviews are contained in appendix 5C of this 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.

5.5.3 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 the unit piece-by-piece and estimate the material and labor cost of each component using a process commonly called a physical teardown. A supplementary method, called a catalog teardown, uses published manufacturer catalogs and supplementary component data to estimate the major physical differences between a product that has been physically disassembled and another similar product. DOE performed physical teardown analysis on both clothes dryers and room air conditioners. The teardown methodology is explained in section 5.5.3.1 and section 5.5.3.2.

Selection of Units

During the process of selecting units for teardown, DOE considered 3 main questions:

- What efficiency levels should be captured in the teardown analysis?
- Are there units on the market that capture all potential efficiency levels and design options?
- Which of the available units are most representative?

In responding to the preceding questions, 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, if possible, the selected products should come from the same manufacturer and be within the same product series;
- The selected products should primarily come from manufacturers with large market share in that product class, although the highest efficiency products were 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.

Additional criteria for selecting the teardown units specific to each product category are described in section 5.6.1.3 for clothes dryers and section 5.6.2.3 for room air conditioners.

5.5.3.1 Generation of Bill of Materials

The end result of each teardown is a structured bill of materials (BOM). Structured BOMs describe each equipment 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 equipment needed (*e.g.*, stamping presses, injection molding machines, spot-welders, etc.) and the process cycle times. The result is a thorough and explicit model of the production process.

The BOMs incorporate all materials, components, and fasteners, classified as either raw materials or purchased parts and assemblies. The classification into raw materials or purchased parts is based on DOE's previous industry experience, recent information in trade publications, and discussions with high- and low-volume original equipment manufacturers (OEMs).

For purchased parts, the purchase price is an estimate based on volume-variable price quotations and detailed discussions with suppliers. For parts fabricated in-house, the prices of "raw" metals (*e.g.*, tube, sheet metal) are estimated on the basis of 5-year averages. Other "raw" materials such as plastic resins, insulation materials, etc. are estimated on a current-market basis.

The cost of raw materials was determined using prices for copper, steel and aluminum from the American Metals Market.[4] The prices for rifled and unrifled copper tubing were obtained directly from a tubing manufacturer.

The price of steel drastically increased in 2005, and the price of copper has increased steadily since 2004. Because DOE is using a 5-year average in material prices from 2005-2009, these price increases are normalized, which better represents long-term material prices.

In order to assure that raw material prices DOE used in manufacturing cost estimates are representative of actual costs paid by OEMs, DOE sent a separate material cost questionnaire to the manufacturers that participated in the technical interviews.

5.5.3.2 Cost Structure of the Spreadsheet Models

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

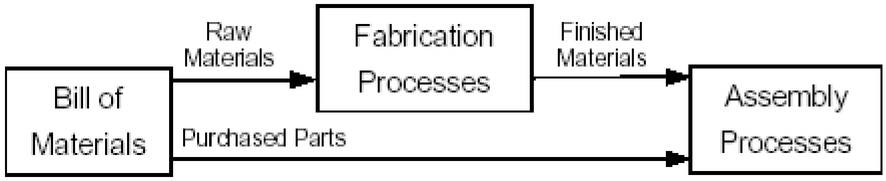


Figure 5.5.1 Manufacturing Cost Assessment Stages

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

Following the development of a detailed BOM, the major manufacturing processes were identified and developed for the spreadsheet model. These processes are listed in Table 5.5.2.

Table 5.5.2 Major Manufacturing Processes

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

Fabrication process cycle times were estimated and entered into the BOM. In the final step of the cost assessment, assembly times and associated direct labor costs were estimated. 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.

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

5.5.3.3 Cost Model and Definitions

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

- Materials: Purchased parts (*i.e.*, gas valves, blower motors, 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.
- Indirect labor: Labor costs that scaled with fabrication and assembly labor. This included the cost of technicians, manufacturing engineering support, stocking, etc. that were assigned on a span basis.
- Equipment and plant depreciation: Money allocated to pay for initial equipment installation and replacement as the production equipment is amortized.
- Tooling depreciation: Cost for initial tooling (including non-recurring engineering and debugging of the tools) and tooling replacement as it wears out or is rendered obsolete.
- Building depreciation: Money allocated to pay for the building space and the conveyors that feed and/or make up the assembly line.
- Utilities: Electricity, gas, telephones, etc.
- Maintenance: Annual money spent on maintaining tooling and equipment.
- Insurance: Appropriated as a function of unit cost.
- Property Tax: Appropriated as a function of unit cost.

5.5.3.4 Cost Model Assumptions

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

5.5.4 Review of Previous Technical Support Documents and Models

DOE reviewed previous rulemaking TSDs to assess their applicability to the current standard setting process for residential clothes dryers and room air conditioners. These previous rulemaking TSDs served as a source for design options and energy consumption analysis, in addition to other sources. For room air conditioners, the energy model used in the previous rulemaking was updated for use in the current one.

5.5.5 Product Testing

DOE conducted product testing on clothes dryers and room air conditioners according to the relevant DOE test procedures to develop a better understanding of the potential efficiency improvements of design options and to develop disaggregated efficiency data. In addition, DOE performed standby and off mode testing to help evaluate possible standby and off modes, energy use in each mode, and strategies manufacturers may take to reduce standby power.

5.6 ANALYSIS AND RESULTS

5.6.1 Clothes Dryers

The clothes dryer engineering analysis was performed by considering cost and efficiency information from multiple sources. AHAM provided incremental manufacturing costs for all but the highest efficiency levels of interest to DOE for vented electric standard and gas clothes dryers. No data were provided for vented electric compact (120 V) and (240 V) or ventless electric compact (240 V) and electric combination washer/dryer product classes. DOE supplemented these data points by conducting its own engineering analysis, comprised of performance testing at an independent laboratory, standby power testing, and manufacturing cost estimates from detailed teardowns of currently-available clothes dryers. Manufacturer interviews were also conducted to obtain greater insight into the design strategies to improve efficiency and the associated costs. DOE conducted preliminary manufacturer interviews after the framework document. DOE also conducted additional manufacturer interviews for the final rule analysis.

5.6.1.1 AHAM Data

AHAM provided to DOE shipment data from its member companies for clothes dryers. Table 5.6.1 shows market share by EF[e] ranges for electric standard and gas clothes dryer shipments in the years 2005 and 2006. AHAM noted that, in order to maintain confidentiality, market share for electric standard dryers between EF of 3.20 and 3.29 were incorporated into the EF range between 3.10 and 3.19. Similarly, market share for gas clothes dryers with an EF > 2.94 was incorporated into the EF > 2.85 efficiency bin. AHAM stated it was not able to obtain sufficient data for vented electric compact (120 V) and (240 V). In addition, market share data for ventless dryers was unavailable since EF is not currently measured.

Table 5.6.1 AHAM Clothes Dryer Market Share Data Submittal

Vented Electric Standard			**Vented Gas**		
EF Range *(lb/kWh)*	**Market Share for 2005** *(%)*	**Market Share for 2006** *(%)*	**EF Range** *(lb/kWh)*	**Market Share for 2005** *(%)*	**Market Share for 2006** *(%)*
3.01-3.09 (Baseline = 3.01)	26	33	2.67-2.74 (Baseline = 2.67)	25	28
3.10-3.29	74	67	2.75-2.84	42	44
3.20-3.29			>2.85	32	27
>3.29					

On a shipment-weighted basis, the average efficiencies of electric standard and gas clothes dryers sold in the United States have been stable for the past few years, according to the AHAM-submitted data shown in Table 5.6.2.

[e]All clothes dryer EF data provided by AHAM is based on EF values as measured by the previous DOE clothes dryer test procedure.

Table 5.6.2 AHAM Clothes Dryer Shipments and Shipment-Weighted Efficiency Data Submittal

Year	Shipments, Domestic + Imports (*Thousands of Units*)						Shipment-Weighted Average Efficiency(EF, *cycles/kWh*)			
	Vented				Ventless		Vented			
	Electric				Electric		Electric			
	All Electric	Standard	All Compact	Gas	Compact 240 V	Combo	Standard	Compact 120 V	Compact 240 V	Gas
1993	3,674			1,156						
1994	3,838			1,239						
1995	3,823			1,169						
1996	3,947			1,193						
1997	4,115			1,195						
1998	4,482			1,307						
1999	4,865			1,444						
2000	5,095			1,480						
2001	5,117			1,384						
2002	5,402			1,490						
2003	5,718	5,622	96	1,616						
2004	6,262	6,159	103	1,660						
2005	6,408	6,330	78	1,707			3.10			2.70
2006	6,360	6,246	114	1,614			3.10			2.70

AHAM provided incremental manufacturing cost data for the first three efficiency levels for vented electric standard and gas clothes dryers presented in the framework document, as shown in Table 5.6.3. At the time DOE requested data from AHAM, the efficiency levels of interest were specified as those in the framework document, which were subsequently updated during the preliminary analysis based on more recent market information, comments from interested parties, and manufacturer interviews. Therefore, the AHAM cost data are presented at the original values of EF to which the aggregated data correspond, while DOE's cost estimates are presented at the updated levels.

Table 5.6.3 AHAM Clothes Dryer Incremental Cost Data Submittal

		Vented Electric Standard			Vented Gas		
Efficiency Level		**1**	**2**	**3**	**1**	**2**	**3**
EF Level, [Original] *(lb/kWh)*		**3.10**	**3.16**	**3.39**	**2.75**	**2.77**	**3.02**
Average Shipment-Weighted Incremental Cost *($)* for each EF level	Material	9	42	140	20	60	81
	Labor	2	11	45	2	6	32
	Overhead	2	4	12	2	4	12
Conversion Capital Expenditure Assumptions, *(Million $)*, Total for all Manufacturers	Building	0.25	9.02	50.18	0.46	29.83	
	Tooling and Equipment	5.25	37.68	118.93	2.62	37.24	16.15
Avg. One-Time Product Conversion Expenses, *(Million $)*, Total for all Manufacturers	R&D	3.62	15.87	58.97	2.99	15.46	12.91
	Marketing						

Notes
1. While all members use straight-line depreciation, AHAM was not able to obtain a consistent response on the years used in the calculation.
2. Shaded cells indicate that AHAM did not receive enough input to aggregate incremental cost data.

Figure 5.6.1 plots the average incremental cost as a function of EF (based on the previous DOE clothes dryer test procedure) for the AHAM clothes dryer data. The lowest point on the graph indicates the baseline level and therefore has a cost increment of $0. Note that the gas curve exhibits a steep increase between EL 2 and EL 3. Based on manufacturer interviews, DOE believes that AHAM members suggested fairly significant design changes in order to reach EL 3, even though the original EF values for EL 2 and EL 3 were quite close.

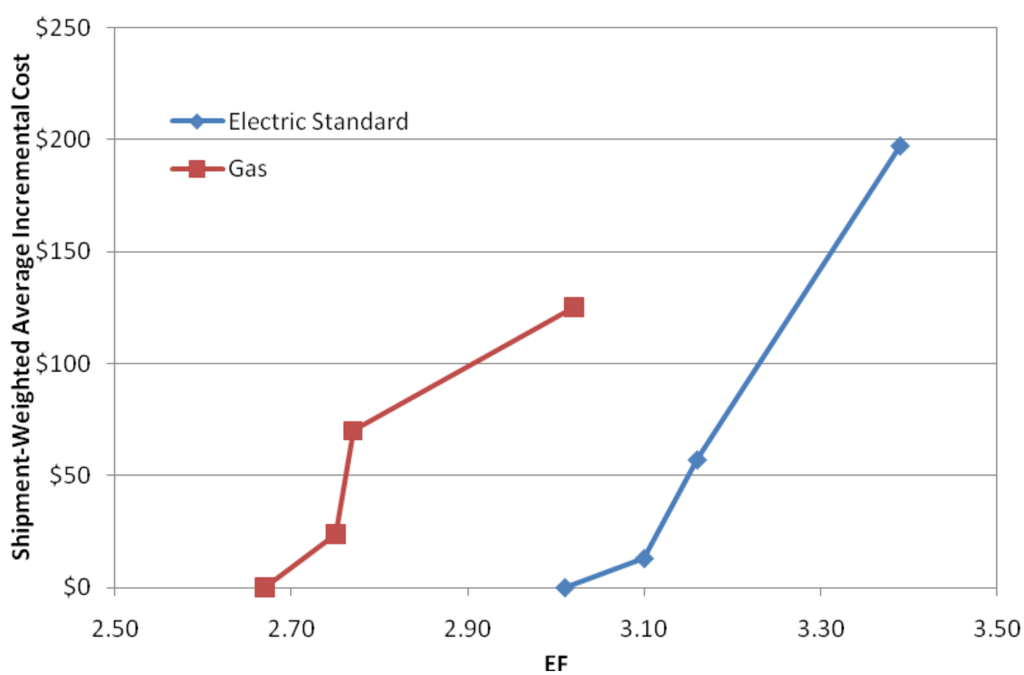


Figure 5.6.1 AHAM Clothes Dryer Cost-Efficiency Curves

In addition to the cost and efficiency data, AHAM provided information to help DOE evaluate a potential change to the clothes dryer test procedure to reflect more current product characteristics. The previous DOE clothes dryer test procedure assumed an initial RMC of the test cloth load of 70.0 ± 3.5 percent. However, DOE noted that this RMC value is likely no longer representative of typical residential clothes washers that use higher spin speeds to remove moisture at the end of the wash cycle. Therefore, DOE requested data from AHAM to help evaluate the effect of a lower initial RMC on measured EF, as well as to characterize the trends in shipment-weighted clothes washer RMC. Figure 5.6.2 illustrates the data AHAM provided for the change in EF that is measured when RMC is reduced from nominally 70 percent to nominally 56 percent. It can be seen that, in AHAM's test sample of 11 baseline clothes dryers, EF decreased by an average of 4 percent when RMC was reduced as described and the existing test procedure was used to calculate EF. Average EF decreased from 3.09 to 2.97 lb/kWh. The test procedure, however, contains a provision in the calculation of per-cycle energy consumption that is intended to normalize EF by the reduction in RMC over the course of the drying cycle. There is a scaling factor applied of 66, which is supposed to represent the nominal change in percent from the starting RMC to the ending one, which is derived from the assumption that the nominal starting RMC is 70 percent and the nominal ending RMC is 4 percent. If the calculation in the test procedure is adjusted to maintain what DOE believes is the intent for normalization of the results, the scaling factor should be changed to 52 to reflect a starting point of 56 percent RMC rather than 70 percent. If that adjustment is made to the AHAM data, EF increases by an average of 22 percent by changing from 70 to 56 percent initial RMC.

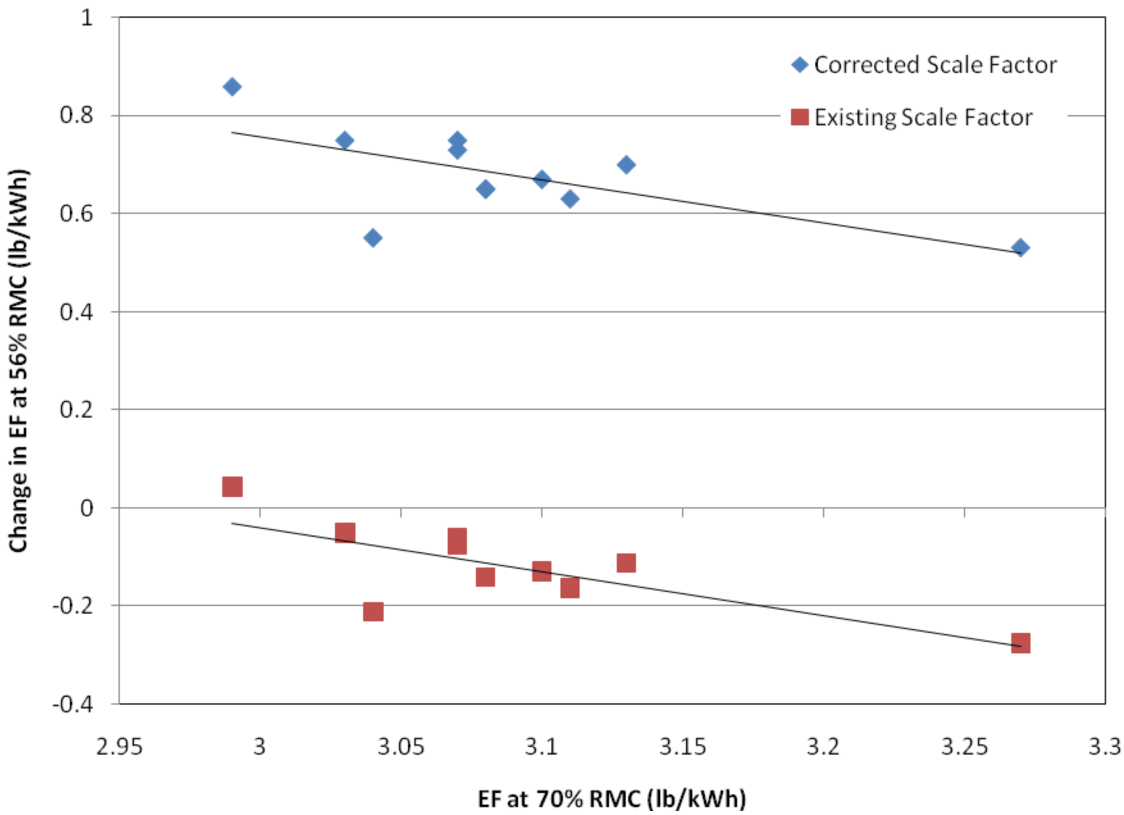


Figure 5.6.2 AHAM Data Submittal for Impact of Initial RMC on Clothes Dryer EF

AHAM also provided data for shipments of residential clothes washers for which RMC was reported, along with shipment-weighted RMC. (See Table 5.6.4) These data sets, each of which were disaggregated for front-loading and top-loading clothes washers as well as reported as overall values for all clothes washers, provide insight into what initial clothes dryer RMC would be most representative of current clothes washers. RMC has been decreasing consistently, and the data suggest that the initial RMC in the clothes dryer test procedure of nominally 70 percent is higher than the current shipment-weighted clothes washer average.

Table 5.6.4 AHAM Shipment-Weighted Clothes Washer RMC Data Submittal

Year	Clothes Washer Shipments for Which RMC was Reported			Shipment-Weighted RMC* *(%)*		
	Front-Loading	Top-Loading	Total	Front-Loading	Top-Loading	Overall
2000	232,714	686,440	919,154	43.6	57.4	53.9
2001	235,989	473,629	709,618	41.3	57.7	52.2
2002	280,667	529,265	809,932	41.5	58.1	52.3
2003	351,411	1,676,877	2,028,288	43.1	54.5	52.5
2004	1,179,813	5,270,285	6,450,098	42.2	52.8	50.9
2005	1,563,108	5,394,511	6,957,619	40.8	52.7	50.1
2006	1,851,218	15,528,279	17,379,497	39.3	51.8	50.5
2007	1,973,825	15,271,142	17,244,967	38.3	51.8	50.2
2008	2,043,024	4,492,059	6,535,083	38.1	51.0	47.0

* Shipment-weighted average clothes washer RMC data measured using the DOE clothes washer test procedure which applies an RMC correction factor

5.6.1.2 Product Testing

For the preliminary analysis, DOE conducted a market survey of clothes dryer models and their associated features and selected five electric standard, one electric compact (240 V), and four gas vented clothes dryers from multiple manufacturers. For ventless clothes dryers, DOE selected one electric compact (240 V) and one electric combination washer/dryer model. These selections were based on the proposed efficiency levels and the range of product efficiencies available on the market. Because there is no EnergyGuide label required for residential clothes dryers, DOE based the selection of units for teardown on the efficiency data available in the CEC product database. DOE was unable to test an electric compact (120 V) clothes dryer since no such model was found to be on the market in the United States. Table 5.6.5 and Table 5.6.6 list features of the tested units.

Table 5.6.5 Vented Electric Standard Clothes Dryer Test Unit Features

Feature	Clothes Dryer Test Unit Designation				
	Vented Electric Standard				
	#1	#2	#3	#4	#5
Rated EF *(cycle/kWh)*	3.06	3.10	3.15	3.20	3.4
Rated Drum Capacity (ft^3)	7	7	7	5.9	6.1
Controls	Electromechanical	Electromechanical with Moisture Sensor PCB	Electronic	Electromechanical	Electronic
Drum Type	Full Cylinder	Open Cylinder	Open Cylinder	Open Cylinder	Full Cylinder
Number of Motors	2	1	1	1	1
Motor Type(s)	PSC + Induction	Induction	Induction	Induction	PSC
Air Flow Direction	Back to Front	Back to Back	Back to Back	Back to Back	Back to Front
Dedicated Hot Air Duct?	No	Yes	Yes	Yes	Yes
Inlet Air Preheat?	No	No	No	No	No
Heating Modulation?	No	No	No	No	No
Automatic Cycle Termination?	Yes	Yes	Yes	Yes	Yes
Sensor Type(s)	Temp	Temp + Moisture	Temp + Moisture	Temp + Moisture	Temp + Moisture

Table 5.6.6 Vented Electric Compact (240 V), Gas, and Ventless Clothes Dryer Test Unit Features

Feature	Clothes Dryer Test Unit Designation						
	Vented Electric Compact (120 V)	Vented Gas				Ventless Electric Compact (240 V)	Ventless Electric Combo
	#6	#7	#8	#9	#10	#11	#12
Rated EF *(cycle/kWh)*	2.98	2.67	2.76	2.80	3.00		
Rated Drum Capacity (ft^3)	3.4	5.2	6.7	7	7,3	2.5	2.5
Controls	Electromechanical	Electromechanical	Electronic	Electronic	Electronic	Electronic	Electronic
Drum Type	Open Cylinder	Full Cylinder	Open Cylinder	Open Cylinder	Open Cylinder	Full Cylinder	Full Cylinder
Number of Motors	1	1	1	1	1	1	2
Motor Type(s)	Induction	Induction	Induction	Induction	Induction	PSC	PSC + Induction
Air Flow Direction	Back to Back	Back to Front	Back to Front	Back to Front	Back to Front	Back to Front	Front to Back
Dedicated Hot Air Duct?	Yes	No	Yes	Yes	Yes	Yes	Yes
Inlet Air Preheat?	No	No	No	No	No	No	No
Heating Modulation?	No	No	No	No	No	No	No
Automatic Cycle Termination?	Yes	Yes	Yes	Yes	Yes	Yes	No
Sensor Type(s)	Temp + Moisture	Temp	Temp + Moisture	Temp + Moisture	Temp + Moisture	Temp	

Active Mode Testing

Clothes dryer testing was performed for the preliminary analysis on the twelve units in the test sample. The test results included not only the measurements required to evaluate the performance according to the previous DOE test procedure, but sub-metered component energy consumption data as well, which enabled DOE to quantify patterns of energy consumption during various stages of the cycle and identify energy efficiency and other drying performance strategies. Each clothes dryer was tested at an independent laboratory according to the previous DOE test procedure (10 CFR 430 subpart B, appendix D). For the ventless units, the test was run without the use of the exhaust simulator.

The test procedure consisted of running a load of preconditioned test cloth in the clothes dryer at the maximum temperature setting and, if equipped with a timer, at the maximum time setting. For standard-size dryers (*i.e.*, with a drum capacity of 4.4 cubic feet (ft^3) or greater), the nominal test load weight is 7.00 lb. For compact-size dryers (*i.e.*, with a drum capacity less than 4.4 ft^3), the nominal test load weight is 3.00 lb. Prior to loading the drum, the cloth is dampened and spun to obtain an RMC of 66.5–73.5 percent. Once the cycle is started, the test load is dried until the RMC is 2.5–5.0 percent, resetting the timer or automatic dry control if necessary.

During this test cycle, the total kWh of electric energy consumed by the clothes dryer is measured, in addition to the “bone dry”[f] weight of the test load and the starting and ending RMC. For gas clothes dryers, the measurements also include the cubic feet of gas used during the cycle and, for gas dryers equipped with a continuously burning pilot light, the cubic feet of gas consumed by the pilot light during 1 hour. In order to calculate EF according to the DOE test procedure, the following calculations are performed.

For electric clothes dryers, the total per-cycle electric dryer energy consumption, E_{ce}, is defined as:

$E_{ce} = (66/W_w - W_d) \times E_t \times FU$ where,

66 = an experimentally established value for the percent reduction in the moisture content of the test load during a laboratory test cycle, expressed as a percent
W_w = the moisture content of the wet test load
W_d = the moisture content of the dry test load
E_t = the total kWh of electrical energy measured during the test
FU = a Field Use factor
= 1.18 for time termination control systems
= 1.04 for automatic termination control systems

For gas clothes dryers, the total per-cycle gas dryer electrical energy consumption, E_{ge}, is calculated in the same manner as for electric dryers. Total per-cycle gas dryer energy consumption expressed in kWh, E_{cg}, is defined as:

$E_g = E_{ge} + [(66/W_w - W_d) \times E_{tg} \times FU \times GEF + E_{pg} \times (8760\text{-}140/416) \times GEF]/3412$ where,

E_{tg} = the cubic feet of gas used during the cycle
GEF = the corrected gas heat value (Btu/ft^3)
= 1.18 for time termination control systems
= 1.04 for automatic termination control systems
E_{pg} = the cubic feet of gas used by a continuously burning pilot light in 1 hour
8760 = the number of hours in a year
416 = the representative average number of clothes dryer cycles in a year
140 = the estimated number of hours that the continuously burning pilot light is on during the operation of the clothes dryer for the representative average use cycle for clothes dryers (416 cycles per year)

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

3412 = the conversion factor of Btu/kWh

The value of 66, W_w, W_d, FU, and GEF are the same as were defined for electric clothes dryers.

Finally, EF, expressed in lb per kWh, is derived from the per-cycle electrical energy consumption according to:

EF = M/ E_{ce} for electric clothes dryers
= M/ E_g for gas clothes dryers

M = the test load size in lb

Additional instrumentation was provided during these tests to measure disaggregated component energy consumption in order to assess which strategies and features could have the greatest impact on efficiency. Watt meters were attached to the following major components which together account for virtually all of the electrical energy usage of the clothes dryer:

- heating element for electric units;
- gas valve for gas units;
- drum motor;
- blower motor, if separate from the drum motor;
- controller;
- pump for ventless units, which removes condensate; and
- water valve for ventless electric combination washer/dryer.

Overall trends in key parameters of the clothes dryers under DOE testing are shown in Figure 5.6.3 and Figure 5.6.4, including average drying times and total per-cycle electrical energy consumption. Each data point represents the average of three tests. DOE also compared measured EF to rated EF for each of the clothes dryers in the test sample because manufacturers indicated during interviews that the tolerances in the existing test procedure can introduce uncertainty in the EF measurement. By ensuring the testing was conducted under consistent test conditions, DOE intended to normalize the data against allowable variations in ambient conditions and test parameters. Because the ventless clothes dryers have not been rated, the EF for these units could only be represented by the value measured during testing.

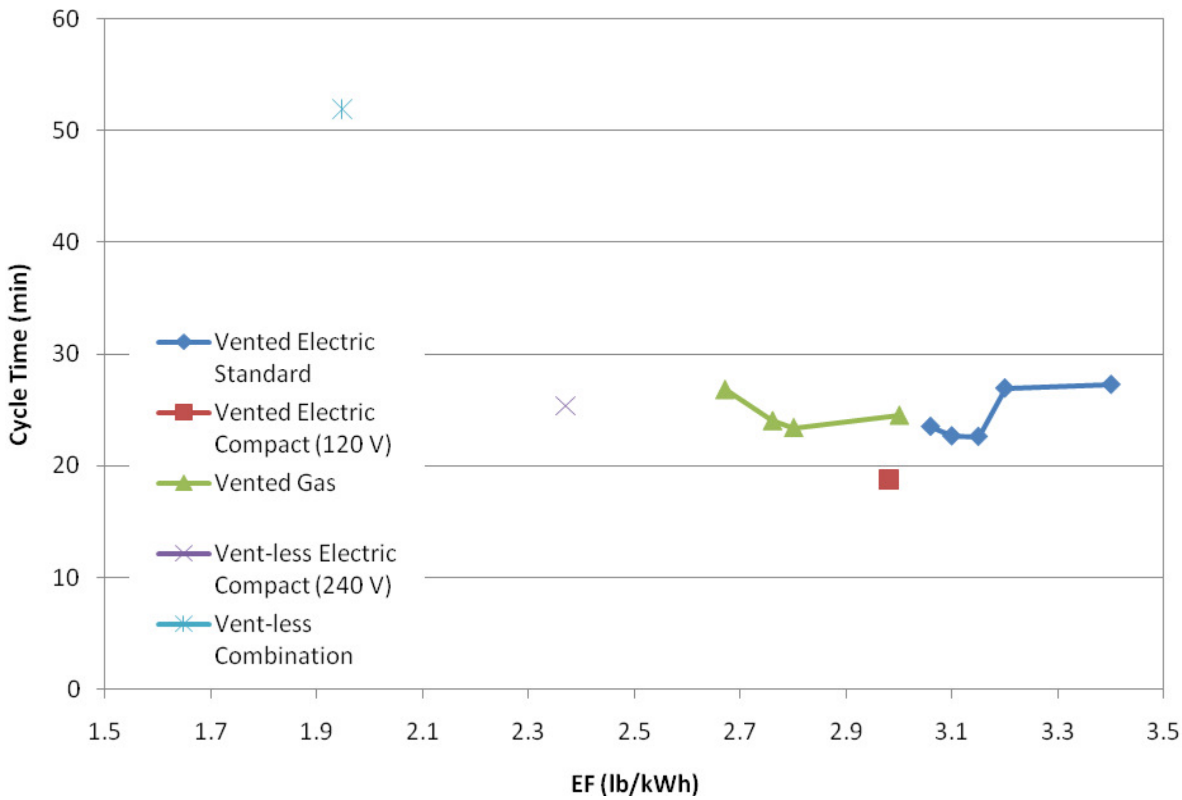


Figure 5.6.3 Measured Clothes Dryer Cycle Time versus Rated EF

These data show that cycle times for vented electric standard and gas clothes dryers are shorter between baseline and mid-efficiency units. However, in both product classes, this trend reverses at the higher efficiency levels. The data also show that, for the compact-size dryers, a ventless unit requires about 35 percent more time to dry than the vented version, although this result is likely somewhat skewed by the fact that the vented clothes dryer heating element draws about 10 percent more power than the ventless dryer's heater. Finally, these data show a significantly longer drying time associated with the ventless electric combination washer/dryer. For that particular model tested, the heating element drew less than half the power than that in the other compact clothes dryers (vented and ventless).

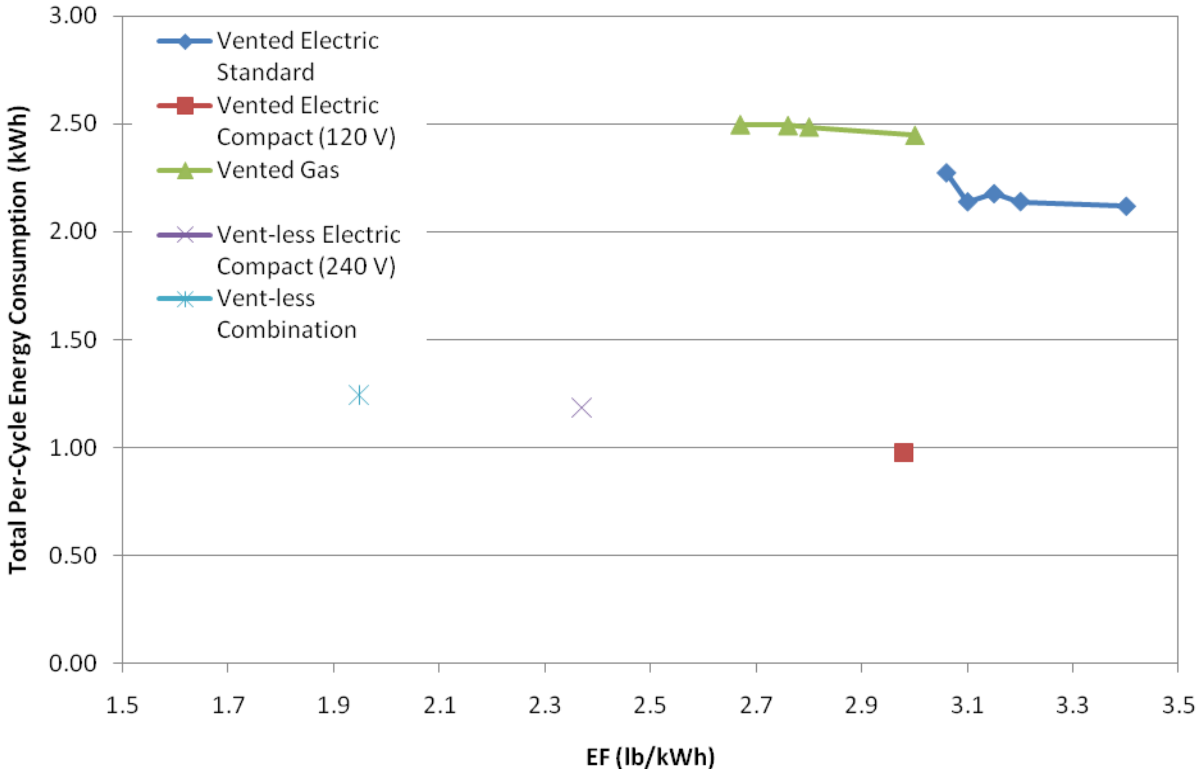


Figure 5.6.4 Measured Clothes Dryer Energy Consumption versus Rated EF

The data for total per-cycle energy consumption demonstrate the expected trend of measured energy use decreasing as a function of rated EF, again with the ventless data plotted as a function of measured rather than rated EF. The slope for compact units (which include the ventless combination washer/dryer) is fairly consistent with the slope for gas clothes dryers, with a somewhat steeper slope observed for vented electric standard clothes dryers. This potentially demonstrates uncertainty in the EF measurement, since EF should scale directly with total energy consumption. The test procedure may allow enough variation in the measurement of EF due to the specified tolerances to introduce uncertainty in the correlation between measured energy consumption and rated EF.

Such uncertainty can be explored by comparing the rated EFs, which are obtained under varying allowable conditions in multiple test laboratories, to DOE's measured EFs, which were obtained under consistent conditions in a single laboratory. Figure 5.6.5 presents the comparison for the clothes dryers for which rated EF was available, with a trend-line included to show what the correlation ideally would be. It can be seen that, for many of the units, measured EF does not correlate particularly closely with rated EF. In particular, the measured EFs for gas clothes dryers showed little variation among the four test units. In addition, the max-tech units in both vented electric standard and gas clothes dryers had measured EFs that were lower than the certification data would indicate.

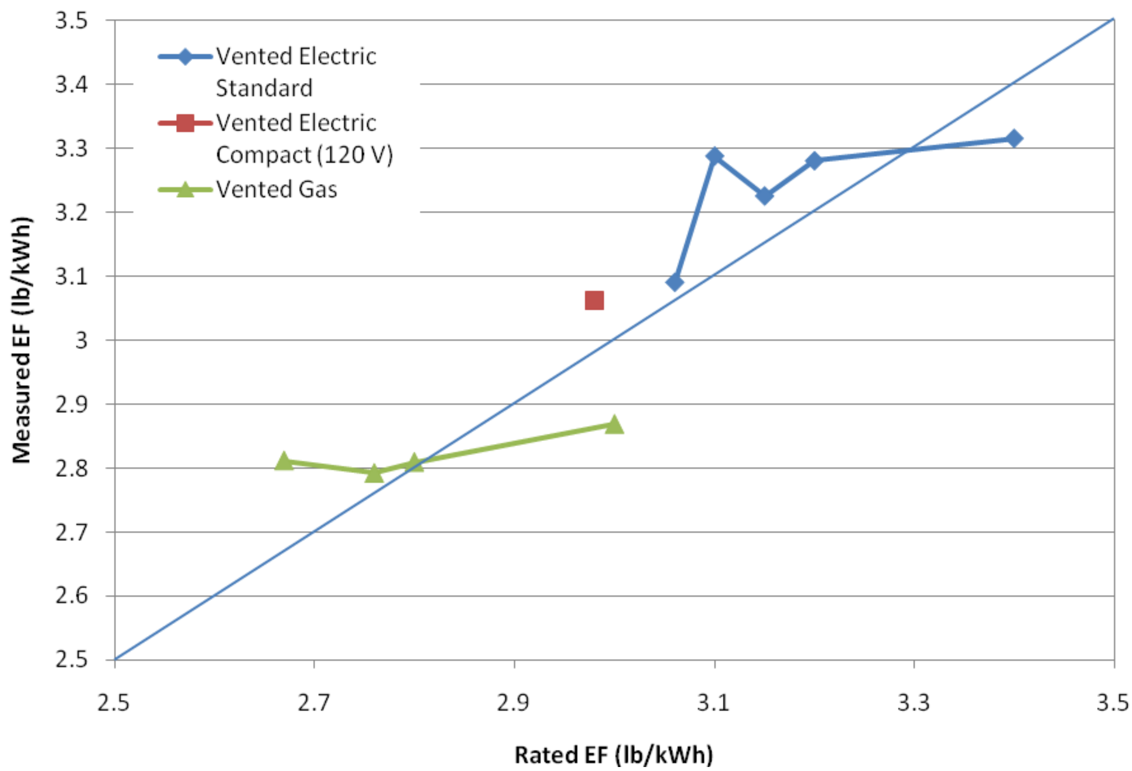


Figure 5.6.5 Measured versus Rated Clothes Dryer EF

DOE believes that the lack of strong correlation between measured and rated clothes dryer EF can be traced to the tolerances that are allowed in the test procedure, notably for the ambient test room conditions. Whirlpool Corporation (Whirlpool) submitted data to DOE that demonstrates the effect of a change in ambient relative humidity and temperature on EF. Parametric variations in relative humidity from 40 to 60 percent and ambient temperature from 72 to 78 °F, which are the limits allowed under the test procedure, produce measured EFs for an electric compact (120 V) clothes dryer that range from 2.98 to 3.35 lb/kWh. The Whirlpool data submission is reproduced in appendix 5B of this TSD. These data and their implications are currently being considered in a clothes dryer test procedure rulemaking.

Component-level data recorded from the watt meters during the DOE tests disaggregated the power consumption of individual components, allowing DOE to evaluate what strategies a manufacturer might choose to pursue higher energy efficiency. Figure 5.6.6 shows the component average power consumption while in use during the cycle for each of the test units. Within a product class, the models are arranged in the figure from lowest to highest EF. For purposes of visualization, heater power consumption and the gas use in equivalent W have been divided by a factor of 10, so that relative contributions from the other components can be compared. Also, it is recognized that the heater and gas burner are cycled on and off towards the end of the drying cycle. While the heating element watts are averages of instantaneous measurements during the periods when the heater is energized, and thus the power measurement is meaningful, the equivalent gas W are obtained from the total gas energy consumption during the cycle divided by the cycle time. Such an approach does not account for the periods during the cycle when the burner is off, but a comparison of instantaneous gas flow rates to the total cubic feet of gas used during the test shows that the assumption of constant burner usage introduces at most a 3 percent error. Therefore, it can be determined from Figure 5.6.6 that the heating element/gas burner is by far the largest contributor to per-cycle energy consumption, and therefore optimization of its usage and design will have a significant effect on efficiency. The drum motor (and potentially separate blower motor) have a second-order impact, while the gas valve, pump, and water valve (if any) are negligible in comparison.

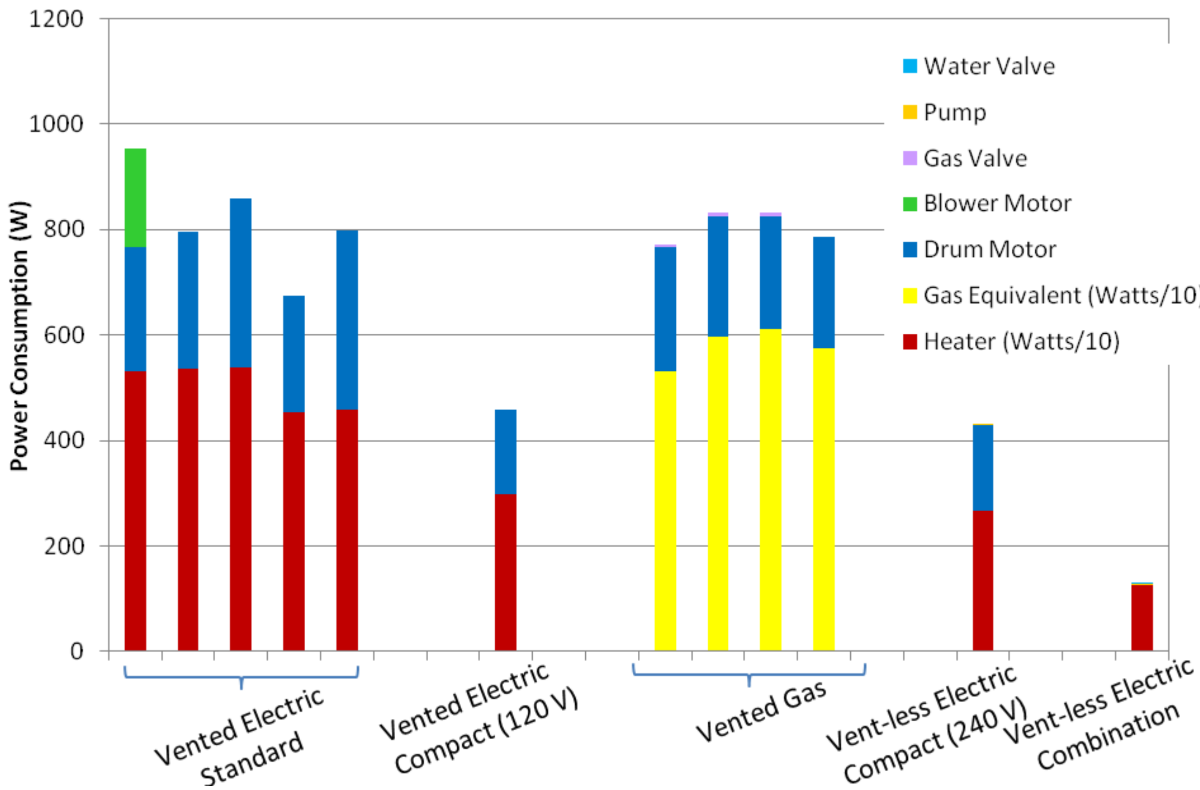


Figure 5.6.6 Disaggregated Clothes Dryer Power Consumption

It is difficult to generalize from these data what strategies manufacturers are taking to improve efficiency. Among vented electric standard clothes dryers, it appears that manufacturers are reducing heating element and motor power to achieve higher EFs, although the trend is not strong. That trend is even weaker among the tested gas clothes dryers. However, DOE notes that it did not see significant differences in measured EF among these units, so potentially the test sample did not fully capture possible design improvements.

To summarize key findings from the testing of a small number of clothes dryers, DOE observed that:

- Test procedure tolerances introduce uncertainty in the EF measurement that is significant in comparison to the EF range between a baseline and high efficiency clothes dryer.

- Improvements in the heating element or gas burner may provide a key opportunity for improving EF. A second-order impact could be achieved by improvements in the motor(s).

- Modest increases in EF over the baseline can result in reduced drying cycle times.

- Ventless electric compact (240 V) clothes dryers do not require drying times that are longer than those acceptable to consumers (*i.e.*, typical drying times associated with vented electric standard clothes dryers.

Standby Mode and Off Mode Testing

For the preliminary analysis, DOE measured standby and off mode power for 10 of the 12 clothes dryers in the test sample, using methodology provided in the International Electrotechnical Commission (IEC) Standard 62301 Ed. 1.0 (2005-06), *Household electrical appliances – Measurement of standby power*. The remaining two clothes dryers, both ventless units, incorporated components contributing to standby power that were energized by 240 V line power that could not be measured with the standby power meter used for these tests. Data obtained from this testing are presented in section 0.

RMC Testing

DOE also conducted tests for four representative clothes dryers (one each of vented electric standard, vented electric compact (120 V), vented gas, and ventless electric compact (240 V) product classes) to evaluate the impact of changes in initial RMC on measured EF, supplementing the RMC data AHAM submitted. The units were each tested at three different initial RMC levels: (1) nominally 70 percent, representing the conditions specified in the current DOE test procedure; (2) nominally 56 percent, to compare directly with the AHAM data submittal; and (3) nominally 39 percent, which was selected to be close to the weighted-average RMC of front-loading residential clothes washers currently on the market.

Results of these tests, with EF calculated according to the formula provided in the DOE test procedure, are shown in Figure 5.6.7. In general, reducing initial RMC produced a decrease in measured EF for all product classes. Average percentage reductions in EF as a function of initial RMC are summarized in Table 5.6.7.

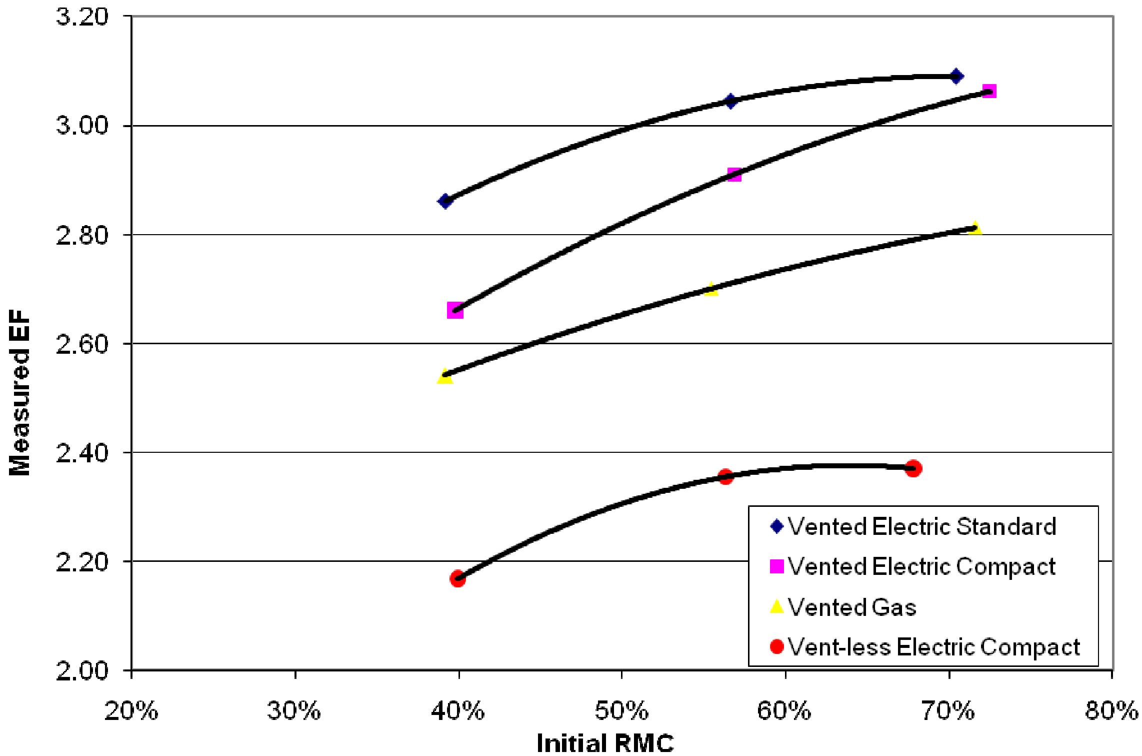


Figure 5.6.7 Impact of Initial RMC on Clothes Dryer EF (Calculated According to the Existing DOE Test Procedure)

However, as discussed in section 5.6.1.1, the scaling factor of 66 in the current DOE test procedure is intended to normalize the calculated EF, for which initial and ending RMCs can vary slightly within allowable tolerances, to a reduction in RMC over the course of the test from 70 percent to 4 percent. For tests in which the nominal starting RMC is no longer 70, DOE believes that the scaling factor may not be meaningful. Therefore, DOE subsequently calculated the EFs for the test units using scaling factors at each starting RMC that reflected a change from that RMC to 4 percent. For example, for a starting RMC of 56 percent, the scaling factor would be 52 (56 percent initial RMC minus 4 percent ending RMC). The results using adjusted scaling factors are presented in Figure 5.6.8.

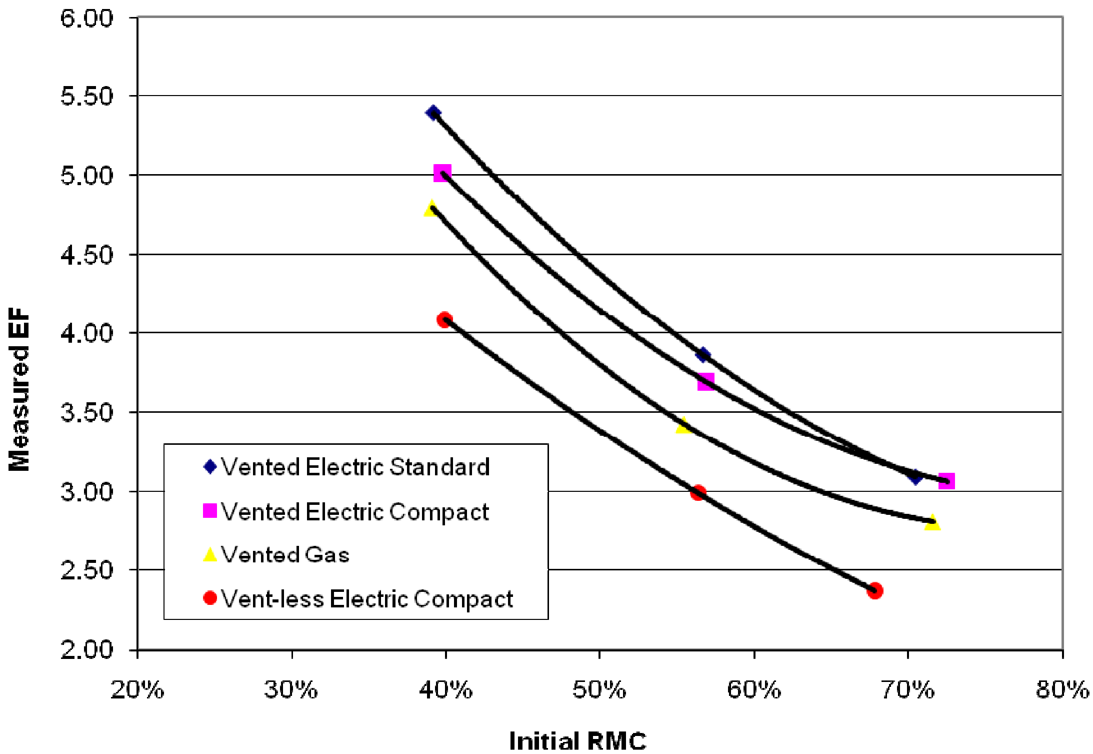


Figure 5.6.8 Impact of Initial RMC on Clothes Dryer EF (Calculated Using Adjusted Scaling Factors)

Using the revised scaling factor methodology, DOE determined that reducing the initial RMC increased EF significantly, as shown in Table 5.6.7.

Table 5.6.7 Average Change in Clothes Dryer Energy Factor as a Function of Initial RMC as Compared to Initial RMC of 70 Percent

Initial RMC %	Change in EF using Existing Scaling Factor (%)		Change in EF using Adjusted Scaling Factor (%)	
	DOE Results	AHAM Results	DOE Results	AHAM Results
56	-3	-4	23	22
39	-10		70	

At the time of the preliminary analysis, DOE was considering amendments to its clothes dryer test procedure to revise the initial RMC to reflect the performance of residential clothes washers currently on the market, but had not yet published a NOPR proposing active mode test procedure amendments. Therefore, in the preliminary analysis, DOE did not analyze energy conservation standards based on initial RMCs lower than the existing 70 percent.

Maximum-Available Vented Gas Clothes Dryer Testing

After the framework document was published, DOE determined several models of vented gas clothes dryers were listed in the CEC product database with an EF (based on the previous

DOE test procedure) above the maximum-available efficiency level proposed in the framework document. As discussed in section 5.6.1.5, multiple manufacturers stated during interviews that the current maximum efficiency that is listed for vented gas clothes dryers in the CEC product database is not achievable. Therefore, DOE tested the model that was rated as the maximum-available efficiency vented gas clothes dryer to help determine an appropriate max-tech level value for the preliminary analysis. DOE purchased three identical units of this model and tested each three times according to the previous DOE clothes dryer test procedure. Table 5.6.8 shows the results from this testing, which indicate that the maximum-available model was measured as having an EF significantly lower than its rated value. Therefore, DOE did not consider this EF value for the max-tech level analysis.

Table 5.6.8 Results from DOE Testing of Maximum-Available Vented Gas Clothes Dryers

Unit	**Measured Average EF *(lb/kWh)***	**% Difference from CEC Product Database Value (3.44 EF)**
1	2.83	-17.7
2	2.75	-20.1
3	2.82	-18.0

5.6.1.3 Product Teardown

As part of its reverse-engineering process, DOE tore down clothes dryers to identify design features, and corresponding manufacturing costs, that are associated with successively higher efficiency levels. The clothes dryer teardown analysis performed for this engineering analysis included the 12 teardown units total for four of the five product classes selected for the preliminary analysis, excluding only vented electric compact (120 V) clothes dryers due to lack of availability. For the other vented product classes, DOE selected products such that within that class, the chosen models span the range of EF from baseline to max-available.

DOE first notes that all of the clothes dryers it examined are constructed with an outer sheet metal assembly comprising panels that had been formed by stamping, joined, and painted. This assembly houses the cylindrical drum, drive motors, heater systems, and the associated ducting. Details of these components and sub-assemblies are as follows.

Baseline Construction

For the baseline vented units, the bottom base plate of the cavity holds a single 1/4–1/3 horsepower (hp) induction motor which drives both the drum and the blower. For gas clothes dryers, the bottom base plate also holds the gas burner system, which consists of a single stage gas valve, venturi, and gas inlet pipe. A conical duct then directs the hot air generated from the gas burner towards the back of the cabinet, where it flows through a duct to the rear of drum. For the baseline electric standard clothes dryers, the heating system consists of an electrical resistance heater which is contained in a duct which covers the back wall of the drum.

For the baseline unit construction, the laundry basket consists of a metal cylinder which has a circular plate attached on the rear to form a drum. The drum is driven by the single induction motor (installed on the bottom base plate) and a drive belt. The drum rotates about a shaft mounted on the plate on the rear of the drum. On the front edge of the drum, the drum spins on smooth plastic strips mounted to the front face of the cavity.

The hot air from both gas and electric heating systems enters from behind the drum, passes through the clothes load, and exits the drum near the front door. The moist air is then pulled through the lint filter and through the blower fan, which is driven by the same single induction motor that rotates the drum. Subsequently, the moist flue air exits through the exhaust pipe leading out the rear of the exterior sheet metal assembly.

The baseline clothes dryer is also equipped with electromechanical controls which allow the user to select specific cycle settings. DOE also noted in its teardown of baseline units and through surveys of products available on the market that baseline clothes dryers feature automatic cycle termination using temperature switches and timer controls. All baseline clothes dryers torn down feature temperature switches in the heater duct and blower/exhaust duct sections.

The baseline ventless electric compact (240 V) clothes dryer has a similar construction to the baseline vented electric clothes dryer, with the following differences. A baseline ventless clothes dryer is equipped with a permanent split capacitor (PSC) motor which drives both the drum and the blower fan. The drum rotates about a shaft mounted on the plate on the rear of the drum; however, the front edge of the drum spins on two roller wheels mounted to the front face of the cavity. DOE also noted in its teardown that a baseline unit features electronic controls as well as automatic cycle termination using temperature sensors.

The baseline ventless electric compact (240 V) electrical resistance heater is in a dedicated duct mounted behind the rear of the drum. The hot air from the heating system enters from behind the drum, passes through the clothes load, and exits the drum near the front door. The moist air is then pulled through the lint filter and through the blower fan, whereupon the air flows through a duct mounted to the base of the cabinet containing an air-to-air cross-flow heat exchanger. Moisture in the warm, moist air condenses as the air flows past the heat exchanger towards the back of the cabinet, where it again enters the dedicated electric heater duct and repeats the airflow cycle. As part of the heat exchanger system, an additional blower fan is mounted to the single PSC motor, which pulls ambient air from the surroundings and blows it past the air-to-air heat exchanger in a direction perpendicular to the dry cycle air flow. The heat exchanger duct also houses a drain pump, which pumps the condensed moisture from the heat exchanger out of the cabinet.

The construction of the baseline combination washer/dryer is more complex than that of a conventional clothes dryer since it is able to run both washing and drying cycles in a single cabinet using a single drum. The wash basket is contained in a tub, which prevents water from escaping into the cabinet. The tub is mounted on four shock absorbers, which in turn are mounted to the base of the cabinet. Mounted to the bottom of the tub is a large cement block, which dampens vibrations from the wash and spin cycles. An induction motor spins a drive wheel mounted on the back of the tub via a belt. This induction motor is capable of the high rotational speeds required for spin cycles. The wash basket, comprising a metal cylinder which has a circular plate attached on the rear, rotates about a shaft mounted to the rear of the drum. The drive system also uses two large ball bearings for the drive wheel and the rear drum shaft.

A PSC motor is also mounted to the bottom of the tub, which drives a blower fan contained in a dedicated duct mounted to the rear of the tub via a drive belt. The air is blown from this duct to a duct mounted to the top of the tub, which contains the electrical resistance heater. The hot air flows from the heater duct into the front of the tub, passes through the clothes load, and exits through the rear of the tub into a space between the wash basket and the tub. The air is then pulled back through the dedicated blower fan duct and the airflow cycle repeats.

The combination washer/dryer is also different from a conventional dryer in that it does not use a lint filter. DOE also noted in its teardown that the baseline unit features electronic controls, but that it does not have an automatic termination feature.

Based upon product teardowns, DOE developed the following baseline production cost distributions and materials costs distributions, shown in Figure 5.6.9 through Figure 5.6.18. Depending on the manufacturer and the production volume, the depreciation costs may vary from those shown in the figures, which assume a “green-field” site. For product classes such as vented electric compact (120 V and 240 V), ventless electric compact (240 V) and ventless combination washer/dryers, DOE assumed much smaller production volumes than for vented electric standard and vented gas dryers.

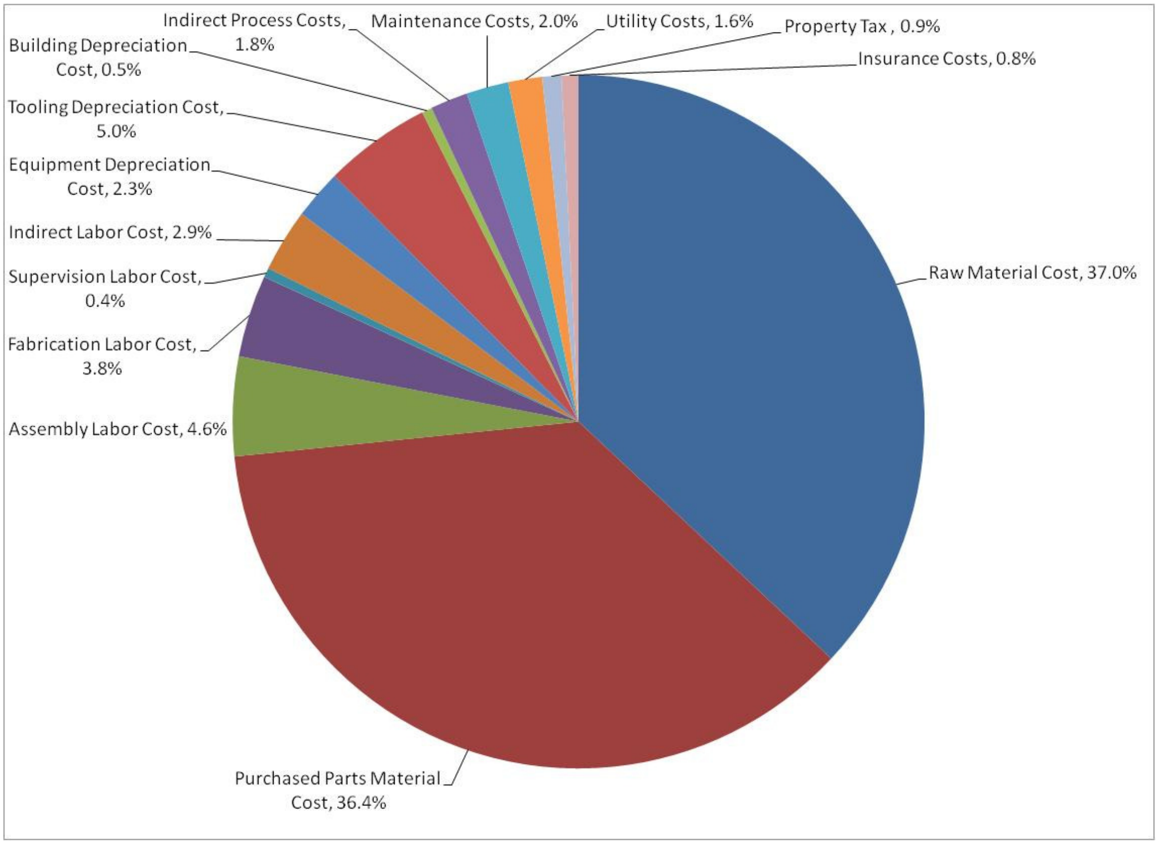


Figure 5.6.9 Baseline Vented Electric Standard Clothes Dryer Full Production Cost Distribution

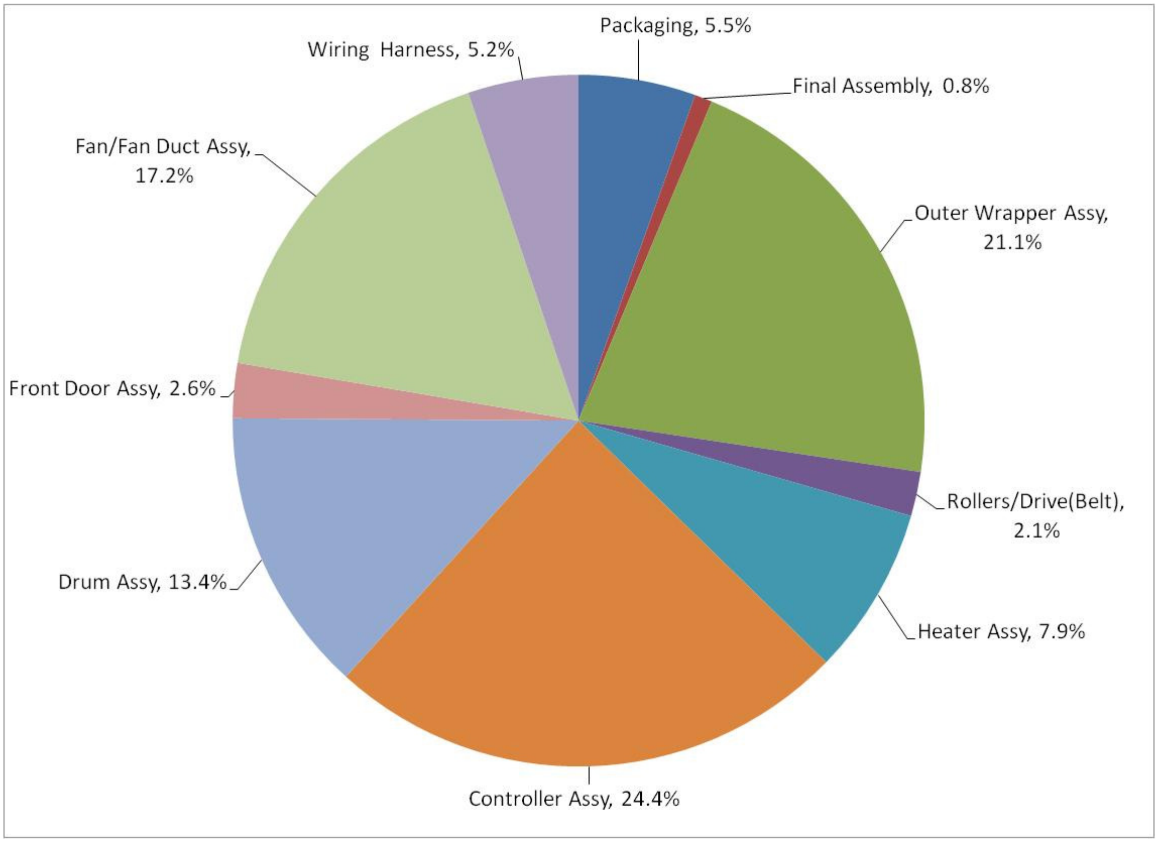


Figure 5.6.10 Baseline Vented Electric Standard Clothes Dryer Materials Cost Distribution

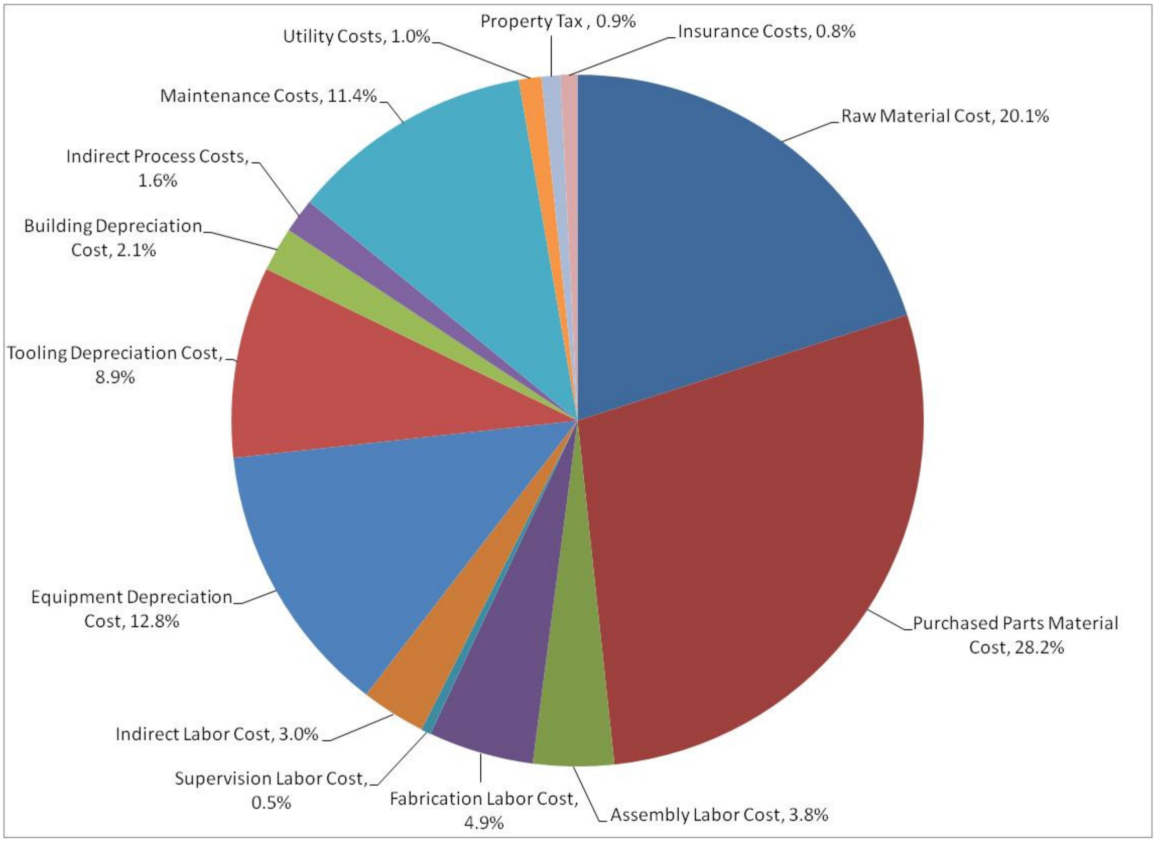


Figure 5.6.11 Baseline Vented Electric Compact (240V) Clothes Dryer Full Production Cost Distribution

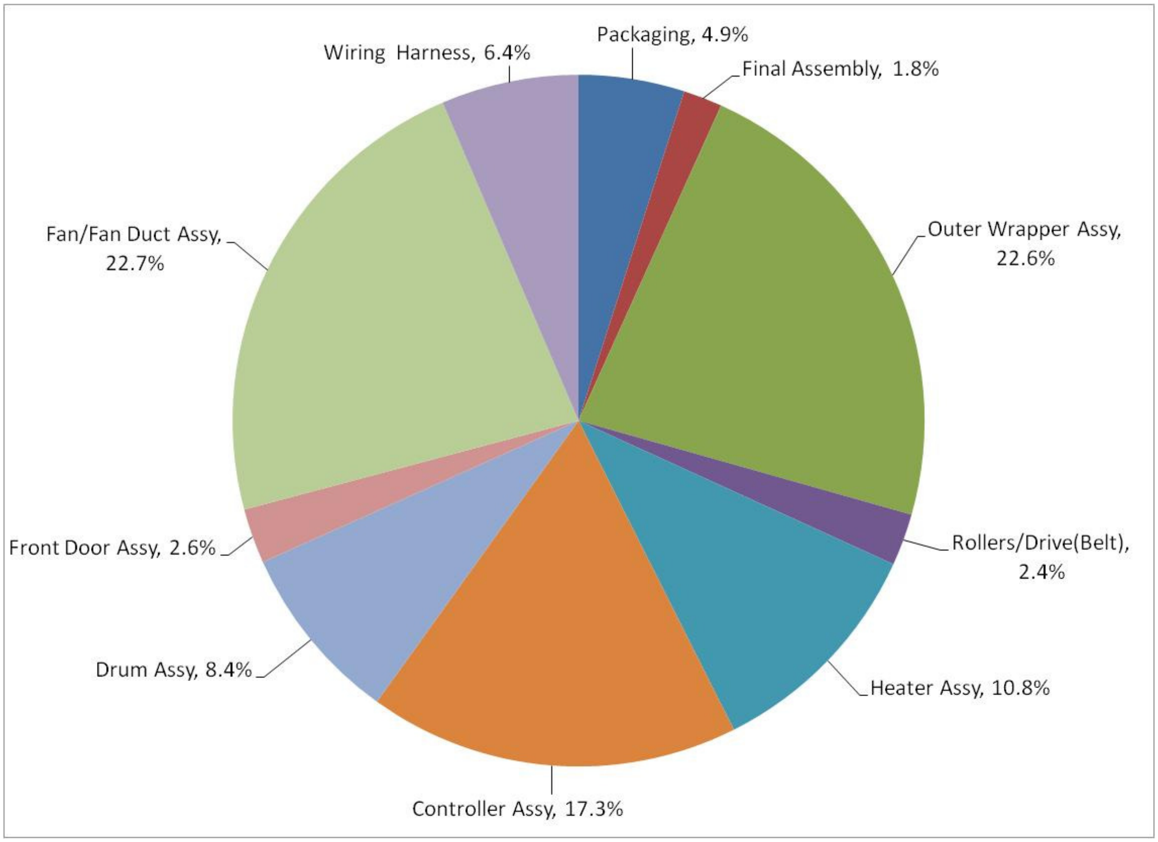


Figure 5.6.12 Baseline Vented Electric Compact (240V) Clothes Dryer Materials Cost Distribution

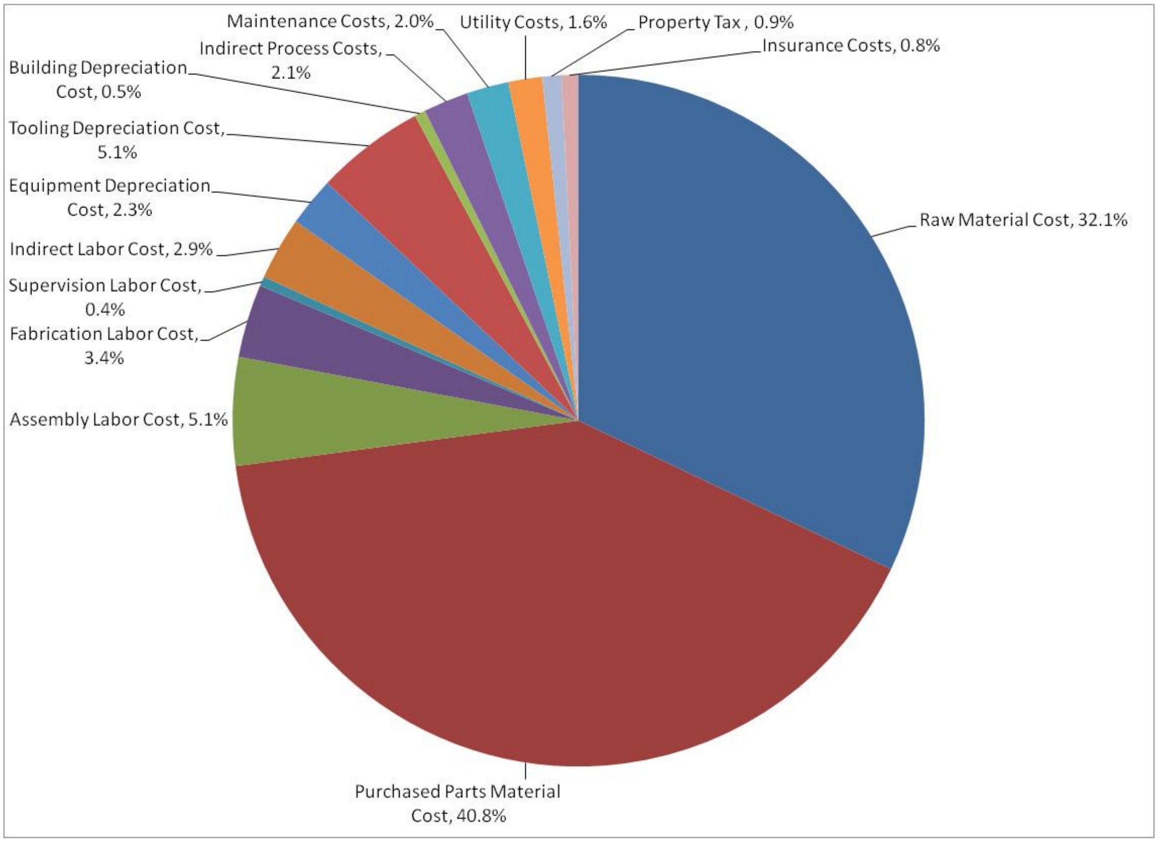


Figure 5.6.13 Baseline Vented Gas Clothes Dryer Full Production Cost Distribution

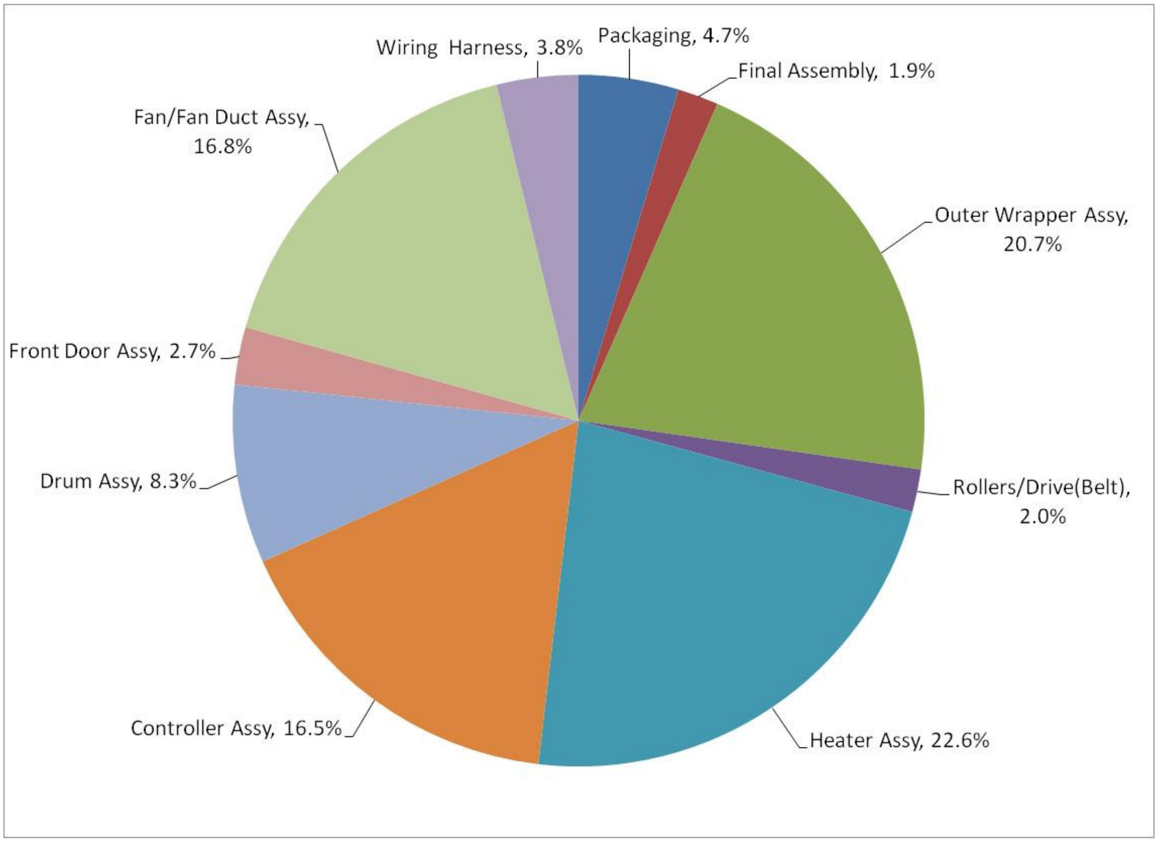


Figure 5.6.14 Baseline Vented Gas Clothes Dryer Materials Cost Distribution

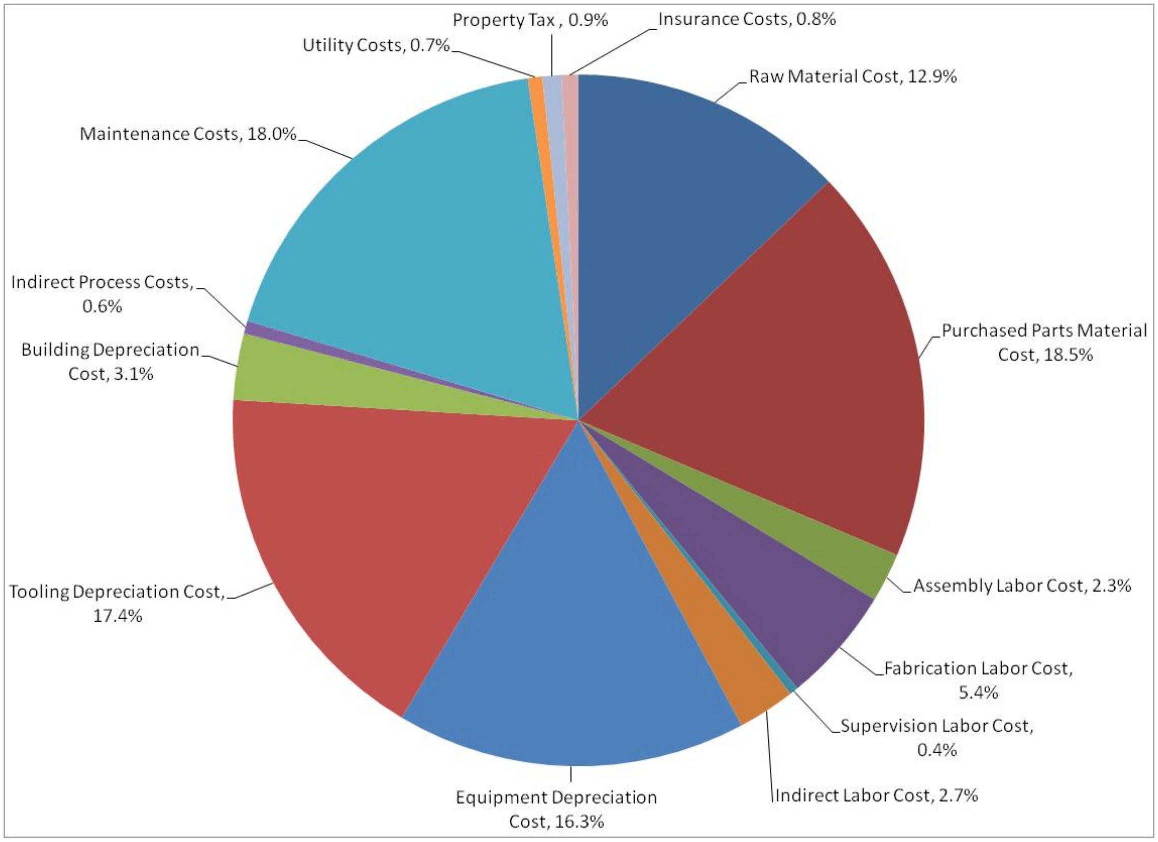


Figure 5.6.15 Baseline Ventless Electric Compact (240V) Clothes Dryer Full Production Cost Distribution

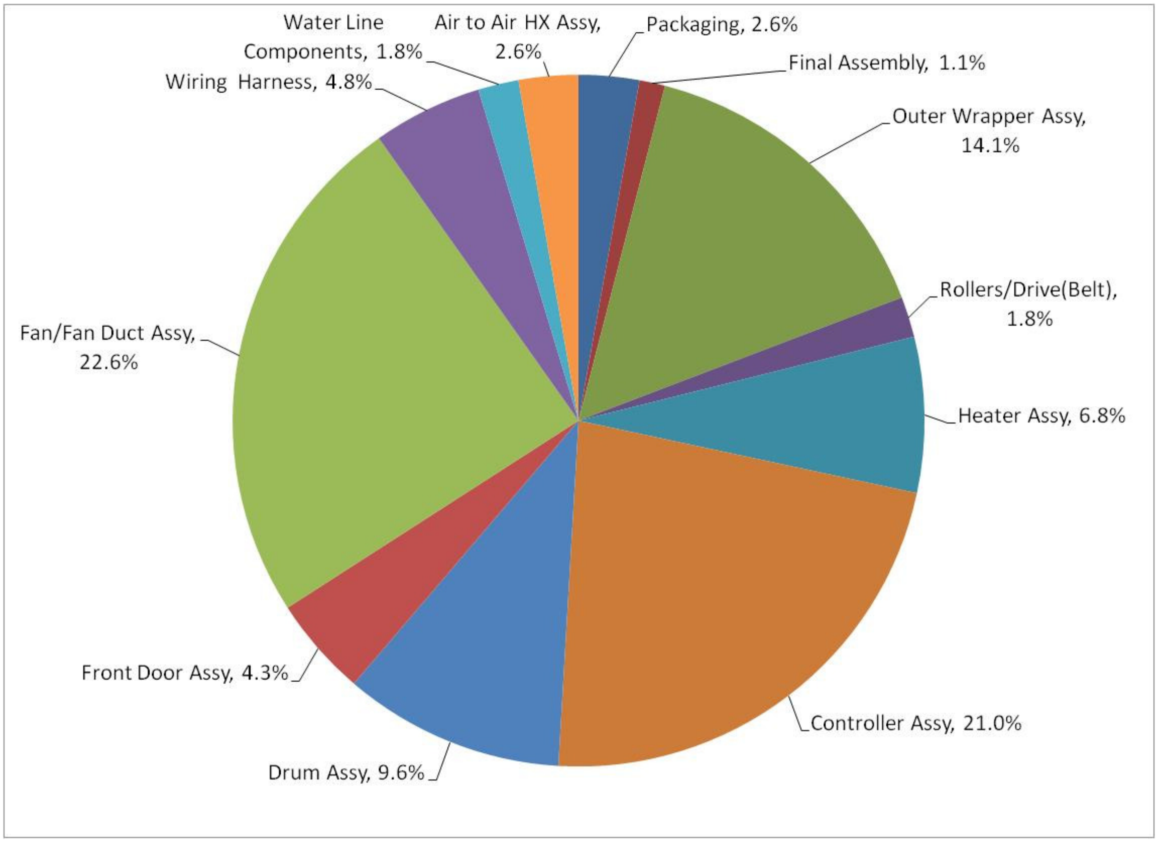


Figure 5.6.16 Baseline Ventless Electric Compact (240V) Clothes Dryer Materials Cost Distribution

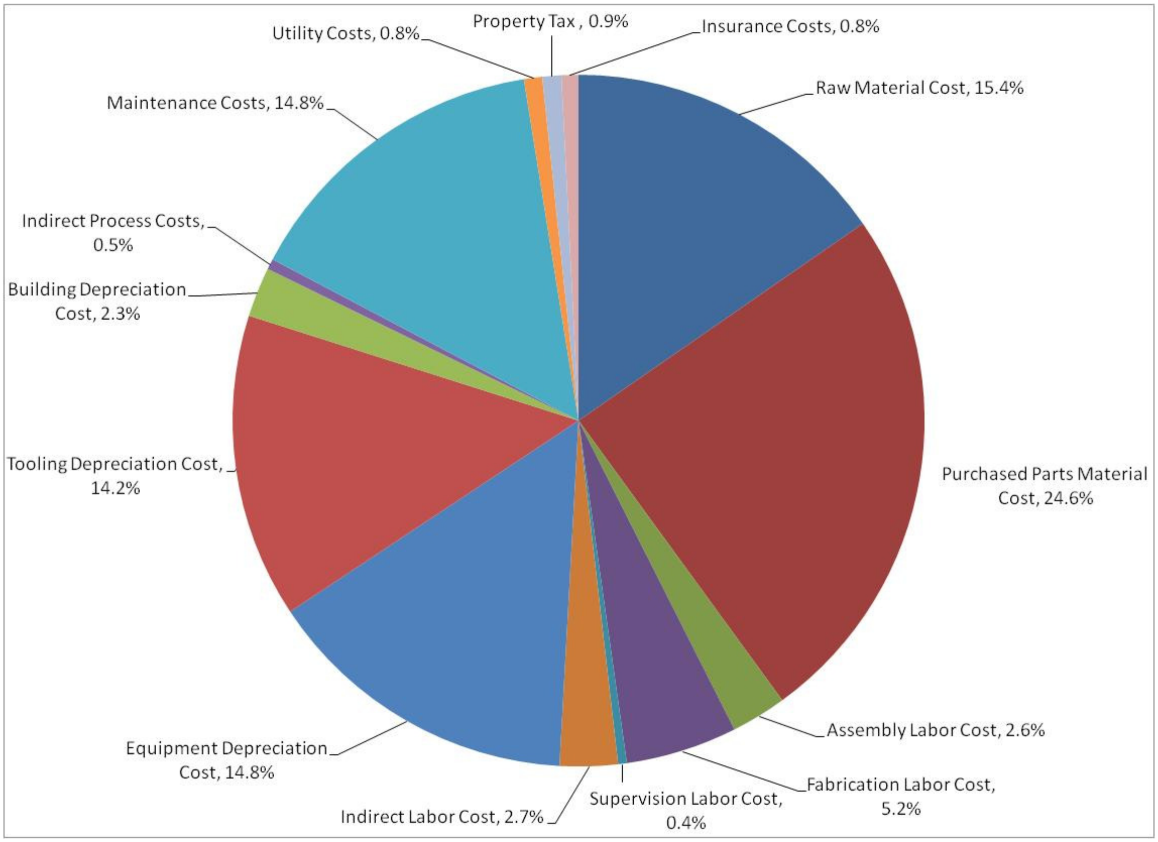


Figure 5.6.17 Baseline Ventless Combination Washer/Dryer Full Production Cost Distribution

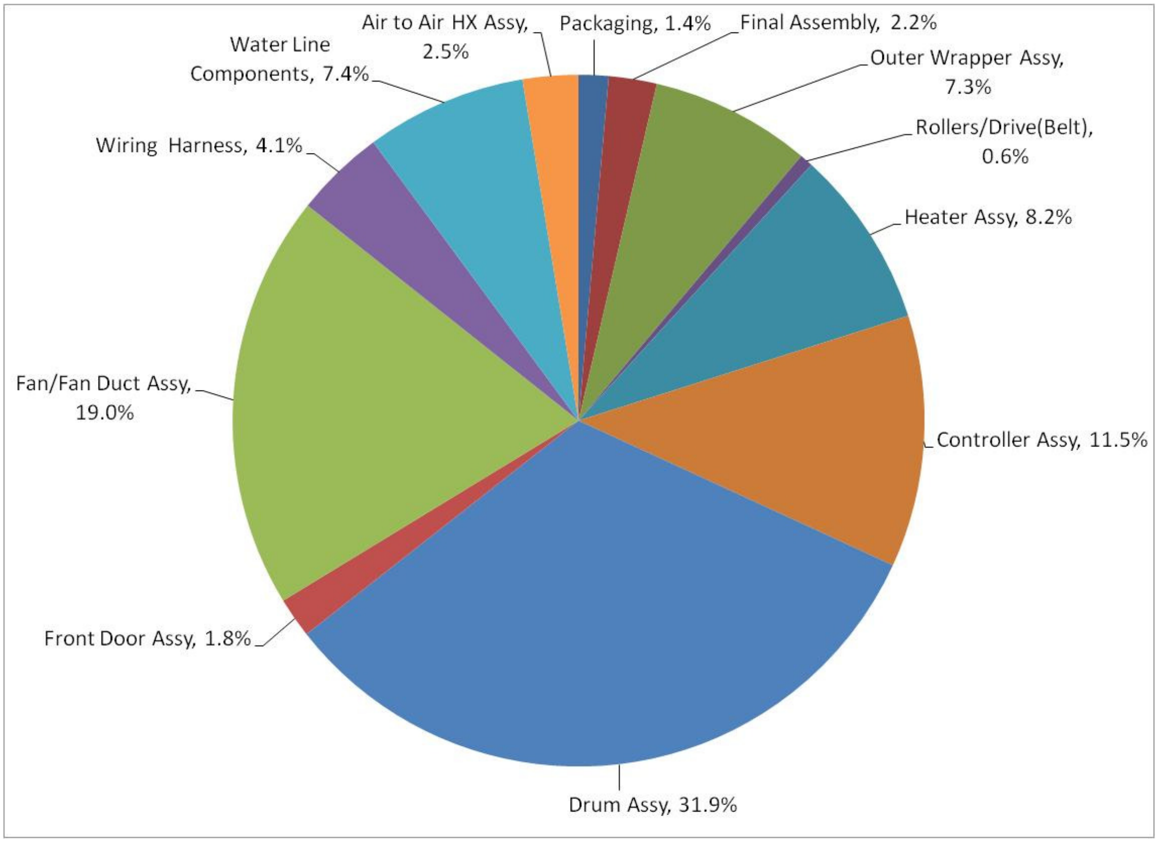


Figure 5.6.18 Baseline Ventless Combination Washer/Dryer Materials Cost Distribution

Construction at Higher Efficiency Levels

Based on the design options retained from the screening analysis (see chapter 4 of this preliminary TSD), the reverse engineering analysis, and discussions with manufacturers, summarized in section 5.6.1.5 and 5.6.1.6, DOE developed manufacturing costs associated with various design features necessary to achieve higher efficiencies.

The following are the design changes DOE believes would be necessary to meet each efficiency level, which were subsequently modeled to obtain incremental manufacturing cost estimates.

Vented Electric Clothes Dryers

Efficiency Level 1

Based on characteristics of units selected for teardown and based on discussions with manufacturers, DOE research suggests that EL 1 is achieved in vented electric clothes dryers through three changes:

1. Switching to Open Cylinder Drum

This design change can allow better air flow through the drum. The drum suspension system is also changed to a roller wheel design with wheels at the front and back edges of the drum as the bearing system in order minimize frictional losses and decrease the load on the motor.

2. Dedicated Heater Duct

The hot air flow duct that directs the air into the drum through the back would be changed from the baseline duct to a dedicated duct which directs air flow more directly into the drum and reduces heat losses.

3. Change in Air Flow Patterns

The air flow through the drum would change from a baseline back to front air flow, to flowing in through one side of the back and exiting on the other. This design change requires an outlet duct from the drum that attaches to the rear of the drum, which then leads to the blower duct and the exhaust duct. DOE notes that the costs associated with these design options will differ for standard-size and compact-size dryers because of the different amounts of materials required for structural design changes.

Efficiency Level 2

For the preliminary analysis, DOE stated that it believed that for EL2, manufacturers would apply the same design changes as used for EL 1 and additionally incorporate inlet air preheating, which requires better airflow and moisture control. However, based on further research and more recent discussions with manufacturers, DOE believes that for EL2, manufacturers would apply the same design changes as used for EL1, but additionally incorporate 2-stage modulating heat, which would require moisture sensing and multi-speed airflow

1. 2-Stage Modulating Heat

For this design change, the conventional single electric resistance heater would be replaced by two smaller-sized electric resistance heaters to allow for 2-stage control of the heat output. The resistance heaters would be controlled by the control board that also reads the moisture (discussed below), and would require and additional relay to control the additional heater.

2. Moisture Sensing and Multi-Speed Airflow

Moisture sensing requires a separate measurement and control board, which can be used in conjunction with electromechanical controls. Since baseline motors drive both the drum and the fan, variable airflow requires the adoption of dedicated drum and fan blower motors. Both motors would likely be PSC-style motors, with the drum motor featuring single-speed and the blower motor triple-speed operation to match the heat output of the 2-stage heater. The speed of the blower motor would be controlled by the control board that also reads the moisture.

Efficiency Level 3

For the preliminary analyses, DOE stated that manufacturers would likely add fully modulating heat to the platform described for EL 2 to achieve EL 3, without inlet air-preheating. Because DOE is not aware of any gas clothes dryers with fully modulating burner systems currently on the market, DOE did not consider this technology further in developing the standards set forth in today's direct final rule. DOE does include this technology as a longer-term means to achieve energy efficiency improvements in a sensitivity analysis described in chapter 16 of this TSD. Based on further research and more recent discussions with manufacturers, DOE believes that for EL 3, manufacturers would apply the same design changes as used for EL 2 and additionally incorporate inlet air preheating, which requires better airflow and more advanced control systems.

1. Inlet air pre-heating

Inlet air pre-heating requires an air-to-air heat exchanger (with added ducting) in order to recover exhaust heat energy with which to preheat inlet air. To prevent condensation, moisture sensors and variable-speed blowers are required to adjust airflow rates and to allow for more accurate control of the drying cycle. The control system would have to be upgraded to electronic controls to allow for more accurate control of the airflow, heaters, and sensors.

2. Variable Airflow

A variable-speed fan motor is likely required to seamlessly match the heat output of the heater coil and the rate of heat recovery from the inlet air pre-heating to prevent condensation. Typically, manufacturers incorporate electronically-commutated motors or equivalent motor designs for such applications. Such a motor is also more efficient than the standard induction motor of PSC motor, which results in a slight increase of the overall efficiency of the clothes dryer.

Efficiency Level 4

DOE research suggests that EL 4 would require the use of heat pump technology. As a starting point, this level would incorporate most features described for EL 2. Two features would likely be omitted, however: the airflow rerouting described in EL 1 as well as the pre-heater described in EL 2. Other required design features would be a more sophisticated control system, an upgraded air flow system, a booster heater, and a condensate removal system.

1. Heat Pump System

The heat pump system would be made up of a reciprocating compressor, evaporator, condenser, and sealed system components. Existing heat pump clothes dryer design schematics suggest the use of tube and fin heater exchangers with wide evaporator fin spacing to prevent lint foiling. In order to handle the variation in heating load throughout the drying cycle, a thermostatic expansion valve is used to control the refrigerant flow. Standard-size and compact-size dryers would require different material costs for this design option because of the different sizes of the heat exchangers and shipping packaging.

2. Electronic Controller, Thermal and Moisture Sensing

A heat pump dryer would likely require sophisticated moisture, airflow, and temperature control to maximize the energy savings. Thus, an electronic controller, moisture sensors, and multiple thermal sensors are incorporated into this efficiency level.

3. Upgraded Airflow System

A heat pump dryer is expected to require dedicated fan and drum motors, as described in EL 2. However, the additional pressure drop imposed by ducting, heat exchangers, etc. will likely double the shaft power requirements of the fan motor. The size and wire density of the lint filter would also need to be increased to prevent lint migration past the filter to the heat exchanger.

4. Booster Heater

Because of the long warm-up times associated with a heat pump system, and the consumer demand for shorter dry cycles, DOE believes that manufacturers could incorporate a booster heating element. This heating element would be undersized compared to the conventional heating element and would run only during the warm-up phase.

5. Condensate Removal

Since a heat pump dryer produces condensate, a condensate removal system is expected to be standard feature in a heat pump dryer, just as it is in condensing dryers.

Gas Clothes Dryers

DOE believes that the same fundamental design changes described above for vented electric standard dryers for EL 1 through EL 3 would be applied to vented gas clothes dryers. Because of inherent differences in the designs between gas and electric clothes dryers (*e.g.*, different ducting, heat sources, etc.), the costs at each efficiency level are not identical. Most notably for EL 2, the 2-stage modulation of gas heat requires significantly different component changes as compared to 2-stage modulating electric heat.

For EL 2, DOE believes that manufacturers would switch from the baseline single-stage gas valve to a 2-stage modulating gas valve. DOE notes that gas-fired clothes dryers with 2-stage modulating gas valves are available on the market today. Additional controls would be required to control the gas valve modulation. As with the EL 2 design changes for electric standard dryers, the same disaggregated motor design (with additional controls) would also be incorporated into this level.

Ventless Electric Compact (240 V) Clothes Dryers

DOE believes that essentially the same changes described above for vented electric clothes dryers for EL 1, EL 2, and EL 4 would be applied to ventless electric compact (240 V) clothes dryers. However, because the baseline unit already contains a dedicated heat duct, only the remaining design options for vented electric clothes dryer EL 1 would need to be applied to EL 1 for this product class. Also, because the EL 3 design changes applied to vented electric clothes dryers were based upon inlet air preheating, these design changes would not be applied to a ventless electric compact (240 V) clothes dryer because it already recirculates the air back through the system. For this reason, the EL 2 and EL 4 design changes for vented electric clothes dryers are applied as EL 2 and EL 3, respectively, for this product class. DOE also notes that the baseline ventless electric compact (240 V) clothes dryer already contains electronic controls; therefore, certain design options such as moisture sensing and variable speed motor control will require a smaller incremental manufacturing cost.

Ventless Electric Combination Washer Dryer

Because the baseline unit in this product class does not have automatic cycle termination, DOE believes that EL 1 would be achieved by incorporating such a feature. Because the baseline unit already has a number of temperature sensors as well as electric controls, the changes required to implement an automatic cycle termination feature would likely be minimal, consisting primarily of an additional temperature sensor in the exhaust air as well as control logic reprogramming.

Because of the complex construction of the baseline combination washer/dryer, DOE believes that the design changes for EL 2 for vented electric clothes dryers (*i.e.*, inlet air preheating) could not be applied to this product class. Further, for the reasons described above for ventless electric compact (240 V) clothes dryers, DOE believes that the EL 2 and EL 4 design changes for vented electric clothes dryers would be applied to EL 2 and EL 3, respectively, for this product class. Again, because the baseline unit already incorporates a two motor design, as well as electronic controls, the incremental manufacturing costs will be smaller for this product class as compared to vented electric clothes dryers.

Standby Mode Construction

As part of the reverse engineering analysis, DOE investigated the design options and incremental manufacturing costs for decreasing standby power consumption. DOE developed the following design pathways for the standby levels identified in section 5.4.2.2.

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

5.6.1.4 Cost-Efficiency Curves

Active Mode

Based upon product teardowns and cost modeling, DOE developed the following cost-efficiency relationships for each product class, shown in

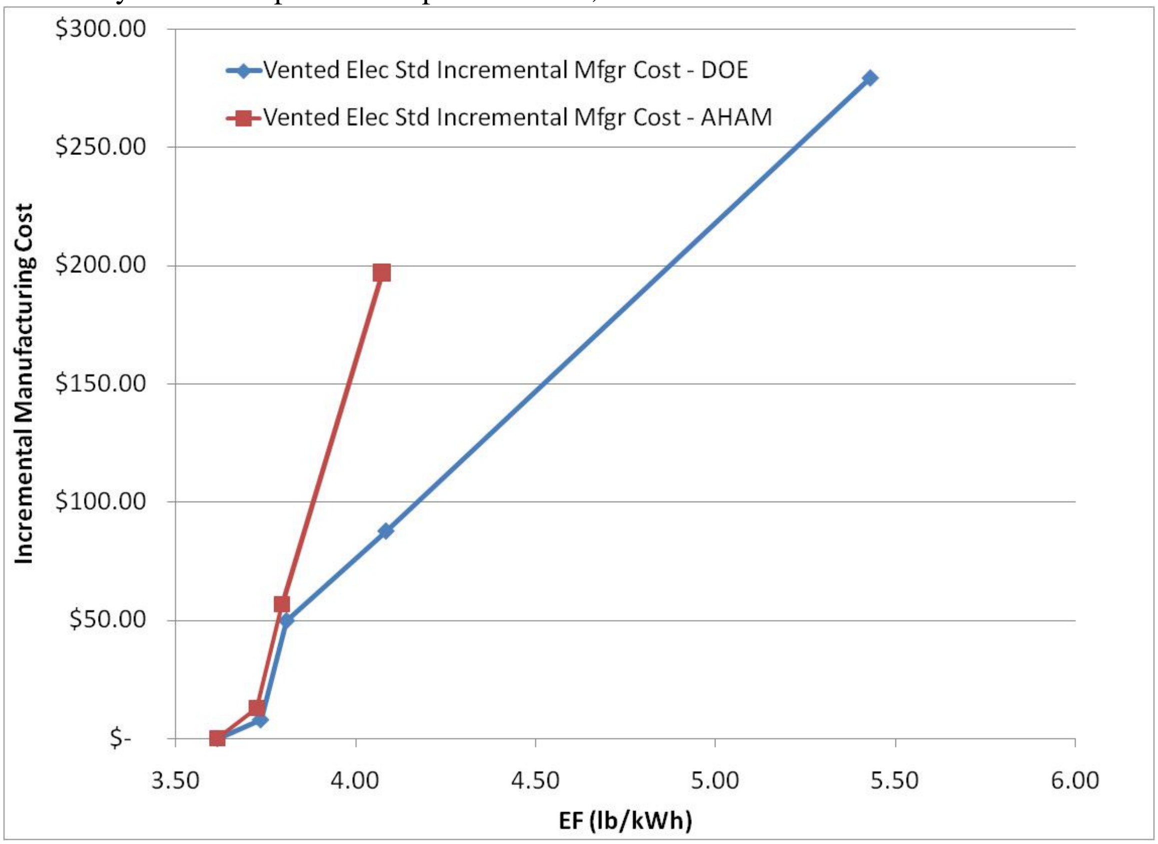


Figure **5.6.19** through Figure 5.6.24 and Table 5.6.9 through Table 5.6.14. DOE updated the manufacturing cost model data developed for the preliminary analysis based on the revisions to the design options at each efficiency level. In addition, DOE updated raw material and purchased parts costs based on the latest available data, as well as updating costs for manufacturing equipment, labor, and depreciation. For product classes for which AHAM provided data, the corresponding cost-efficiency curves are plotted as well. The EF values (for both DOE and AHAM data) shown below are adjusted using the percentage increases to account for the amendments to the DOE clothes dryer test procedure (10 CFR part 430, subpart B, appendix D1), as discussed above in section 5.4.1.1.

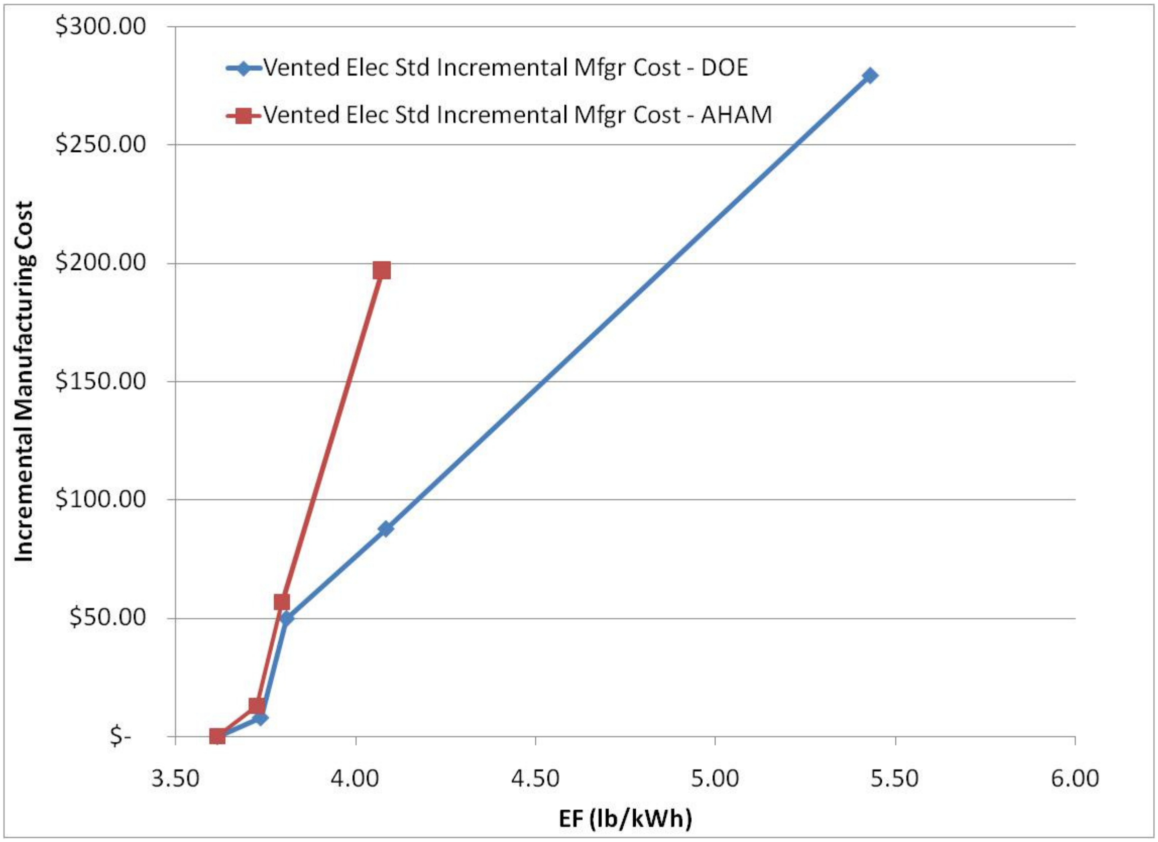


Figure 5.6.19 Vented Electric Standard Clothes Dryer Cost-Efficiency Curves

Table 5.6.9 Vented Electric Standard Clothes Dryer Incremental Manufacturing Costs

Efficiency Level (EF, *lb/kWh*)	**Incremental Cost**
Baseline (3.62)	$0
1 (3.74)	$7.92
2 (3.81)	$49.85
3 (4.08)	$87.79
4 (5.43)	$279.43

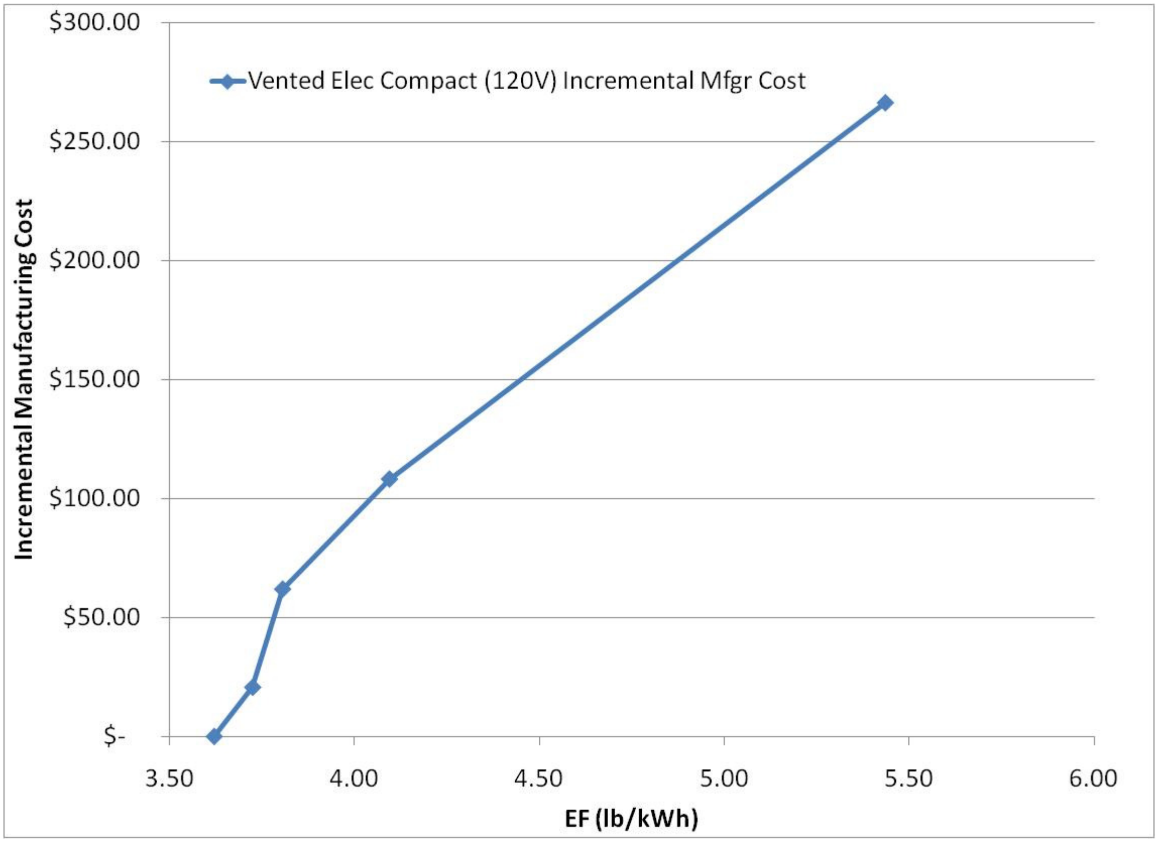


Figure 5.6.20 Vented Electric Compact (120V) Clothes Dryer Cost-Efficiency Curve

Table 5.6.10 Vented Electric Compact (120V) Clothes Dryer Incremental Manufacturing Costs

Efficiency Level (EF, ***lb/kWh*****)**	**Incremental Cost**
Baseline (3.62)	$0
1 (3.72)	$20.64
2 (3.80)	$61.94
3 (4.09)	$108.21
4 (5.44)	$266.37

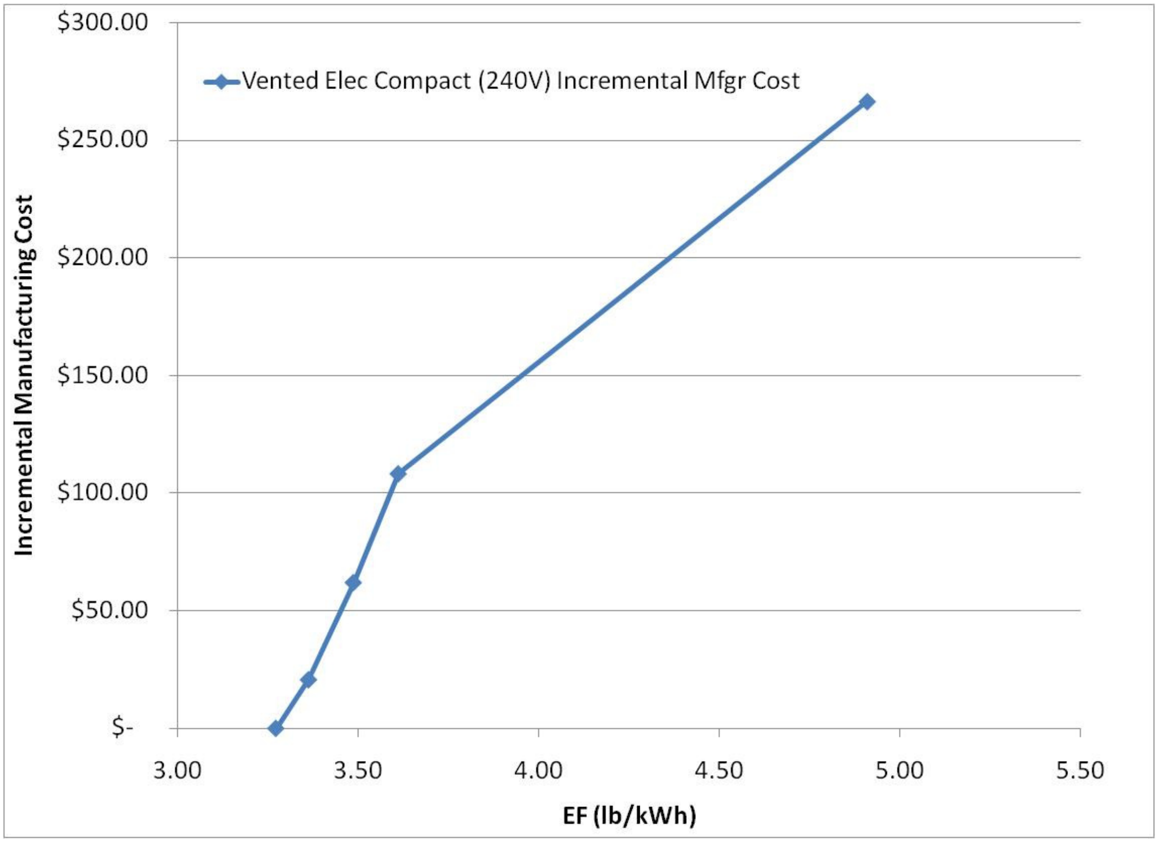


Figure 5.6.21 Vented Electric Compact (240V) Clothes Dryer Cost-Efficiency Curve

Table 5.6.11 Vented Electric Compact (240V) Clothes Dryer Incremental Manufacturing Cost

Efficiency Level (EF, *lb/kWh*)	**Incremental Cost**
Baseline (3.27)	$0
1 (3.36)	$20.64
2 (3.49)	$61.94
3 (3.61)	$108.21
4 (4.91)	$266.37

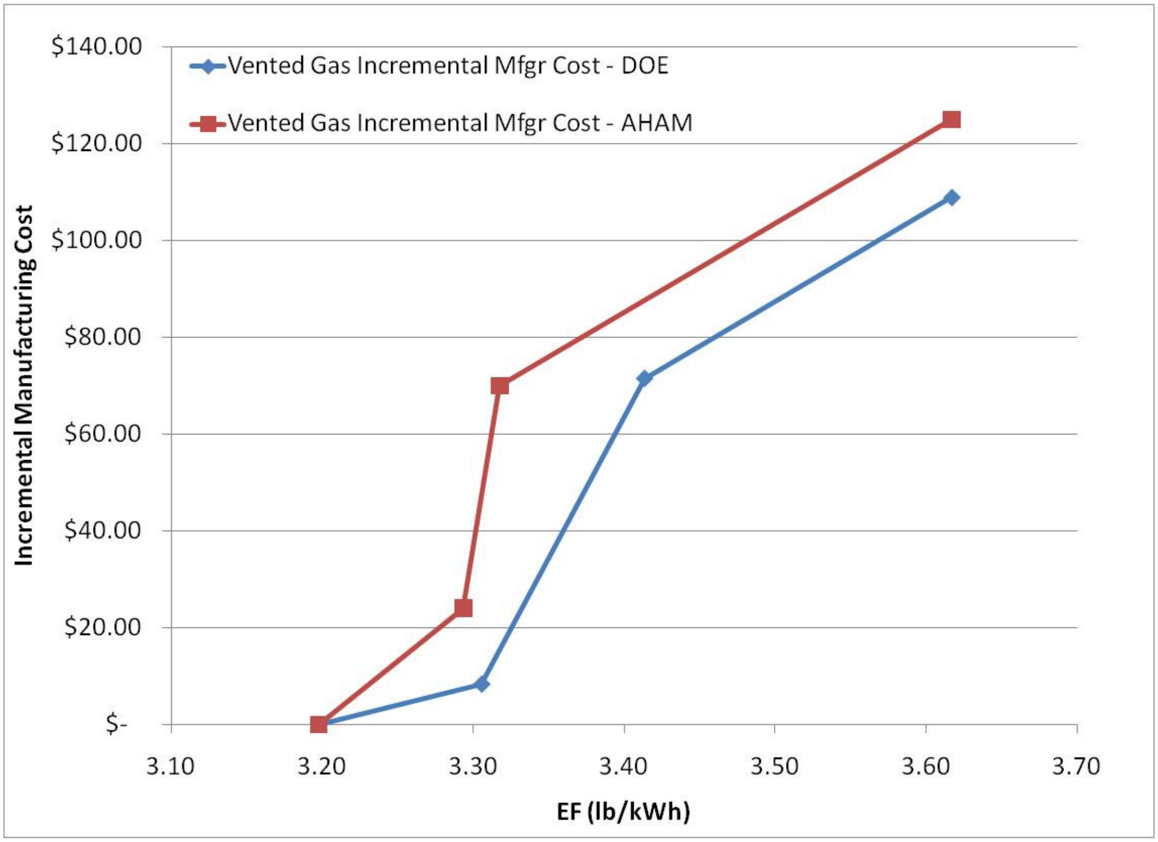


Figure 5.6.22 Vented Gas Clothes Dryer Cost-Efficiency Curves

Table 5.6.12 Vented Gas Clothes Dryer Incremental Manufacturing Cost

Efficiency Level (EF, *lb/kWh*)	**Incremental Cost**
Baseline (3.20)	$0
1 (3.31)	$8.30
2 (3.41)	$71.50
3 (3.62)	$108.87

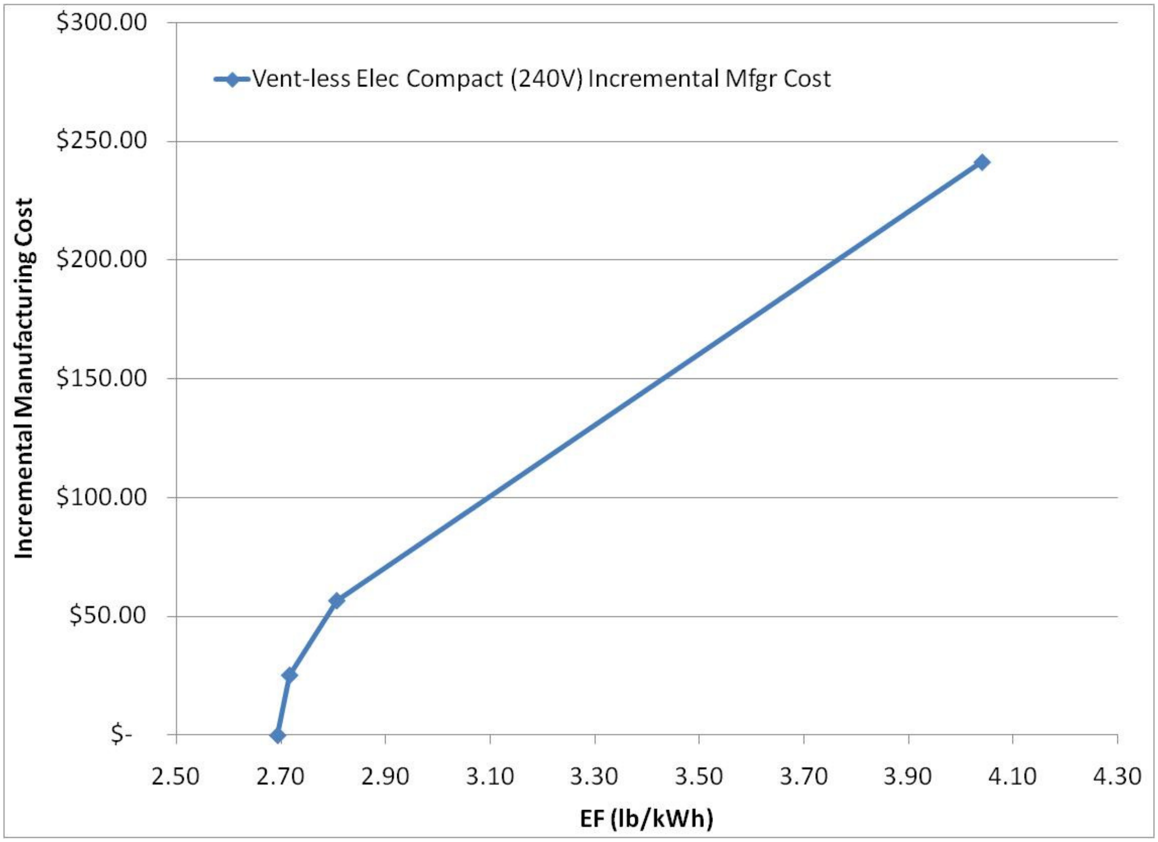


Figure 5.6.23 Ventless Electric Compact (240V) Clothes Dryer Cost-Efficiency Curve

Table 5.6.13 Ventless Electric Compact (240V) Clothes Dryer Incremental Manufacturing Cost

Efficiency Level (EF, *lb/kWh*)	**Incremental Cost**
Baseline (2.69)	$0
1 (2.72)	$25.31
2 (2.81)	$56.69
3 (4.04)	$241.25

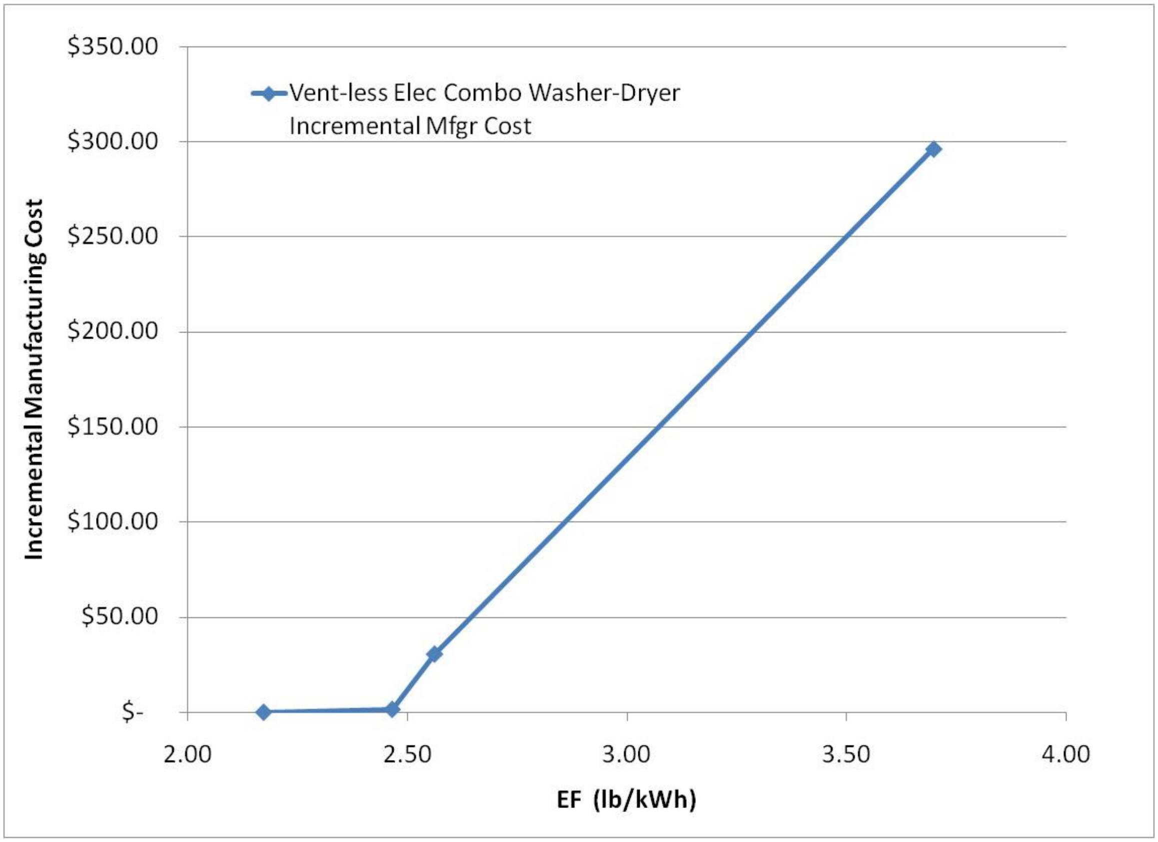


Figure 5.6.24 Ventless Electric Combination Washer/Dryer Cost-Efficiency Curves

Table 5.6.14 Ventless Electric Combination Washer/Dryer Incremental Manufacturing Cost

Efficiency Level (EF, *lb/kWh*)	**Incremental Cost**
Baseline (2.17)	$0
1 (2.46)	$1.51
2 (2.56)	$30.58
3 (3.70)	$296.43

Standby Mode

Based upon the product teardowns and cost modeling, DOE developed the incremental costs associated with decreasing standby power consumption, shown in Table 5.6.15. As discussed above for the active mode incremental manufacturing costs, DOE updated the incremental costs for standby power design changes based on the latest available electronics components pricing.

Table 5.6.15 Standby Power Incremental Manufacturing Cost

Standby Power Level *(W)*	Incremental Cost
Baseline (2.0)	$0
1 (1.5)	$0.93
2 (0.08)	$1.11

Incremental Costs by CEF

As discussed in section 5.4, the clothes dryer analysis for this rulemaking is based on the integrated metric, CEF. DOE analyzed the improvement in CEF associated both with design options that improve EF and design options that reduce standby power. DOE developed overall cost-efficiency relationships for the CEF efficiency levels presented in section 5.4.2.3. As noted above in section 5.4.2.3, DOE incorporated incremental standby power levels into CEF efficiency levels where DOE determined them to be most cost effective. In addition, as discussed above in section 5.4.2.3, DOE analyzed baseline efficiency products available on the market, and weighted the efficiency improvement and incremental manufacturing cost associated with standby power based on the percentage of baseline efficiency products that have electronic controls. For the integrated efficiency levels for which electronic controls would be required as part of the active mode design changes, DOE assumed that the standby power levels and incremental manufacturing costs affected 100 percent of clothes dryer models. Table 5.6.16 through Table 5.6.21 present DOE's estimates of incremental manufacturing cost for improvement of clothes dryer CEF above the baseline.

Table 5.6.16 Cost-Efficiency Relationship for Vented Electric Standard Clothes Dryers

Integrated Efficiency Level (CEF, *lb/kWh*)	Incremental Manufacturing Cost
Baseline (3.55)	$0
1 (3.56)	$0.68
2 (3.61)	$0.82
3 (3.73)	$8.74
4 (3.81)	$50.67
5 (4.08)	$88.89
6 (5.42)	$280.54

Table 5.6.17 Cost-Efficiency Relationship for Vented Electric Compact (120V) Clothes Dryers

Integrated Efficiency Level (CEF, *lb/kWh*)	Incremental Manufacturing Cost
Baseline (3.43)	$0
1 (3.48)	$0.68
2 (3.61)	$0.82
3 (3.72)	$21.46
4 (3.80)	$62.76
5 (4.08)	$109.31
6 (5.41)	$267.48

Table 5.6.18 Cost-Efficiency Relationship for Vented Electric Compact (240V) Clothes Dryers

Integrated Efficiency Level (CEF, *lb/kWh*)	Incremental Manufacturing Cost
Baseline (3.12)	$0
1 (3.16)	$0.68
2 (3.27)	$0.82
3 (3.36)	$21.46
4 (3.48)	$62.76
5 (3.60)	$109.31
6 (4.89)	$267.48

Table 5.6.19 Cost-Efficiency Relationship for Vented Gas Clothes Dryers

Integrated Efficiency Level (CEF, *lb/kWh*)	Incremental Manufacturing Cost
Baseline (3.14)	$0
1 (3.16)	$0.68
2 (3.20)	$0.82
3 (3.30)	$9.12
4 (3.41)	$72.32
5 (3.61)	$109.98

Table 5.6.20 Cost-Efficiency Relationship for Ventless Electric Compact (240V) Clothes Dryers

Integrated Efficiency Level (CEF, *lb/kWh*)	Incremental Manufacturing Cost
Baseline (2.55)	$0
1 (2.59)	$0.93
2 (2.69)	$1.11
3 (2.71)	$26.42
4 (2.80)	$57.80
5 (4.03)	$242.36

Table 5.6.21 Cost-Efficiency Relationship for Ventless Electric Combination Washer/Dryers

Integrated Efficiency Level (CEF, *lb/kWh*)	Incremental Manufacturing Cost
Baseline (2.08)	$0
1 (2.35)	$1.51
2 (2.38)	$2.44
3 (2.46)	$2.62
4 (2.56)	$31.69
5 (3.69)	$297.54

5.6.1.5 Manufacturer Interviews – Preliminary Analysis

DOE conducted interviews with residential clothes dryer manufacturers to determine appropriate efficiency levels for the preliminary analysis and to develop a better understanding of the technologies used to improve energy efficiency. During these interviews, DOE asked manufacturers what max-tech efficiency levels would be appropriate for each clothes dryer product class. DOE also asked manufacturers what groupings of design options are used in baseline designs and what would be implemented to increase the energy efficiency in order to meet the efficiency levels proposed in section 0 for residential clothes dryers. The discussion helped DOE understand what proposed design options have already been implemented and what additional design options DOE should consider. In addition, DOE conducted discussions regarding issues with the DOE test procedure for clothes dryers. The discussion below represents a consolidation of the responses. DOE subsequently conducted another series of interviews with manufacturers to solicit feedback on preliminary manufacturing cost estimates DOE developed through the reverse engineering analysis.

Max-Tech Efficiency Levels

Manufacturers indicated that the current maximum-available EF for vented gas clothes dryers listed in the CEC product database is not achievable. Multiple manufacturers stated that the CEC product database has had errors in the values listed in the past for other products, and at least one manufacturer suggested that DOE test the maximum-available model to determine an appropriate max-tech level. As discussed in section 0, DOE tested the maximum-available gas clothes dryer and determined that it did not achieve the rated EF.

Multiple manufacturers indicated that an EF of approximately 3.0 would be an appropriate max-tech value. In addition, AHAM submitted incremental manufacturing cost data, aggregated from manufacturer inputs, for the max-tech active mode efficiency level for vented gas clothes dryers proposed in the framework document (3.02 EF).

Components That Influence Energy Efficiency

Manufacturers identified components that influence energy efficiency in residential clothes dryers that are related to baseline designs. DOE also identified components and design options that it believed could potentially influence energy efficiency in residential clothes dryers. DOE requested comment on each of these design options and their potential for increasing energy efficiency.

Manufacturers indicated that they use a single 4-pole induction motor to drive both the drum and the blower in their baseline clothes dryer. Manufacturers also use a single-element electric resistance heater for electric clothes dryers and a single-stage gas valve for gas clothes dryers. In addition, manufacturers generally incorporate electromechanical controls into their baseline units along with some form of automatic termination control by temperature sensing.

A number of manufacturers indicated that improvements to energy efficiency can be made by implementing more efficient fan motors in place of the standard 4-pole induction motor. Manufacturers believed that 1 to 5 percent improvement can be achieved using more efficient fan motors, such as electronically-commutated motors (ECM), however the costs are high.

Manufacturers also indicated that all of their units incorporate some form of automatic termination sensing control. Manufacturers stated that thermostatically controlled automatic termination control with electromechanical controls is generally the least accurate form of automatic termination sensing. Using moisture sensors along with the thermostat controlled automatic termination sensing can improve the accuracy of these systems. To increase the accuracy further, manufacturers indicated that they would use moisture sensing controls with thermistors, which give continuous feedback, along with electronic controls.

At least one manufacturer indicated that adding insulation could improve efficiency minimally. However, most manufacturers believed that there is no significant efficiency improvement with insulation.

A number of manufacturers indicated that modifying the air flow can improve efficiency. For example, multiple manufacturers indicated that switching the drum air flow design from front to back to a design flowing in through one side of the drum on the back and out through the other side of the back can improve efficiency 1 to 3 percent.

Manufacturers also indicated that preheating inlet air, either through the use of an air-to-air heat exchanger or recirculation of process air, can improve energy efficiency. Manufacturers indicated varying degrees of potential improvements to energy efficiency associated with this design option, ranging from 1 to 12 percent.

With regards to modulating heat, manufacturers indicated that they would incorporate a modulating heater to reach different efficiency levels. They also indicated that modulating gas valves are significantly more expensive than single-stage gas valves.

A number of manufacturers have indicated that they manufacture heat pump dryers for international markets. Most manufacturers stated that 30 to 50 percent efficiency improvement is possible using heat pump technology. Manufacturers indicated that they would generally consider using a R-134a compressor along with tube and fin heat exchangers.

Strategies to Increase Energy Efficiency

Manufacturers generally supported the proposed efficiency levels for the vented dryer product classes. However, a number of manufacturers indicated that the max-available gas efficiency level above 3.44 EF (proposed in the first set of preliminary manufacturer interviews) may be difficult to achieve. Manufacturers generally indicated that the max-available efficiency level for vented gas dryers should be between 3.0 and 3.06 EF (90 percent of the max-available level for vented electric standard). DOE subsequently adjusted the max-available gas dryer efficiency level based on updates to the CEC database. For the vented electric compact 120V product class, at least one manufacturer was in agreement with the method used to develop the efficiency levels. However, other manufacturers indicated that meeting even the baseline efficiency would be difficult.

For the ventless electric compact 240V product class, at least one manufacturer indicated that it believed the proposed efficiency levels were appropriate. However, a few manufacturers also indicated that the proposed efficiency levels were low compared to the efficiencies achieved by the units that they manufacture.

Although manufacturers cited different design pathways for meeting the proposed efficiency levels, in general they cited the following strategies to increase energy efficiency: (1) air flow system improvements, (2) modulating heat design, (3) inlet air preheating, (4) higher-efficiency motor designs, and (5) heat pump technology for electric dryers.

Manufacturers indicated that air flow system changes would be included in design changes to meet the proposed efficiency levels. Some manufacturers cited such changes as using direct duct heaters to provide better heating and minimize heat losses. Other manufacturers indicated that better air flow sealing or insulation could also be used to meet efficiency levels. Manufacturers generally indicated that air flow system changes would be incorporated as part of design changes to meet EL 1 or EL 2 for vented dryers.

Manufacturers cited modulating heat designs as a strategy to improve energy efficiency. Some manufacturers indicated that the costs for this design change would be 3 to 4 times higher for a gas dryer, which would require a modulating gas valve and additional controls, as compared to an electric dryer, which would use either a multi-element resistance heater or a single element with modulating current. Various manufacturers indicated that they would use modulating heat as part of the design changes to meet EL 1 through EL 3 for vented dryers. Manufacturers also indicated that when adopting a modulating heater, they would additionally implement improved moisture sensing and more complicated controls systems.

Manufacturers also indicated that preheating inlet air is important to consider for achieving efficiency improvements. Some manufacturers indicated that this could be achieved by partial recirculation of the process air through the burner or heater system for all or part of the cycle. Manufacturers indicated that if they were to recirculate the process air, they would add or modify lint screens to prevent lint migration into the heater system. Other manufacturers believed that inlet air could be pre-heated by using a heat exchanger. Manufacturers that commented they would incorporate this design option, believed that it would be used as part of the design changes to meet either EL 2 or EL 3 for vented dryers.

Manufacturers cited improved motor efficiency as a strategy for meeting the proposed efficiency levels. Most manufacturers that commented that they would incorporate improved motor efficiency stated that they would likely incorporate this into the design changes for EL 3. Manufacturers indicated that they would likely use a separate ECM motor for the fan.

Manufacturers indicated that heat pump technology would provide the largest improvement to efficiency. Most manufacturers indicated that 30 to 50 percent improvement in efficiency can be achieved with heat pump dryers. However, manufacturers that produce compact-size heat pump clothes dryers for international markets indicated that the very long cycle times would be a consumer utility issue for U.S. consumers as well as the much higher initial cost of the unit.

A few manufacturers indicated that they would need to incorporate heat pump technology to reach EL 3 for vented electric standard dryers, which would be a 13 percent improvement over the baseline EF. DOE notes that there are currently units available on the market which meet EL 3 which do not incorporate heat pump technology and DOE believes that using heat pump technology can improve the efficiency beyond this point to the proposed EL 4. DOE also notes that some manufacturers indicated design changes to meet EL 3 that did not include switching to a heat pump design.

Manufacturers also noted that a number of the above mentioned design changes would require improved control systems using moisture sensing and electronic controls.

Manufacturers indicated that for ventless electric compact (240V) dryers, they would apply the same design changes as were used for vented electric dryers. In addition, they would consider modifications to the heat exchanger as a potential source for improving energy efficiency.

With regards to the proposed standby power levels for clothes dryers, at least one manufacturer commented in agreement with the proposed design changes for decreasing standby power in clothes dryers. They indicated that both incorporating a switching power supply and a transformerless power supply with a Triac to control power through the transformer are reasonable approaches to achieving standby levels 1 (1.5W) and 2 (0.08W). Again at least one manufacturer agreed that the incremental manufacturing costs associated with standby levels 1 and 2 that DOE developed through its reverse engineering analysis are appropriate.

Incremental Manufacturing Cost

In the initial set of preliminary manufacturing interviews, DOE requested feedback on whether the aggregated costs submitted by AHAM were representative of the manufacturing costs developed by each manufacturer. Most manufacturers indicated that the aggregated costs submitted by AHAM were representative of their costs for each efficiency level.

After DOE conducted the first round of preliminary manufacturer interviews, DOE developed incremental manufacturing cost-efficiency curves based on manufacturer inputs and reverse engineering analysis. DOE subsequently requested feedback from manufacturers on these incremental manufacturing cost-efficiency curves in order to refine its analysis. Manufacturers indicated that although they were not always in agreement with the design changes used to meet each efficiency level, they were generally in agreement with the incremental manufacturing cost-efficiency curves, indicating that values developed by DOE were generally within 20 percent of the values submitted by these manufacturers. Manufacturers also provided indications of the appropriateness of component pricing estimates used in DOE's cost model. DOE used information learned during these discussions to revise its reverse engineering analysis and incremental manufacturing costs.

Test Procedure Issues

DOE requested comment on a number of issues regarding the DOE test procedure for clothes dryers. Manufacturers indicated that they have observed test to test variation from 0.03 to 0.1 EF points for a single unit tested multiple times. At least one manufacturer indicated that latest test cloth may have some problems, showing variations in measured EF as the test cloth is used for multiple test runs. A number of manufacturers also indicated that variation in results can be seen within the allowable range ambient humidity and temperatures. Manufacturers stated that variations in ambient humidity had more of an effect on results than temperature. However, at least one manufacturer indicated that the ambient conditions are difficult to maintain and it would be hard to justify tighter tolerances given the requirements of increased control.

5.6.1.6 Manufacturer Interviews – Final Rule

DOE conducted additional interviews with residential clothes dryer manufacturers to discuss the efficiency levels and incremental manufacturing costs proposed in the preliminary analysis and to develop a better understanding of the challenges that manufacturers face in order to improve energy efficiency. During these interviews, DOE asked manufacturers what groupings of design options are used in baseline designs and what would be implemented to increase the energy efficiency in order to meet higher efficiency levels for residential clothes dryers. DOE also asked manufacturers about repair and maintenance costs for residential clothes dryers at higher efficiencies, as well as the manufacturing costs associated with complying with the Underwriters Laboratory (UL) Standard 2158 "Electric Clothes Dryers" (UL 2158) fire containment requirements. In addition, DOE conducted discussions regarding issues with the DOE test procedure for clothes dryers. The discussion below represents a consolidation of the responses.

Strategies to Increase Energy Efficiency

Manufacturers generally supported the design changes and efficiency levels analyzed by DOE for the preliminary analysis. However, a number of manufacturers indicated that they would likely incorporate 2-stage modulating heat as part of the design changes to meet active mode EL2 for vented clothes dryer product classes, and that inlet-air preheating would be incorporated to the design changes used for active mode EL2 to achieve active mode EL3.

Manufacturers also indicated that inlet-air preheating would theoretically result in a 5 to 15 percent improvement in efficiency. Manufacturers noted that in real-world situations, the potential efficiency improvement would be limited the necessary fin spacing for heat exchangers to prevent lint fouling. In addition, manufacturers indicated that improvements in efficiency would be limited by issues with condensation

Repair and Maintenance Costs

DOE requested information on how repair and maintenance costs would be impacted by more stringent energy conservation standards. A number of manufacturers indicated that repair and maintenance costs and frequency of repairs would likely increase with increased complexity and number of parts. Manufacturers also indicated that heat pump technology would significantly increase time and cost of repair and maintenance due to the addition of more complex refrigeration systems.

Underwriters Laboratory Standard 2158 - Electric Clothes Dryers

DOE requested information from clothes dryer manufacturers on the manufacturing costs and design changes required to comply with the UL 2158 fire containment requirements. Manufacturers indicated that, among other changes, a number of plastic components would have to be changed to metal, in particular for airflow ducting. However, DOE did not receive sufficient data to determine the incremental manufacturing costs to baseline clothes dryers to comply with the fire containment requirements of UL 2158. In addition, DOE did not receive sufficient information to indicate that the cost associated with complying with UL 2158 would vary at efficiency levels above the baseline. As a result, DOE did not include additional cost to comply with UL 2158 in the baseline manufacturing production cost. As discussed in chapter 13 of this TSD, DOE has investigated the costs of complying with the fire containment requirements in UL 2158 in the cumulative regulatory burden for the manufacturer impact analysis (MIA).

Test Procedure Issues

DOE requested comment on a number of issues regarding the DOE test procedure for clothes dryers. Multiple manufacturers stated that if DOE were to change the 50 percent cotton/50 percent polyester mix test cloth to a 100 percent cotton test cloth would increase the test-to-test variation. Multiple manufacturers also indicated that increasing the clothes dryer load size would increase the measured efficiency.

With regards to test load preparation, a number of manufacturers indicated that changing the water temperature for clothes dryer test load preparation from 100 °F ± 5 °F to 60 °F ± 5 °F would be more representative of consumer usage. Manufacturers also stated that such a change would result in a reduction in the measured efficiency because of the additional energy required to heat the clothes load from a lower starting temperature.

5.6.2 Room Air Conditioners

DOE considered cost and efficiency information obtained from multiple sources for the room air conditioner engineering analysis. During the preliminary analysis, DOE conducted room air conditioner teardown assessments and developed a manufacturing cost model to calculate the manufacturing costs for designs of varying efficiency levels. The preliminary analysis reverse engineering work was primarily based on the HCFC-22 refrigerant products available at that time. During the final rule analysis, DOE supplemented this information with room air conditioner teardowns for selected products using R-410A refrigerant. DOE also carried out energy modeling supported by manufacturing cost analysis to determine the incremental cost associated with efficiency improvements for products using R-410A. DOE also conducted interviews with room air conditioner manufacturers to obtain greater insight into design strategies and their associated costs to improve efficiency. DOE conducted preliminary manufacturer interviews after the framework comment period. DOE also conducted additional manufacturer interviews after the preliminary analysis. DOE did not receive aggregated industry data from AHAM for the incremental costs to achieve higher efficiency levels, because too few manufacturers reported data to allow aggregation and reporting of the data.

5.6.2.1 AHAM Data

In support of the room air conditioner rulemaking, AHAM requested incremental manufacturing cost data from its member companies. As mentioned above, not enough responses were obtained to allow reporting to DOE. Table 5.6.22 and Table 5.6.23 describe market share by product class from 2005 to 2007. A large majority of the shipped products are from product classes 1 through 5, products without reverse cycle and with louvered sides.

Table 5.6.22 AHAM Room Air Conditioner Product Class Market Share Data Submittal: Product Classes 1 Through 5

	Without Reverse Cycle (RC) and With Louvered Sides (LS)				
Product Class	**1**	**2**	**3**	**4**	**5**
	<6k	**6–8k**	**8–14k**	**14–20k**	**>20k**
2005	37%	19%	30%	3%	2%
2006	23%	19%	34%	5.5%	3.9%
2007	32%	16%	36%	6%	2.6%

Table 5.6.23 AHAM Room Air Conditioner Product Class Market Share Data Submittal: Product Classes 6 through 16

	Without Reverse Cycle and Without Louvered Sides	With Reverse Cycle and With Louvered Sides		With Reverse Cycle and Without Louvered Sides		Casement Only	Casement Slider
		<20k	>20k	<14k	>14k		
Product Class	**6 - 10**	**11**	**13**	**12**	**14**	**15**	**16**
2005	7%	0.7%	0.1%	0.4%		0.4%	
2006	12%	1.0%		0.6%		0.6%	
2007	7%	**	**	**	**	0.4%	

**Insufficient responses were received by AHAM to allow reporting for these product classes.

Table 5.6.24 and Table 5.6.25 detail the shipment-weighted average energy efficiency of room air conditioner shipments from 2005 to 2007 by product class. AHAM did not provide data for product classes 6, 7, 10, 13, 14, and 15. The efficiency trends for presented in the tables are mixed, with EER increasing for some product classes and decreasing for others.

Table 5.6.24 AHAM Room Air Conditioner Shipment Weighted Efficiency Data (EER) Submittal: Product Classes 1 through 5

	Without Reverse Cycle (RC) and With Louvered Sides (LS)				
Product Class	**1**	**2**	**3**	**4**	**5**
	<6k	**6–8k**	**8–14k**	**14–20k**	**>20k**
2005	9.5	10.2	10.3	10.3	9
2006	9.8	10.4	10.4	10.5	9.2
2007	9.8	9.9	10.1	10.3	9.1

Table 5.6.25 AHAM Room Air Conditioner Shipment Weighted Efficiency Data (EER) Submittal: Product Classes 6 through 16

	Without Reverse Cycle and Without Louvered Sides		With Reverse Cycle and With Louvered Sides	With Reverse Cycle and Without Louvered Sides	Casement Slider
	8–14k	**14–20k**	**<20k**	**<14k**	
Product Class	**8**	**9**	**11**	**12**	**16**
2005	9.5	**	10.6	9.6	9.9
2006	9.5	**	10.5	9.6	**
2007	9.5	9.0	**		9.5

**Insufficient responses were received by AHAM to allow reporting for these product classes.

In addition to market share by product class and shipment-weighted average energy efficiency for room air conditioners, AHAM also submitted data disclosing market share by efficiency level and year. These data are tabulated in appendix 5B of this TSD.

5.6.2.2 Manufacturer Interviews

During the preliminary analysis in 2008, DOE conducted interviews with room air conditioner manufacturers to develop a better understanding of the technologies used to improve energy efficiency. These interviews took place as manufacturers were developing R-410A designs for 2010 but before ramp-up of manufacturing of these units. During these interviews, DOE asked manufacturers what groupings of design options would be required to increase the energy efficiency to meet the efficiency levels proposed in section 5.4.2 for room air conditioners. The discussions helped DOE understand which design options have already been implemented and which additional design options DOE should consider. The discussion below represents a consolidation of the responses.

DOE also conducted interviews with room air conditioner manufacturers during the final rule analysis, in 2010. These interviews took place after manufacturers' initial experience of full-line production of products using R-410A refrigerant. During these interviews, DOE asked manufacturers what groupings of design options are used in baseline designs and what would be implemented to increase the energy efficiency in order to meet higher efficiency levels for room air conditioners. DOE asked about the state of the R-410A transition and the technical challenges still facing manufacturers to meet higher efficiencies.

Components That Influence Energy Efficiency

Manufacturers identified the components that influence energy efficiency in room air conditioners as fans, blowers, fan motors, heat exchanger coils, and compressors. Most manufacturers use PSC fan motors. Some manufacturers have considered electronically-commutated motors (ECM), which use less energy than PSC fan motors, but generally have not pursued using them because of cost.

Manufacturers currently use rotary compressors in their room air conditioners, and the efficiency range of compressors available today varies by product class. Manufacturers were required to stop using HCFC-22 refrigerant starting in 2010, so manufacturers now use R-410A refrigerant. Compressor vendors were still developing their lines of R-410A compressors during the course of the analysis, so some of the information about them has been changing. Manufacturers mentioned during the preliminary analysis phase that the EER range for R-410A compressors currently available tops out at 10.0, as compared to 11.0 for HCFC-22 compressors. Manufacturers expected to be able to make up for much but not all of the difference as a result of the better heat transfer performance of R-410A. Manufacturers have not implemented variable-speed compressors because of the higher cost and because the steady conditions of the DOE test procedure do not capture the actual-use benefits of such compressors. Other compressor technologies, such as scroll or reciprocating compressors, are available only for higher capacity room air conditioners but are generally not used due to size, weight, and/or vibration issues.

Strategies to Increase Energy Efficiency

Manufacturers consider material cost, shipping cost, and weight as key design parameters. Manufacturers cited the following strategies to increase energy efficiency: (1) heat exchanger coil improvements or face area increase, (2) air system design improvement to increase air flow, (3) use of higher-efficiency fan motors, (4) higher-efficiency compressors, and (5) subcooler coils.

Manufacturers cited compressors as a key strategy to increase energy efficiency. However, as mentioned above, compressors vendors were not initially offering as full a range of compressor EER levels with R-410A compressors as have been available for HCFC-22. This is expected to change over the next few years, but initial R-410A designs were constrained by limitations in compressor availability.

Manufacturers are emphasizing heat exchanger coil improvements to increase energy efficiency, since this design option offers the most potential for improvement. Further increases in efficiency are typically only possible via increasing the coil area. Larger coils require more material, which manufacturers cited as a concern due to high material prices. Also, as coils grow, the chassis may have to grow as well. If the unit size and weight increase past a certain point, consumer utility is impacted. For larger capacity products, window sizes won't allow further size increases. Fewer products can fit in a shipping container, which results in higher per-unit shipping costs.

Manufacturers mentioned that maximizing air flow is also an important consideration in achieving efficiency improvements. This may involve reducing fin density or coil depth, using more powerful fans and/or blowers, and paying closer attention to minimizing losses in the air flow passages. However, more powerful fans can have a detrimental impact on consumer utility by making the room air conditioner noisier. Finally, while both higher efficiency PSC motors and subcooling coils were cited as having the potential to improve efficiency, the overall impact of these design options is relatively small.

Final Rule Analysis Interviews

Manufacturers in 2010 had experience with R-410A designs. However, because compressor vendors' product lines were not fully developed and because only one year of products had been produced, not all issues associated with the new refrigerant had been resolved.

All manufacturers stated that R-410A compressors were available, but choices were limited. Manufacturers reported that there were less compressor choices, in terms of efficiency and capacity. The maximum R-410A rotary compressor efficiency available for use in most products was still 10 EER, according to most manufacturers interviewed. However, testing and development of higher efficiency compressors was on-going.

The majority of manufacturers continued to concentrate on heat exchanger improvements, mainly through increases in product size. Some manufacturers reported limits in the potential size of heat exchangers, due to the impacts from excess refrigerant charge and possible impacts on dehumidification performance. Some manufacturers have had to increase the number of tube rows (*i.e.*, the depth) of the heat exchangers in their units. The increase of heat exchanger size often is accompanied by use of compressors with lower nominal capacity, because the operating capacity of the compressor increases when evaporating temperature is raised and condensing temperature lowered, as occurs with larger heat exchangers.

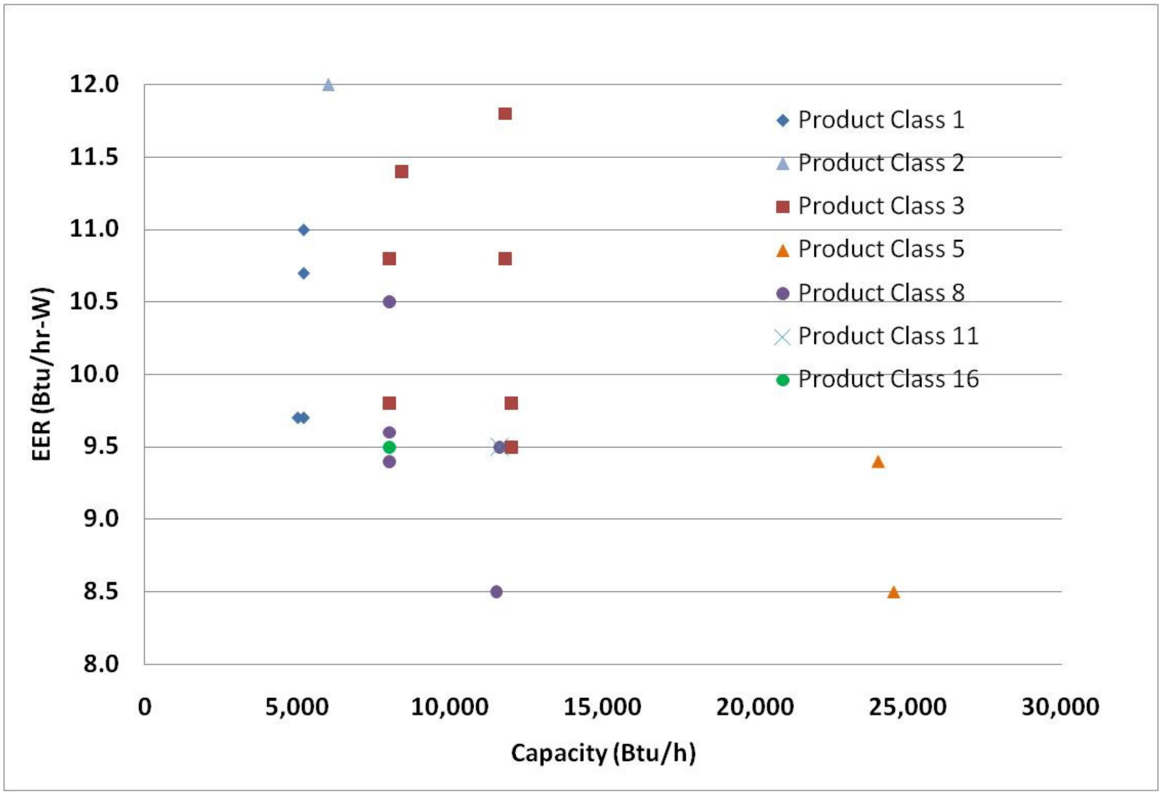
To implement new R-410A designs, some manufacturers reported that they had to grow their units to accommodate the larger heat exchangers, either by developing new product sizes or by using the next chassis size available (*e.g.*, using last year's 10,000 Btu/h product chassis for this year's 8,000 Btu/h product). All manufacturers are very sensitive to the cost of increasing the size of units, as larger sizes mean more material and more costs. Many times, the additional product costs have been borne by the manufacturers themselves, because the market is extremely competitive. However, manufacturers realize that they are reaching the limit of current box sizes.

Through-the-wall units (products with non-louvered sides) of higher capacity have faced an extreme challenge, because product size cannot be increased for these products. Some manufacturers reported that larger capacity products may be unable to meet efficiency standards, and may disappear from the market.

5.6.2.3 Product Teardowns

During the preliminary analysis, DOE conducted reverse engineering for 21 room air conditioners across 6 product classes to identify design options, and their associated costs, that can be used to raise EER. To the extent possible, DOE selected reverse engineering products of similar nominal capacity but varying efficiencies. Figure 5.6.25 shows the efficiency ranges of the selected products. The efficiency ranges for the products selected from product classes 1, 3, and 5 cover the range of efficiency levels of available products. For product classes 3 and 8, products were selected at capacity levels of both 8,000 Btu/h and 12,000 Btu/h.

DOE notes that all the room air conditioners torn down in the preliminary analysis used HCFC-22 as their refrigerant. DOE identified only one commercially available R-410A room air conditioner when this analysis was conducted. DOE purchased this unit and conducted reverse engineering, but did not conduct a full teardown of this unit. Nevertheless, DOE was able to obtain sufficient information about this unit to allow development of both an energy model and manufacturing cost model for it. The reverse engineering included close examination of all heat exchanger details, identification of the compressor and fan motor model number, and measurement of fan power input, among other things.



Note: The product class 2 unit did not undergo full teardown and uses R-410A refrigerant. All other products use HCFC-22 refrigerant. The 12,000 Btu/h 9.5 EER product class 3 product was advertised as being a through-the-wall product (product class 8).

Figure 5.6.25 Efficiency Range of Room Air Conditioner Teardowns

During the final rule phase, DOE conducted teardown analysis of commercialized R-410A products. This allowed confirmation and validation of information developed in the preliminary analysis. DOE tore down four R-410A room air conditioners, listed in Table 5.6.26.

Table 5.6.26 R-410A Teardown Products selected for validation of analysis

Teardown Unit	Product Class	Capacity (*Btu/hr*)	EER
1	1	5000	9.7
2	2	6,000	12.0
3	3	12,000	10.8
4	5B	28,500	8.5

During teardown analysis, DOE groups costs into key materials categories. Figure 5.6.26 shows the breakdown of material costs for a typical HCFC-22 baseline product class 3 room air conditioner, as generated from DOE's BOM, developed during the preliminary analysis. Note that the refrigeration system, heat exchangers, and fan components (components that largely determine energy consumption) make up 63 percent of the material costs. Figure 5.6.27 shows the various costs comprising a typical baseline product class 3 room air conditioner's full production cost. Depending on the manufacturer and the production volume, the depreciation costs may vary from those shown in the figure, which assumes a "green-field" site. Figure 5.6.28 and Figure 5.6.29 show the same breakdown for an R-410A ENERGY-STAR product class 3 room air conditioner. Note that the refrigeration system, heat exchangers, and fan components make up 73 percent of the material costs for this product.

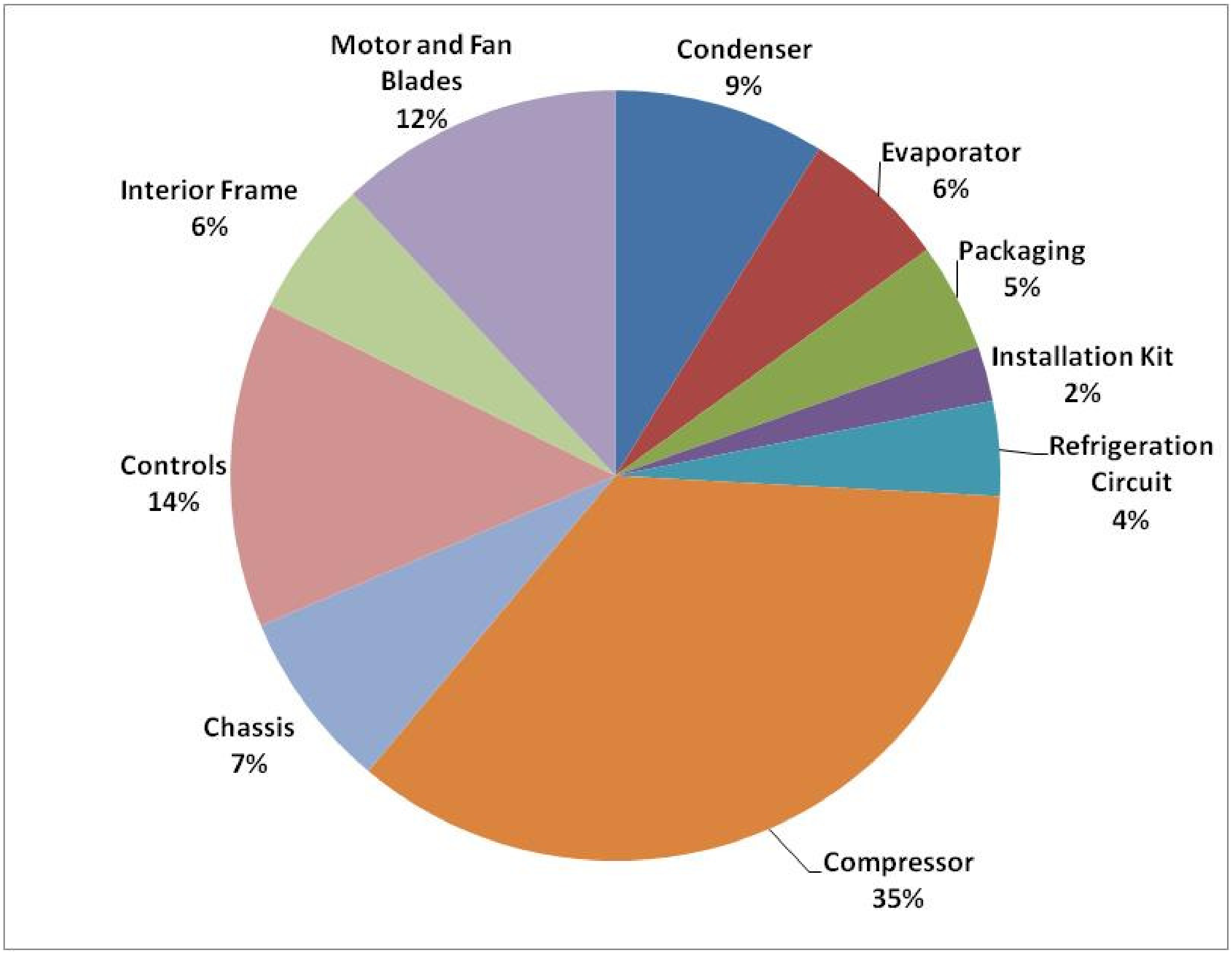


Figure 5.6.26 Baseline HCFC-22 Product Class 3 (12,000 Btu/h) Room Air Conditioner Material Cost Distribution ($157 total)

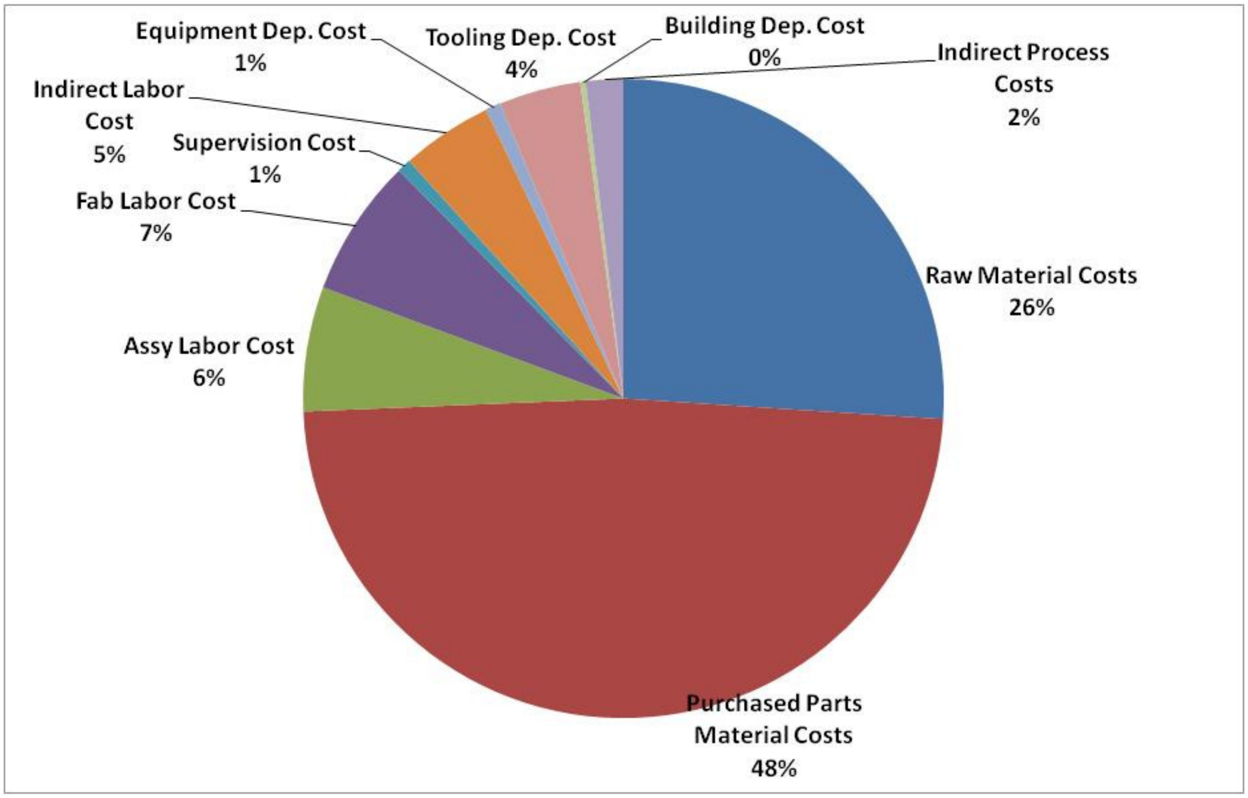


Figure 5.6.27 Baseline HCFC-22 Product Class 3 12,000 Btu/h Room Air Conditioner Full Production Cost Distribution ($195 total)

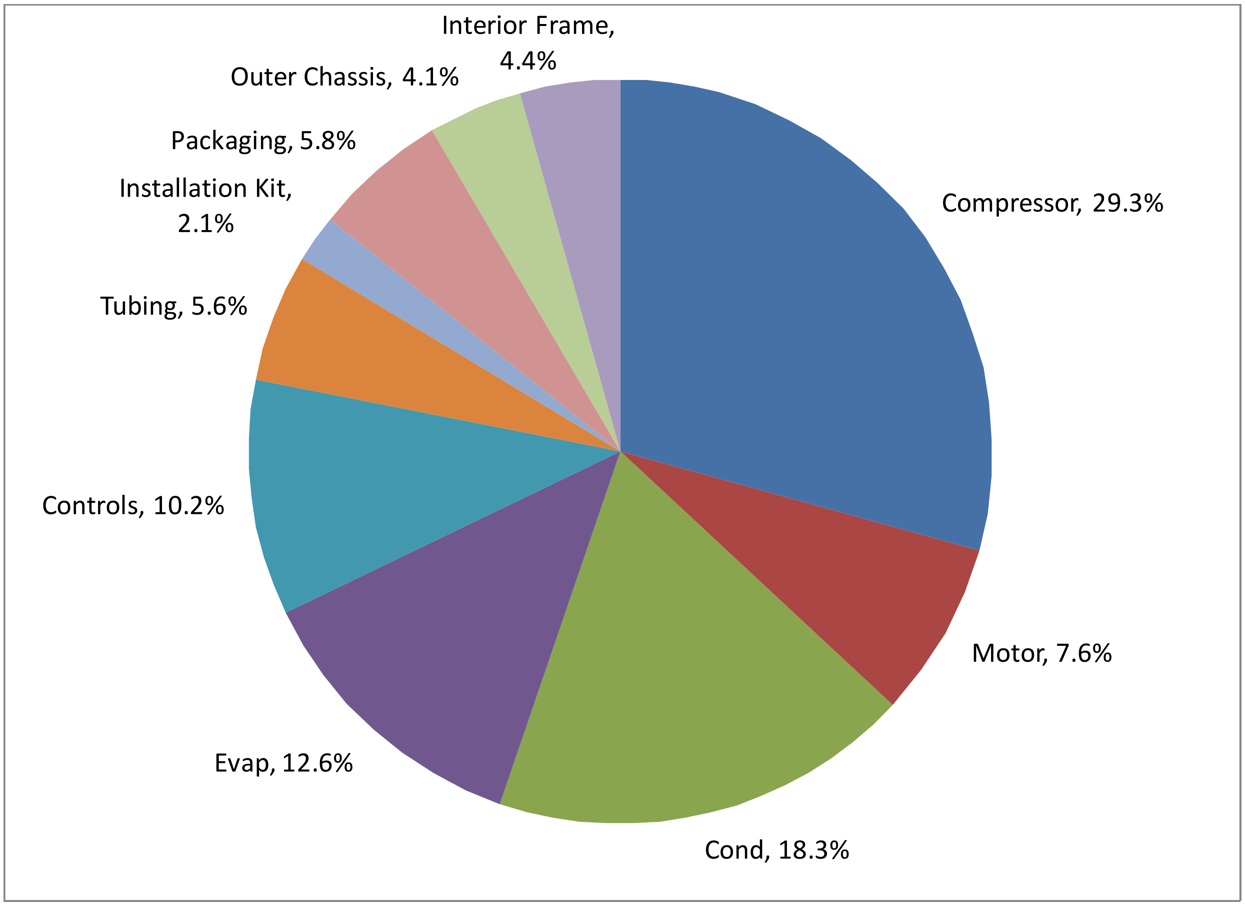


Figure 5.6.28 ENERGY-STAR R-410A Product Class 3 (12,000 Btu/h) Room Air Conditioner Material Cost Distribution ($150 total)

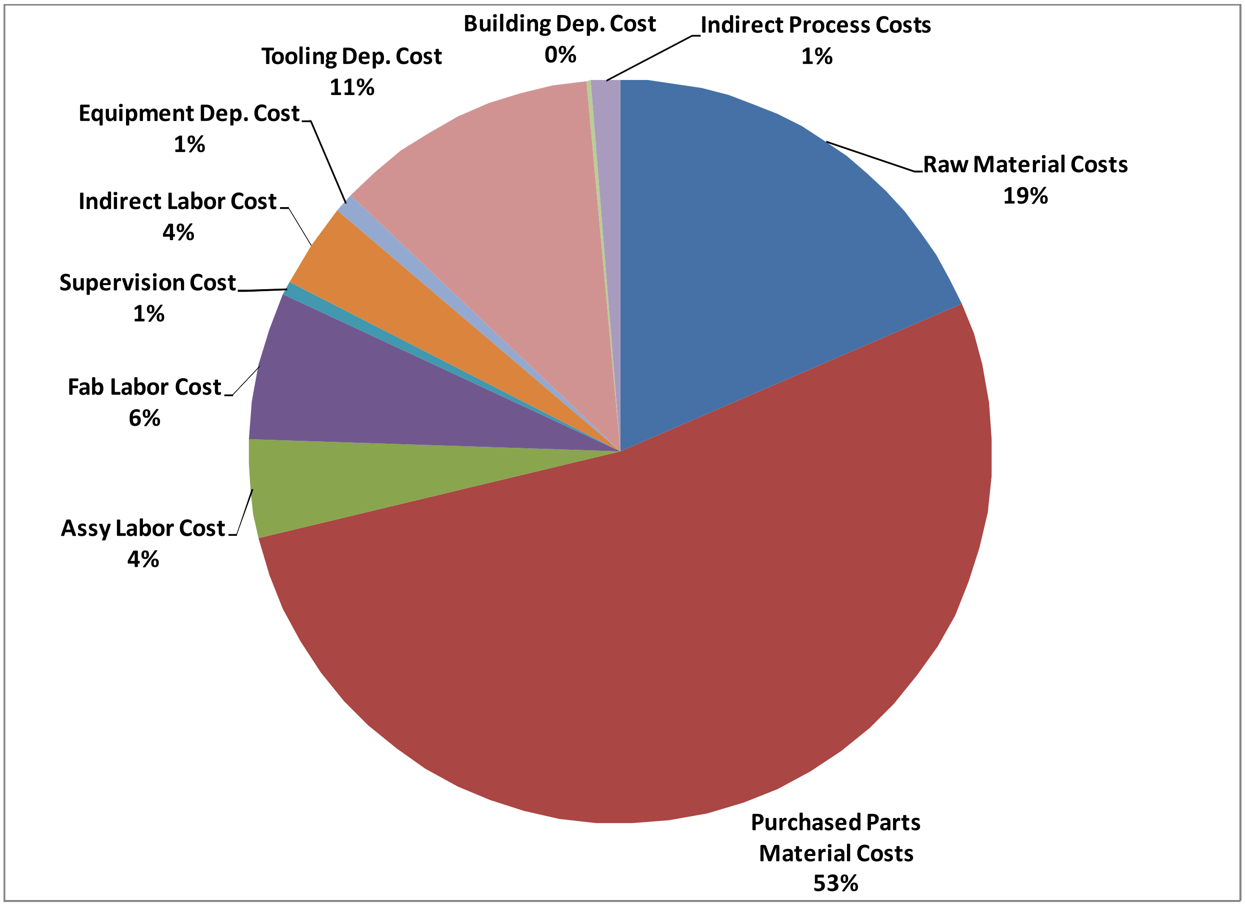


Figure 5.6.29 ENERGY-STAR R-410A Product Class 3 12,000 Btu/h Room Air Conditioner Full Production Cost Distribution ($211 total)

The manufacturing cost model was used in subsequent analysis to determine the cost of room air conditioner designs incorporating series of design options to increase efficiency. The results of these analyses are discussed in section 5.6.2.9.

Teardown of Max-Tech 6,000 Btu/h Units

During the preliminary analysis public meeting, General Electric (GE) noted that the 6000 Btu/h, 12.0 EER R-410A product DOE had identified during its preliminary analysis had been mentioned in a Consumer Reports article indicating that a sample tested by Consumer Union did not meet the 12.0 EER rating[g]. GE recommend that DOE should consider another heavier 6,000 Btu/h, 12.0 EER R-410A unit as more representative for its analysis. A comparison of these two units is presented in Table 5.6.27.

[g] Consumer Reports. October 2008. Pg. 24 Vol. 73 No. 10. Copyright 2008 Consumers Union of U.S., Inc.

Table 5.6.27 R-410A Characteristics of Selected R-410A 6,000 Btu/h 12.0 EER Units

Brand	Haier	Friedrich
Model	ESA4066	XQ06M10
Product Dimensions (W×H×D)	13.63” × 19.75” × 17.75”	14” × 19.75” × 21.38”
Product Volume (*cubic feet*)	2.75	3.5
Weight (*lb*)	57	72

DOE considered the Consumer Reports article regarding this product, which was initially considered to represent 12.0 EER using R-410A. Matching this performance level with the energy model required making some input assumptions at the optimistic end of reasonable expectations, particularly for the condenser air flow rate. Given the information now available, DOE has revised its analysis, using the Friedrich 12.0 EER product to represent the highest-efficiency available for low-capacity room air conditioners with louvered sides. The revised analysis for product class 1 is based on calibration of the energy model to match the performance of the Friedrich product. DOE conducted a teardown of this product to verify its design details. The Friedrich unit has a capacity of 6,000 Btu/h, just above the capacity range for product class 1. Section 5.6.2.7 describes the adjustments to the product class 1 engineering analysis in greater detail.

DOE conducted energy modeling in order to determine what design options are required to achieve increased efficiency levels in room air conditioners using R-410A refrigerant. DOE upgraded the energy model developed as part of the previous room air conditioner energy conservation standard rulemaking for this purpose. The original room air conditioner energy model was an adaptation of the Oak Ridge National Laboratory Mark III Heat Pump program for modeling of room air conditioner cooling performance and is described in the 1997 TSD from the previous room air conditioner energy conservation standards rulemaking.[5] Additional modifications made during this rulemaking to upgrade the program for modern room air conditioners include the following.

- Revision of the heat exchanger performance models to reflect more recent correlations for airside heat transfer and pressure drop performance. This includes correlations for the slit fins typically used in today’s room air conditioners as well as for microchannel heat exchangers.

- Incorporation of property routines for other refrigerants, including R-410A.

- Development of a platform to allow running the program in the Microsoft Windows operating system.

The modified program is called MarkN. Because MarkN does not incorporate calculation of the performance of fans or blowers or the air pressure drops associated with components other than the heat exchangers, DOE conducted some modeling external to the program to properly account for system changes that impact air flows. DOE developed airside models that calculated the pressure losses within the room air conditioner of air passages, flow transitions, inlets, and outlets, and that incorporated heat exchanger pressure drop results from MarkN for both the evaporator and condenser. The airside models also included models of the fan or blower performance. With the airside model used in conjunction with MarkN, DOE was able to properly account for the impacts on air flow and fan motor shaft power associated with the analyzed design modifications.

Fan performance information was generally not available for the fans and blowers of the teardown models that were analyzed. DOE obtained performance data for similar fans and blowers from vendors. DOE adjusted the available fan and blower performance information using the fan laws from the 2008 ASHRAE Handbook, HVAC Systems and Equipment[6], to approximate the performance of the components in the products that were analyzed. Further information on the airside models is available in appendix 5D of this TSD.

DOE modeled the energy use for each of the teardown units and compared to the rated performance for these units to verify the validity of the upgraded energy model. DOE based inputs for the individual models on the design details determined during teardown of the products. DOE determined some of the system operating parameters using energy testing, as discussed in section 5.6.2.4. DOE set evaporator air flow equal to the rated evaporator air flow. DOE also made hot wire anemometer measurements of condenser air flow and fan motor power input measurements prior to teardown to provide model input for these parameters. DOE used data obtained from compressor vendors to represent compressor performance.

Comparisons of energy model results and rated performance of the teardown units are shown in Figure 5.6.30 below. The figure shows that both capacity and efficiency of the products were well predicted by the energy model. Of these products, only the 6,000 Btu/h 12.0 EER room air conditioner used R-410A refrigerant. All other units used HCFC-22 refrigerant.

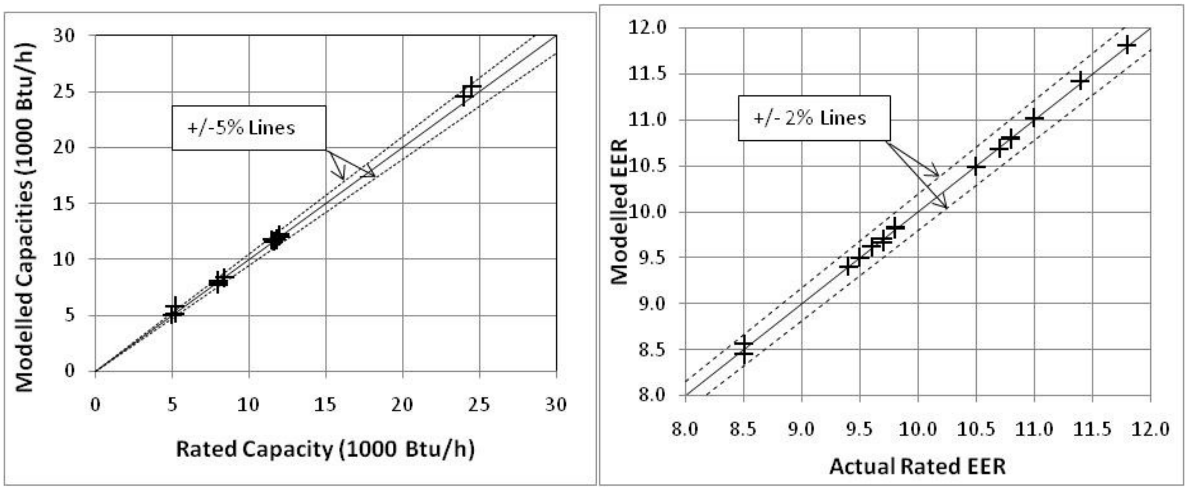


Figure 5.6.30 Comparison of Energy Modeling Results with Rated Air Conditioner Performance

After calibration of the energy models by comparison with rated performance data as discussed above, DOE used the energy model to determine the energy impact of conversion to R-410A refrigerant. DOE conducted this analysis for all of the teardown products using HCFC-22 refrigerant, assuming only drop-in of an R-410A compressor with no other adjustments for the new refrigerant. DOE obtained performance data of the R-410A compressors from compressor vendors. The R-410A drop-in analyses are compared with the baseline HCFC-22 analyses in Figure 5.6.31 below. The models generally show a reduction in EER in the range of 0 to 15 percent.

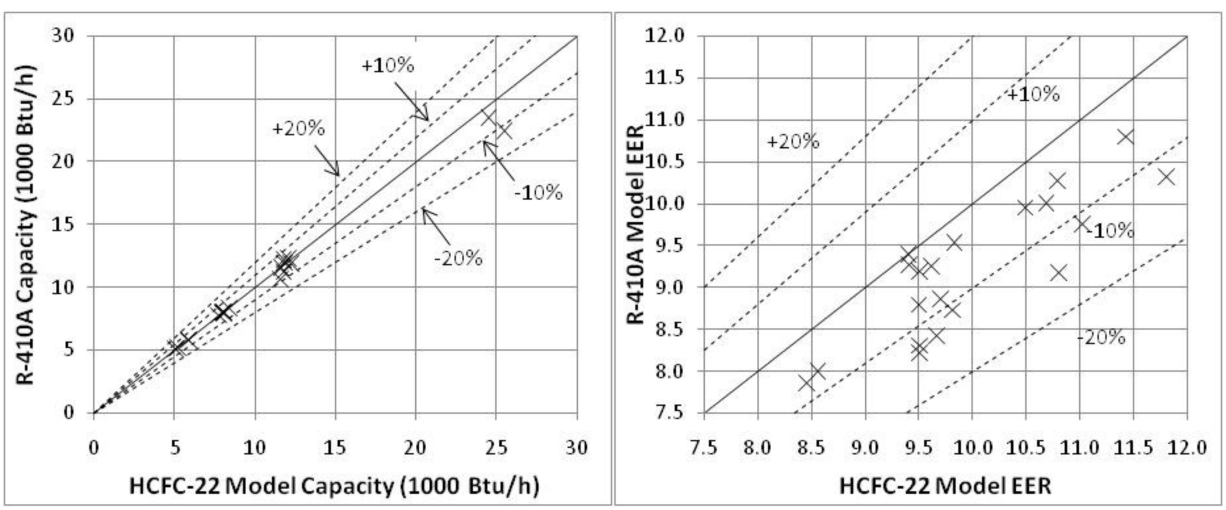
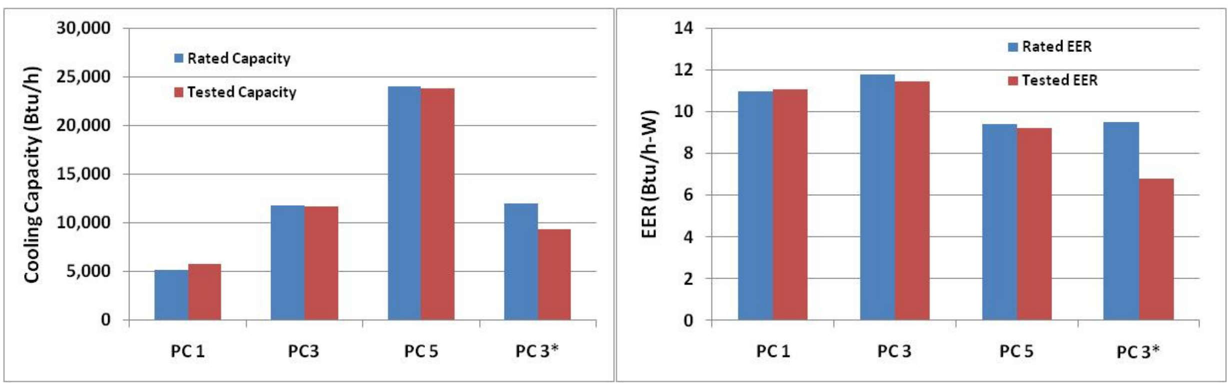


Figure 5.6.31 Energy Modeling Results for R-410A Drop-In

DOE conducted further energy analysis on designs modified by a series of design options in order to determine the energy efficiency improvement possible with each of these design options. For the final rule analysis, DOE performed this analysis for the seven baseline-efficiency products of product classes 1, 3, 5A, 5B, 8A, and 8B (DOE conducted analysis for product class 3 designs at 8,000 Btu/h and 12,000 Btu/h capacities). For all of these products, some improvement was required for the initial R-410A design in order to achieve EER levels meeting the current DOE energy standards. Additional improvements allowed examination of the incremental cost for efficiency improvements for R-410A room air conditioners. The results of the design option energy modeling analyses are discussed in section 5.6.2.9 below.

5.6.2.4 Energy Testing

During the preliminary analysis, DOE tested four units prior to teardown. DOE used the energy test results to verify performance of some of the higher-efficiency products. The comparison between rated and tested performance is shown in Figure 5.6.32 below. Test results for three of the units were close to the rated performance, while the results of the fourth were not.



*This product was advertised as being for through-the-wall installations (*i.e.* product class 8), but it had louvered sides.

Figure 5.6.32 Room Air Conditioner Energy Test Results

The energy testing conducted with additional instrumentation to allow recording of system temperatures. These measurements were used during energy modeling to help in calibration of the models with test results. Refrigerant temperatures were approximated by measurement of tube surface temperatures with thermocouples adhered to the tubes and externally insulated. The additional system measurements included:

- compressor discharge;
- condenser mid (a return bend roughly halfway between the condenser inlet and outlet, a location where the refrigerant is expected to be at saturated conditions);
- condenser outlet or subcooler outlet (for those units having a subcooler);
- evaporator inlet;
- evaporator outlet; and
- suction.

5.6.2.5 R-410A Conversion Costs

DOE determined, from manufacturer and vendor interviews, that there were intrinsic costs associated with the conversion from HFC-22 to R-410A. From these interviews, DOE determined that these cost increases include increased compressor costs, increased costs of the switch to polyolester (POE) oil, and increased refrigerant cost. DOE considered the impacts of each effect when calculating the cost of manufacturing for each room air conditioner.

Compressor Costs

From interviews with manufacturers and compressor vendors, DOE determined that rotary compressors designed for use with R-410A carried a higher price than compressors for HCFC-22 refrigerant. R-410A compressors require a thicker shell due to the higher pressures of R-410A, which is a key factor in the cost increase. Using the feedback from a variety of interviews, DOE used a compressor cost premium of 10 percent for R-410A compressors. This cost is for an R-410A compressor matching the capacity of the R-22 compressor it replaces.

Compressor Oil Switch

Due to miscibility issues, HFC refrigerants generally cannot be used in compressors lubricated with mineral oils, which have been used with HCFC-22. POE oils are being used in R-410A rotary compressors. DOE calculated the additional cost of oil based on the price difference between mineral oil and POE oils. The cost of the compressor oil switch was added separately, because the 10 percent compressor cost increase mentioned above is based on purchasing compressors without oil. The prices of mineral oil and POE oil were based on manufacturer and oil vendor inputs.

Refrigerant Switch

During interviews, manufacturers mentioned that R-410A costs more than HFC-22. DOE calculated the cost increase associated with the refrigerant based on the HCFC-22 charge of the teardown units. The costs of R-410A and HFC-22 refrigerants were based on inputs from manufacturers and retail sources of refrigerant.

DOE added the impacts of these three factors to calculate the total cost increase of the R-410 drop-in conversion. Table 5.6.28 below summarizes these costs for each analyzed product class. Note that the designs associated with these costs have lower EER than the baseline, and hence additional costs need to be added to represent the cost increase to maintain the baseline efficiency with an R-410A product. These additional costs were determined as the first step in the analysis of design options for improvement of efficiency, and they are discussed in section 5.6.2.5.

Table 5.6.28 Manufacturing Cost Increase for Drop-In Conversion to R-410A

Product Class	Total Costs Due to Refrigerant Switch
1 (5,000 Btu/h Capacity)	$3.29
3 (8,000 Btu/h Capacity)	$4.48
3 (12,000 Btu/h Capacity)	$6.27
5 (24,000 Btu/h Capacity)	$11.43
5B (28,000 Btu/h Capacity)	$ 11.43
8A (8,000 Btu/h Capacity)	$4.78
8B (12,000 Btu/h Capacity)	$6.73

5.6.2.6 Analysis Treatment of Design Options

To generate cost-efficiency curves, DOE examined both design options that influence EER and design options that influence standby or off mode energy use.

After the screening analysis and further elimination of design options discussed in section 5.2.2, DOE retained the design options listed in Table 5.6.29 below for improvement of efficiency.

Table 5.6.29 Retained Design Options for Room Air Conditioners

Increased Heat Transfer Surface Area
1. Increased frontal coil area
2. Increased depth of coil (add tube rows)
3. Increased fin density
4. Add subcooler to condenser coil
Increased Heat Transfer Coefficients
5. Microchannel heat exchangers
Component Improvements
6. Improved blower/fan motor efficiency
7. Improved compressor efficiency
Standby Power Improvements
8. Switching Power Supply

DOE determined the energy savings associated with each of these design options using energy modeling. DOE determined the cost impact per option using the manufacturing cost model established during the teardown analysis, obtaining additional input on component costs from vendor inquiries and manufacturer interviews. Details regarding the approach to savings and cost calculations for each of the design options are discussed below in greater detail.

Increased Frontal Coil Area

The energy and manufacturing cost models directly calculate the benefit and cost of increasing frontal coil area. DOE considered a number of variants on this design option, depending on the details of the baseline product under consideration.

Increases in Evaporator Width

In some of the baseline products, the evaporator width was limited unnecessarily by placement of the electronic control board next to the evaporator, preventing its expansion along the face of the unit. In many cases, there was sufficient space in alternative locations for the controls, such as above the evaporator adjacent to the vent. One variant of this design option that DOE examined was placing the controls above the evaporator, rather than beside it, thus freeing space to expand the evaporator. Some teardown units already incorporated the placement of the controls above the evaporator, especially the high-efficiency units. It did not appear to have an impact on utility.

Bending of the Condenser Coil

For some products, it may be possible to add a bend to the condenser coil in order to fit more coil frontal area within an existing chassis size. DOE examined this approach for the product class 1 unit and for both product class 8 units (products without louvered sides). DOE observed that some of the teardown units had bent condensers.

Increasing Physical Size of Product

DOE believes that larger coil frontal area (and larger package size to allow it) are key factors in maximizing EER in the max-tech products of product classes 1, 3, and 5 (products with louvered sides). The sizes and weights of these units are shown in Table 5.6.30 below. This table includes both the HCFC-22 units of the preliminary analysis, and the R-410A teardown units of the final rule analysis. Each analyzed product class group (1, 3, 5A, 5B) contains a baseline efficiency product that was analyzed, all but product class 5B contains an ENERGY-STAR rated unit, and analyzed product classes 1 and 3 contain max-tech units. Product class 2 was included because DOE tore down the max-tech 6,000 Btu/h 12 EER unit.

Table 5.6.30 Sizes and Weights of Product Class 1, 3, 5A, and 5B Teardown Units

Design Description	Refrigerant	Width *(in)*	Height *(in)*	Depth *(in)*	Weight *(lb)*
Product Class 1					
Baseline 1, 9.7 EER	HCFC-22	15.5	11.75	12	38.6
Baseline 2, 9.7 EER	HCFC-22	17.28	11.16	7.28	36.5
Baseline 3, 9.7 EER	R-410A	17.28	12.84	11.16	38
10.7 EER	HCFC-22	18.91	12.46	14.69	48.2
11 EER*	HCFC-22	18.5	12.5	14	44.4
Product Class 2, 6,000 Btu/h					
12.0 EER*	R-410A	19.75	14	20.25	72
Product Class 3, 8,000 Btu/h					
Baseline, 9.8 EER	HCFC-22	18.5	12.5	15.5	49.4
10.8 EER	HCFC-22	18.59	12.75	16.34	49.4
11.4 EER	HCFC-22	25.94	15.94	27.38	108
Product Class 3, 12,000 Btu/h					
Baseline, 9.8 EER	HCFC-22	19.58	13.75	19.63	73
10.8 EER	HCFC-22	23.63	15	22.25	78.6
11.8 EER*	HCFC-22	25.94	22.25	27.38	108.8
10.8 EER	R-410A	19	14.5	21.25	67
Product Class 5A, 24,000 Btu/h					
Baseline, 8.5 EER	HCFC-22	26	17.69	28.41	132
9.4 EER	HCFC-22	26.5	18.63	25	135.2
Product Class 5B, 28,500 Btu/h					
Baseline, 8.5 EER	R-410A	26.5	18.75	25.5	138

* Max-tech Unit

In the preliminary analysis, DOE considered increase of the physical size of the room air conditioner for product classes 1, 3, and 5. For product class 8, size increase was not considered—since much of the market for room air conditioners without louvered sides involves installation in existing wall sleeves, size increase for product classes 6 through 10 (including 8) (products without reverse cycle without louvered sides), 12, and 14 (products with reverse cycle without louvered sides) are not possible. The sizes of the product class 1, 3, and 5 that DOE used to represent baseline and higher efficiency products in DOE's preliminary analysis are compared in Figure 5.6.33 with a distribution of product sizes of baseline-efficiency room air conditioners from the database developed by DOE from the CEC, ENERGY STAR, and AHAM databases described in chapter 3. The comparisons show that the sizes of the analyzed products could be increased without exceeding the size of other current baseline-efficiency products. DOE drew a similar conclusion when comparing weights of the analyzed product designs with the weights of other baseline products in the database. With an overall unit size increase, the frontal areas of both the evaporator and condenser can be increased. The sizes DOE used in the analysis are summarized in Table 5.6.33 below.

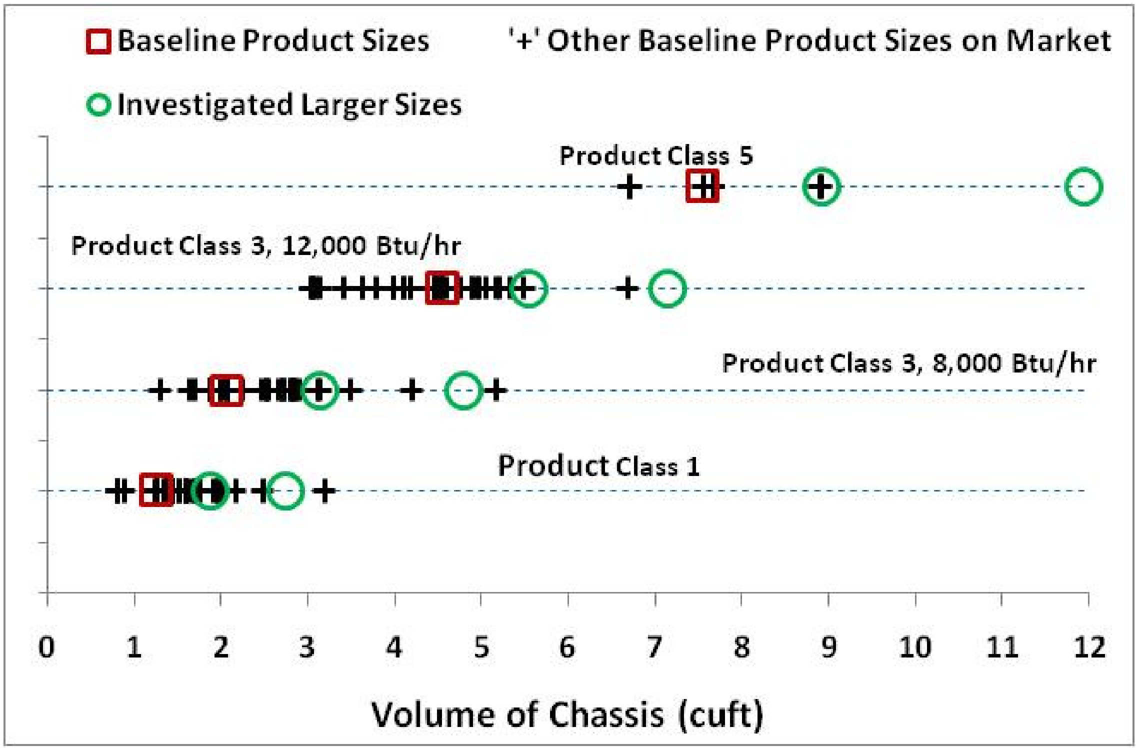


Figure 5.6.33 Size Distributions of Baseline-Efficiency Room Air Conditioners – HCFC Products on the Market

During the final rule analysis, DOE again compared the preliminary analysis product sizes against products on the market, in this case R-410A units. The results are shown in Figure 5.6.34 below. This assessment shows that the distribution of sizes of commercially available HCFC-22 room air conditioners examined during the preliminary analysis did not differ significantly from the size distribution of currently available R-410A products.

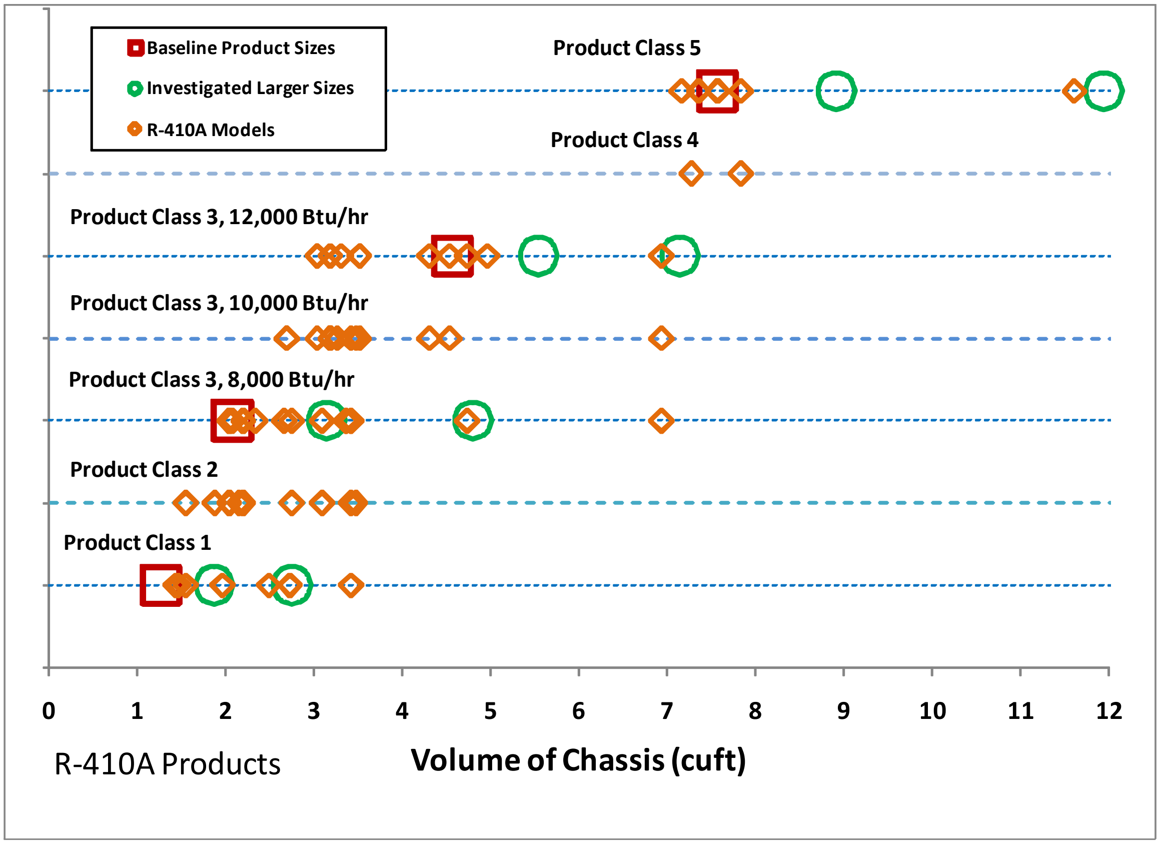


Figure 5.6.34 Size Distributions of Baseline-Efficiency Room Air Conditioners – R-410A Products on the Market

DOE observed that the physical sizes chosen for the analyzed baseline products matched the sizes of the smallest available baseline products well, except for the product class 3 unit of 12,000 Btu/h capacity. To adjust, DOE revised its analysis for this product class and capacity, using the 12,000 Btu/h R-410A baseline teardown product as a basis for the new analysis. The size data for this product is presented in Table 5.6.31 below.

Table 5.6.31 Adjusted Baseline Size for Product Class 3 – 12,000 Btu/h Analysis

	Width (*in*)	Height (*in*)	Depth (*in*)	Volume (*cf*)
Baseline PC3-12k Unit	19	14.5	21.25	3.39

Because of the split of product class 5, DOE also reviewed chassis sizes for the new product classes 5A (capacity between 20,000 and 27,999 Btu/h) and 5B (capacity larger than 27,999 Btu/h). DOE selected products of capacities 24,000 Btu/h 28,000 Btu/h room air conditioner to represent the analysis for these new product classes. DOE observed that no products on the market within the capacity range of the new product class 5A had chassis size near the roughly 12 cubic feet volume used as the maximum size in the DOE analysis. However, for products on the market with capacities within the range of the new product class 5B, this size level is required to achieve better than baseline efficiency, as shown in Table 5.6.32 below. Product 1 of this list is not within the product class 5B capacity range, but nevertheless, the largest chassis size is required for this product to achieve ENERGY STAR efficiency level.

Table 5.6.32 Product Class 5B – R-410A Product Sizes

	Capacity (*Btu/h*)	EER	Product volume (*cf*)
Product 1	27,800	9.7	11.6
Product 2	28,500	8.5	7.6
Product 3	36,000	8.5	11.6

DOE adopted the following approach for size selection of these product classes:

- For Product Class 5A, DOE did not consider growth to a volume near 12 cubic feet.
- For Product Class 5B, DOE did allow growth to this size.

The examined size increases in the final rule analysis are summarized in Table 5.6.33 below.

Table 5.6.33 Size Increases Examined During Room Air Conditioner Design Option Analysis

Design Description	**Width** *(inches (in))*	**Height** *(in)*	**Depth** *(in)*	**Weight** *(lb)*
Product Class 1				
Baseline	15.5	11.75	12	38.6
First Size Increase	18.5	12.5	14	42.7
Second Size Increase	19.69	13.63	17.72	46.8
Product Class 3, 8,000 Btu/h				
Baseline	18.5	12.5	15.5	49.4
First Size Increase	19.3	15.63	18	55.7
Second Size Increase	22.5	15.63	23.6	63.6
Product Class 3, 12,000 Btu/h				
Baseline	19	14.5	21.25	76.5
First Size Increase	23.5	15.63	23.6	81.2
Second Size Increase	26	15.63	28.4	87.6
Product Class 5A				
Baseline	26	17.69	28.41	129.2
First Size Increase	27.75	17.94	30.94	136.4
Second Size Increase	-	-	-	-
Product Class 5B				
Baseline	26	17.69	28.41	129.2
First Size Increase	27.75	17.94	30.94	136.4
Second Size Increase	29.81	22.38	30.94	156.5

DOE is aware that product size has a significant impact on efficiency, and requested comment during the preliminary analysis phase on acceptable maximum product sizes for louvered room air conditioners.

DOE received the following comments from stakeholders, on maximum product sizes:

- AHAM noted that smaller products (especially those in product classes 1 (room air conditioners without reverse cycle, with louvered sides, and capacities less than 6,000 Btu/h) and 2 (room air conditioners without reverse cycle, with louvered sides, and capacities 6,000 to 7,999 Btu/h)) would be most negatively impacted by an increase in weight. AHAM indicated that the Occupational Safety and Health Administration (OSHA) recommends an additional person for lifting and installing products weighing over 50 lbs. AHAM stated that the 50 lbs. limit is expected to influence consumer acceptance of these products.

- NPCC recommended that DOE compare the maximum unit dimensions in each preliminary analysis to the dimensions of the highest efficiency model available on the market. NPCC recommended that, if these two product dimensions are similar, that DOE assume that all units can be equally as large. NPCC also recommended that, if the market unit is smaller than the unit proposed by DOE, that DOE determine whether a redesign of the proposed unit would eliminate the size constraint.

DOE implemented the following changes in its analysis based on the comments submitted by stakeholders:

- DOE limited the maximum weight for product class 1 unit to 50 lbs., based on the Occupational Safety and Health Administration (OSHA) and National Institute of Occupational Safety and Health (NIOSH) suggested weight limits.

- DOE adopted maximum product heights and widths consistent with max-tech products.

Further details of each analysis are detailed in the sections below.

50 lbs Weight Limit

NIOSH lists among its hazard evaluation checklist the handling of loads exceeding 50 lbs as a risk factor used to identify potential problems.[h] OSHA, in its *Ergonomics eTool: Solutions for Electrical Contractors*, states that lifting loads heavier than 50 lbs will increase the risk of injury, and recommends use of more than one person to lift weights greater than 50 lbs.[i] These

[h] http://www.cdc.gov/niosh/docs/2007-131/

[i] http://www.osha.gov/SLTC/etools/electricalcontractors/materials/heavy.html

guidelines calling for additional personnel for product lifting represent distinct changes in consumer utility for products that currently weigh less than 50 lbs.

DOE notes that all but the smallest room air conditioners weigh more than 50 lbs, a trend illustrated by the weights of the teardowns in Table 5.6.34 above. A summary of the baseline weights for each analyzed product class is included in Table 5.6.34 below.

Table 5.6.34 Baseline Product Weights of the Units for the Analyzed Product Classes

Product Class	Capacity (*Btu/h*)	Baseline CEER Analyzed Weight (*lb.*)*
1	5,200	40.0
3	8,000	50.1
3	12,000	68.03
5A	24,000	132.5
5B	28,000	140.3
8A	8,000	61.7
8B	12,000	67.4

*Product weights for the analyzed design options are calculated using the manufacturing cost model

DOE limited the total weight of the product class 1 baseline unit with integrated design options to 50 lbs, to avoid exceeding OSHA and NIOSH guidelines for single-person lifting. DOE did not consider limiting the weight of the other analyzed product classes, since they already exceeded this limit.

Maximum Chassis Sizes on the Market

DOE based the maximum chassis width and height of each analyzed product class on the dimensions of the largest R-410A room air conditioners in each product class on the market. DOE's maximum chassis sizes were based on HCFC-22 and R-410A products. Table 5.6.35 below compares DOE's max-tech design dimensions with the largest available products, for each product class. For each of these product classes, the physically largest product on the market also has the maximum available efficiency.

Table 5.6.35 Comparison of DOE Analysis Chassis Size and Market Chassis Size

Product Class	Large Chassis Size in DOE Analysis (*w x h x d*)	R-410A Max-Tech Unit on the Market (*w x h x d*)
1	19.69 × 13.63 × 17.72	19.75 × 14.0 × 21.38
3 (8000 Btu/h)	22.5 × 15.63 × 23.6	25.94 × 15.94 × 29
3 (12,000 Btu/h)	26 × 15.63 × 23.6	25.94 × 15.94 × 29
5A	27.75 × 17.84 × 30.94	26 × 17.5 × 29.75

5B	29.81 × 22.38 × 30.94	28 × 20.19 × 35.5

DOE chose maximum product heights and widths consistent with the largest products on the market. These dimensions set the face areas available for heat exchangers. However, DOE observed that the depths of the max-tech available products are significantly larger than expected—these depths are out of proportion when considering the relationship between depth and width or height of other products. DOE's analysis indicated that depths consistent with the proportions observed in most other products are sufficient to provide max-tech performance. Hence, DOE analysis selected max-tech design depths less than those observed in the max-tech available products. DOE used this approach for product classes 3 (room air conditioners without reverse cycle, with louvered sides, and capacities 8,000 to 13,999 Btu/h), 5A (room air conditioners without reverse cycle, with louvered sides, and capacities 20,000 to 27,999 Btu/h), and 5B (room air conditioners without reverse cycle, with louvered sides, and capacities 28,000 Btu/h or more). This limitation did not apply to product class 1 (room air conditioners without reverse cycle, with louvered sides, and capacities 5,999 Btu/h or less), for which growth was limited by consideration of the 50 lbs maximum weight.

Added Shipping Costs for Chassis Size Increases

The room air conditioner reverse-engineering included documentation of the packaging used for shipping the product, and additional accessories (remote control, window installation kit, bracing). As the chassis expands, the surrounding packaging also increases in size. The costs associated with all of these increases are part of the calculated incremental cost for the efficiency improvements. Most of the shipping material packaging cost is the cost of the surrounding cardboard box.

Most room air conditioners are shipped from overseas, and manufacturers mentioned during interviews the added shipping costs associated with larger chassis sizes. DOE calculated the cost of shipping to a U.S. distribution facility based on the size of the room air conditioner being shipped; the cost is determined based on the volume of the unit. This cost was reported separately from the manufacturing production cost (MPC). DOE expects that the manufacturer markup does not apply to this cost because manufacturers indicated that many room air conditioners are shipped by retailers. Hence, in determining the incremental cost associated with efficiency improvements, the shipping cost increase would be added to the incremental manufacturer sales price (MSP).

The shipping cost was determined as follows. DOE estimated the total shipping costs for a standard shipping container, based on interviews with manufacturers and quotes from shipping companies. The costs include shipping from the factory to a U.S. distribution facility. The number of units per container was calculated by volume, and divided by the cost of shipping to determine the cost of shipping per unit. For design options that involved increase in chassis size, DOE calculated incremental shipping costs to account for the larger size. The cost estimate including distribution within the U.S. is considered to be conservative, because part of this cost may already be included in the typical retailer markup, which has not be reduced to account for separate consideration of part of the shipping cost.

Increased Depth of Coil

DOE examined increasing the depth of the evaporator and/or condenser. Energy impacts were determined using the energy model, and cost impacts were determined using the manufacturing cost model. DOE determined that increasing coil depth beyond two tube rows generally is not effective in increasing EER. Most room air conditioners use heat exchangers with two tube rows, although some have more rows. However, the DOE analysis shows that the airflow reduction or fan power increase associated with increases in coil depth often negates the benefits of the additional heat exchanger surface area.

Increased Fin Density

DOE examined increases in fin density for all of the products. Energy impacts were determined using the energy model, and cost impacts were determined using the manufacturing cost model. DOE considered a maximum fin density of 22 fins per inch (FPI). In some cases, increasing fin density improves performance. For many cases, the airflow resistance of the additional fins leads to reduced airflow and/or higher fan power which negates the benefit of the increased heat exchanger surface area. Many units already use high fin densities, so increased fin density often results in minimal or no gains. Lastly, high fin densities have been mentioned by manufacturers as having potential detrimental effects on long-term unit efficiency, since cleaning coils with high fin densities is very difficult.

Add Subcooler to Condenser Coil

DOE examined the use of subcoolers for all room air conditioners. Energy impacts were determined using the energy model, and cost impacts were determined using the manufacturing cost model. DOE used a subcooler exit temperature of 95 °F, based on information provided by manufacturers.[5] In all cases, the subcooler made a small improvement in efficiency, but was highly cost-effective. Inspection of the teardown units revealed that many high-efficiency units placed the subcooler within the condenser plenum. DOE determined that the addition of a subcooler to a unit would not require any chassis size increase.

In selecting the appropriate subcooler length for each product class, DOE considered the subcoolers from the teardown units. In each product class, the highest-efficiency unit contains a subcooler. The length of this subcooler provided the basis for the length of the subcooler added for a product of the same capacity. In some cases DOE determined that the chosen subcooler length was excessive for the baseline chassis size. DOE reduced the selected length and performance of the subcooler in these cases. DOE maintained a fixed subcooler length with subsequent chassis size increases.

Microchannel Heat Exchangers

DOE analyzed microchannel condensers as a design option during the preliminary analysis. Performance modeling of microchannel heat exchangers is included in the upgraded room air conditioner energy model. Information provided from vendors indicates that, in most cases, this technology is not suitable for evaporators because (1) the geometry is not suitable for quick drainage of condensate from the heat exchanger surface; and (2) uniform refrigerant distribution into the many parallel tubes is not assured. Therefore, microchannel heat exchangers were considered only for condensers. Use of this technology resulted in a small efficiency improvement in most of the analysis. DOE determined microchannel condenser incremental manufacturing costs based on prices provided by a vendor for two representative sizes, one suitable for a 5,000 Btu/h room air conditioner and the other suitable for a 24,000 Btu/h unit, assuming high-volume production. In addition to purchase price, the costs also incorporate the cost of brazing two pieces of copper tubing to the all-aluminum microchannel heat exchanger, since many purchasers do not have the capability of brazing copper to aluminum and such fabrication would represent an additional step in the manufacturing process.

The sizes and cost estimates of the microchannel heat exchanger designs considered in the analysis are presented in Table 5.6.36 below. For the most part, the costs are an order of magnitude greater than that of any of the other design options considered. The table also shows the modeled efficiency improvements calculated for this design option. The improvements were low or zero.

Table 5.6.36 Microchannel Condenser Costs - Preliminary Analysis

Room Air Conditioner Capacity *(Btu/h)*	**Condenser Core Dimensions** *(Height x Length, in)*	**Condenser Core Depth** *(in)*	**Cost**	**EER Increase Benefit from Baseline**
5,000	11.25 × 15.25	1	$75	0.3
8,000	12.75 × 17.25	1	$85	-
12,000	16 × 21.63	1	$110	-
24,000	16.37 × 22	1	$115	0.1

Improved Fan/Blower Motor Efficiency

Room air conditioners almost exclusively use double-shafted PSC motors to power the condenser fan and evaporator blower. DOE considered improved motor efficiency as a design option, in the form of high efficiency PSC motors and brushless DC (BLDC) motors. DOE considered the cost of the motors as a function of motor type, shaft power, and efficiency, although only one efficiency level was considered for BLDC motors. DOE obtained cost data from vendors, both for room air conditioner motors and for single-shaft motors with similar power output and speed used in other applications. DOE selected a typical range of motor shaft power rating for each product class it analyzed, based on the motors used in the teardown units, and sought information about similar motors at higher efficiencies. The selected shaft power levels are shown in Table 5.6.37 below.

Table 5.6.37 Motor Power Rating by Product Capacity

Room air conditioner capacity *(Btu/h)*	**Fan Motor Shaft Power Rating** *(W)*
<6,000	25-35
8,000 to 13,999	60-75
>20,000	150-200

DOE selected a motor efficiency of 50 percent for the PSC motors of baseline room air conditioner. This was consistent with the motors in the teardown units, as well as the information obtained during manufacturer interviews. DOE selected a peak PSC motor efficiency of 70 percent for the analysis.

BLDC motors are a more efficient alternative to PSC motors, and BLDC motors are used in similar applications, such as packaged terminal air conditioners (PTACs). DOE obtained information about BLDC motors from motor vendors, motor catalogs, and discussions with room air conditioner manufacturers. Reported BLDC motor efficiencies were in the range 75 percent to 90 percent. DOE selected an efficiency level of 80 percent for the analysis.

DOE examined PSC motor prices from a wide variety of motor vendors. DOE conducted analysis on this motor data to establish a robust correlation for motor cost based on motor characteristics including efficiency, shaft power, weight, current, and voltage. The assessment included single-shafted and double-shafted PSC motors intended for HVAC applications. DOE found the strongest correlation between motor price and weight, and used this relationship as the basis for calculating the incremental costs for PSC motor efficiency improvements. Figure 5.6.35 below shows the calculated cost of increasing the efficiency of a PSC motor from 50 percent to 70 percent as a function of motor shaft power output, for shaft outputs from 20 W to 100 W. This range included motors for product classes 1, 3 and 8. For the product class 5 baseline motor, with a rated shaft output of 200 W, DOE extrapolated the cost of the motor from the smaller motor sizes. Further information on the assessment of PSC motor costs is available in appendix 5D of this TSD.

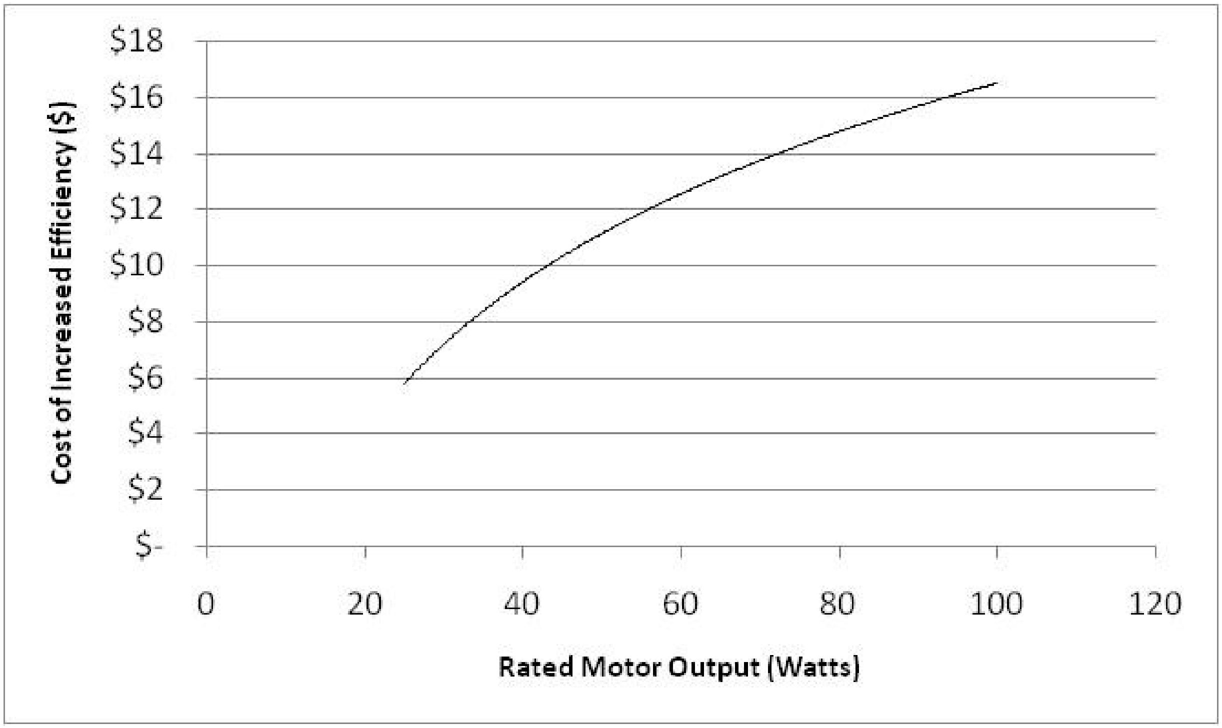


Figure 5.6.35 Cost Differential for Increasing PSC Motor Efficiency from 50% to 70%

DOE also compiled pricing and size information on BLDC motors from motor vendors and catalogs. DOE found prices for BLDC motors with the same motor shaft output as the PSC motors found in the reverse engineering units, and calculated the cost of replacing the baseline PSC motors with the BLDC motors. Figure 5.6.36 below shows the calculated cost of replacing a baseline PSC motor with a BLDC motor.

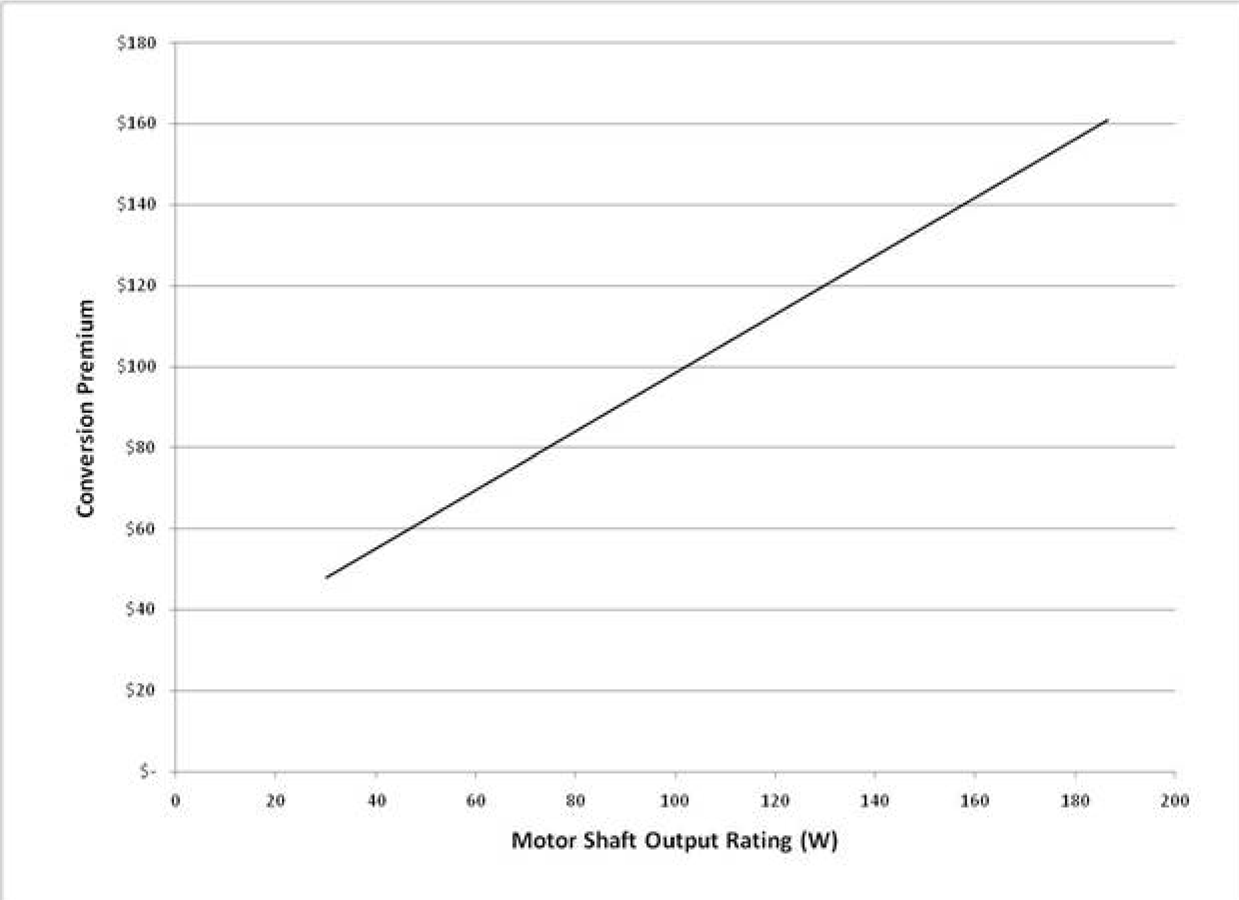


Figure 5.6.36. Cost Differential for Replacing a Baseline PSC Motor with a BLDC Motor.

Some manufacturers raised concerns regarding the use of BLDC motors, stating that they are physically much larger than PSC motors and thus may not fit into the small space allowed in a room air conditioner. Table 5.6.38 shows the characteristics of a typical 70 W PSC motor, and the characteristics of a typical 70 W BLDC motor observed by DOE. These ranges are derived from motor vendor catalog data. The data show that the BLDC motor has greater weight and length than the comparable double-shafted PSC motor. However, DOE did not conclude that the size increase of these motors would prevent their use in room air conditioners.

Table 5.6.38 Comparison of a typical range of sizes for a 70W PSC Double-Shafted Motor and a 70W BLDC Motor

Typical Characteristics	Double-Shafted PSC	BLDC
Typical Efficiency	50%	80%
Weight	8–10 lbs.	12 lbs.
Outer Diameter	3.75–5.0 in	1.73–2.63 in
Motor Length (w/o Shaft)	3.0–4.25 in	4.5–6.39 in

Improved compressor efficiency

DOE conducted the engineering analysis based on use of R-410A refrigerant, since this is the refrigerant currently used by all new room air conditioners

During the preliminary analysis, DOE sought information on the performance of R-410A rotary compressors of varying efficiency levels for all of the products under analysis. In many cases, the range of efficiency for which vendors were willing to provide performance data was limited. Conducting the analysis generally required knowledge not just of design point capacity and EER—DOE requested performance data for a representative range of evaporating and condensing conditions, as required for input into the energy model. In some cases, the trends of compressor performance as a function of operating conditions were extrapolated from the trends exhibited by a compressor of the same refrigerant of nearly the same capacity. For product class 5, DOE also analyzed scroll compressors as a design option. The EER and capacity of the compressors for which DOE obtained performance data are illustrated in Figure 5.6.37 below. As can be seen, there were data for many more HCFC-22 compressors than for R-410A rotary compressors. The EER ratings of the R-410A compressors were not only generally lower than those of HCFC-22 rotary compressors of similar capacity, but exhibited a much more limited EER range (*i.e.*, HCFC-22 compressor EER levels ranged from 9.0 to 11.2 near 5,000 Btu/h nominal capacity, whereas the R-410A compressor EER range was roughly 9.0 to 10.0). The chart shows that reduction in the EER when switching to R-410A compressors was greater for lower capacities than for higher capacities. The chart also shows that the use of scroll compressors does not improve efficiency for most of the capacity range of interest for room air conditioners.

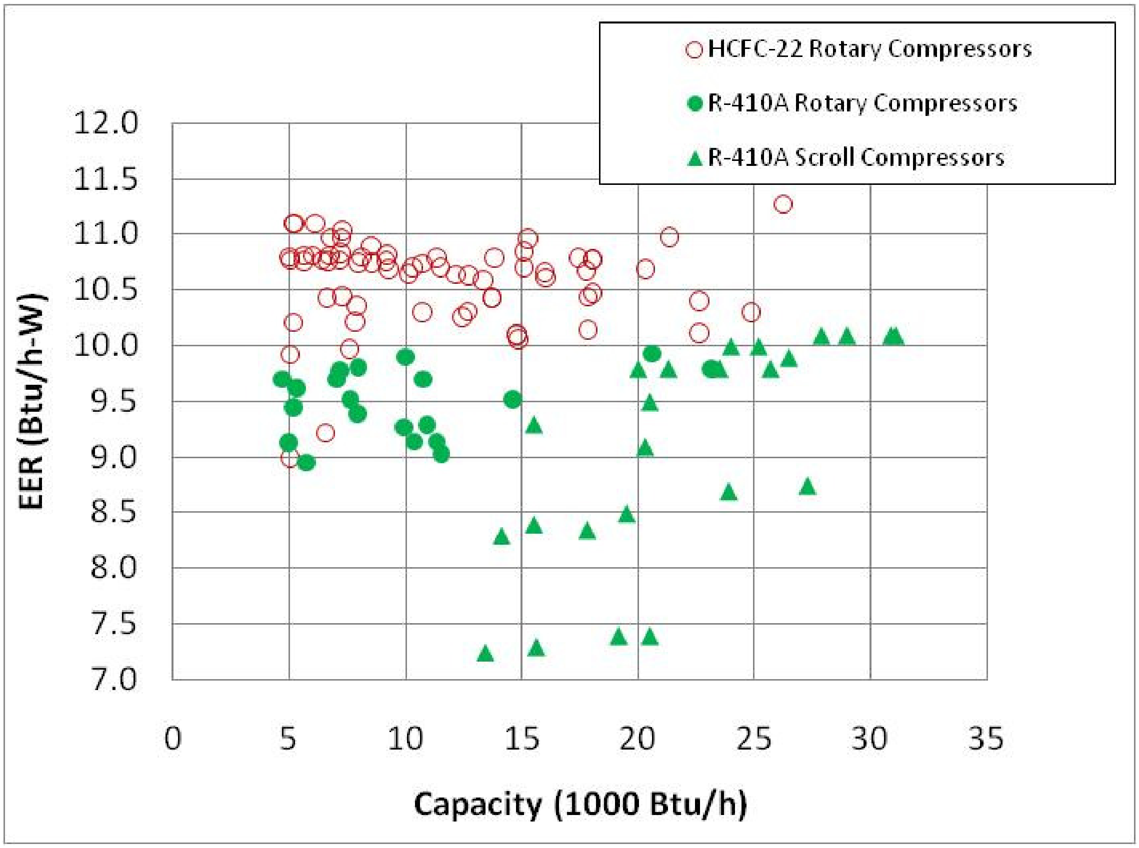


Figure 5.6.37 Compressor Performance Specifications – Preliminary Analysis

During the final rule analysis, DOE again reviewed R-410A compressors, checking vendor websites and speaking with vendor representatives about performance of commercially available, developmental, and future compressors. Website data for R-410A compressors are illustrated in Figure 5.6.38 below.

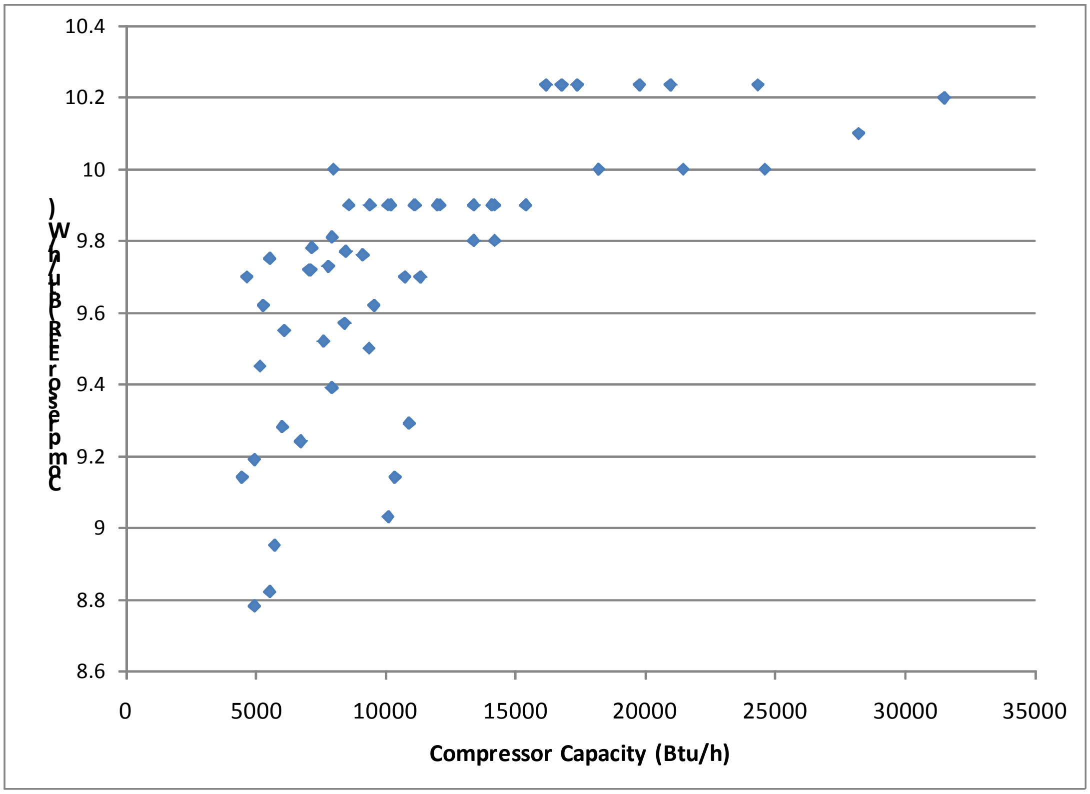


Figure 5.6.38 R-410A Compressor Performance Characteristics – Final Rule Analysis

Based on DOE's research and manufacturer interviews (see above), DOE decided to consider maximum compressor-rating EER of 10.0 for lower-capacity compressors, and EER of 10.3 for higher-capacity compressors. The data clearly showed availability of R-410A compressors spanning a range of EER, so DOE added "high efficiency compressor" as a design option in the analysis. The maximum EERs considered for the analyzed product classes are listed in Table 5.6.39 below.

Table 5.6.39 Maximum Compressor EER Levels

Product Class	Maximum Compressor EER in Final Rule Analysis
1,3,8A,8B	10.0
5A,5B	10.3

DOE used detailed performance maps data (capacity and EER as a function of suction and discharge pressures) to model many of the compressors. However, in some cases, where such detailed data was not available from vendors, DOE used maps of compressors with nearly the same capacity or EER, adjusted for the modeled compressor's design-point performance.

The relationship between R-410A compressor cost and baseline-efficiency room air conditioner capacity that DOE used in the analysis is illustrated in Figure 5.6.39 below. This relationship was developed based on information collected during past rulemakings, discussions with manufacturers, and cost information provided by compressor vendors. It includes the 10 percent cost premium for R-410A compressors discussed in section 5.6.2.5. The figure is based on room air conditioner capacity, and not compressor rating point capacity.

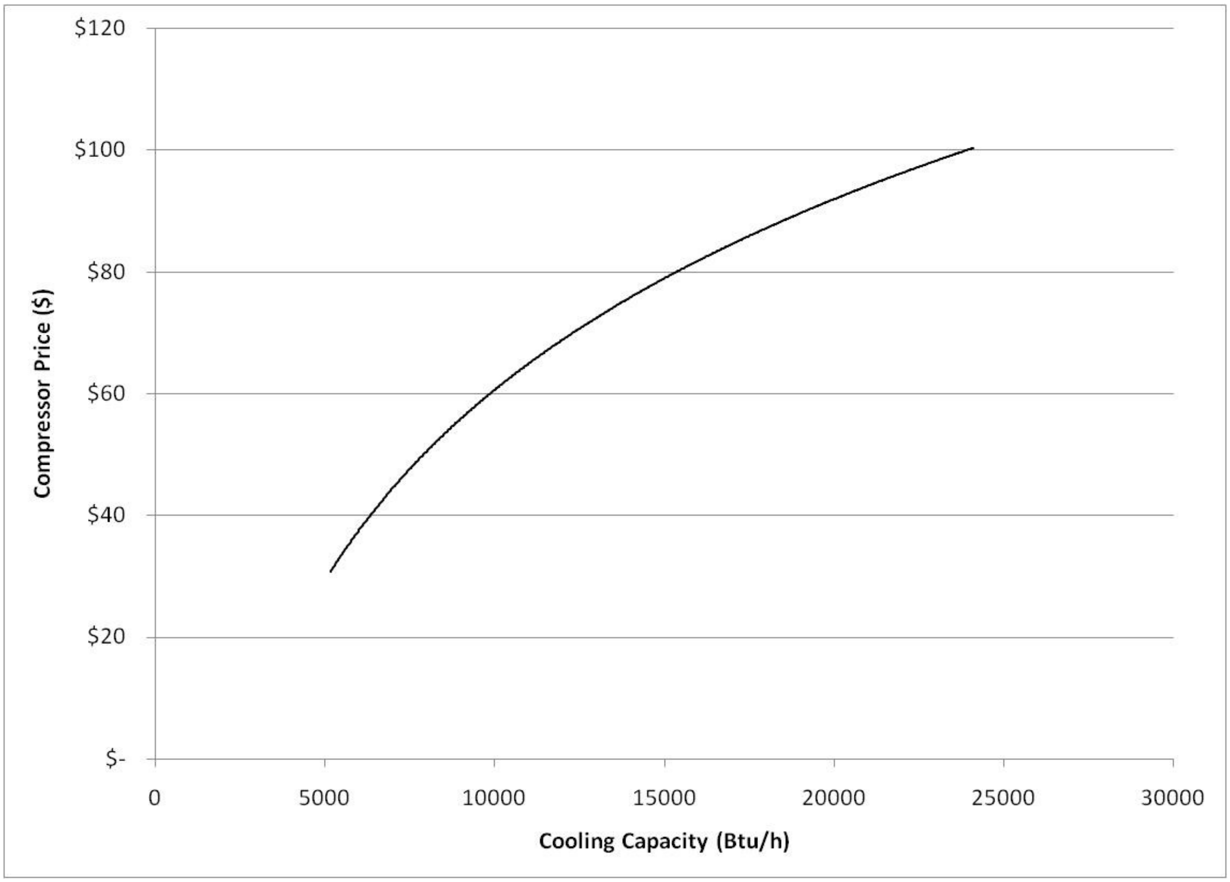


Figure 5.6.39 R-410A Compressor Cost

Scroll Compressors

During the preliminary analysis phase, DOE considered scroll compressors as a design option for product class 5. However, scroll compressors do not provide additional efficiency above the 10.3 maximum EER considered in the analysis for rotary compressors. They are also heavier and more costly. Thus, for the final rule analysis, DOE did not consider scroll compressors as a cost-effective design option in room air conditioners.

Standby Mode and Off Mode

DOE identified and analyzed only one option for reducing standby and off mode energy use–changing from a transformer-based power supply to a switching power supply. DOE conducted energy measurements of electronic boards, and determined that the total standby mode power for a typical baseline control board is roughly 1.4 W, and that the transformer consumes about 75 percent of this power. DOE concluded that the main source of power consumption in standby mode for a room air conditioner is the power supply, as shown in Table 5.6.40. The measurements reported in this table were made by disconnecting more loads for the successive measurements, thus showing that nearly 1 W of the 1.32 W associated with the standby mode for this unit represents the transformer loss (the transformer loss could actually be a larger portion of the 1.32 W, since disconnecting the loads as indicated reduces power supplied by the transformer, and thus could also be reducing the its loss in the successive measurements).

Table 5.6.40 Standby Energy Consumption by Component

Example Stand-by Energy Breakdown for Electronic Board	
Components Energized	**Power Consumption (*W*)**
User Interface Board + Control Board	1.32
Control Board	1.28
Transformer	0.96

Two of the teardown units with electronic control boards used switch-mode power supplies, an alternate technology to the traditional linear regulated power supply. The switching power supply replaces the traditional power supply with a more complex circuit board and a much smaller transformer. The two switching power supply units consumed roughly 0.7 W.

DOE obtained conversion cost information for switching power supplies for cell phone technology, based on similar production volumes and power levels as for room air conditioner control board power supplies. During the preliminary analysis, the increase in direct material costs for converting to a switch-mode power supply based on this information was estimated at approximately $1.00. DOE updated its cost-model, reviewed additional teardown information for these units and reviewed the incremental costs of this technology for similar household appliances, and adjusted its estimate to $0.75 for the final analysis.

5.6.2.7 Summary of Analysis Adjustments

During the final rule analysis, DOE revised its preliminary analysis based on new information collected in 2010, based on investigation of the room air conditioner market after the R-410A conversion. Key changes in the analysis are listed in Table 5.6.31 below.

Table 5.6.41 Summary of Key Adjustments to the Engineering Analysis during Final Rule Analysis

Topic	Preliminary Analysis	Changes made in the final rule analysis
Product Classes	Full analysis of existing product classes 1,3,5,8	Full analysis of product classes 1,3, 5A, 5B, 8A, 8B
Compressor Efficiency	Used available R-410A compressor data, which was limited	Maximum compressor nominal EER of 10.0 for product classes 1, 3, 8A, and 8B; and 10.3 for product classes 5A and 5B
Size Limits for Products with Louvered Sides	Based on the range of sizes of available products	50 lbs weight limit for product class 1
		Maximum height and width consistent with available max-tech products, maximum depth consistent with typical depth/height/width ratios.
Chassis Design	Based on baseline units analyzed	Chassis thicknesses were adjusted based on the calculated weight of each unit, in accordance with teardown analysis. Chassis design was also adjusted from simple basepan design to welded box design as needed.
Scroll Compressors	Considered for product class 5	Not considered.
Cost-Model Material and Labor Costs	Costs updated as of 2008	Costs updated as of 2010

As part of the analysis of product class 1 for this final rule, DOE made adjustments to the product design of the 6,000 Btu/h 12.0 EER unit used as the max-tech model for the product class 1 cost-efficiency curve. These adjustments reflected an adjustment in the capacity of the unit from 6,000 Btu/h to 5,000 Btu/h. DOE adjusted the cost-efficiency curve for product class 1 based on this analysis, and then applied the 50 lbs product limit suggested by stakeholders. DOE noted that the 12.0 EER product that was reverse-engineered did not incorporate all of DOE's analyzed design options, and so the calibration did not only apply to the max-tech of the cost-efficiency curve, but to some intermediate steps as well. The product 1 max-tech level of 11.8 is a product of both this calibration and the 50 lbs product limit.

5.6.2.8 Active Mode Analysis

The cost-efficiency curves based on the active mode metric (EER) are shown in Figure 5.6.40 through Figure 5.6.46 below. The cost axis of these charts represents MSP plus shipping cost. Note that AHAM did not receive a sufficient number of responses regarding costs from manufactures to allow aggregation of this data for submission to DOE. Hence, there is no AHAM data to allow comparisons. The figures do, however, compare preliminary-analysis and final rule analysis results. Each separate point in the plots represents a different design configuration, rather than a specific efficiency level.

Most of the final rule analysis curves are shifted to a higher cost as compared with the preliminary analysis results. The key exception is the 12,000 Btu/h product class 3 analysis, for which DOE decreased the baseline chassis size, using information from the teardown of a 12,000 Btu/h R-410 product.

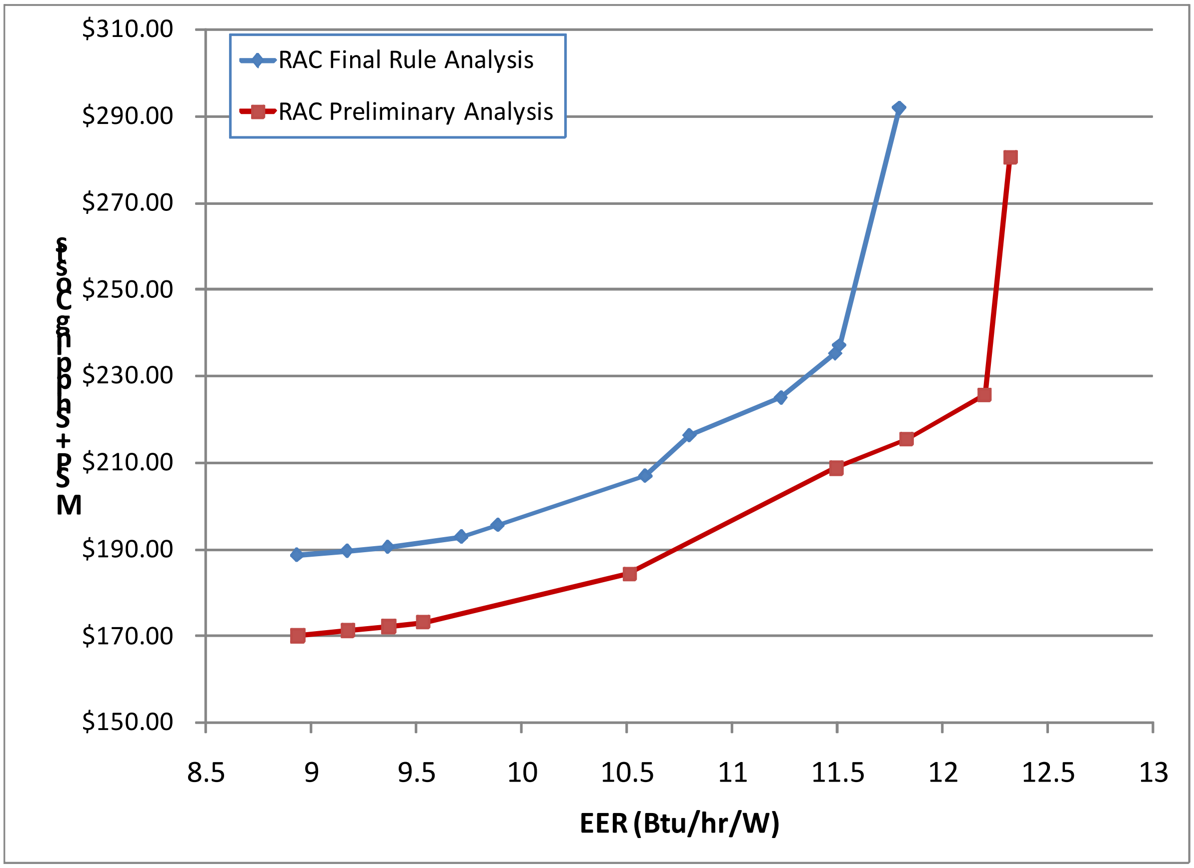


Figure 5.6.40 Product Class 1 Cost-Efficiency Curve

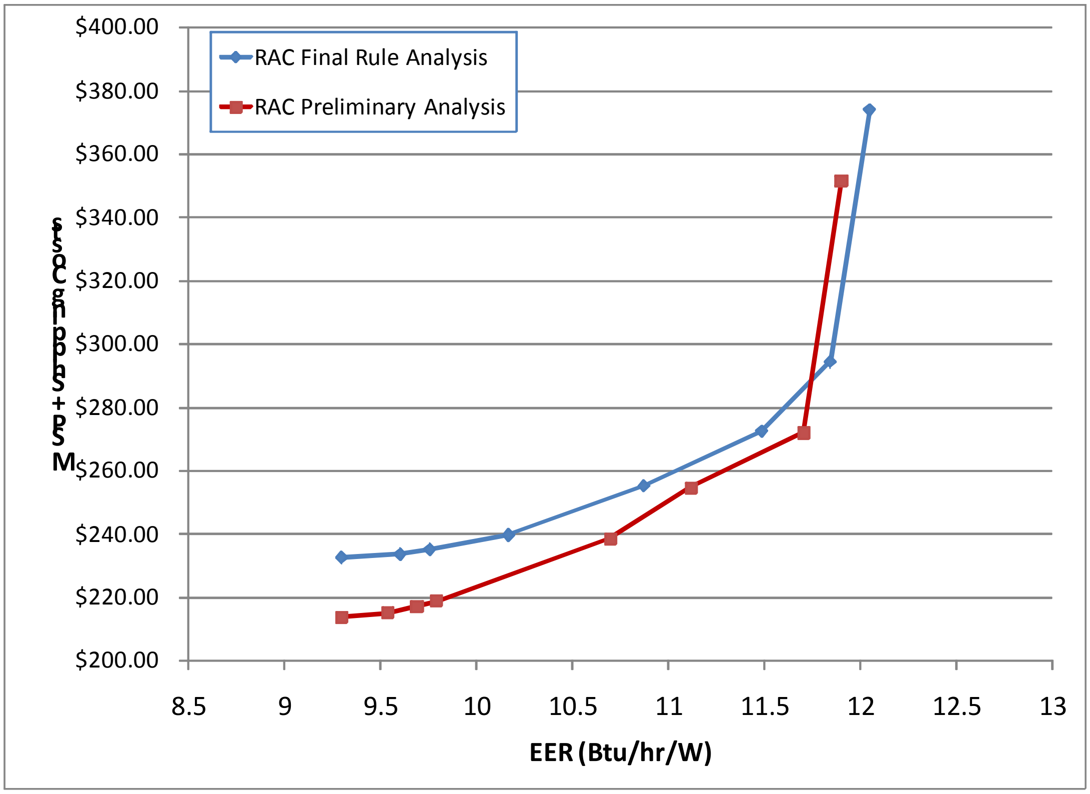


Figure 5.6.41 Product Class 3 - 8,000 Btu/h Capacity Cost-Efficiency Curve

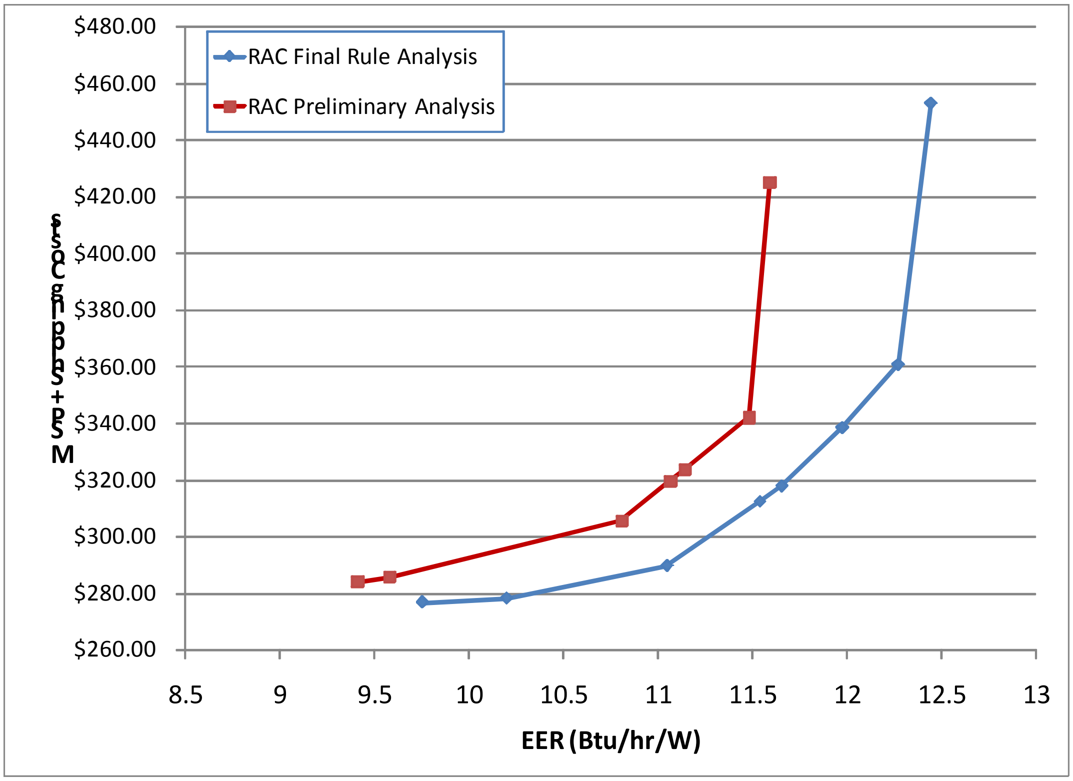


Figure 5.6.42 Product Class 3 - 12,000 Btu/h Capacity Cost-Efficiency Curve

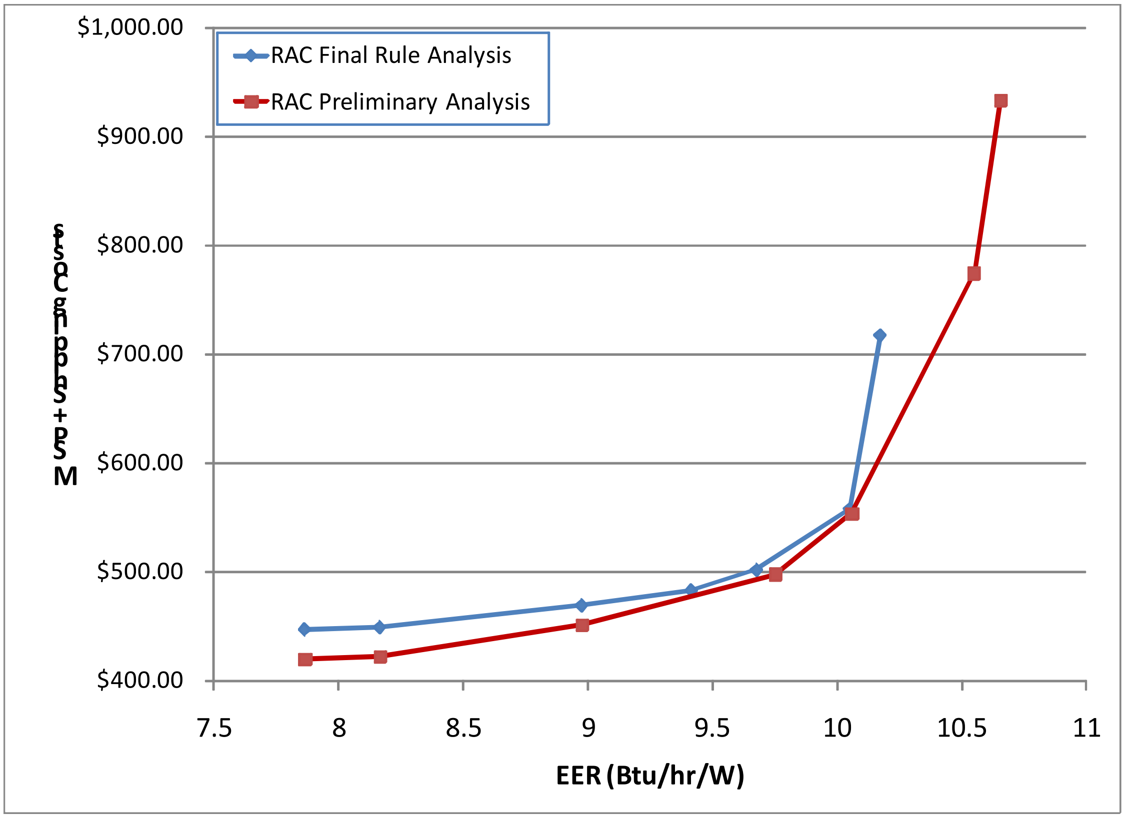


Figure 5.6.43 Product Class 5A – 24,000 Btu/h Cost-Efficiency Curve

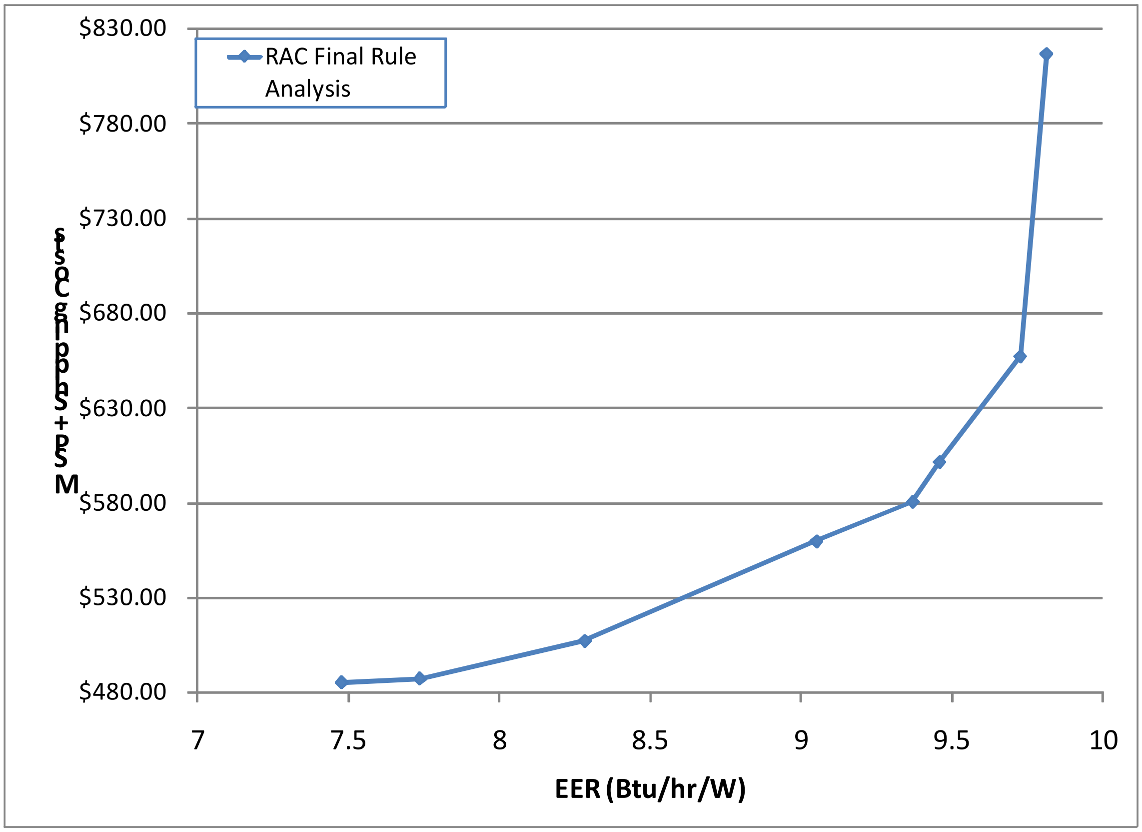


Figure 5.6.44 Product Class 5B – 28,000 Btu/h Cost-Efficiency Curve

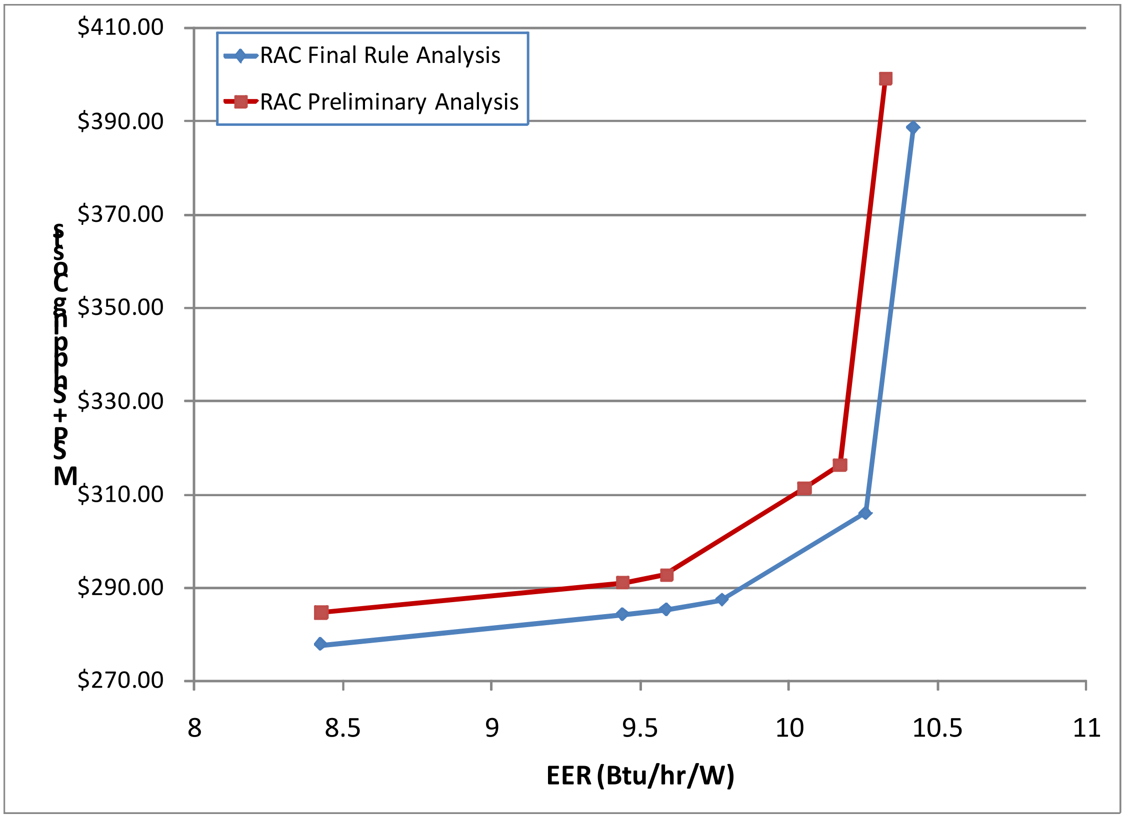


Figure 5.6.45 Product Class 8A - 8,000 Btu/h Capacity Cost-Efficiency Curve

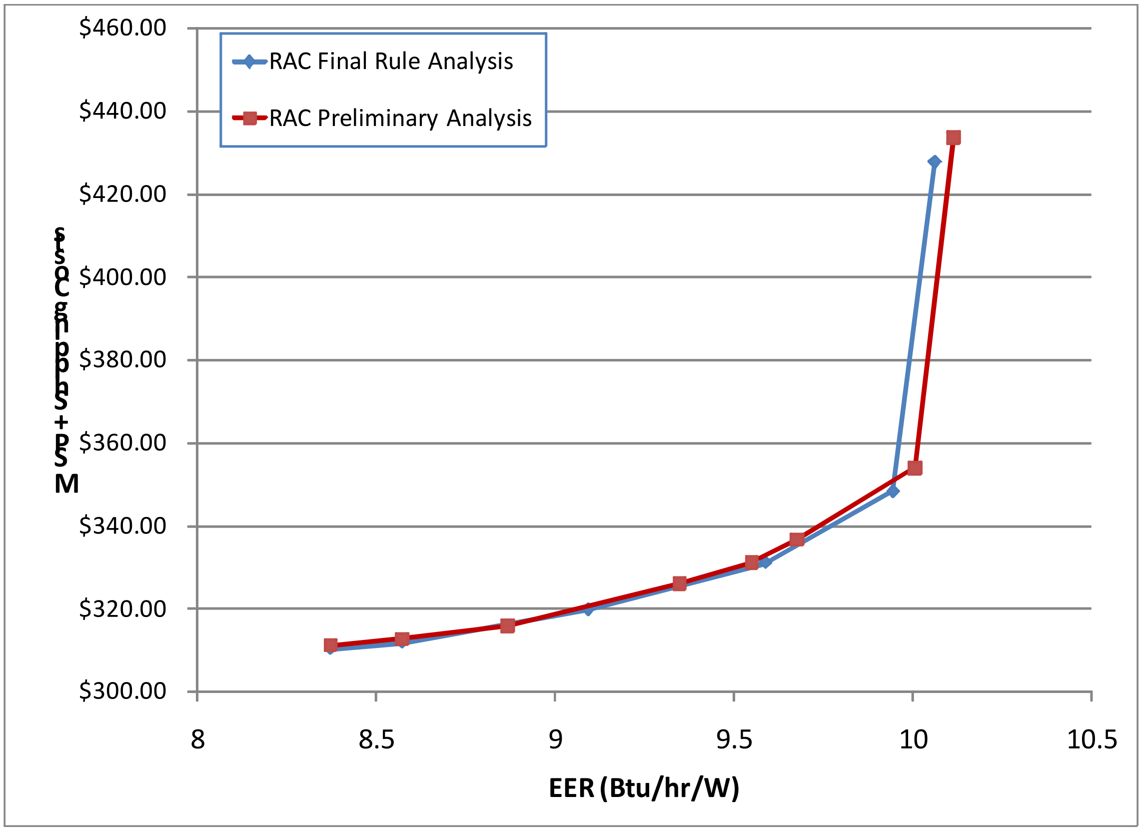


Figure 5.6.46 Product Class 8B - 12,000 Btu/h Capacity Cost-Efficiency Curve

5.6.2.9 Incremental Costs by CEER

The previous section discusses costs associated with increase of the active mode efficiency, measured in EER. As discussed in section 5.4, the analysis for this rulemaking is based on the integrated metric, CEER. DOE analyzed the improvement in CEER associated both with design options that improve EER and design options that reduce standby power. DOE developed overall cost-efficiency relationships for CEER by combining these analysis. In this overall analysis, DOE chose to implement the design options in order of decreasing cost-effectiveness. The reduction in standby power had cost-effectiveness between that of the best and worst active mode design options. This is illustrated for the product class 1 analysis in Figure 5.6.47 below. The plot shows the incremental CEER improvement of the design option divided by incremental manufacturing production cost (MPC) associated with the design option, for the final analysis.

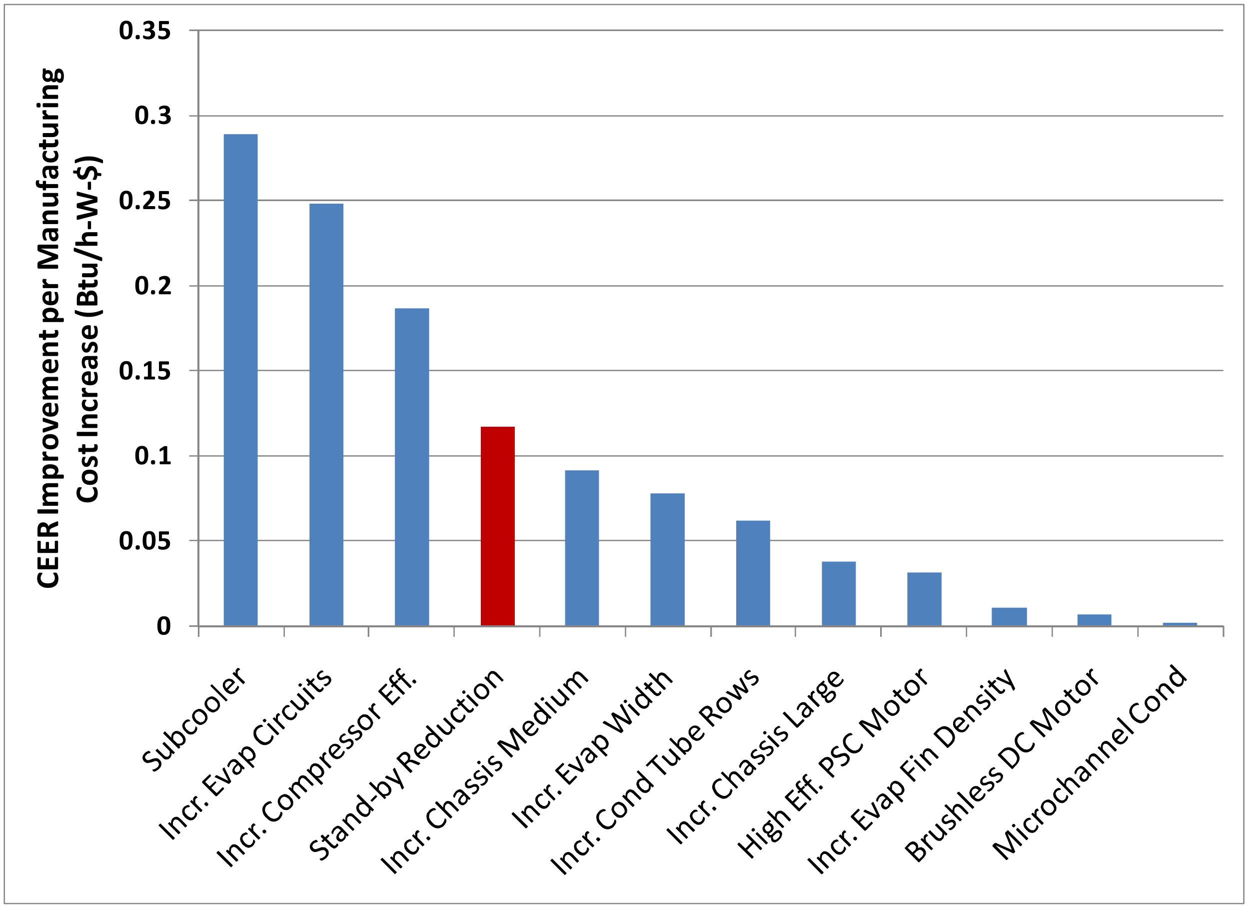


Figure 5.6.47 Comparison of the Cost-Effectiveness of Active and Standby Mode Design Options

As discussed above, DOE determined that the incremental cost for reducing standby mode power consumption from 1.4 W to 0.7 W is $0.75. Table 5.6.42 below summarizes this incremental cost.

Table 5.6.42 Room Air Conditioner Cost-Standby/Off Mode Power Relationship

Standby Level	Power *(W)*	Incremental Cost
Baseline	1.4	$0
1	0.7	$0.75

Table 5.6.43 through Table 5.6.49 present DOE's estimates of incremental cost in terms of MPC for improvement of room air conditioner CEER above the baseline. DOE updated this analysis from the preliminary analysis based on information collected during the final rule analysis phase. For the final rule analysis, DOE calculated the incremental costs for product classes 1, 3 (8,000Btu/h and 12,000Btu/h), 5A, 5B, 8A, and 8B. The incremental costs start at zero additional cost for the baseline R-410A unit.

The tables also present the calculated shipping cost at each efficiency level, based on the shipping package size. The first level of each table reflects the calculated CEER of a unit with a baseline EER rating and a standby power consumption of 1.4 W. The cost for this level represents the estimated cost associated with regaining the current standard EER level with the new refrigerant. DOE calculated the costs for each CEER level based on appropriate selection of active mode and standby mode design options. In cases where the CEER efficiency level does not coincide with the CEER determined for the design configuration directly analyzed with energy and manufacturing cost modeling, DOE took the following approach. If the next design option could be partially applied, DOE interpolated between costs and CEER levels calculated for the nearest design configurations. This approach applied to heat exchanger or chassis size increases, PSC motor efficiency improvement, and addition of a subcooler. In cases where the next design option could not be partially applied, the full cost of the design option was applied. This approach applied to increase in the number of heat exchanger circuits, change in heat exchanger tube size, and switch to BLDC motor technology.

Table 5.6.43 Room Air Conditioner Cost-Efficiency Relationships for Product Classes 1

Product Class 1: Without Reverse Cycle, With Louvered Sides, < 6,000 Btu/h			
Efficiency Level	**CEER**	**MPC Increase**	**Shipping Costs**
Baseline	9.52	$0.00	$3.86
1	10.1	$6.31	$4.68
2	10.6	$13.53	$7.22
3	11.1	$22.72	$8.39
4	11.4	$32.32	$8.39
5	12.7	$75.82	$8.39

Table 5.6.44 Room Air Conditioner Cost-Efficiency Relationship for Product Class 3 – 8,000 Btu/h Capacity Unit

Product Class 3 – 8,000 Btu/h: Without Reverse Cycle, With Louvered Sides, 8,000 - 13,999 Btu/h			
Efficiency Level	**CEER**	**MPC Increase**	**Shipping Costs**
Baseline	9.69	$0.00	$6.32
1	10.2	$5.30	$6.76
2	10.7	$12.30	$9.11
3	10.9	$15.95	$9.58
4	11.5	$30.92	$10.91
5	12.0	$103.87	$14.63

Table 5.6.45 Room Air Conditioner Cost-Efficiency Relationship for Product Class 3 – 12,000 Btu/h Capacity Unit

Product Class 3 – 12,000 Btu/h: Without Reverse Cycle, With Louvered Sides, 8,000 - 13,999 Btu/h			
Efficiency Level	**CEER**	**MPC Increase**	**Shipping Costs**
Baseline	9.72	$0.00	$10.33
1	10.2	$2.00	$10.33
2	10.7	$7.42	$10.33
3	10.95	$9.33	$10.33
4	11.5	$29.43	$10.33
5	12.0	$47.81	$16.08

Table 5.6.46 Room Air Conditioner Cost-Efficiency Relationships for Product Class 5A – 24,000 Btu/h

Product Class 5A: Without Reverse Cycle, With Louvered Sides, 20,000 to 27,999 Btu/h			
Efficiency Level	**CEER**	**MPC Increase**	**Shipping Costs**
Baseline	8.47	$0.00	$24.79
1	9.0	$8.85	$27.22
2	9.4	$19.04	$27.22
3	9.8	$50.66	$27.22
4	10.15	$204.62	$27.22

Table 5.6.47 Room Air Conditioner Cost-Efficiency Relationships for Product Class 5B – 28,000 Btu/h

Product Class 5B: Without Reverse Cycle, With Louvered Sides, ≥ 28,000 Btu/h			
Efficiency Level	**CEER**	**MPC Increase**	**Shipping Costs**
Baseline	8.48	$0.00	$29.75
1	9.0	$23.52	$36.15
2	9.4	$50.27	$36.46
3	9.8	$229.01	$36.46

Table 5.6.48 Room Air Conditioner Cost-Efficiency Relationship for Product Class 8A – 8,000 Btu/h

Product Class 8A – 8,000 Btu/h: Without Reverse Cycle, Without Louvered Sides, 8,000 – 10,999 Btu/h			
Efficiency Level	**CEER**	**MPC Increase**	**Shipping Costs**
Baseline	8.41	$0.00	$12.26
1	9.3	$4.61	$12.26
2	9.6	$6.68	$12.26
3	10.0	$16.63	$12.26
4	10.4	$88.45	$12.26

Table 5.6.49 Room Air Conditioner Cost-Efficiency Relationship for Product Class 8B – 12,000 Btu/h

Product Class 8B – 12,000 Btu/h: Without Reverse Cycle, Without Louvered Sides, 11,000 – 13,999 Btu/h			
Efficiency Level	**CEER**	**MPC Increase**	**Shipping Costs**
Baseline	8.44	$0.00	$12.26
1	9.3	$11.72	$12.26
2	9.5	$15.39	$12.26
3	9.8	$26.06	$12.26
4	10.0	$93.36	$12.26

DOE used consolidated product class 3 results in the downstream analysis. The consolidated results are the average of results of the two product capacities examined. The incremental cost averages for product class 3 are shown in Table 5.6.50 below.

Table 5.6.50 Room Air Conditioner Cost-Efficiency Relationship for Product Class 3 – Average

Product Class 3 – Average: Without Reverse Cycle, With Louvered Sides, 8,000 – 13,999 Btu/h			
Efficiency Level	**CEER**	**MPC Increase**	**Shipping Costs**
Baseline	9.71	$1.25	$8.33
1	10.2	$4.90	$8.55
2	10.7	$11.11	$9.72
3	10.9	$13.89	$9.95
4	11.5	$31.43	$10.62
5	12.0	$77.09	$15.36

The incremental cost data for active mode design options are detailed further in appendix 5D of this TSD. The appendix also provides incremental cost data for both the integrated metric (CEER) and non-integrated metric (EER).

5.6.2.10 Product Class Modifications

As discussed above, DOE is making changes to the existing product class structure for room air conditioners. During the preliminary phase, DOE proposed no changes to the existing product class structure. DOE received one comment addressing product classes during the preliminary analysis comment period from AHAM, and one comment after the end of the comment period titled, "Agreement on Minimum Federal Efficiency Standards, Smart Appliances, Federal Incentives and Related Matters for Specified Appliances" from a group of joint petitioners representing manufacturers, industry representatives, and efficiency and consumer advocates. This latter group is referred to as the Joint Petitioners. The comments were as follows:

- AHAM recommended that product class 5 be split into two product classes based on product cooling capacity, the first class including products with capacity from 20,000 Btu/h to 24,999 Btu/h, and the second with capacity greater than 25,000 Btu/h. AHAM also recommended that product class 8 be split into two product classes, the first with capacity from 8,000 Btu/h to 10,999 Btu/h, and the second with capacity from 11,000 Btu/h to 13,999 Btu/h.
- The Joint Petitioners also proposed splitting both product classes 5 and 8, but recommended splitting product class 5 at a different capacity than suggested by AHAM. This comment recommended a split at 28,000 Btu/h.

Product Class 5 Modifications

DOE based its considerations regarding the product class 5 split (room air conditioners without reverse cycle, with louvered sides, and capacity 20,000 Btu/h or more) on the following inputs:

- Individual discussions with manufacturers
- Research on available product sizes and available product efficiencies.
- Reverse engineering of three product class 5 units, including a 28,500 Btu/h unit and two 24,000 Btu/h units
- Engineering analysis of R-410A product class 5 baseline products at the 24,000 Btu/h and 28,000 Btu/h capacity levels.

DOE's research indicates that efficiency drops off monotonically as capacity increases.. For current product class 5, the current standard requires a minimum energy efficiency ratio (EER)[j] of 8.5 Btu/h-W. DOE's research found that no 2010 product of this class with a capacity higher than 28,000 Btu/h has an EER exceeding this minimum level, whereas products with lower capacity do exceed the minimum efficiency level. The trend for all room air conditioners with louvered sides without reverse cycle (current product classes 1, 2, 3, 4, and 5) is illustrated in Figure 5.6.48 below.

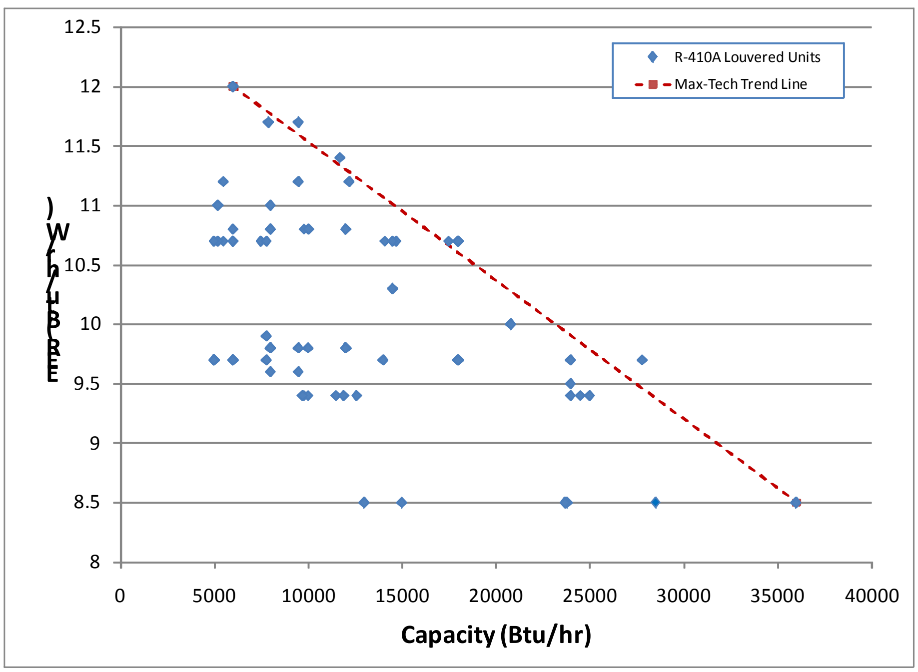


Figure 5.6.48 R-410A Louvered Products – Efficiency versus Capacity

DOE produced cost-efficiency curves for product class 5 products at both 24,000 Btu/h and 28,000 Btu/h capacity levels. Additional information of this analysis is available in chapter 5

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[j] Energy Efficiency Ratio (EER) is equal to the product's cooling capacity, expressed in Btu/h, divided by the power input, in Watts (W).

of this TSD. Table 5.6.51 shows the results of these analyses, which clearly show (1) much steeper increase in cost as the CEER increases and (2) significantly lower max tech for the larger capacity.

Table 5.6.51 Comparison of 24,000 Btu/h and 28,000 Btu/h Incremental Costs

Efficiency Level	PC5A – 24,000 Btu/h		PC5B – 28,000 Btu/h	
	CEER	Incremental Cost	CEER	Incremental Cost
1	8.47	$0.00	8.48	$0.00
2	9.0	$8.85	9.0	$23.52
3	9.4	$19.04	9.4	$50.27
4	9.8	$50.66	9.8	$229.01
5	10.15	$204.62	-	-

In addition, DOE's analysis of the 28,000 Btu/h size shows that two growths in product size are needed to reach these efficiency levels, including one to a very large size; for the 24,000 Btu/h, only one growth was required to achieve the same level of efficiency. Despite the additional product growth, the 28,000 Btu/h product did not reach the same max-tech efficiency level as the 24,000 Btu/h product. Additional information of this analysis is available in chapter 5 of this TSD. Table 5.6.52 shows the product sizes analyzed.

Table 5.6.52 Size Increases Examined During Room Air Conditioner Design Option Analysis – Product Classes 5A and 5B

Design Description	**Width** *(inches (in))*	**Height** *(in)*	**Depth** *(in)*	**Volume** *(cubic feet (cf))*	**Weight** *(lb)*
Product Class 5A					
Baseline	26	17.69	28.41	7.56	129.2
First Size Increase	27.75	17.94	30.94	8.91	136.4
Second Size Increase	-	-	-	-	-
Product Class 5B					
Baseline	26	17.69	28.41	7.56	129.2
First Size Increase	27.75	17.94	30.94	8.91	136.4
Second Size Increase	29.81	22.38	30.94	11.94	156.5

This analysis demonstrates the much greater potential for efficiency improvement in products lower than 28,000 Btu/h. DOE's decision to establish the new product classes 5A and 5B that take the place of the previous product class 5 is based on the stakeholder comments and DOE's analysis. DOE believes that the new product classes are needed to ensure establishment of meaningful efficiency levels over the full range of capacities.

Product Class 8 Modifications

DOE considered the following inputs when considering whether to split product class 8 (Non-louvered, non-reverse-cycle, capacity of 8,000 to 13,999 Btu/h):

- Individual discussions with manufacturers

- Research on available product sizes and available product efficiencies.
- Reverse engineering of six product class 8 units, including three 8,000 Btu/h units and three 12,000 Btu/h units
- Engineering analysis of R-410A product class 8 baseline products at the 8,000 Btu/h and 12,000 Btu/h capacity levels.

The max tech EERs of available room air conditioners without louvered sides using R-410A refrigerant are very dependent on capacity range. These products are designed to fit in sleeves installed in the building wall. Due to the heavy dependence of this market on replacement sales, as reported by manufacturers during interviews for the final rule analysis, there is little opportunity to adjust the physical size of the product. This is in distinct contrast to products with louvered sides, which are designed to fit in windows; this design allows more flexibility for size increase to improve efficiency. The max tech levels of non-louvered products are very dependent on the individual product's capacity. Products with capacity greater than 12,600 Btu/h are unable to meet the current ENERGY-STAR EER level. See Figure 5.6.49 for the results of DOE's survey of non-louvered, non-reverse-cycle R-410 products, completed in May 2010. DOE further notes that ENERGY STAR products in the capacity range 11,500 to 12,600 Btu/h require oversized sleeves. At a slightly higher capacity level, products cannot be designed to meet the DOE energy standard—the available data show that there are currently no available products having greater than 13,999 Btu/h capacity. During interviews, manufacturers reported that there is great technical difficulty in producing non-louvered products greater than 15,000 Btu/h that would meet the DOE's current efficiency standards.

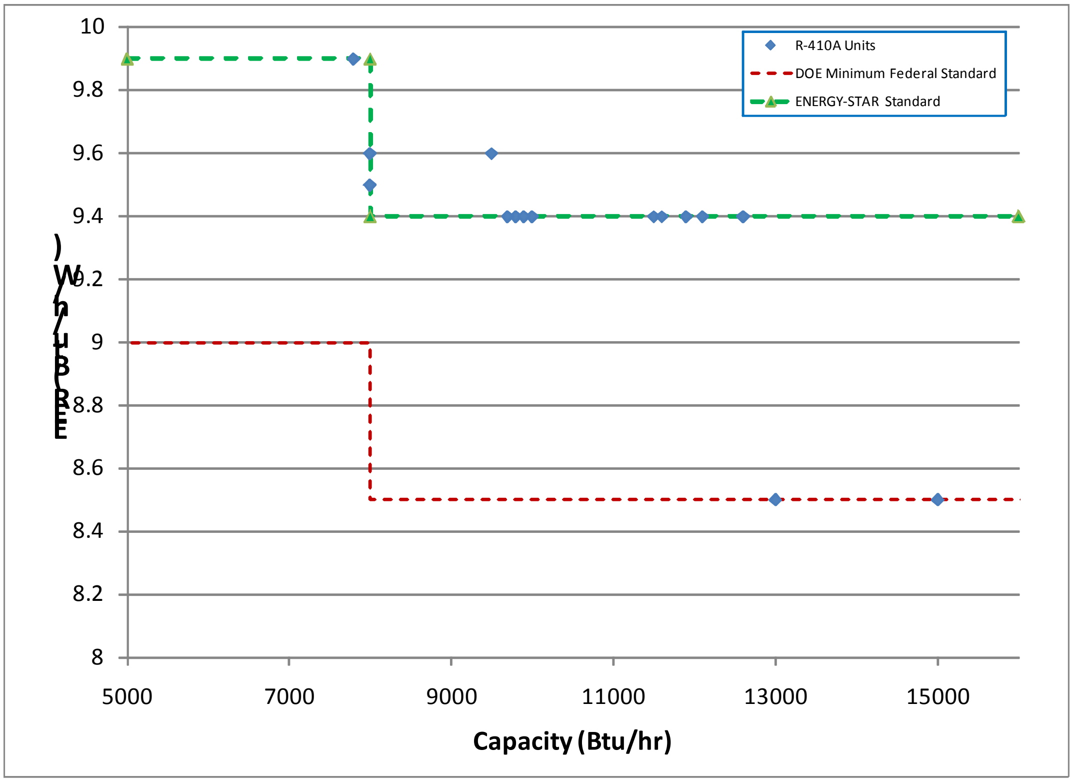

Figure 5.6.49 R-410A Products from DOE Survey of Non-louvered, Non-reverse-cycle Products

DOE produced cost-efficiency curves for non-louvered R-410A room air conditioners at 8,000 Btu/h and 12,000 Btu/h capacities, shown in Table 5.6.53 below. Additional information of this analysis is available in chapter 5 of this TSD. As with the product class 5 analyses, the results of the analysis of product class 8 show the significantly steeper increase in cost as efficiency level is raised above the baseline and the reduced max tech level for the higher-capacity product.

Table 5.6.53 Comparison of 8,000 Btu/h and 12,000 Btu/h Incremental Costs

Efficiency Level	PC8A – 8,000 Btu/h		PC8B – 12,000 Btu/h	
	CEER	Incremental Cost	CEER	Incremental Cost
1	8.41	$0.00	8.44	$0.00
2	9.3	$4.61	9.3	$11.72
3	9.6	$6.68	9.5	$15.39
4	10.0	$16.63	9.8	$26.06
5	10.4	$88.45	10.0	$93.36

This analysis demonstrates the much greater potential for efficiency improvement for the lower-capacity products. DOE's decision to establish the new product classes 8A and 8B that take the place of the current product class 8 is based on the stakeholder comments and DOE's analysis. DOE believes that the new product classes are needed to ensure establishment of meaningful efficiency levels over the full range of capacities.

5.6.2.11 Analysis Extension to All Product Classes

The process of extending incremental cost data for **room air conditioner** product classes not directly analyzed is discussed in this section. The methodology for estimating the incremental costs associated with efficiency increases for these product classes is described below.

During the preliminary analysis, DOE used interpolation and extrapolation methods, based on the IEER/CEER levels of the analyzed product classes, to estimate efficiency levels and incremental costs for the remaining product classes. DOE's downstream analysis were constructed just for the directly analyzed product classes. The other product classes have been assigned to each of the full analysis, based on determination of which of the fully-analyzed classes provided the best representation of life cycle costs. DOE used the criteria described in Table 5.6.54 below to establish the final product groupings.

Table 5.6.54 Product Class Grouping Criteria

Criterion	Description
Energy Use	Grouping of product classes with similar capacity and estimated operating hours. Table 5.6.55 provides a summary of representative capacities and operating hours by product class.
Ability to reach high efficiencies	Some product classes have limited potential for efficiency increase. Product classes without louvered sides, high-capacity products, and casement-slider or casement-only have limited potential for physical size increase, thus they also have reduced potential for efficiency improvement.
Extrapolated cost-efficiency curve	During the preliminary analysis, DOE estimated cost-efficiency curves for the non-analyzed product classes (see the preliminary TSD, chapter 5, section 5.6.2.7) DOE compared these extrapolated curves to the final rule results for the fully analyzed product classes to assist in selecting product class groups. DOE ranked each analyzed product class, in order of cost efficiency, to assist in this analysis.

Capacity and energy use characteristics for each product class are listed in Table 5.6.55 below. DOE used this information to assist in the grouping of product classes.

Table 5.6.55 Room Air Conditioner Representative Capacities and Operating Hours

Product Class	Description	Representative Capacity (*Btu/h*)	Estimated Operating Hours
With Louvers, Without Reverse Cycle			
1	< 6,000 Btu/h	5000	1281
2	6,000 to 7,999 Btu/h	6000	913
3	8,000 to 13,999 Btu/h	10,000	545
4	14,000 to 19,999 Btu/h	18,000	438
5A	20,000 to 27,999 Btu/h	24,000	331
5B	> 28,000 Btu/h	28,000	331
Without Louvers, Without Reverse Cycle			
6	< 6,000 Btu/h	5,000	1281
7	6,000 to 7,999 Btu/h	6,000	913
8A	8,000 to 10,999 Btu/h	8,000	545
8B	11,000 to 13,999 Btu/h	12,000	545
9	14,000 to 20,000 Btu/h	14,000	438
10	> 20,000 Btu/h	20,000	331
With Louvers, With Reverse Cycle			
11	< 20,000 Btu/h	12,000	545
13	> 20,000 Btu/h	14,000	331
Without Louvers, With Reverse Cycle			
12	< 14,000 Btu/h	10,000	545
14	> 14,000 Btu/h	14,000	438
Casement			
15	Casement-only	10,000	545
16	Casement-slider	10,000	545

The final product class groupings are presented in Table 5.6.56 below. These groupings were used in the subsequent LCC analysis.

Table 5.6.56 Room Air Conditioner Product Class Groupings

Group	Analyzed Product Class	Extrapolated Product Classes
1	1	-
2	3	2,4,11
3	5A	12
4	5B	10
5	8A	6,7,13,15,16
6	8B	9,14

REFERENCES

[2] D.R. Tree, V.W. Goldschmidt, R.W. Garrett, and E. Kach. 1978. "Effect of Water Sprays on Heat Transfer of a Fin and Tube Heat Exchanger." *Sixth International Heat Transfer Conference.* Vol. 4, pp. 339–44.

[3] Kao, J. "Energy Test Results of a Conventional Clothes Dryer and a Condenser Clothes Dryer," National Institute of Standards and Technology, Gaithersburg, MD, 1998.

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

[5] 2005 ASHRAE Handbook: Fundamentals. ASHRAE, Atlanta, GA 2005.

[5] U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy. Technical Support Document for Energy Conservation Standards for Room Air Conditioners: September 1997. Washington, D.C. Available at: www.eere.energy.gov/buildings/appliance_standards/residential/room_ac.html

[6] 2008 ASHRAE Handbook: Fundamentals. ASHRAE, Atlanta, GA 2008.

CHAPTER 6. MARKUPS ANALYSIS

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CHAPTER 6. MARKUPS ANALYSIS

6.1 INTRODUCTION

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

6.1.1 Distribution Channels

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

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

6.1.2 Markup Calculation Methodology

As just discussed, at each point in the distribution channel, companies mark up the price of the equipment to cover their business costs and profit margin. In financial statements, gross margin is the difference between the company revenue and the company cost of sales or cost of goods sold (*CGS*). The gross margin includes the expenses of companies in the distribution channel—including overhead costs (sales, general, and administration); research and development (R&D) and interest expenses; depreciation, and taxes—and company profits. To cover costs and to contribute positively to company cash flow, the price of products must include a markup. Products command lower or higher markups, depending on company expenses associated with the product and the degree of market competition. In developing markups for manufacturers and retailers, DOE obtained data about the revenue, *CGS*, and expenses of firms that produce and sell the products of interest.

6.2 MANUFACTURER MARKUPS

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

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

where:

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

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

DOE developed an average manufacturer markup by examining the annual Securities and Exchange Commission (SEC) 10-K reports filed by four publicly-traded manufacturers primarily engaged in appliance manufacturing and whose combined product range includes residential refrigeration products.[2] The four manufacturers represent a nearly 50 percent market share for major appliances. Because these companies are typically diversified, producing a range of different appliances, an industry average markup was assumed by DOE to be representative for the manufacture of refrigeration products. DOE evaluated markups for the years 2002─2005.

Table 6.2.1 lists the average corporate gross margin during the years 2002─2005, and corresponding markups, for each of the four manufacturers. The average markup value based on these four companies is 1.26, which is the value that DOE used.

Table 6.2.1 Major Appliance Manufacturer Gross Margins and Markups

	Mfr A	**Mfr B**	**Mfr C**	**Mfr D**
Average Net Revenues (Million)	$372	$280	$4770	$12,682
Corporate Gross Margin	15%	28%	16%	22%
Markup	1.18	1.39	1.19	1.28

Source: SEC 10-K reports (2002-2005)

6.3 RETAILER MARKUP

6.3.1 Approach for Calculating Retailer Markups

DOE based the retailer markups for room air conditioners and clothes dryers on financial data for Electronics and Appliance Stores from the 2002 U.S. Census Business Expenses Survey (BES), which is the most recent available survey.[3] DOE organized the financial data into statements that break down cost components incurred by firms in this category. DOE assumes that the income statements faithfully represent the various average costs incurred by firms selling home appliances. Although Electronics and Appliance Stores handle multiple commodity lines, the data provide the most accurate available indication of expenses for selling home appliances.

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

6.3.1.1 Baseline Retailer Markup

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

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

where:

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

Table 6.3.1 shows the calculation of the baseline retailer markup.

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

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

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

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

6.3.1.2 Incremental Retailer Markup

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

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

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

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

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

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

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

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

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

where:

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

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

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

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

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

By dividing expenses into fixed and variable components, the incremental markup approach envisions that retailers cover costs without changing profits. Although retailers may be able to reap higher profits for a time, DOE's approach assumes that competition in the appliance retail market, combined with relatively inelastic demand (*i.e.*, the demand is not expected to decrease significantly with 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 and Material and Supplies Dealers, and General Merchandise Stores. The FFCR represents the market share of the four largest firms in the relevant industry. Generally, an FFCR of less than 40% indicates that the industry is not concentrated and an FFCR of more than 70% indicates that an industry is highly concentrated.[b] [c]

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

Table 6.3.3 Electronics and Appliance Stores, Concentration by Four Firms

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

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

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

6.4 SALES TAXES

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

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

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

Census Division/State	Tax Rate (2010 July)
New England	5.55%
Mid Atlantic	6.62%
East North Central	6.94%
West North Central	6.86%
South Atlantic	6.44%
East South Central	7.90%
West South Central	8.42%
Mountain	6.50%
Pacific	5.21%
New York State	8.45%
California	9.15%
Texas	8.05%
Florida	6.70%

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

Table 6.4.2 Average Sales Tax Rates by Product

Product	Tax Rate
Room air conditioners	7.18%[d]
Clothes dryers	7.15%

[d] This figure includes both residential room air conditioners which cover all Census division and large states and commercial room air conditioners which only cover Census division.

6.5 SUMMARY OF MARKUPS

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

Table 6.5.1 Summary of Markup

	Room Air Conditioners		**Clothes Dryers**	
Markup	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.26		1.26	
Retailer	1.45	1.17	1.45	1.17
Sales Tax	1.0718		1.0715	
Overall	1.96	1.58	1.96	1.58

REFERENCES

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

[2] Security Exchange Commission, *SEC 10-K Reports*, Various dates, 2002-2005, Security Exchange Commission. <http://www.sec.gov/>

[3] U.S. Census Bureau. *2002 Economic Census, Business Expenses Survey, Retail Trade, Household Appliance Stores*, 2002. Washington, DC. <http://www.census.gov/csd/bes/bes97.htm>

[4] *Dale, Larry et al., "An Analysis of Price Determination and Markups in the Air-Conditioning and Heating Equipment Industry", LBNL-52791, January 2004.*

[5] Sales Tax Clearinghouse, Inc. *State sales tax rates along with combined average city and county rates*. <http://thestc.com/STrates.stm>

[6] U.S. Department of Energy-Energy Information Administration. *Residential Energy Consumption Survey, 2005Public Use Data Files*. Washington, DC. <http://www.eia.doe.gov/emeu/recs/recspubuse05/pubuse05.html>

CHAPTER 7. ENERGY USE ANALYSIS

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CHAPTER 7. ENERGY USE ANALYSIS

7.1 INTRODUCTION

To carry out the life-cycle cost (LCC) and payback period (PBP) analyses described in chapter 8, DOE must determine the operating cost savings to consumers from more efficient products. This chapter describes how DOE determined the annual energy consumption of room air conditioners and clothes dryers for use in the LCC and PBP analyses.

The engineering analysis described in chapter 5 reports energy use based on the DOE test procedure. This test provides standardized results that serve as the basis for comparing the performance of different appliances used under the same conditions. Actual usage in the field varies depending on the conditions in which the appliances are operated.[a]

To establish a reasonable range of energy consumption in the field for room air conditioners and clothes dryers in residential applications, DOE primarily used data from the Energy Information Administration (EIA)'s 2005 Residential Energy Consumption Survey (RECS 2005).[1] RECS is a national sample survey of housing units that collects statistical information on the consumption of and expenditures for energy in housing units along with data on energy-related characteristics of the housing units and occupants. RECS 2005 collected data on 4,381 housing units and was constructed by EIA to be a national representation of the household population in the United States.

Room air conditioners are predominantly used in homes, but they are also used in some commercial buildings. To determine the energy use patterns of room air conditioners in commercial applications, DOE used EIA's 2003 Commercial Building Energy Consumption Survey (CBECS)[2] to develop a representative sample of commercial buildings using room air conditioners. CBECS 2003 collected energy-related data for 5,215 buildings and was constructed by EIA to be a national representation of the commercial building stock in the United States.

The details of each building sample are described in the following section.

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[a] DOE assembled estimates of the average annual energy use of room air conditioners from several studies and sources. Unfortunately, none of the studies is based on metered data. The studies rely on power measurements and assumptions regarding usage to derive the annual energy consumption values.

7.2 CONSUMER SAMPLES

7.2.1 Clothes Dryer Household Sample

The subset of RECS 2005 records used for the clothes dryer sample met all of the following criteria:

- The household had a clothes dryer.
- The household had and used a clothes washer.
- Clothes dryer fuel was electricity, natural gas, or LPG.
- Clothes dryer use was greater than zero.

Table 7.2.1 shows how the sample was divided into three sub-samples to match to the product classes analyzed. For compact electric dryers, DOE developed a sub-sample consisting of households with an electric dryer in multifamily buildings, manufactured homes, and single-family homes with less than 1,000 square feet and no garage or basement, since DOE reasoned that these products are most likely to be found in these housing types.

Table 7.2.1 Selection of RECS 2005 Records for Clothes Dryer Sample

Product Class	Selection Criterion	No. of Records	No. of U.S. Households Represented *(million)*
Electric Standard Dryer	Has Dryer = Yes Fuel Type = Electricity Use of Dryer > 0	2655	67.0
Electric Compact Vented Dryer and Vent-less Dryer	Has Dryer = Yes Fuel Type = Electricity Use of Dryer > 0 Type of Housing = Mobile home, multifamily, or single family (≤1000 sq. ft., no attached garage, no basement)	570	14.4
Gas Dryer	Has Dryer = Yes Fuel Type = Natural Gas or LPG Use of Dryer > 0	756	20.3

7.2.2 Room Air Conditioners

7.2.2.1 Residential Sample

The subset of RECS 2005 records used for the room air conditioner sample met all of the following criteria:

- A room air conditioner was present in the household.
- Room air conditioner energy consumption was greater than zero.

Households were assigned to the sub-samples based on the average adjusted capacity of the unit needed for the household. The average adjusted capacity was calculated based on ENERGY STAR sizing guidelines for room air conditioners[b] combined with household characteristics such as shading, insulation, window and glass type, number of household members, and ceiling type. See appendix 7-A for more details. Table 7.2.2 shows the number of RECS records in each sub-sample and the selection criteria. DOE used EIA's weightings for each RECS 2005 household. The weightings indicate how commonly each household configuration occurs in the general population.

Table 7.2.2 Selection of RECS 2005 Records for Residential Room Air Conditioner Samples

Product Class	Selection Criterion	No. of Records	No. of U.S. Households Represented *(million)*	No. of U.S. RAC Units Represented *(million)*
Total sample		1222	28.2	50.6
1	Average adjusted capacity ≤ 6,000 Btu/h	266	9.2	16.9
3 and 8	Average adjusted capacity > 6,000 Btu/h and ≤ 14,000 Btu/h	890	38.9	97.1
5	Average adjusted capacity ≥ 18,000 Btu/h	66	2.5	5.4

7.2.2.2 Commercial Building Sample

The subset of CBECS 2003 records used for the commercial-sector room air conditioner sample met all of the following criteria:

[b] http://www.energystar.gov/index.cfm?c=roomac.pr_properly_sized

- A room air conditioner served as a source of air conditioning.[c]
- Building is not vacant.
- A room air conditioner is used as the primary equipment to cool at least a portion of the building.

The sample was divided into sub-samples to match to the product classes analyzed. CBECS 2003 provides the total cooling square footage and the fraction of cooling by the room air conditioner for each building record, but it does not provide the number of room air conditioners used by the building, so the total room air conditioner cooling square footage is used to determine the subsamples. Table 7.2.3 shows the number of CBECS records in each sub-sample. DOE used EIA's weightings for each CBECS 2003 building. The weightings indicate how commonly each building configuration occurs in the general population.

Table 7.2.3 Selection of CBECS 2003 Records for Commercial Room Air Conditioner Samples

Product Class	Selection Criterion	No. of Records	No. of U.S. Buildings Represented *(million)*
Total sample		440	0.4
>6,000 Btu/h	Total RAC Cooling sq. ft. > 0	440	0.4
8,000 to 13,999 Btu /h	Total RAC Cooling sq. ft. > 300	400	0.3
≥ 20,000 Btu /h	Total RAC Cooling sq. ft. > 900	352	0.3

7.3 CLOTHES DRYERS

DOE determined the annual energy consumption of clothes dryers by multiplying the number of cycles per year by the energy use per cycle.

7.3.1 Number of Cycles

DOE estimated the number of clothes dryer cycles per year for each sample household using data given by RECS 2005 on the number of laundry loads washed (clothes washer cycles) per week and the frequency of clothes dryer use. The responses in RECS 2005 fall into one of the bins shown in Tables 7.3.1 and 7.3.2. For each question, DOE assumed a uniform

[c] PTAC systems could also be listed as room air conditioners, so DOE tried to select buildings with only room air conditioners. A building was selected as having a room air conditioner if it did not have a PTAC type heating system.

distribution within the boundaries of each bin and randomly assigned a value from within the appropriate range to each sample household.

Table 7.3.1 Number of Loads Washed per Week Based on RECS 2005 Sample

Bin	Loads per Week	Derived Loads per Year*	
		Min	Max
1	1 load or less	0	78
2	2 to 4 loads	78	234
3	5 to 9 loads	234	494
4	10 to 15 loads	494	806
5	More than 15 loads	806	1118

* The ranges reflect the inclusion of values in between the given bin boundaries.

Table 7.3.2 RECS 2005 Sample Clothes Dryer Usage

Bin	Description	Fraction of Washer Cycles When Dryer is used	
		Min	Max
1	Use it every time wash clothes	1	1
2	Use it for some, but not all, loads of wash	0.50	1
3	Use it infrequently	0.00	0.50

The responses to the above questions vary among sample households using different clothes dryer products, so they yield somewhat different values for the average annual number of clothes dryer cycles for each product class (see Table 7.3.3).

Table 7.3.3 Average Clothes Dryers Utilization Derived from RECS 2005 Sample

	Electric Standard	Gas	Electric Compact and Vent-less
Washer loads per year	301	292	268
Clothes dryer frequency*	0.95	0.93	0.94
Clothes dryer loads per year	283	274	251

* Fraction of washer loads
** Accounts for fraction of households that have a clothes washer, but no clothes dryer

7.3.2 Energy Use Calculation

For each considered efficiency level, DOE derived the field energy use by separately estimating the active mode and standby mode energy use and then adding them together. The

DOE clothes dryer test procedure[3] calculates active mode energy consumption by dividing the weight (lbs) of clothes dried per cycle (8.45 lbs for standard and 3 lbs for compact clothes dryers) by the Combined Energy Factor (CEF) (lbs/kWh) and subtracting standby power.[d] DOE adjusted the test procedure energy use to reflect field conditions by making an adjustment for clothes dryer load weight and moisture removal factor.

For each household, DOE determined the per-cycle test procedure clothes dryer energy use during active mode by using the following formula:

$$TP_{Active} = \left[\left(\frac{avgLoadWeight_{TP}}{CEF} * CD\_Cycles_{TP} \right) - \left(Stby\_hrs_{TP} * \frac{Stby}{1000} \right) \right] / CD\_Cycles_{TP}$$

Where:

$avgLoadWeight_{TP}$ =	average load weight in the test procedure, lbs,
CEF =	efficiency of the clothes dryer during active mode, lbs per kWh,
CD_Cycles_{TP} =	test procedure clothes dryer cycles per year,
$Stby\_hrs_{TP}$ =	test procedure standby hours, and,
$Stby$ =	clothes dryers standby power usage, watts.

For each household, DOE determined the field adjustment for clothes dryer energy use during active mode by using the following formula:

$$EnergyUse_{Active} = \left[\left(TP_{Active} - RMC_{adj} \right) * \left(\frac{avgLoadWeight_{Field}}{avgLoadWeight_{TP}} \right) * \left(\frac{RMC_{Field} - RMC_{Field,Enc}}{RMC_{TP} - RMC_{TP,End}} \right) + RMC_{Adj} \right] * CD\_Cycles$$

Where:

TP_{Active} =	test procedure energy use per cycle, kWh per cycle,
RMC_{adj} =	RMC adjustment factor for the fixed energy use, kWh per cycle,
$avgLoadWeight_{TP}$ =	average load weight in the test procedure, lbs,
$avgLoadWeight_{Field}$ =	average load weight for each household, lbs,
RMC_{TP} =	remaining moisture content in the test procedure, 57.5 percent,
$RMC_{TP,Enc}$ =	remaining moisture content at the end of the cycle in the test procedure, 5 percent,
RMC_{Field} =	remaining moisture content for the household, percent,
$RMC_{Field,End}$ =	remaining moisture content at the end of the cycle for the household, percent,
CD_Cycles =	clothes dryer cycles per year.

---

[d] See chapter 5 for more information on how to convert from CEF to EF.

DOE assigned a fixed energy use adjustment (RMC_{adj}) equal to 0.25 kWh/cycle to account for energy required to heat the clothes dryer cabinet.

To assign a field average load weight ($avgLoadWeight_{Field}$) for each household, DOE developed a distribution of load weights by matching the listed tub sizes for models in the July 2010 California Energy Commission (CEC) directory[4] with the correlations between tub size and average pounds in the DOE test procedure. To account for a wider distribution of households that do not wash the average pounds in the DOE test procedure, DOE added a ±25 percent adjustment factor. The average load weights for standard-size units range from 3.8 lbs. to 13.7 lbs., with a mean value of 8.45 lbs, which matches DOE's clothes dryer procedure value.[3]

To assign a field remaining moisture content (RMC_{Field}) value for each household, DOE used the 2008 shipment weighted values provided by AHAM for front loader and top loader washers.[5] The shipment weighted value is 38.1 percent for front loaders and 51 percent for top loaders, with an overall shipment weighted RMC value of 47 percent. In 2008, front loaders represented 31 percent of shipments, while top loaders represented the remaining 69 percent, so the overall RMS shipment weighted value is 47-percent. This shipment weighted average RMC value in the AHAM data is based on the clothes washer RMC which uses a correction factor to normalize testing results from different lots of test cloth. As a result, DOE determined that an initial clothes dryer RMC of 57.5 percent more accurately represents the moisture content of current laundry loads after a wash cycle and therefore adjusted the shipment weighted value for front loaders and top loaders accordingly. In order to get a distribution of values, DOE used the number of models listed at each unadjusted RMC in the July 2010 CEC directory.[4] The adjusted RMC values used in the analysis range from 36 percent to 64 percent for front loaders, with an average of 47 percent, and from 42 percent to 75 percent for front loaders, with an average of 62 percent. The overall average value of 57.5 percent matches DOE's clothes dryer procedure value.

To assign a field remaining moisture content at the end of the cycle ($RMC_{Field,End}$) value for each household, DOE used a uniform distribution of 0 to 5 percent. In comparison, the DOE test procedure uses 5 percent.

Using the above approach, DOE calculated a unique value for the clothes dryer annual active mode energy consumption for each sample household with an electric clothes dryer using the number of dryer cycles specified for that household. For gas clothes dryers, DOE used a similar approach as for electric clothes dryers, but added an estimate of the energy use of the electric components. An estimate of 0.107 kWh per cycle, which was derived from tests done by DOE, was applied for all efficiency levels except for the max-tech level. For the latter, which has a more efficient motor, the tests found a value of 0.091 kWh.

For each household, DOE determined the field-adjusted clothes dryer energy use during standby mode by using the following formula:

$$ClothesDryerEnergyUse_{Standby} = \left[8760 - CD\_Cycles * \left(\frac{CD\_Time}{60}\right)\right] * Standby\_Power$$

Where:

8760 =	number of hours in one year, hrs,
CD_Time =	clothes dryer time to complete one cycle, min/cycle,
60 =	number of minutes in one hour, min/hr,
Standby_Power =	standby power, kW, and
CD_Cycles =	clothes dryer cycles per year.

DOE assumed that clothes dryers take 60 minutes on average to complete a cycle.[6, 7, 8] Standby power varies by efficiency level as discussed in chapter 5.

DOE also considered the impact of clothes dryer operation on home heating and cooling loads. A clothes dryer releases heat to the surrounding environment. If the dryer is located indoors, its use will tend to slightly reduce the heating load during the heating season and slightly increase the cooling load during the cooling season. To calculate this impact, DOE first estimated whether the clothes dryer in a RECS sample home is located in conditioned space (referred to as indoors) or in unconditioned space (such as garages, unconditioned basements, outdoor utility closets, or attics). Based on the 2005 RECS[9] and the 2009 American Housing Survey (AHS)[10], DOE assumed that 50 percent of vented standard electric and gas dryers are located indoors, while 100 percent of compact and ventless clothes dryers are located indoors. For these installations, DOE utilized the results from a European Union study about the impacts of clothes dryers on home heating and cooling loads to determine a the appropriate factor to apply to the total clothes dryer energy use.[11] This study reported that for vented dryers there is a factor of negative 3 to 9 percent (average 6 percent) and for ventless dryers there is a factor of positive 7 to 15 percent (average 11 percent). DOE believes that this effect is the same for all of the considered efficiency levels because the amount of air passing through the clothes dryer does not vary.

7.3.3 Variability of Annual Energy Consumption

Figures 7.3.1 to 7.3.7 show the range of average annual energy consumption (active and standby mode) for clothes dryers in the household sample for each product class.

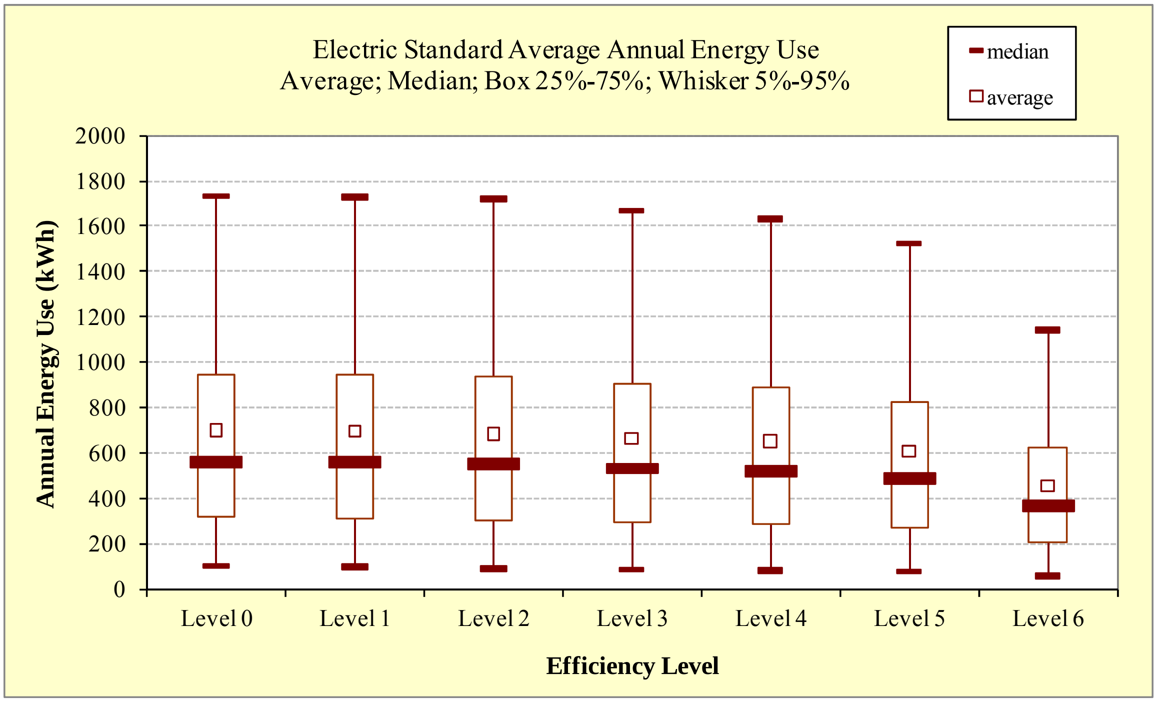

Figure 7.3.1 Range of Annual Energy Use for Vented Electric Standard Clothes Dryers

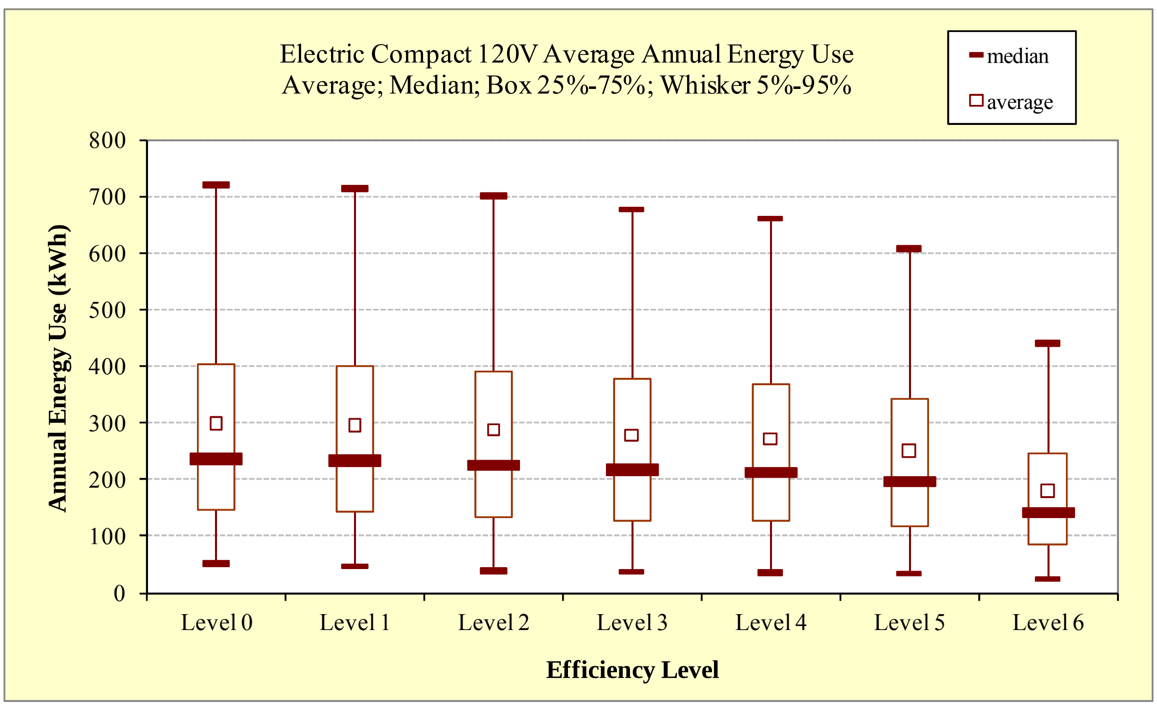

Figure 7.3.2 Range of Annual Energy Use for Vented Electric Compact 120V Clothes Dryers

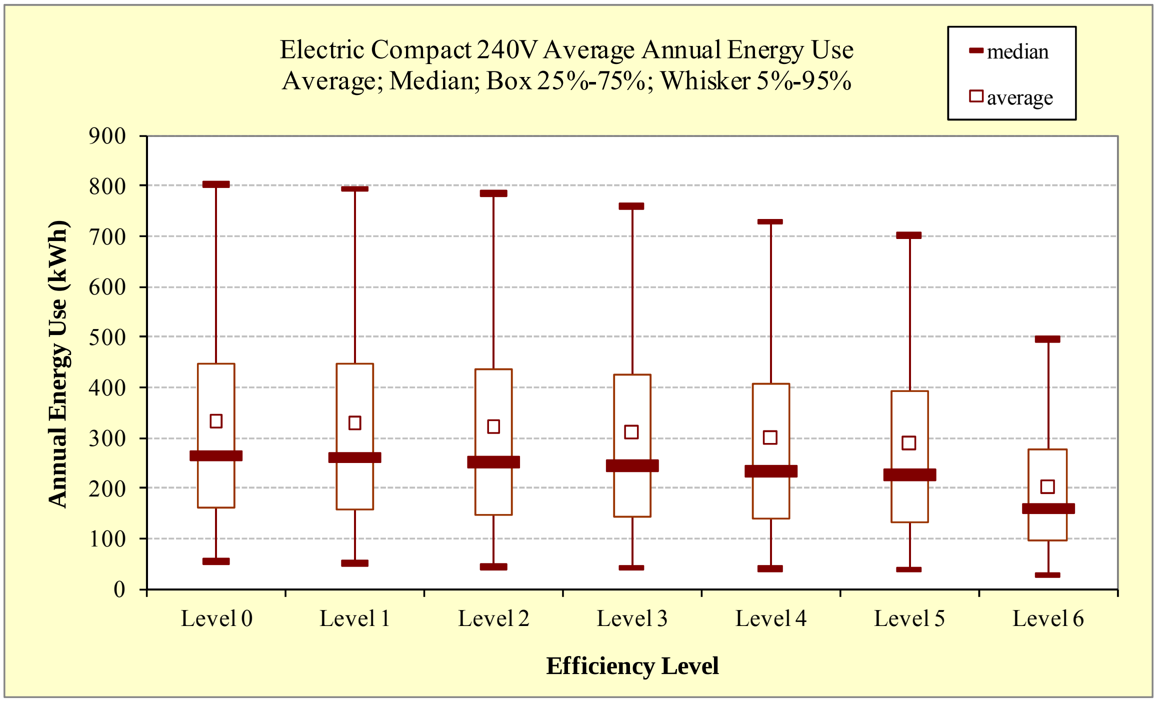

Figure 7.3.3 Range of Annual Energy Use for Vented Electric Compact 240V Clothes Dryers

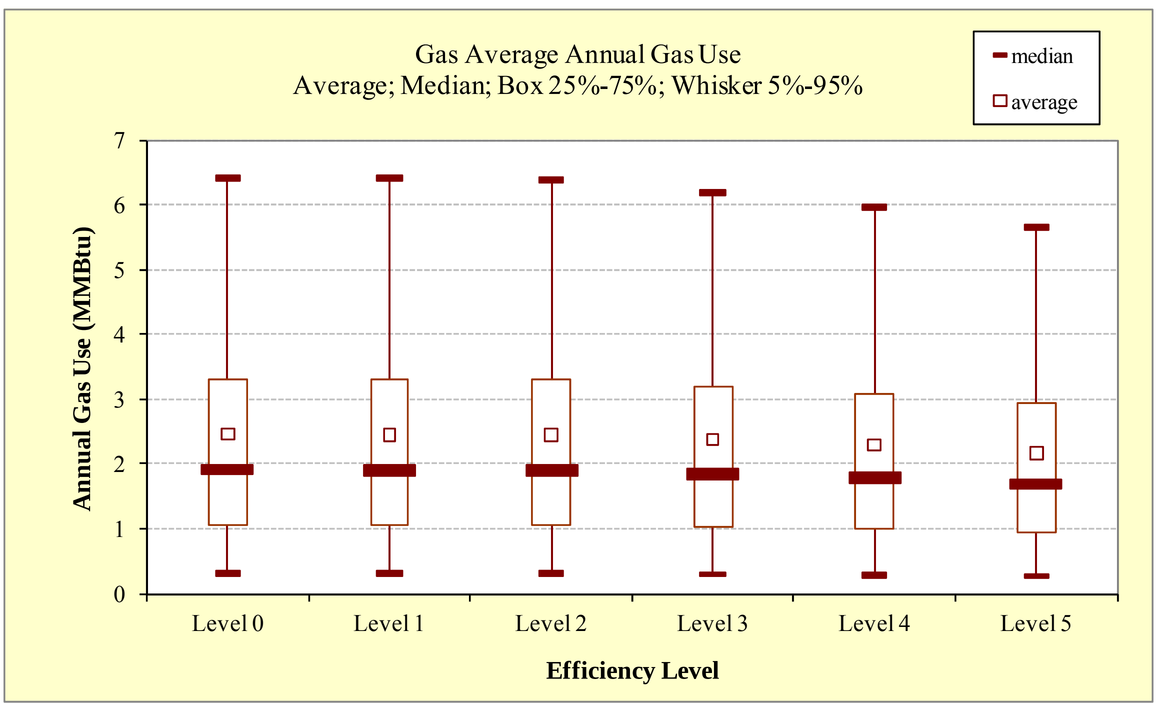

Figure 7.3.4 Range of Annual Gas Use for Vented Gas Clothes Dryers

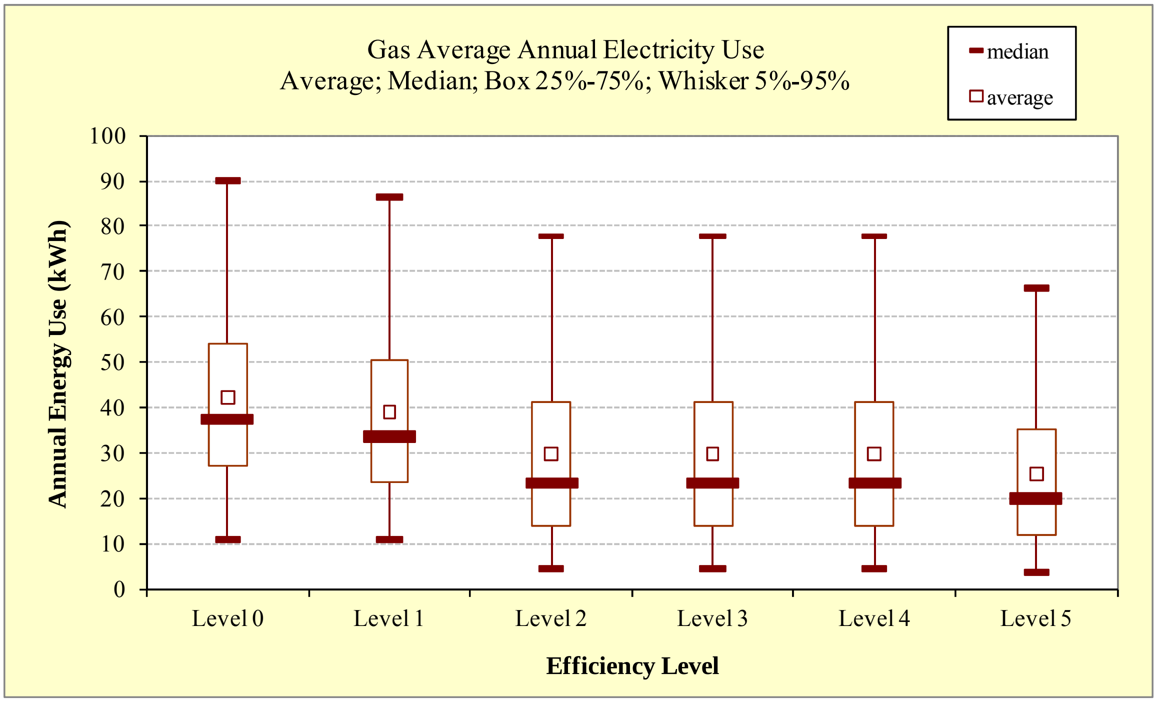

Figure 7.3.5 Range of Annual Electricity Use for Vented Gas Clothes Dryers

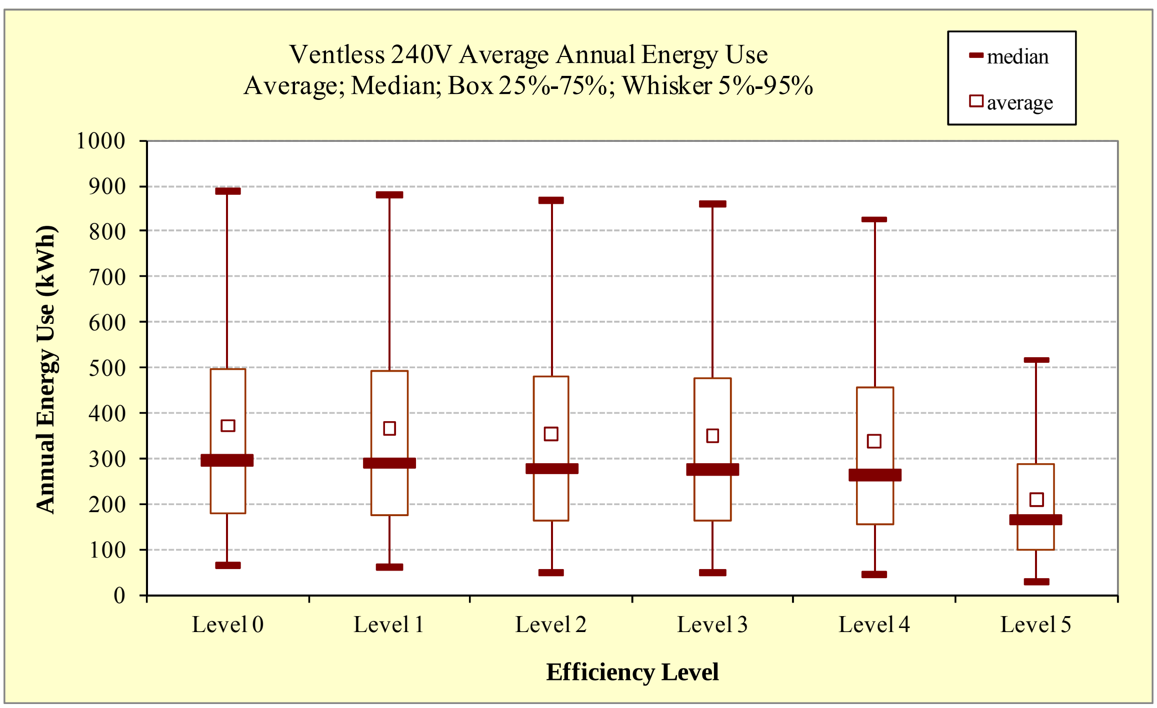

Figure 7.3.6 Range of Annual Energy Use for Vent-less 240V Clothes Dryers

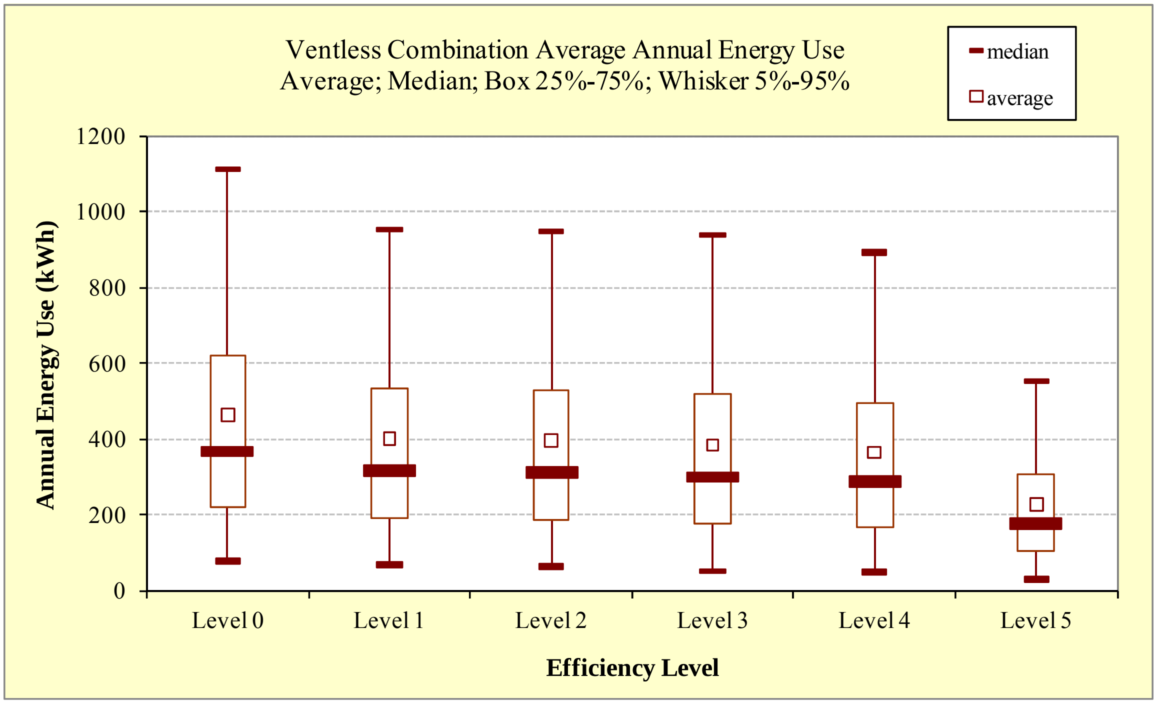

Figure 7.3.7 Range of Annual Energy Use for Vent-less Combination Washer/Dryers

7.3.4 Average Annual Energy Consumption by Efficiency Level

Tables 7.3.4 through 7.3.6 present the average annual energy consumption by efficiency level for each considered clothes dryer product class.

Table 7.3.4 Electric Standard and Gas Clothes Dryer: Average Annual Energy Consumption by Efficiency Level

Electric		Gas		
CEF (lb/kWh)	kWh/year	CEF (lb/kWh)	MMBtu/ year	kWh/year
3.55	718	3.14	2.53	42.2
3.56	716	3.16	2.53	39.0
3.61	707	3.20	2.53	29.8
3.73	684	3.30	2.45	29.8
3.81	670	3.41	2.37	29.8
4.08	627	3.61	2.25	25.5
5.42	476	--	--	--

Table 7.3.5 Electric Compact Vented Dryer: Average Annual Energy Consumption by Efficiency Level

120V		240V	
CEF (lb/kWh)	kWh/year	CEF (lb/kWh)	kWh/year
3.43	317	3.12	353
3.48	314	3.16	349
3.61	305	3.27	340
3.72	295	3.36	331
3.80	289	3.48	319
4.08	268	3.60	308
5.41	198	4.89	223

Table 7.3.6 Electric Compact Vent-less Dryer and Combination Washer/Dryer: Average Annual Energy Consumption by Efficiency Level

Compact Vent-less Dryer (240V)		Combination Washer-Dryer	
CEF (lb/kWh)	**kWh/year**	**CEF (lb/kWh)**	**kWh/year**
2.55	372	2.08	463
2.59	366	2.35	399
2.69	354	2.38	394
2.71	351	2.46	383
2.80	337	2.56	365
4.03	210	3.69	226

7.4 ROOM AIR CONDITIONERS

7.4.1 General Approach

DOE calculated the annual energy consumption of a room air conditioner using the following equation:

$$RAC_{ENERGY} = \frac{Capacity * OH}{IEER}$$

Where:

RAC_{ENERGY} = room air conditioner annual energy consumption (kWh/year),
Capacity = rated capacity in Btu/h,
OH = operating hours per year,
CEER = Combined Energy Efficiency Ratio in Btu/h/W.

DOE began with the data reported by RECS 2005 on the annual energy consumption (field energy consumption) for room air conditioning, referred to as $FEC(all)_{RECS}$. The reported end-use quantities were not based on metering of individual appliances; rather, EIA used a regression technique to estimate how much of the total annual electricity consumption for each household can be attributed to each end-use category.[e] The reported field energy consumption refers to the consumption of all of the room air conditioners in a home.

[e] The desire to use a large number of independent variables without using a large number of interaction terms and the desire to adapt the regression procedures to account for heteroscedastic error terms led to the use of a nonlinear regression technique. For more information, see: http://www.eia.doe.gov/pub/consumption/residential/append_c.pdf

RECS 2005 also reports the number of room air conditioners in the home. Of all homes that use a room air conditioner, 35 percent have two room air conditioners and 14 percent have three or more room air conditioners. To estimate the energy consumption of a single room air conditioner, referred to as $FEC_{RECS,}$ DOE divided $FEC(all)_{RECS}$ by the reported number of room air conditioners. For houses with both central air conditioning and room air conditioning, DOE scaled $FEC(all)_{RECS}$ using a relative use factor. For more information on the relative use factor used, see Appendix 7-C. Although in reality the utilization of each of the room air conditioners in a home may vary, DOE has no way to estimate such variation.

For commercial-sector room air conditioners, CBECS does not report annual energy consumption for room air conditioning, so DOE estimated the energy consumption using variables specific to each building in the sample and data on cooling degree-days.

In conducting the analysis of energy use by products that would meet some future standard, DOE effectively substituted the room air conditioners in the sample residential and commercial buildings with a new product of identical product class (capacity) but with different energy efficiency. In order for the estimate of new room air conditioner energy consumption to reflect field conditions, DOE needed to estimate the number of room air conditioner operating hours for each household or commercial building in the samples.

7.4.2 Operating Hours

7.4.2.1 Residential

DOE calculated the annual room air conditioner active mode operating hours for each residential sample unit using the following formula:

$$OH = \frac{FEC_{RECS} * EER_{RECS}}{Capacity} * BldgShellAdj * CDDAdj$$

Where:

OH = operating hours per year,
FEC_{RECS} = field energy consumption for a room air conditioner,
EER_{RECS} = the estimated EER of the room air conditioner in the sample home,
$Capacity$ = the room air conditioner capacity in Btu/h,
$BldgShellAdj$ = adjustment to building shell efficiency in 2014, precent,
$CDDAdj$ = cooling degree days (CDD) adjustment in Btu/h.

The derivation of FEC_{RECS} was discussed above. The capacity is given by the product class; DOE used the same representative capacities for each class as it did in the engineering analysis.

To ensure that the estimated operating hours are representative of future conditions, DOE used the building shell index factor from *Annual Energy Outlook* (*AEO) 2010* in 2014 for space cooling in all homes of 0.96 and 115 year historical average CDD by census division. The building shell index factor decreased energy use by 4 percent, while the CDD adjustment factor decreased energy use by 10 percent on average.

DOE estimated the EER of the room air conditioner in each sample household by matching the age of the room air conditioner given by RECS with the average EER for the specific product class in the year of its vintage. In RECS, the age of a room air conditioner is given in one of the five bins shown in Table 7.4.1. DOE assumed a uniform distribution within each vintage bin and assigned an age to the room air conditioner in each sample household.

Table 7.4.1 RECS Vintage Bins for Room Air Conditioner

Bin	Age of unit
1	Less than 2 years old
2	2 to 4 years old
3	5 to 9 years old
4	10 to 19 years old
5	20 years or older

Once the vintage year was determined, DOE assigned an EER to the unit equal to the average EER for the appropriate capacity for that year. To derive a time series of average EER by capacity, DOE began with data from AHAM on total shipment-weighted average EER for 1972–2007.[12] AHAM also provided average EER data by product class (capacity) for 2005–2007.[12] To develop the EER values by product class (capacity) for earlier years, DOE first assumed that all of the products shipped in each product class had the minimum efficiency required by the standard in each particular year. DOE then estimated the shares of total shipments by product class in each year using data for 1990, 1993 and 2005–2007, and calculated a total shipment-weighted EER. DOE then calculated scalars for each year from the ratio of the actual total shipment-weighted EER to the calculated EER, and then applied the scalars to the minimum efficiency required for each product class in each year. Table 7.4.2 shows the AHAM data on total shipment-weighted average EER and the average EER estimated for the representative product classes.

Table 7.4.2 Average Room Air Conditioner EER by Product Class and Year Sold

Year	Shipment Weighted EER	Derived Average EER*			
		< 6000 Btu/h	8000-13,999 Btu/hr (PC 3)	≥ 20,000 Btu/hr	8000-13,999 Btu/hr (PC 8)
2007	9.81	9.80	10.10	9.10	9.50
2006	10.02	9.80	10.40	9.20	9.50
2005	9.95	9.80	10.10	9.10	9.40
2004	9.71	9.70	9.86	8.83	9.15
2003	9.75	9.70	9.92	8.89	9.21
2002	9.75	9.70	9.92	8.88	9.21
2001	9.63	9.70	9.80	8.50	8.73
2000**	9.3	9.03	9.70	8.50	8.73
1999	9.07	8.56	9.63	8.50	8.73
1998	NA	8.56	9.63	8.50	8.73
1997	9.09	8.57	9.64	8.50	8.73
1996	9.08	8.55	9.62	8.50	8.73
1995	9.03	8.49	9.55	8.50	8.73
1994	8.97	8.42	9.47	8.50	8.73
1993	9.05	8.50	9.56	8.50	8.73
1992	8.88	8.31	9.35	8.50	8.73
1991	8.8	8.24	9.27	8.45	8.73
1990**	8.73	8.18	9.20	8.39	8.69
1989	8.48	7.95	8.95	8.15	8.45
1988	8.23	7.72	8.68	7.91	8.20
1987	8.06	7.56	8.51	7.75	8.03
1986	7.8	7.32	8.23	7.50	7.77
1985	7.7	7.22	8.13	7.40	7.67
1984	7.48	7.02	7.89	7.19	7.45
1983	7.29	6.84	7.69	7.01	7.27
1982	7.14	6.70	7.53	6.86	7.12
1981	7.06	6.62	7.45	6.79	7.04
1980	7.02	6.58	7.41	6.75	7.00
1978	6.72	6.44	7.25	6.60	6.85
1972	5.98	6.30	7.09	6.46	6.70

* Shaded area values were provided by AHAM[12]
** Years in which standards became effective

The estimated mean number of operating hours for the residential room air conditioner sample is 756 hours for the <6,000 Btu/h product class, 611 hours for 8,000 to 13,999 Btu/h product classes, and 175 hours for the ≥ 20,000 Btu/h product classes. For comparison, the DOE test procedure uses 750 hours per year for all room air conditioners.[3]

7.4.2.2 Commercial

DOE calculated the annual operating hours for each sample commercial-sector room air conditioner by establishing a relationship between cooling degree-days and operating hours for a number of building type and building schedule combinations. DOE assumed that a room air conditioner is operated when the outdoor air conditions are above the comfort zone described by ANSI/ASHRAE Standard 55-2004 Thermal Environmental Conditions for Human Occupancy.[13] To estimate how often this occurs, DOE used the following general equation:

$$OH55 = (a * CDD) + b$$

Where:

OH55 = average annual hours when the outdoor air conditions are above the ASHRAE Standard 55 comfort zone,

CDD = the number of annual cooling degree-days (65 F) for a given location; *a* and *b* are linear fit parameters.

DOE used data on cooling degree-days from the National Solar Radiation Database (NSRDB).[14] The 1991–2005 NSRDB is an update of the 1961–1990 NSRDB. This updated NSRDB dataset is an hourly ground-based data set of solar and meteorological fields for 1,454 stations. A total of 858 sites have a complete 15-year period of record.

After removing the sites in Hawaii, Guam, and the Caribbean islands, regressions were done to predict the hours per year above Standard 55 from the number of cooling degree-days for each year. The data points and regression lines are shown in Figure 7.4.1 for all hours of the year. The data represent 842 sites for 15 years each in the continental United States.

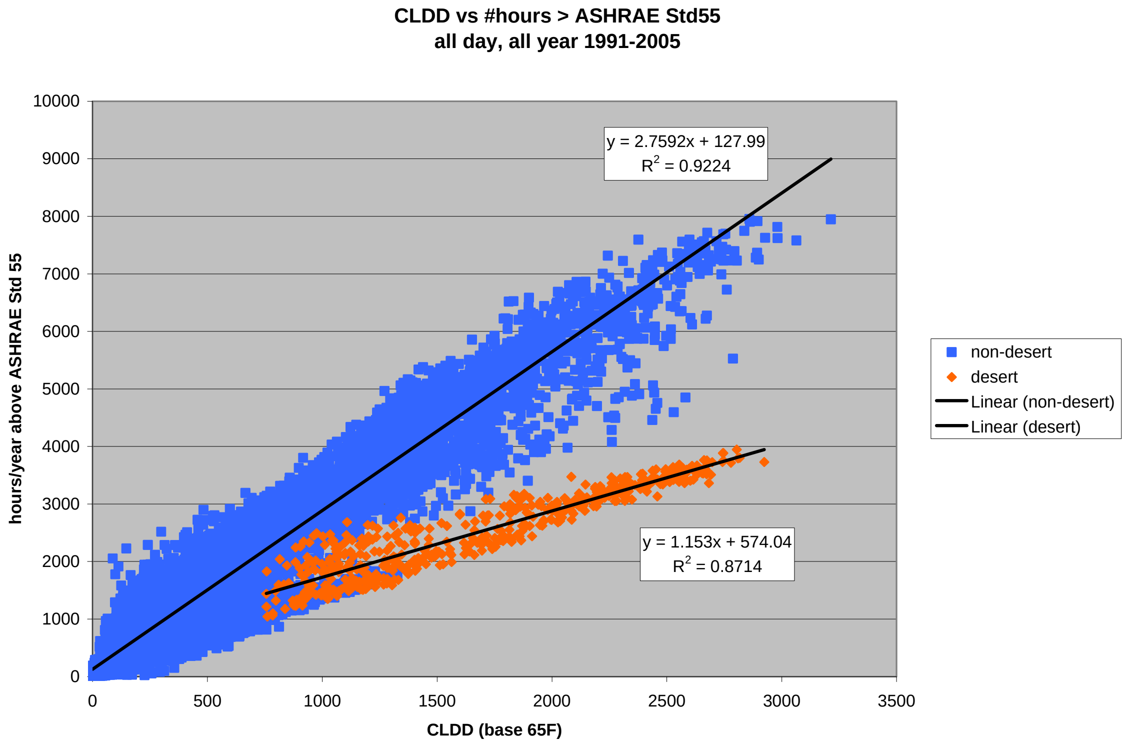

Figure 7.4.1 Hours Above ANSI/ASHRAE Standard 55-2004 as a Function of Cooling Degree-Days

As can be seen in the graph above, the data patterns are different for desert locations, where humidity is not a present factor affecting comfort. The regression equations developed from the data are shown in Table 7.3.3.

Table 7.4.3 Regression Equations

Region	Equation	R^2	# sites
Non-desert	OH55 = 2.759 x CLDD + 127.99	0.9224	809
Desert	OH55 = 1.153 x CLDD + 574.04	0.8714	33

For a given location, the number of annual hours above the ASHRAE Standard 55 comfort zone varies by schedule, which refers to the time that a building is open. Thus, DOE performed the regression for a number of combinations of building type and building schedule, yielding somewhat different equations for each combination. The building types included are: Assembly, Education, Food Service, Office, Retail, and Warehouse. For each building type, DOE estimated operating hours for the following building schedules: (1) open 24 hours a day and seven days a week (24/7); (2) open business hours Monday through Friday; (3) open business hours Monday through Saturday; (4) open business hours Monday through Friday and Sunday; (5) open business hours all week. Each of these schedules yields a variation of the above equations.

To estimate the room air conditioner operating hours for each of the buildings in the CBECS room air conditioner sample, DOE identified the building type and the building schedule using information provided by CBECS, and used the appropriate equation (non-desert or desert) combined with the number of cooling degree-days for the location of the building. It adjusted the results with a scaling factor to account for the difference between the number of building operating hours assumed to derive the equations and the actual building operating hours reported by CBECS.

The above approach provides a 'best guess' of the room air conditioner operating hours for a particular CBECS building. However, operating hours are affected by some factors not included in the analysis, such as interior heat gains from equipment or people and solar gains. To develop a range for the number of operating hours for each sample building, DOE added an error band to the value derived using the regression equation. The error band includes values that are ± 10% from the regression line for the appropriate building type/schedule combination.

The estimated mean number of operating hours is 1,142 hours for the < 6,000 Btu/hr product class, 1,054 hours for the 8,000 to 13,999 Btu/hr product classes, and 1,113 hours for the greater than 20,000 Btu/hr product classes.

The commercial sector operating hours were estimated based on the cooling climate in 2003. To match the 115 year CDD average values, DOE decreased the estimated commercial sector operating hours by 2 percent on average.

7.4.3 Variability of Room Air Conditioner Annual Energy Consumption

Figures 7.4.2 to 7.4.13 show the range of average annual energy consumption by efficiency level within the residential and commercial samples for each representative product class. The higher utilization of room air conditioners in the commercial sector is evident in the figures.

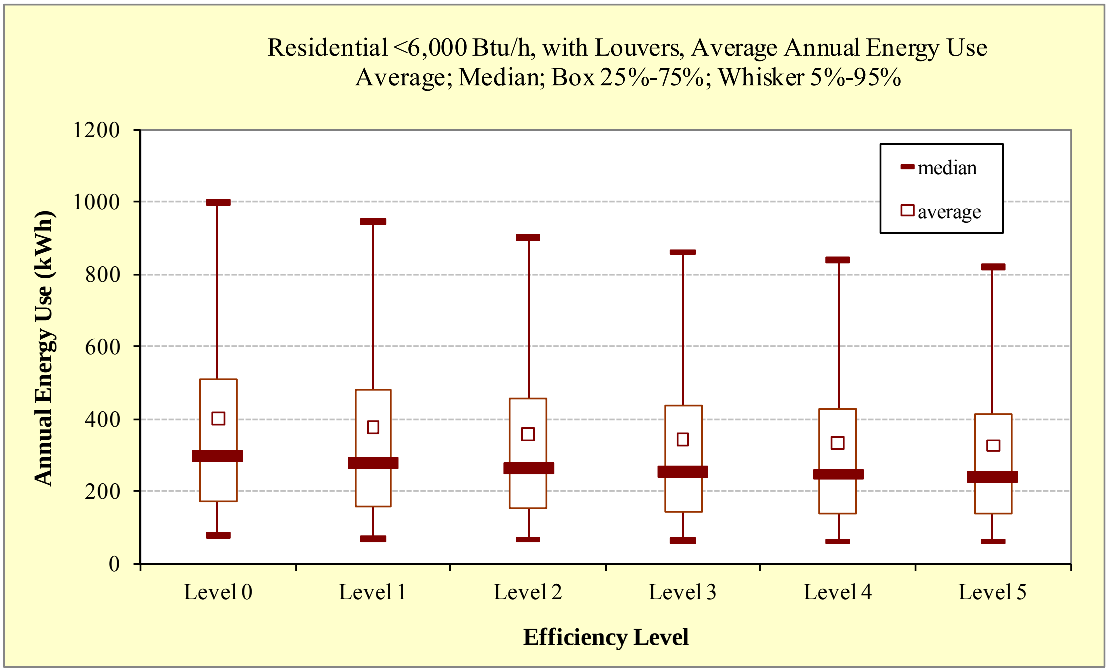

Figure 7.4.2 Range of Annual Energy Use for Residential Room Air Conditioners without Reverse Cycle and with Louvers, less than 6,000 Btu/h

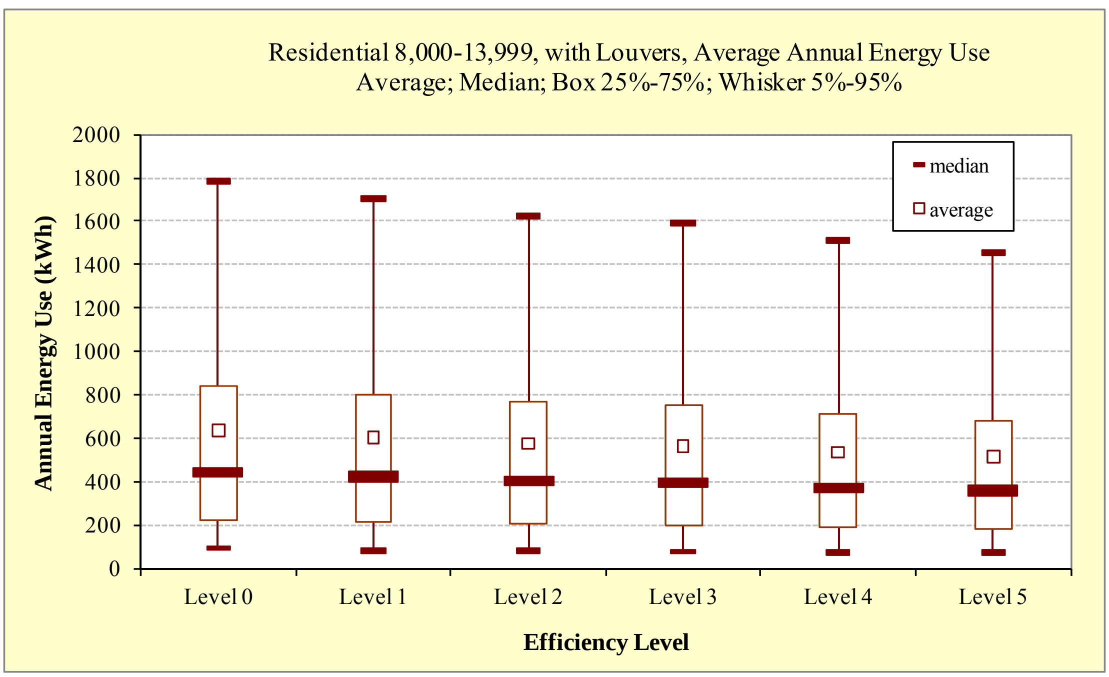

Figure 7.4.3 Range of Annual Energy Use for Residential Room Air Conditioners without Reverse Cycle and with Louvers, 8,000–13,999 Btu/h

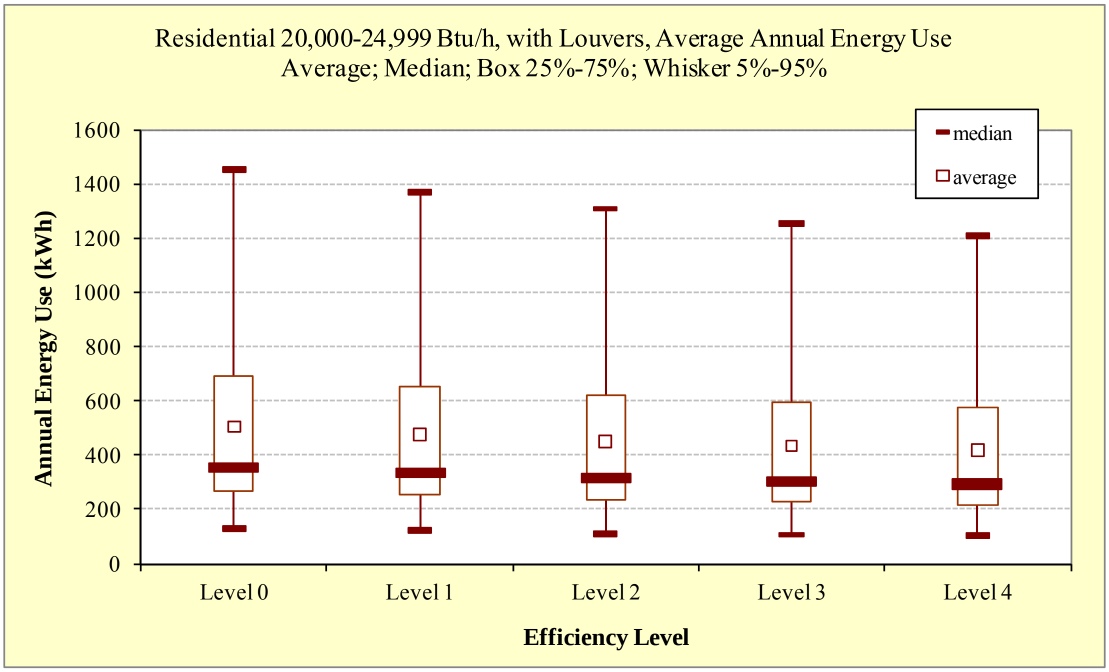

Figure 7.4.4 Range of Annual Energy Use for Residential Room Air Conditioners without Reverse Cycle and with Louvers, 20,000–24,999 Btu/h

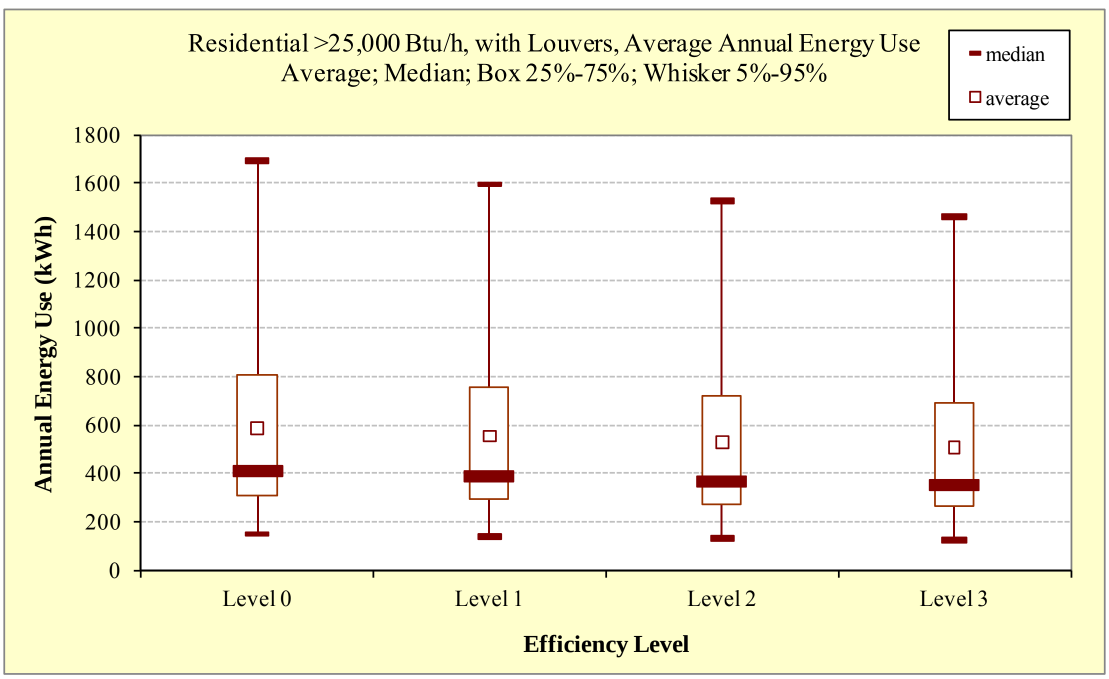

Figure 7.4.5 Range of Annual Energy Use for Residential Room Air Conditioners without Reverse Cycle and with Louvers, greater than 25,000 Btu/h

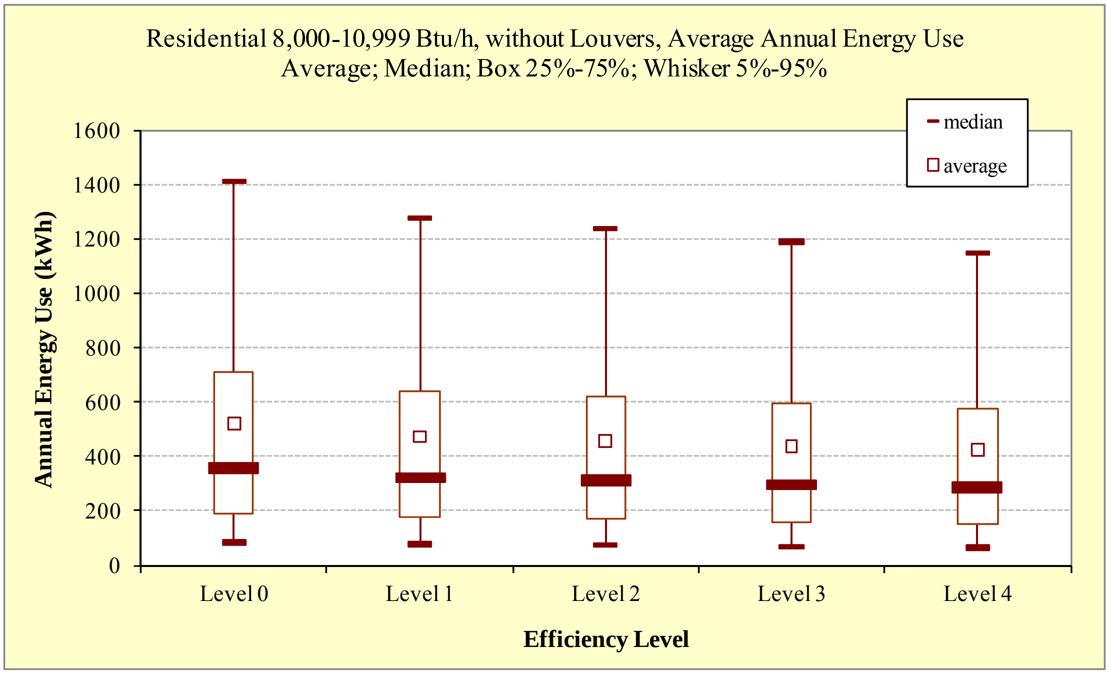

Figure 7.4.6 Range of Annual Energy Use for Residential Room Air Conditioners without Reverse Cycle and without Louvers, 8,000–10,999 Btu/h

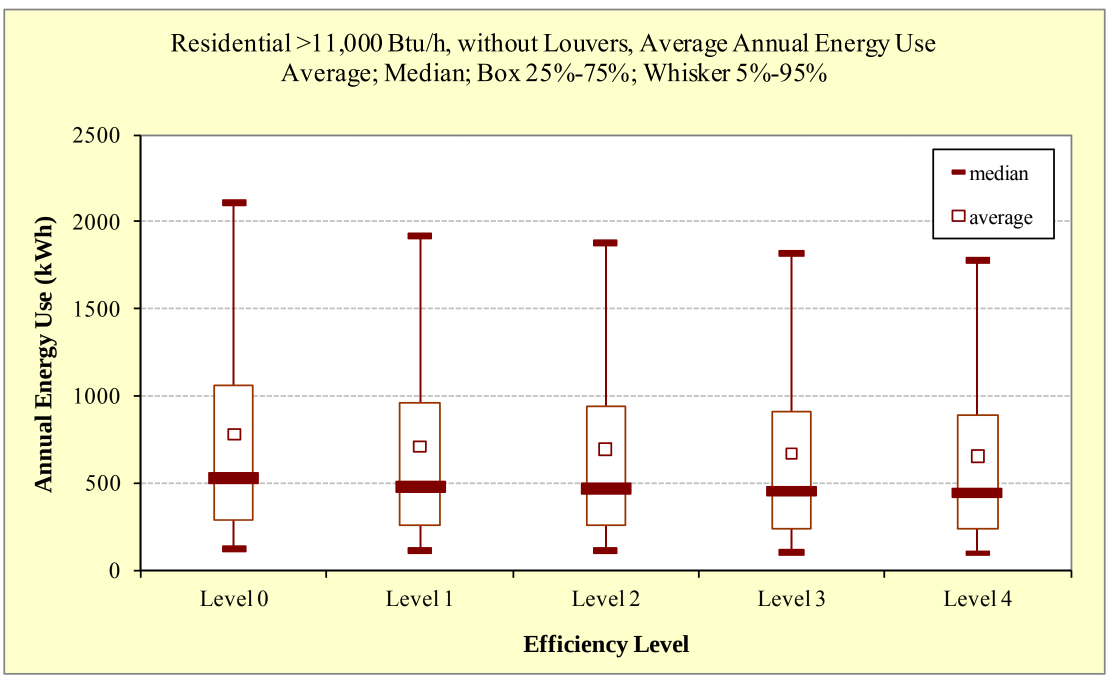

Figure 7.4.7 Range of Annual Energy Use for Residential Room Air Conditioners without Reverse Cycle and without Louvers, greater than 11,000 Btu/h

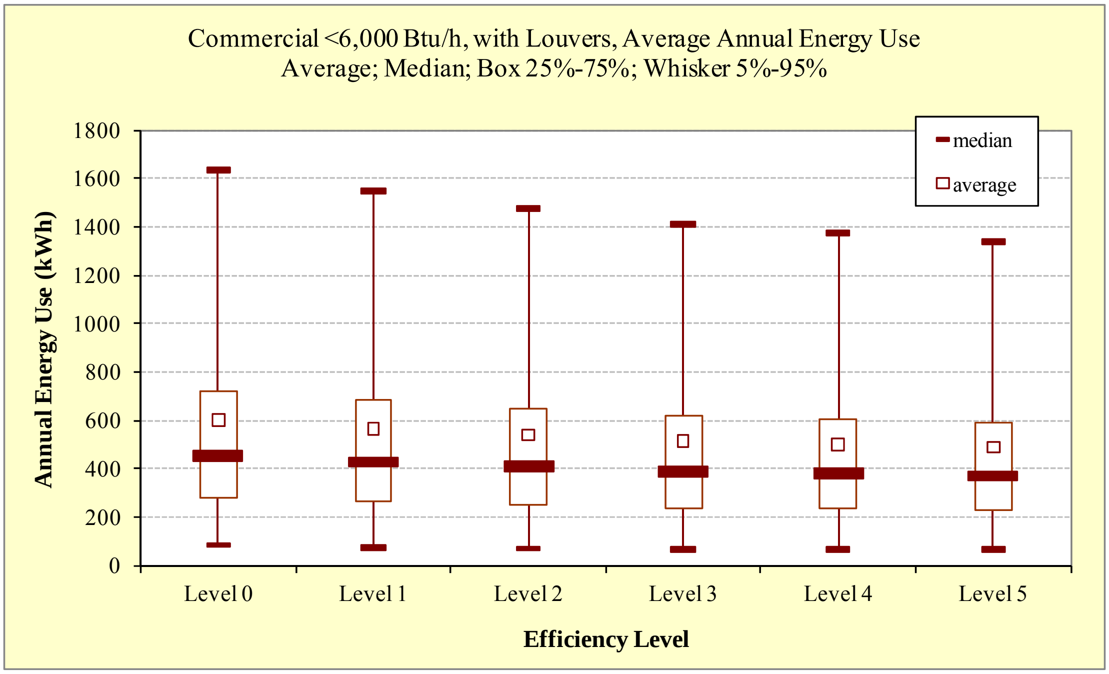

Figure 7.4.8 Range of Annual Energy Use for Commercial Room Air Conditioners without Reverse Cycle and with Louvers, Less than 6,000 Btu/h

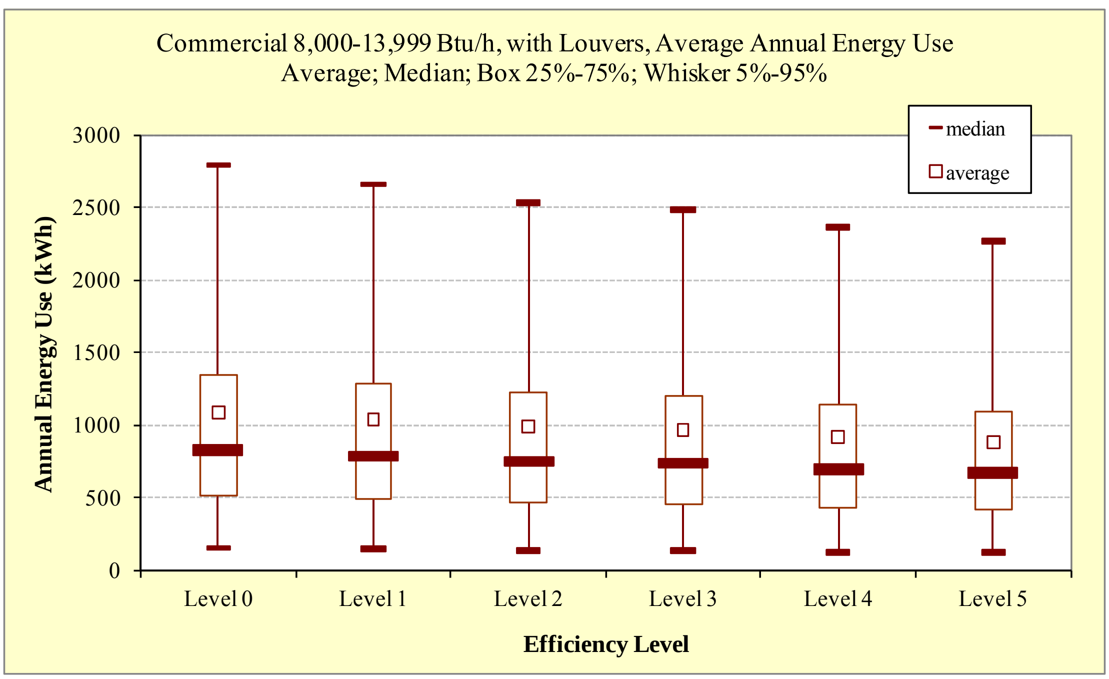

Figure 7.4.9 Range of Annual Energy Use for Commercial Room Air Conditioners without Reverse Cycle and with Louvers, 8,000–13,999 Btu/h

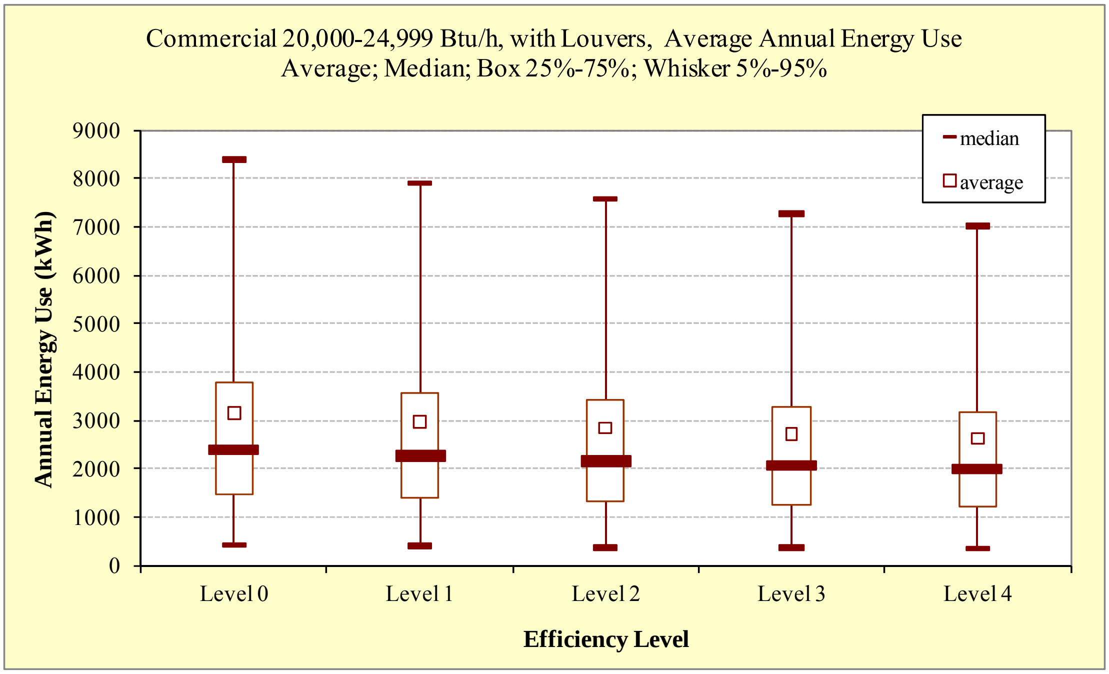

Figure 7.4.10 Range of Annual Energy Use for Commercial Room Air Conditioners without Reverse Cycle and with Louvers, 20,000–24,999 Btu/h

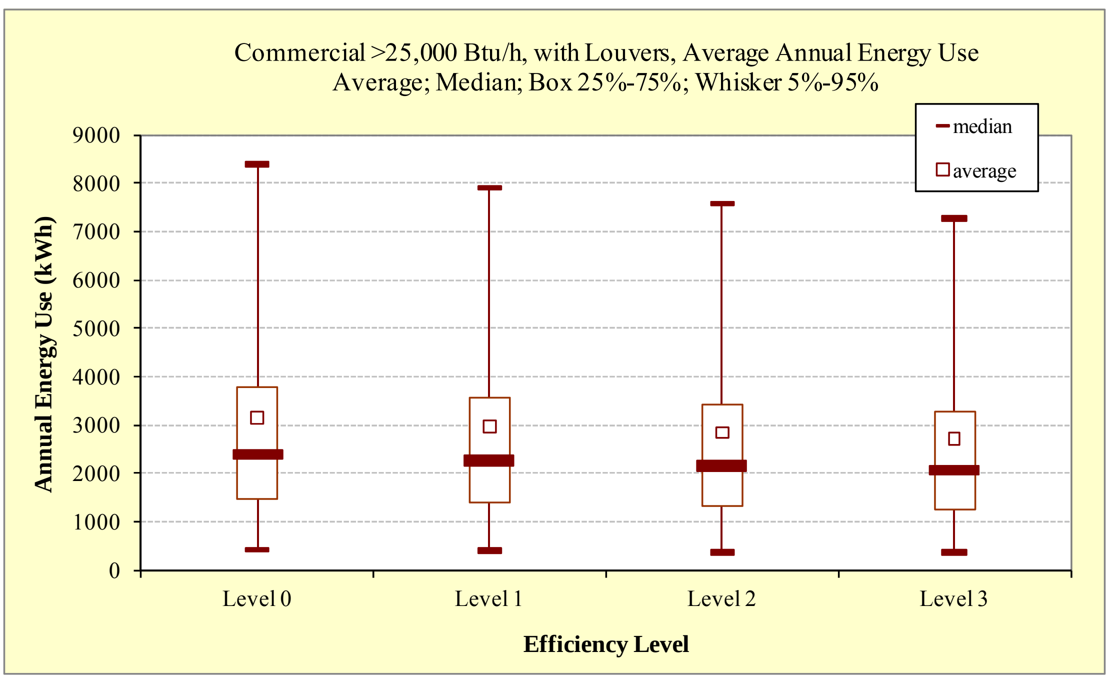

Figure 7.4.11 Range of Annual Energy Use for Commercial Room Air Conditioners without Reverse Cycle and with Louvers, greater than 25,000 Btu/h

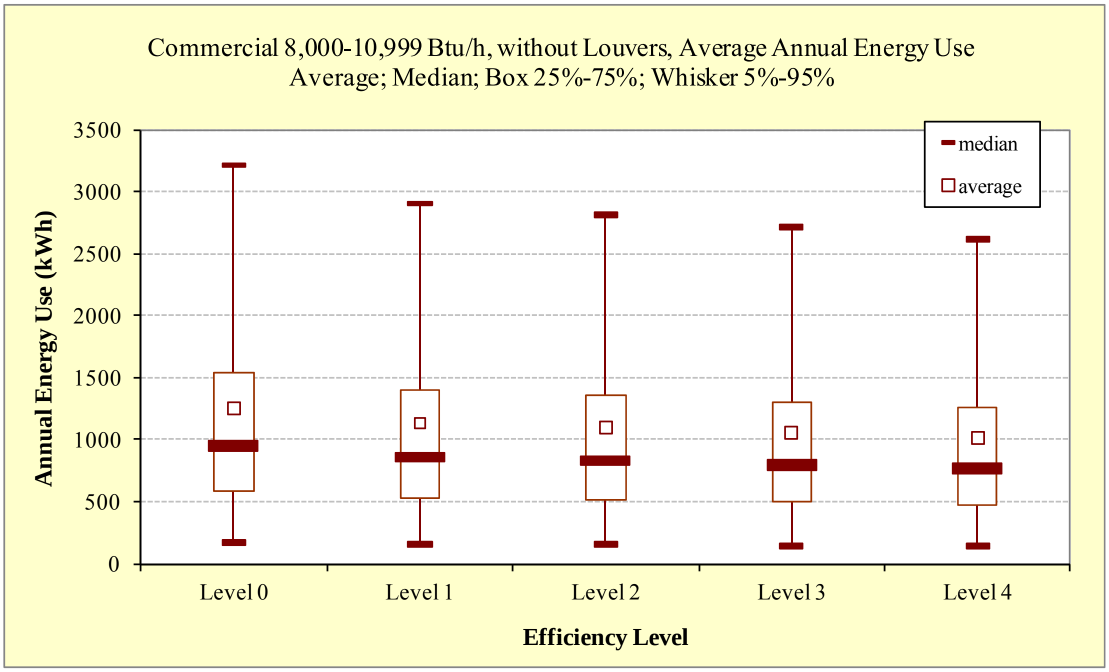

Figure 7.4.12 Range of Annual Energy Use for Commercial Room Air Conditioners without Reverse Cycle and without Louvers, 8,000–10,999 Btu/h

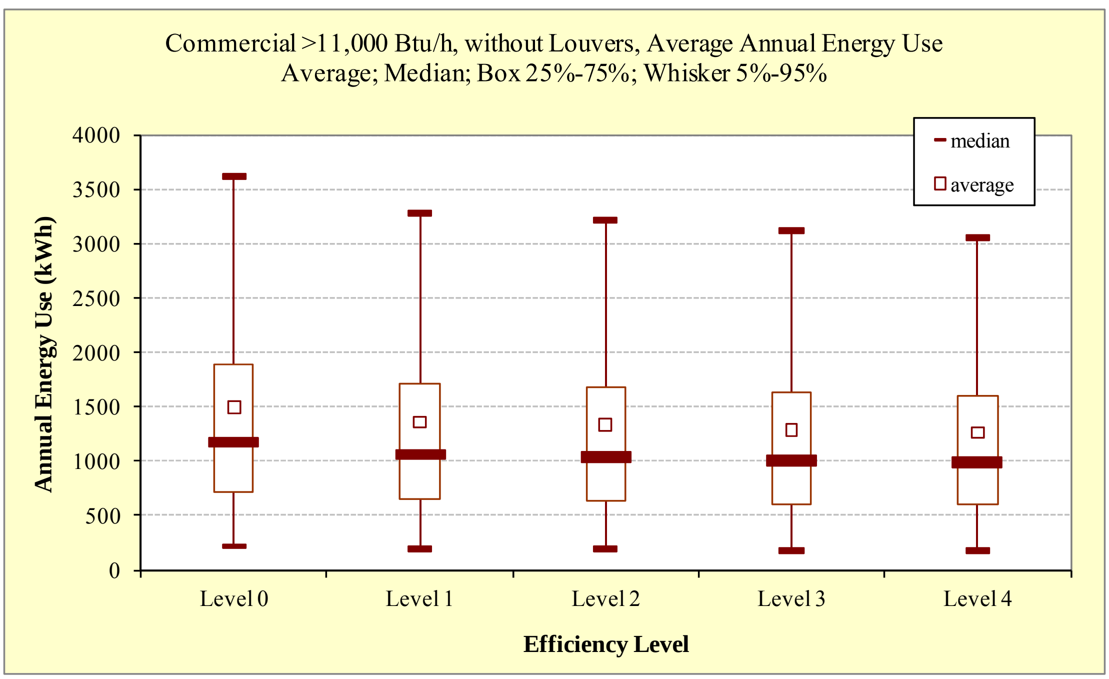

Figure 7.4.13 Range of Annual Energy Use for Commercial Room Air Conditioners without Reverse Cycle and without Louvers, greater than 11,000 Btu/h

7.4.4 Average Annual Energy Consumption by Efficiency Level

Tables 7.4.4 through 7.4.9 show the considered efficiency levels and corresponding calculated average annual energy consumption for each product class when the product is used in the residential or commercial sector.

Table 7.4.4 Room Air Conditioner, Without Reverse Cycle and with Louvers, less than 6,000 Btu/h: Average Annual Energy Use

Efficiency (CEER)	Residential (kWh)	Commercial (kWh)
9.52	401	599
10.1	376	565
10.6	358	539
11.1	342	514
11.4	334	502
11.7	326	489

Table 7.4.5 Room Air Conditioner, Without Reverse Cycle and with Louvers, 8,000–13,999 Btu/h: Average Annual Energy Use

Efficiency (CEER)	Residential (kWh)	Commercial (kWh)
9.69	636	1088
10.2	604	1035
10.7	576	987
10.9	565	969
11.5	535	918
12.0	514	883

Table 7.4.6 Room Air Conditioner, Without Reverse Cycle and with Louvers, 20,000-24,999 Btu/h: Average Annual Energy Use

Efficiency (CEER)	Residential (kWh)	Commercial (kWh)
8.47	506	3153
9.0	477	2968
9.4	452	2841
9.8	434	2726
10.2	419	2630

Table 7.4.7 Room Air Conditioner, Without Reverse Cycle and with Louvers, greater than 25,000 Btu/h: Average Annual Energy Use

Efficiency (CEER)	Residential (kWh)	Commercial (kWh)
8.48	589	3153
9.0	555	2969
9.4	526	2842
9.8	505	2726

Table 7.4.8 Room Air Conditioner, Without Reverse Cycle and with Louvers, greater than 25,000 Btu/h: Average Annual Energy Use

Efficiency (CEER)	Residential (kWh)	Commercial (kWh)
8.41	523	1252
9.3	474	1133
9.6	459	1098
10.0	438	1055
10.4	423	1018

Table 7.4.9 Room Air Conditioner, Without Reverse Cycle and with Louvers, greater than 25,000 Btu/h: Average Annual Energy Use

Efficiency (CEER)	Residential (kWh)	Commercial (kWh)
8.44	779	1498
9.3	707	1360
9.5	693	1332
9.8	668	1291
10.0	654	1262

7.4.5 Estimating Room Air Conditioner Energy Use by Month

Room air conditioner use is concentrated in the warm parts of the year. In conducting the LCC analysis for room air conditioners (see chapter 8), DOE used monthly electricity prices because electricity tariffs show seasonal variation in many parts of the country. Therefore, to properly calculate room air conditioner operating costs, DOE needed to estimate how the annual room air conditioner electricity use for each sample household is apportioned over the year.

To estimate electricity use by month, DOE utilized data on seasonal climate variation, as measured by cooling degree-days. RECS 2005 provides data on yearly heating and cooling degree-days for each household in the sample, but does not break this information down by month. To estimate monthly cooling degree days for the households in the RECS sample, DOE developed an approach to match each household with a corresponding NOAA weather station. After matching the household to a weather station location, DOE utilized the monthly cooling-degree day data from the corresponding weather station to estimate the percentage of household energy use per month. See appendix 7-D for more details.

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

8.1 INTRODUCTION

This chapter describes the U.S. Department of Energy (DOE)'s methodology for analyzing the economic impacts of possible energy efficiency standards for clothes dryers and room air conditioners on individual consumers. The effect of standards on individual consumers includes 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 effect of standards on individual consumers:

- **Life-cycle cost** (LCC) is the total consumer expense over the life of an appliance, including purchase expense 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 consumers 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. Where LCC and PBP are estimated over a range of inputs reflecting actual conditions, rebuttable payback period is based on laboratory conditions, specifically DOE test procedure inputs.

Inputs to the LCC and PBP calculations are discussed in sections 8.2 and 8.3, respectively, of this chapter. Results for the LCC and PBP are presented in section 8.4. The rebuttable PBP is discussed in section 8.5. Key variables and calculations are presented for each metric. DOE performed the calculations discussed here using a series of Microsoft Excel® spreadsheets which are accessible on the Internet (http://www.eere.energy.gov/buildings/appliance_standards/). Details and instructions for using the spreadsheets are discussed in appendix 8-A.

8.1.1 General Approach for LCC and PBP Analyses

LCC is the total consumer expense over the life of an appliance, including purchase expense 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. DOE defines LCC by the following equation:

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

Where:

LCC = Life-cycle cost in dollars,
IC = Total installed cost in dollars,
$\sum$ = Sum over the lifetime, from year 1 to year N,
N = Lifetime of appliance in years,
OC = Operating cost in dollars,
r = Discount rate, and
t = Year for which operating cost is being determined.

The payback period is the amount of time it takes the consumer to recover the estimated higher purchase expense of more energy-efficient products as a result of lower operating costs. Numerically, the PBP is the ratio of the increase in purchase expense (i.e., from a less energy-efficient design to a more energy-efficient design) to the decrease in annual operating expenditures. This type of calculation is known as a "simple" payback period, because it does not take into account changes in operating expense over time or the time value of money; the calculation is done at an effective discount rate of zero percent.

The equation for PBP is:

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

Where:

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

Payback periods are expressed in years. Payback periods greater than the life of the product indicate that the increased total installed cost is not recovered with the 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 analyses by modeling both the uncertainty and variability in the inputs using Monte Carlo simulation and probability distributions. A detailed explanation of Monte Carlo simulation and the use of probability distributions is contained in appendix 8-B. DOE developed LCC and PBP spreadsheet models incorporating both Monte Carlo simulation and probability distributions by using Microsoft Excel® spreadsheets combined with Crystal Ball® (a commercially available add-on program).

In addition to characterizing several of the inputs to the analyses with probability distributions, DOE developed a sample of individual households that use each of the appliances. By developing household samples, DOE was able to perform the LCC and PBP calculations for each household to account for the variability in energy consumption and/or energy price associated with each household. For room air conditioners, DOE also developed a sample of commercial buildings that use this product.

As described in chapter 7, DOE used the DOE Energy Information Administration (EIA)'s 2005 Residential Energy Consumption Survey (RECS) to develop household samples for room air conditioners and clothes dryers.[1] The 2005 RECS consists of 4,382 housing units and was constructed by the EIA to be a national representation of the household population in the United States. DOE used RECS to establish the variability of annual energy use of clothes dryers and room air conditioners and of energy prices. DOE was able to assign a unique annual energy use and/or energy price to each household in the sample. Due to the large sample of households considered in the LCC and PBP analyses, the range of annual energy use and/or energy prices is quite large. (The actual ranges of energy consumption were presented in chapter 7.) The variability across households in annual energy use and/or energy pricing contributes to the range of LCCs and PBPs calculated for any particular standard level.

DOE displays the LCC and PBP results as distributions of impacts compared to the baseline conditions. Results are presented at the end of this chapter and are based on 10,000 samples per Monte Carlo simulation run. To illustrate the implications of the analyses, DOE generated a frequency chart depicting the variation in LCC and PBP for each standard level considered.

8.1.2 Overview of LCC and PBP Inputs

DOE categorizes inputs to the LCC and PBP analyses as follows: (1) inputs for establishing the purchase expense, otherwise known as the total installed cost, and (2) inputs for calculating the operating cost.

The primary inputs for establishing the total installed cost are:

- *Baseline manufacturer cost*: The costs incurred by the manufacturer to produce products meeting existing minimum efficiency standards.

- *Standard-level manufacturer cost increases*: The change in manufacturer cost associated with producing products to meet a particular standard level.

- *Markups and sales tax*: The markups and sales tax associated with converting the manufacturer cost to a consumer product cost.

- *Installation cost*: The cost to the consumer of installing the product. The installation cost represents all costs required to install the product other than the marked-up consumer product cost. The installation cost includes labor, overhead, and any miscellaneous materials and parts. Thus, the total installed cost equals the consumer product cost plus the installation cost.

The primary inputs for calculating the operating cost are:

- *Product energy consumption*: The product energy consumption is the site energy use associated with operating the product.

- *Product efficiency*: The product efficiency dictates the product energy consumption associated with standard-level products (i.e., products with efficiencies greater than baseline products).

- *Energy prices*: Energy prices are the prices paid by consumers for energy (i.e., electricity or gas).

- *Energy price trends*: DOE used the EIA *Annual Energy Outlook 2009* (*AEO2009*) to forecast energy prices into the future for the results presented in this chapter.

- *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 discounted future expenditures to establish their present value.

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

Figure 8.1.1 graphically depicts the relationships between the installed cost and operating cost inputs for the calculation of the LCC and PBP. In the figure below, the yellow boxes indicate the inputs, the green boxes indicate intermediate outputs, and the blue boxes indicate the final outputs (the LCC and PBP).

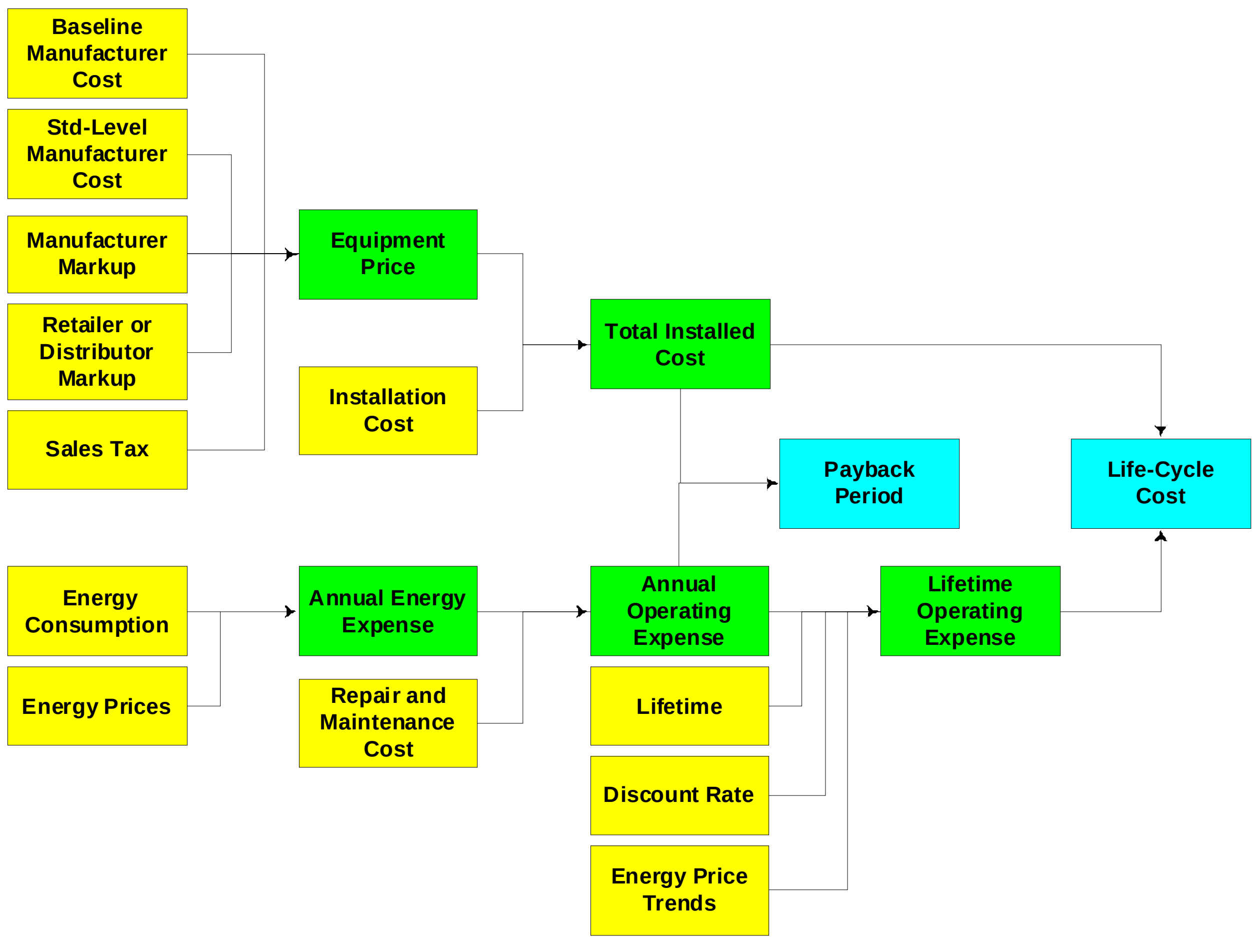

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

Tables 8.1.1 and 8.1.2 summarize the input values that DOE used to calculate the LCC and PBP for clothes dryers and room air conditioners, respectively. Each table summarizes the total installed cost inputs and the operating cost inputs including the lifetime, discount rate, and energy price trends. DOE characterized all of the total cost inputs with single-point values, but characterized several of the operating cost inputs with probability distributions that capture the input's uncertainty and/or variability. For those inputs characterized with probability distributions, the values provided in the following tables are the average or typical values.

Table 8.1.1 Clothes Dryers: LCC and PBP Input Summary

Input	Product Class	Average or Typical Value	Characterization
Baseline Manufacturer Cost (2009$)	Vented Electric Standard	$201.46	Single-Point Value
	Vented Electric Compact 120V	$210.54	Single-Point Value
	Vented Electric Compact 240V	$210.54	Single-Point Value

	Vented Gas	$227.40	Single-Point Value
	Vent-less 240V	$559.31	Single-Point Value
	Vent-less Combination	$805.90	Single-Point Value
Standard-Level Manufacturer Cost Increase (2009$)	Vented Electric Standard	EL1 = $0.68 EL2 = $0.82 EL3 = $8.74 EL4 = $50.67 EL5 = $88.89 EL6 = $280.54	Single-Point Value
	Vented Electric Compact 120V	EL1 = $0.68 EL2 = $0.82 EL3 = $21.46 EL4 = $62.76 EL5 = $109.31 EL6 = $267.48	Single-Point Value
	Vented Electric Compact 240V	EL1 = $0.68 EL2 = $0.82 EL3 = $21.46 EL4 = $62.76 EL5 = $109.31 EL6 = $267.48	Single-Point Value
	Vented Gas	EL1 = $0.68 EL2 = $0.82 EL3 = $9.12 EL4 = $72.32 EL5 = $109.98	Single-Point Value
	Vent-less 240V	EL1 = $0.93 EL2 = $1.11 EL3 = $26.42 EL4 = $57.80 EL5 = $242.36	Single-Point Value
	Vent-less Combination	EL1 = $1.51 EL2 = $2.44 EL3 = $2.62 EL4 = $31.69 EL5 = $297.54	Single-Point Value
Manufacturer Markup	All	1.26	Single-Point Value
Retailer Markup	All	Baseline = 1.45 Incremental = 1.17	Single-Point Value
Sales Tax	All	7.15%	Single-Point Value

Baseline Installation Cost (2009$)	Vented Electric Standard	$101.38	Single-Point Value
	Vented Electric Compact 120V	$101.38	Single-Point Value
	Vented Electric Compact 240V	$101.38	Single-Point Value
	Vented Gas	$131.49	Single-Point Value
	Vent-less 240V	$99.34	Single-Point Value
	Vent-less Combination	$99.34	Single-Point Value
Annual Energy Use	Vented Electric Standard	Baseline = 718 kWh	Variability based on usage
	Vented Electric Compact 120V	Baseline = 317 kWh	Variability based on usage
	Vented Electric Compact 240V	Baseline = 353 kWh	Variability based on usage
	Vented Gas	Baseline = 2.53 MMBtu (gas) and 42 kWh (elec.)	Variability based on usage
	Vent-less 240V	Baseline = 372 kWh	Variability based on usage
	Vent-less Combination	Baseline = 463 kWh	Variability based on usage
Energy Prices	Electricity	10.8 ¢/kWh	Variability based on region
	Gas	13.09 $/MMBtu	Variability based on region
Repair and Maintenance Costs	All	Cost increases with efficiency	No cost increase with efficiency
Lifetime	All	15.94 years	Weibull distribution: 1 to 40 years
Discount Rate	All	5.0%	Custom distribution
Energy Price Trend	All	AEO 2010 Reference Case	Two sensitivities: High & Low Growth Cases

Table 8.1.2 Room Air Conditioners: LCC and PBP Input Summary

Input	Product Class	Average or Typical Value	Characterization
Baseline Manufacturer Cost (2009$)	Less than 6,000 Btu/h, with Louvers	$149.89	Single-Point Value
	8,000–13,999 Btu/h, with Louvers	$181.98 (for 8 kBtu/h) $211.49 (for 12 kBtu/h)	Single-Point Value
	20,000–24,999 Btu/h, with Louvers	$343.63	Single-Point Value
	Greater than 25,000 Btu/h, with Louvers	$390.66	Single-Point Value
	8,000–10,999	$211.07	Single-Point

<table>
<tr><td></td><td>Btu/h, without Louvers</td><td colspan="2"></td><td>Value</td></tr>
<tr><td></td><td>Greater than 11,000 Btu/h, without Louvers</td><td colspan="2">$237.29</td><td>Single-Point Value</td></tr>
<tr><td rowspan="8">Standard-Level Manufacturer Cost Increase (2009$)</td><td>Less than 6,000 Btu/h, with Louvers</td><td colspan="2">EL 1 = $6.31
EL 2 = $13.53
EL 3 = $22.72
EL 4 = $32.32
EL 5 = $75.82</td><td>Single-Point Value</td></tr>
<tr><td rowspan="2">8,000–13,999 Btu/h, with Louvers</td><td>8 kBtu/h</td><td>12 kBtu/h</td><td rowspan="2">Single-Point Value</td></tr>
<tr><td>EL 1 = $5.30
EL 2 = $12.30
EL 3 = $15.95
EL 4 = $30.92
EL 5 = $103.87</td><td>EL 1 = $2.00
EL 2 = $7.42
EL 3 = $9.33
EL 4 = $29.43
EL 5 = $47.81</td></tr>
<tr><td>20,000–24,999 Btu/h, with Louvers</td><td colspan="2">EL 1 = $8.85
EL 2 = $19.04
EL 3 = $50.66
EL 4 = $204.62</td><td>Single-Point Value</td></tr>
<tr><td>Greater than 25,000 Btu/h, with Louvers</td><td colspan="2">EL 1 = $23.52
EL 2 = $50.27
EL 3 = $229.01</td><td>Single-Point Value</td></tr>
<tr><td>8,000–10,999 Btu/h, without Louvers</td><td colspan="2">EL 1 = $4.61
EL 2 = $6.68
EL 3 = $16.63
EL 4 = $88.45</td><td>Single-Point Value</td></tr>
<tr><td>Greater than 11,000 Btu/h, without Louvers</td><td colspan="2">EL 1 = $11.72
EL 2 = $15.39
EL 3 = $26.06
EL 4 = $93.36</td><td>Single-Point Value</td></tr>
<tr><td>Manufacturer Markup</td><td>All</td><td colspan="2">1.26</td><td>Single-Point Value</td></tr>
<tr><td>Retailer Markup</td><td>All</td><td colspan="2">Baseline = 1.45
Incremental = 1.17</td><td>Single-Point Value</td></tr>
<tr><td>Sales Tax</td><td>All</td><td colspan="2">7.2%</td><td>Single-Point Value</td></tr>
<tr><td rowspan="2">Baseline Installation Cost (2009$)</td><td>Less than 6,000 Btu/h, with Louvers</td><td colspan="2">$75.42</td><td>Single-Point Value</td></tr>
<tr><td>8,000–13,999 Btu/h, with Louvers</td><td colspan="2">$108.54</td><td>Single-Point Value</td></tr>
</table>

	20,000–24,999 Btu/h, with Louvers	$178.94	Single-Point Value
	Greater than 25,000 Btu/h, with Louvers	$205.31	Single-Point Value
	8,000–10,999 Btu/h, without Louvers	$90.50	Single-Point Value
	Greater than 11,000 Btu/h, without Louvers	$126.18	Single-Point Value
Annual Energy Use	Less than 6,000 Btu/h, with Louvers	Residential baseline use = 401 kWh Commercial baseline use = 599 kWh	Variability based on usage
	8,000–13,999 Btu/h, with Louvers	Residential baseline use = 636 kWh Commercial baseline use = 1088 kWh	Variability based on usage
	20,000–24,999 Btu/h, with Louvers	Residential baseline use = 506 kWh Commercial baseline use = 3153 kWh	Variability based on usage
	Greater than 25,000 Btu/h, with Louvers	Residential baseline use = 589 kWh Commercial baseline use = 3153 kWh	Variability based on usage
	8,000–10,999 Btu/h, without Louvers	Residential baseline use = 523 kWh Commercial baseline use = 1252 kWh	Variability based on usage
	Greater than 11,000 Btu/h, without Louvers	Residential baseline use = 779 kWh Commercial baseline use = 1498 kWh	Variability based on usage
2014 Average Energy Prices (2009$)	Less than 6,000 Btu/h	Residential = 12.7 c/kWh Commercial = 12.0 c/kWh	Variability based on region.
	8,000–13,999 Btu/h	Residential = 13.5 c/kWh Commercial = 12.0 c/kWh	
	Greater than 20,000 Btu/h	Residential = 14.8 c/kWh Commercial = 12.0 c/kWh	
2014 Marginal Energy Prices (2009$)	Less than 6,000 Btu/h	Residential = 11.6 c/kWh Commercial = 23.0 c/kWh	Variability based on region.
	8,000–13,999 Btu/h, with Louvers	Residential = 12.4 c/kWh Commercial = 19.2 c/kWh	
	Greater than 20,000 Btu/h	Residential = 13.8 c/kWh Commercial = 19.2 c/kWh	
Annual Baseline Maintenance Costs	Less than 6,000 Btu/h, with Louvers	$0.06	Single-Point Value

	8,000–13,999 Btu/h, with Louvers	$0.14	Single-Point Value
	20,000–24,999 Btu/h, with Louvers	$0.49	Single-Point Value
	Greater than 25,000 Btu/h, with Louvers	$0.49	Single-Point Value
	8,000–10,999 Btu/h, without Louvers	$0.14	Single-Point Value
	Greater than 11,000 Btu/h, without Louvers	$0.14	Single-Point Value
Lifetime	All	10.26 years	Weibull distribution
Discount Rate	All	Residential = 5.0% Commercial = 5.7%	Custom distribution
Energy Price Trend	All	AEO 2010 Reference Case	Two sensitivities: High & Low Growth Cases

8.1.3 New Home and Replacement Fractions of Shipments

The LCC and PBP analyses use separate values for new home applications and replacement applications for some variables, because the type of application influences these variables. Such variables are markups, installation costs, and discount rates. The derivation of the appropriate values in each case for new home applications and replacement applications is given in chapter 6 for markups and given in this chapter for installation costs and discount rates.

For clothes dryers, DOE found indications that some builders install a washer and dryer in new homes. Using 1997–2007 American Housing Survey (AHS) data,[2, 3, 4, 5, 6, 7] DOE estimated that builders install a clothes dryer in 37 percent of new homes. Thus, 5 percent of total shipments in 2014 are accounted for in new construction applications. For room air conditioners, DOE assumed that there would be no new home installations.

8.2 LIFE-CYCLE COST INPUTS

Because DOE gathered most of its data for the LCC and PBP analyses in 2009, DOE expresses dollar values in 2009$.

8.2.1 Total Installed Cost Inputs

DOE defines the total installed cost using the following equation:

$$IC = CPC + INST$$

Where:

CPC = consumer product cost (i.e., consumer cost for the product only), and
$INST$ = installation cost or the consumer cost to install products.

The product cost is based on how the consumer purchases the product. As discussed in chapter 6, Markups to Determine Product Cost, DOE defined markups and sales taxes for converting manufacturing costs into consumer product costs.

Table 8.2.1 summarizes the inputs for the determination of total installed cost.

Table 8.2.1 Inputs for Total Installed Cost

Baseline Manufacturer Cost
Standard-Level Manufacturer Cost Increase
Markups
Sales Tax (replacement applications)
Installation Cost

The *baseline manufacturer cost* is the cost incurred by the manufacturer to produce products meeting existing minimum efficiency standards. *Standard-level manufacturer cost increases* are the change in manufacturer cost associated with producing products at a standard level. *Markups and sales tax* convert the manufacturer cost to a consumer product cost. The *installation cost* is the cost to the consumer of installing the product and 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.

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

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

Where:

IC_{BASE} = baseline total installed cost,
CPC_{BASE} = consumer product cost for baseline models,
$INST_{BASE}$ = baseline installation cost,

$COST_{MFG}$ = manufacturer cost for baseline models, and
$MU_{OVERALL\_BASE}$ = baseline overall markup (product of manufacturer markup, baseline retailer or distributor markup, and sales tax).

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

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

Where:

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

The remainder of this section provides information about each of the above input variables that DOE used to calculate the total installed cost for room air conditioners and clothes dryers.

8.2.1.1 Forecasting Future Product Prices

Examination of historical price data for certain appliances and equipment that have been subject to energy conservation standards indicates that the assumption of constant real prices and costs may, in many cases, overestimate long-term trends in appliance and equipment prices. Economic literature and historical data suggest that the real costs of these products may in fact trend downward over time according to "learning" or "experience" curves. A draft paper, "Using the Experience Curve Approach for Appliance Price Forecasting," posted on the DOE web site at http://www.eere.energy.gov/buildings/appliance_standards, summarizes the data and literature currently available to DOE that is relevant to price forecasts for selected appliances and equipment.

In light of these data and DOE's aim to improve the accuracy and robustness of its analyses, DOE has decided to assess future costs by incorporating learning over time, consistent with the analysis in the available literature. DOE is using this approach to forecast future prices of clothes dryers and room air conditioners at the considered efficiency levels.

An extensive literature discusses the "learning" or "experience" curve phenomenon, typically based on observations in the manufacturing sector.[a] In the experience curve method, the real cost of production is related to the cumulative production or "experience" with a product. To explain the empirical relationship, the theory of technology learning is used to substantiate a decline in the cost of producing a given product as firms accumulate experience with the technology. 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 rate (LR), and is given by:

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

In typical learning curve formulations, the learning rate parameter is derived using two historical data series: price (or cost) and cumulative production, which is a function of shipments during a long time span.

DOE's derivation of learning rates for clothes dryers and room air conditioners, and their application in the LCC and PBP analysis, are described in appendix 8-J.

[a] In addition to the draft paper mentioned above, see Weiss, M., Junginger, H.M., Patel, M.K., and Blok, K. 2010. A Review of Experience Curve Analyses for Energy Demand Technologies. *Technological Forecasting & Social Change*. 77:411-428.

8.2.1.1 Clothes Dryers

Baseline Manufacturer Cost. DOE developed the baseline manufacturer costs for clothes dryers as described in chapter 5, Engineering Analysis. The baseline manufacturer costs are shown in Table 8.2.2.

Table 8.2.2 Clothes Dryers: Baseline Manufacturer Costs

Product Class	Baseline Combined Energy Factor (lb/kWh)	Baseline Energy Factor (lb/kWh)	Manufacturer Cost (2009$)
Vented, Electric, Standard	3.62	3.55	$201.46
Vented, Electric, Compact (120 v)	3.62	3.43	$210.54
Vented, Electric, Compact (240 v)	3.27	3.12	$210.54
Vented, Gas	3.20	3.14	$227.40
Vent-less, Electric, Compact (240 v)	2.69	2.55	$559.31
Vent-less Electric Combination Washer/ Dryer	2.17	2.08	$805.90

Standard-Level Manufacturer Cost Increases. DOE used cost data submitted by the Association of Home Appliance Manufacturers (AHAM) to develop manufacturer cost increases associated with increases in clothes dryer efficiency levels. Refer to chapter 5, Engineering Analysis, for details. Table 8.1.1 presents the standard-level manufacturer cost increases for the considered product classes.

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 8.2.3 shows the overall baseline and incremental markups for clothes dryers. Refer to chapter 6 for details.

Table 8.2.3 Clothes Dryers: Overall Markups

Markup	Baseline	Incremental
Manufacturer	1.26	
Retailer	1.45	1.17
Sales Tax	1.072	
Overall	1.96	1.58

Installation Cost. The cost of installation covers all labor and material costs associated with the replacement of a product or the installation of a product in a new home. DOE derived baseline installation costs for clothes dryers from data in the 2010 RS Means Residential Cost Data. This book provides estimates on the labor hours and labor cost required to install clothes dryers. Table 8.2.4 provides both bare costs (i.e., costs before overhead and profit) and installation costs including overhead and profit for national average labor costs. DOE estimated that for the new construction market it takes on average a total of one hour to install a clothes dryer, while for the replacement or new owners markets it takes a total of two-and a-half hours to install a clothes dryer (one hour for trip charge, half an hour to remove old clothes dryer, and one hour to install). DOE found no evidence that installation costs would be impacted with increased efficiency levels, except for heat pump clothes dryers, which tend to have larger dimensions compared to standard clothes dryers. For heat pump clothes dryers, DOE assumed that on average one half-hour of additional labor hours would be required.

Table 8.2.4 Clothes Dryer Installation Costs

Installation Type		Labor Hours	Crew Type	Bare Costs (2009$)			Including Overhead & Profit (2009$)*		
				Labor	Material	Total	Labor	Material	Total
Electric Vented and Ventless Clothes Dryers	Retrofit, New Owner	2.5	L-2	$64	$0	$64	$106	$0	$106
	New Construction	1	L-2	$25	$34	$59	$43	$37	$80
Gas Clothes Dryers	Retrofit, New Owner	2.5	L-1	$85	$0	$85	$139	$0	$139
	New Construction	1	L-1	$34	$34	$68	$56	$37	$93
Heat Pump Clothes Dryer Adder	All	0.5	L-2	$13	$0	$13	$21	$0	$21

* Labor costs including overhead and profit equal bare labor costs plus labor markup in RSMeans. Material costs including overhead and profit equal bare costs plus 10 percent profit.

DOE used regional labor costs to more accurately estimate installation costs by region. RS Means provides average national installation costs for different trade groups as shown in Table 8.2.5. Bare costs are given in RS Means, while labor costs including overhead and profit (O&P) are the bare costs multiplied by the RS Means markups by trade shown in Table 8.2.6.

Table 8.2.5 RS Means 2010 National Average Labor Costs by Crew

Crew Type	Crew Description	Laborers per Crew	Cost per Labor-Hour	
			Bare Costs	Incl. O&P*
L-1	1 Plumber and .25 Electrician	1.25	$34.05	$55.73
L-2	1 Carpenter, 1 Carpenter Apprentice	2.00	$25.43	$42.76
1-Carp	1 Carpenter	1.00	$25.43	$42.76

* O&P includes markups in Table 8.2.6

Table 8.2.6 RS Means Labor Costs Markups by Trade

Trade	Workers Comp.	Aver Fixed Overhead	Overhead	Profit	Total
Plumber	7.6%	16.3%	30.0%	10.0%	63.9%
Electrician	6.4%	16.3%	30.0%	10.0%	62.7%
Carpenter	16.9%	16.3%	25.0%	10.0%	68.2%

RS Means also provides labor cost factors for 295 cities and towns in the United States. To derive average labor cost values by State, DOE weighted the price factors by city or town population size using 200 census data. Since RECS 2005 household location is identified by the nine census divisions and 4 large States, DOE then population weighted the State data using 2008 Census data into the appropriate nine census divisions and 4 large States. Table 8.2.7 shows the final regional price factors used in the analysis.

Table 8.2.7 Final Labor Cost Factors by Census Division and Four Large States

Census Division and 4 large states	Census Division Name	States	Labor Cost Factor
1	New England	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	1.19
2	Middle Atlantic*	New Jersey, Pennsylvania	1.28
3	East North Central	Indiana, Illinois, Michigan, Ohio, Wisconsin	1.12
4	West North Central	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota	0.99
5	South Atlantic**	Delaware, District of Columbia, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	0.73
6	East South Central	Alabama, Kentucky, Mississippi, Tennessee	0.75
7	West South Central***	Arkansas, Louisiana, Oklahoma	0.66
8	Mountain	Arizona, Colorado, Idaho, New Mexico, Montana, Utah, Nevada, Wyoming	0.82
9	Pacific****	Alaska, Hawaii, Oregon, Washington	1.08
10		New York	1.66
11		California	1.23
12		Texas	0.66
13		Florida	0.73

* Includes New York, which is separated out as a large state.
** Includes Florida, which is separated out as a large state.
*** Includes Texas, which is separated out as a large state.
**** Includes California, which is separated out as a large state.

The distribution of each RECS 2005 product class sample is different, so the average labor cost weighted by RECS 2005 sample weights is different from the RS Means national average (i.e., labor cost factor of 1.00). Table 8.2.8 shows the fraction of households in each division and four large states for each product class sample and the resulting average labor cost.

Table 8.2.8 Final Labor Cost Factors by Clothes Dryer Product Types

Census Division & 4 large states	Labor Cost Factor	Fraction of Households in RECS 2005 Sample (%)		
		Standard Electric	Compact & Ventless	Gas
1	1.19	4.9%	5.2%	3.1%
2	1.28	5.7%	3.2%	12.0%
3	1.12	14.8%	11.7%	25.5%
4	0.99	7.5%	4.4%	8.0%
5	0.73	16.4%	19.1%	4.8%
6	0.75	8.5%	8.6%	1.2%
7	0.66	5.1%	7.2%	1.2%
8	0.82	7.5%	6.5%	6.0%
9	1.08	4.9%	5.8%	1.9%
10	1.66	3.1%	3.9%	7.4%
11	1.23	6.2%	7.8%	23.3%
12	0.66	7.8%	6.6%	4.0%
13	0.73	7.8%	9.8%	1.5%
Average Labor Cost Factor		1.04	0.93	0.92

Total Installed Cost. The total installed cost is the sum of the consumer product cost and the installation cost. Tables 8.2.9 through 8.2.14 present the consumer product costs, installation costs, and total installed costs in 2014 by efficiency level for the considered clothes dryer product classes.

Table 8.2.9 Vented Dryer, Electric, Standard: Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014

Level	Combined Energy Factor (lb/kWh)	Product Cost (2009$)	Installation Cost (2009$)	Total Installed Cost (2009$)
Baseline	3.55	360	95	455
1	3.56	361	95	455
2	3.61	361	95	456
3	3.73	372	95	467
4	3.81	433	95	528
5	4.08	488	95	583
6	5.42	764	115	879

Table 8.2.10 Vented Dryer, Electric, Compact (120V): Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014

Level	Combined Energy Factor (lb/kWh)	Product Cost (2009$)	Installation Cost (2009$)	Total Installed Cost (2009$)
Baseline	3.43	376	94	470
1	3.48	377	94	471
2	3.61	377	94	471
3	3.72	407	94	501
4	3.80	466	94	560
5	4.08	533	94	627
6	5.41	761	114	875

Table 8.2.11 Vented Dryer, Electric, Compact (240V): Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014

Level	Combined Energy Factor (lb/kWh)	Product Cost (2009$)	Installation Cost (2009$)	Total Installed Cost (2009$)
Baseline	3.12	376	94	470
1	3.16	377	94	471
2	3.27	377	94	471
3	3.36	407	94	501
4	3.48	466	94	560
5	3.60	533	94	627
6	4.89	761	114	875

Table 8.2.12 Vented Dryer, Gas: Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014

Level	Combined Energy Factor (lb/kWh)	Product Cost (2009$)	Installation Cost (2009$)	Total Installed Cost (2009$)
Baseline	3.14	406	148	554
1	3.16	407	148	555
2	3.20	407	148	555
3	3.30	419	148	567
4	3.41	510	148	658
5	3.61	565	148	712

Table 8.2.13 Vent-less 240V Dryer, Electric: Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014

Level	Combined Energy Factor (lb/kWh)	Product Cost (2009$)	Installation Cost (2009$)	Total Installed Cost (2009$)
Baseline	2.55	999	94	1093
1	2.59	1000	94	1094
2	2.69	1000	94	1094
3	2.71	1037	94	1131
4	2.80	1082	94	1176
5	4.03	1348	114	1462

Table 8.2.14 Vent-less Combination Washer/Dryer, Electric: Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014

Level	Combined Energy Factor (lb/kWh)	Product Cost (2009$)	Installation Cost (2009$)	Total Installed Cost (2009$)
Baseline	2.08	1439	94	1533
1	2.35	1441	94	1535
2	2.38	1443	94	1536
3	2.46	1443	94	1537
4	2.56	1485	94	1579
5	3.69	1868	114	1981

8.2.1.2 Room Air Conditioners

Baseline Manufacturer Cost. DOE developed the baseline manufacturer costs for room air conditioners as described in chapter 5, Engineering Analysis. The baseline manufacturer costs are shown in Table 8.2.15.

Table 8.2.15 Room Air Conditioners: Baseline Manufacturer Costs

Product Class	Baseline CEER	Baseline EER	Manufacturer Cost (2009$)
Less than 6,000 Btu/h, with louvers	9.52	9.70	$150
8,000–13,999 Btu/h, with louvers (8 kBtu/h)	9.69	9.80	$182
8,000–13,999 Btu/h, with louvers (12 kBtu/h)	9.72	9.80	$211
20,000 –24,999 Btu/h, with louvers	8.47	8.50	$344
Greater than 25,000 Btu/h, with Louvers	8.48	8.50	$391
8,000–10,999 Btu/h, without louvers	8.41	8.50	$211
Greater than 11,000 Btu/h, without Louvers	8.44	8.50	$237

Standard-Level Manufacturer Cost Increases. DOE used a combination of cost data submitted by AHAM and a reverse engineering analysis to develop manufacturer cost increases associated with increases in room air conditioner efficiency levels. Refer to chapter 5, Engineering Analysis, for details. Table 8.1.2 presents the standard-level manufacturer cost increase for each considered efficiency level.

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 8.2.16 shows the overall baseline and incremental markups for room air conditioners. Refer to chapter 6 for details.

Table 8.2.16 Room Air Conditioners: Overall Markups

Markup	Baseline Cost Markup	Incremental Cost Markup
Manufacturer	1.26	
Retailer	1.45	1.17
Sales Tax	1.072	
Overall	1.96	1.58

Installation Cost. The cost of installation covers all labor and material costs associated with the replacement of a product or the installation of a product in a new home. DOE derived installation costs for room air conditioners from data in the 2010 RS Means Residential Cost Data. This book provides estimates on the labor required to install residential room air conditioners. DOE assumed that a trip charge equal to half an hour for each crew member. Table

8.2.17 provides both bare costs (i.e., costs before overhead & profit) and installation costs including overhead and profit.

Table 8.2.17 Room Air Conditioners: Installation Costs by Capacity

RS Means RAC Size	Labor Hours	Crew Type	Bare Costs (2009$)			Including Overhead & Profit (2009$)*		
			Labor	Material	Total	Labor	Material	Total
5 kBtu/h	1.5	1 Carp	$44	$0	$44	$73	$0	$73
8 and 10 kBtu/h	1.83	1 Carp	$53	$0	$53	$90	$0	$90
12 kBtu/h	3	L-2	$76	$0	$76	$128	$0	$128
17 kBtu/h	3.67	L-2	$93	$0	$93	$157	$0	$157
25 and 29 kBtu/h	5	L-2	$127	$0	$127	$213	$0	$213

* Labor costs including overhead and profit equal bare labor costs plus labor markup in RSMeans.. Material costs including overhead and profit equal bare costs plus 10 percent profit.

To account for additional labor hours in higher efficiency equipment with significant larger dimensions and/or weight, DOE based the labor hour estimates on labor hours for higher capacity room air conditioners with similar dimensions/weight. For example, Table 8.2.18 shows the relationship between efficiency levels and RS Means labor hour capacity size for product class 1 (<6000 Btu/h).

Table 8.2.18 Fraction of RS Means Labor Cost for Product Class 1 (<6000 Btu/h)

Efficiency Level	RS Means RAC Size				
	5 kBtu/h	8 and 10 kBtu/h	12 kBtu/h	17 kBtu/h	25 and 29 kBtu/h
0	100%	0%	0%	0%	0%
1	100%	0%	0%	0%	0%
2	100%	0%	0%	0%	0%
3	75%	25%	0%	0%	0%
4	50%	50%	0%	0%	0%
5	50%	50%	0%	0%	0%

DOE used regional labor costs to more accurately estimate installation costs by region. RS Means provides average national installation costs for different trade groups as shown in Table 8.2.5. Bare costs are given in RS Means, while labor costs including overhead and profit (O&P) are the bare costs multiplied by the RS Means markups by trade shown in Table 8.2.6. As explained above for clothes dryers, DOE determined regional price factors for each division and four large states.

Total Installed Cost. The total installed cost is the sum of the consumer product cost and the installation cost. Tables 8.2.19 through 8.2.24 present the total installed costs in 2014 for the room air conditioner product classes. Costs are presented at the baseline level and each energy efficiency level.

Table 8.2.19 Room Air Conditioners, less than 6,000 Btu/h, with Louvers: Total Installed Costs in 2014

CEER	Residential Total Installed Cost (2009$)	Commercial Total Installed Cost (2009$)
9.52	$352	$348
10.1	$362	$357
10.6	$375	$371
11.1	$393	$389
11.4	$411	$406
11.7	$473	$468

Table 8.2.20 Room Air Conditioners, 8,000–13,999 Btu/h, with Louvers: Total Installed Costs in 2014

CEER	Residential Total Installed Cost (2009$)	Commercial Total Installed Cost (2009$)
9.69	$478	$473
10.2	$483	$478
10.7	$494	$488
10.9	$498	$493
11.5	$526	$521
12.0	$605	$599

Table 8.2.21 Room Air Conditioners, 20,000–24,999 Btu/h, with Louvers: Total Installed Costs in 2014

CEER	Residential Total Installed Cost (2009$)	Commercial Total Installed Cost (2009$)
8.47	$861	$829
9.0	$876	$844
9.4	$890	$859
9.8	$936	$904
10.2	$1,163	$1,130

Table 8.2.22 Room Air Conditioners, greater than 25,000 Btu/h, with Louvers: Total Installed Costs in 2014

CEER	Residential Total Installed Cost (2009$)	Commercial Total Installed Cost (2009$)
8.48	$983	$946
9.0	$1,024	$987
9.4	$1,062	$1,026
9.8	$1,317	$1,280

Table 8.2.23 Room Air Conditioners, 8,000–10,999 Btu/h, without Louvers: Total Installed Costs in 2014

CEER	Residential Total Installed Cost (2009$)	Commercial Total Installed Cost (2009$)
8.41	$489	$484
9.3	$496	$491
9.6	$499	$494
10.0	$513	$508
10.4	$615	$610

Table 8.2.24 Room Air Conditioners, greater than 11,000 Btu/h, without Louvers: Total Installed Costs in 2014

CEER	Residential Total Installed Cost (2009$)	Commercial Total Installed Cost (2009$)
8.44	$574	$568
9.3	$591	$585
9.5	$596	$590
9.8	$611	$605
10.0	$708	$701

8.2.2 Operating Cost Inputs

DOE defines the 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 8.2.25 shows the inputs for determining the annual operating costs and their discounted value over the product lifetime.

Table 8.2.25 Inputs for 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. The annual energy consumption varies with the product efficiency. *Energy prices* are the prices paid by consumers for energy (i.e., electricity or gas). Multiplying the annual energy consumption by the energy prices 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 calculated the annual operating cost for baseline products based on the following equation:

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

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 baseline product operation.

DOE calculated the annual operating cost 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 products,
AEC_{STD} = annual energy consumption for standard-level products,
$PRICE_{ENERGY}$ = energy price,

RC_{STD} = repair cost associated with component failure for standard-level products, and

MC_{STD} = cost for maintaining standard-level products operation.

The remainder of this section provides information about each of the above input variables that DOE used to calculate the operating costs for room air conditioners and clothes dryers.

8.1.1.1 Annual Energy Consumption

As described in chapter 7, Energy Use Characterization, and the beginning of this chapter in section 8.1.1, DOE developed a sample of individual households from RECS 2005 that use each of the appliances. By developing household samples, DOE was able to perform the LCC and PBP calculations for each household to account for the variability in both energy use and energy price associated with each household. The annual energy consumption values in the tables below are averages. DOE captured the variability in energy consumption when it conducted its LCC and PBP analyses.

Clothes Dryers. Tables 8.2.26 through 8.2.28 provide the average annual energy consumption by efficiency level for the considered clothes dryer product classes.

Table 8.2.26 Vented Electric Clothes Dryers: Average Annual Energy Use by Efficiency Level

Electric, Standard		Electric, Compact (120V)		Electric, Compact (240V)	
CEF (lb/kWh)	Energy Use (kWh)	CEF (lb/kWh)	Energy Use (kWh)	CEF (lb/kWh)	Energy Use (kWh)
3.55	718	3.43	317	3.12	353
3.56	716	3.48	314	3.16	349
3.61	707	3.61	305	3.27	340
3.73	684	3.72	295	3.36	331
3.81	670	3.80	289	3.48	319
4.08	627	4.08	268	3.60	308
5.42	476	5.41	198	4.89	223

Table 8.2.27 Vented Gas Clothes Dryers: Average Annual Energy Use by Efficiency Level

CEF (lb/kWh)	Gas Energy Use (MMBtu)	Electrical Energy Use (kWh)
3.14	2.53	42.2
3.16	2.53	39.0
3.20	2.53	29.8
3.30	2.45	29.8
3.41	2.37	29.8
3.61	2.25	25.5

Table 8.2.28 Vent-less Clothes Dryers: Average Annual Energy Use by Efficiency Level

Electric, Compact (240V)		Electric, Combo Washer/Dryer	
CEF (lb/kWh)	Energy Use (kWh)	CEF (lb/kWh)	Energy Use (kWh)
2.55	372	2.08	463
2.59	366	2.35	399
2.69	354	2.38	394
2.71	351	2.46	383
2.80	337	2.56	365
4.03	210	3.69	226

Room Air Conditioners. Tables 8.2.29 through 8.2.32 provide the average annual energy consumption by efficiency level for each room air conditioner product class.

Table 8.2.29 Room Air Conditioners with Louvers: Residential Sector Average Annual Energy Use by Efficiency Level

Less than 6,000 Btu/h		8,000-13,999 Btu/h		20,000-24,999 Btu/h		Greater than 25,000 Btu/h	
CEER	Energy Use (kWh)	CEER	Energy Use (kWh)	CEER	Energy Use (kWh)	CEER	Energy Use (kWh)
9.52	401	9.69	636	8.47	506	8.48	589
10.1	376	10.2	604	9.0	477	9.0	555
10.6	358	10.7	576	9.4	452	9.4	526
11.1	342	10.9	565	9.8	434	9.8	505
11.4	334	11.5	535	10.2	419	--	--
11.7	326	12.0	514	--	--	--	--

Table 8.2.30 Room Air Conditioners without Louvers: Residential Sector Average Annual Energy Use by Efficiency Level

8,000-10,999 Btu/h		Greater than 11,000 Btu/h	
CEER	Energy Use (kWh)	CEER	Energy Use (kWh)
8.41	523	8.44	779
9.3	474	9.3	707
9.6	459	9.5	693
10.0	438	9.8	668
10.4	423	10.0	654

Table 8.2.31 Room Air Conditioners with Louvers: Commercial Sector Average Annual Energy Use by Efficiency Level

Less than 6,000 Btu/h		8,000-13,999 Btu/h		20,000-24,999 Btu/h		Greater than 25,000 Btu/h	
CEER	Energy Use (kWh)	CEER	Energy Use (kWh)	CEER	Energy Use (kWh)	CEER	Energy Use (kWh)
9.52	599	9.69	1088	8.47	3153	8.48	3153
10.1	565	10.2	1035	9.0	2968	9.0	2969
10.6	539	10.7	987	9.4	2841	9.4	2842
11.1	514	10.9	969	9.8	2726	9.8	2726
11.4	502	11.5	918	10.2	2630	--	--
11.7	489	12.0	883	--	--	--	--

Table 8.2.32 Room Air Conditioners without Louvers: Commercial Sector Average Annual Energy Use by Efficiency Level

8,000-10,999 Btu/h		Greater than 11,000 Btu/h	
CEER	**Energy Use (kWh)**	**CEER**	**Energy Use (kWh)**
8.41	1252	8.44	1498
9.3	1133	9.3	1360
9.6	1098	9.5	1332
10.0	1055	9.8	1291
10.4	1018	10.0	1262

8.2.2.2 Clothes Dryer Energy Prices

Using data from EIA, DOE derived average annual energy prices for 13 geographic areas in the United States — the nine U.S. Census Divisions, with four large States (New York, Florida, Texas, and California) treated separately. For Census Divisions containing one of these large States, DOE calculated the regional average values leaving out data for the large State—for example, the Pacific region average does not include California, and the West South Central does not include Texas. Using these data, DOE assigned an appropriate price to each household in the sample, depending on its location.

Residential Electricity Prices. DOE derived 2008 annual electricity prices from EIA Form 861 data.[8] The EIA Form 861 data are published annually and include annual electricity sales, revenues from electricity sales, and number of consumers, for the residential, commercial, and industrial sectors at the utility level. DOE calculated annual regional electricity prices by weighting each utility's average price by the number of electricity consumers in each utility's service area. DOE then aggregated the prices by the nine U.S. Census Divisions and four large states. Table 8.2.33 shows the monthly average results for each geographic area.

Table 8.2.33 Average Electricity Prices in 2008

Geographic Area	Residential (2009$/kWh)
New England	$0.176
Middle Atlantic (excludes NY)	$0.131
East North Central	$0.105
West North Central	$0.088
South Atlantic (excludes FL)	$0.102
East South Central	$0.093
West South Central (excludes TX)	$0.096
Mountain	$0.099
Pacific (excludes CA)	$0.105
New York	$0.191
Florida	$0.138
Texas	$0.130
California	$0.116
U.S.	$0.118

Residential Natural Gas Prices. DOE obtained the data for the natural gas price calculation from EIA's Natural Gas Navigator.[9] This publication includes a compilation of monthly natural gas prices by State, for residential, commercial, and industrial customers. DOE weighted the residential natural gas prices for each State by the number of natural gas consumers in each State[10] and transformed the values from units of $/tcf to $/MMBtu. Finally, DOE aggregated and averaged the prices by the nine U.S. Census Divisions and four large states. Table 8.2.34 displays the 2009 annual natural gas prices.

Table 8.2.34 Average Residential Natural Gas Prices in 2009

Geographic Area	Residential Average Prices (2009$/MMBtu)
New England	$16.37
Middle Atlantic (excludes NY)	$15.24
East North Central	$11.65
West North Central	$11.64
South Atlantic (excludes FL)	$17.17
East South Central	$14.38
West South Central (excludes TX)	$13.74
Mountain	$11.99
Pacific (excludes CA)	$14.69
New York	$15.27
Florida	$9.07
Texas	$12.43
California	$21.01
U.S.	$12.92

Source: EIA *Natural Gas Navigator*.

Residential liquid petroleum gas (LPG) Prices. DOE collected 2008 average LPG prices from EIA's 2008 State Energy Consumption, Price, and Expenditures Estimates (SEDS).[11] SEDS includes annual LPG prices for residential, commercial, industrial, and transportation consumers by State. DOE weighted the average residential LPG prices for each State by the amount of LPG consumed by each State. Finally, DOE aggregated and averaged the prices by 13 geographic areas (Table 8.2.35).

Table 8.2.35 Average Residential LPG Prices in 2008

Geographic Area	Annual Average (2009$/MMBtu)
CD 1 - New England	$33.96
CD 2 - Middle Atlantic (excludes NY)	$34.19
CD 3 - East North Central	$26.95
CD 4 - West North Central	$24.04
CD 5 - South Atlantic (excludes FL)	$31.74
CD 6 - East South Central	$30.86
CD 7 - West South Central (excludes TX)	$27.78
CD 8 – Mountain	$28.78
CD 9 - Pacific (excludes CA)	$31.43
CD 10 - New York	$33.26
CD 11 – California	$33.78
CD 12 – Texas	$30.79
CD 13 – Florida	$38.72
CD 14 - United States	$29.26

8.2.2.3 Room Air Conditioner Energy Prices

For room air conditioners, DOE developed estimates of marginal electricity prices to calculate electricity cost savings. The marginal price for a given consumer is the cost of the next increment of electricity use on their utility bill and is an appropriate estimate of the value of savings that a consumer would see in the real world. For a peak-coincident end use such as air-conditioning, there is a general expectation that the actual cost of operating the appliance is higher than the average price of electricity. These increased costs are often reflected in utility tariff structures, through block rates, different types of demand charges, or mandatory time-of-use rates. Accurate estimation of marginal prices requires taking rate structures into account explicitly.

In general, several methods and data sources can be used to calculate electricity prices. After reviewing the strengths and weaknesses of different approaches and the available data, the Department chose to base the analysis on the utility tariffs comprising the TAP (Tariff Analysis Project) database.[12] This approach provides an up-to-date and geographically diverse data set that can accurately capture real prices. Other data sources have various weaknesses that could lead to significant errors in the estimated electricity cost savings, and do not provide sufficient information to allow the Department to respond adequately to stakeholder comments. A more detailed discussion of electricity price data and calculation methods is presented in appendix 8-E, along with a description of the tariff-based approach, the data used, and validation tests.

For the room air conditioner analysis, electricity prices are required for both residential and commercial consumers. The LCC analysis is based on a consumer sample derived from RECS and CBECS, and both an average annual price and a seasonal marginal price are required for each household or building in the sample. The basic methodology is to estimate the customer's monthly electricity use and use the tariff data to calculate the corresponding electricity bill. Empirical marginal prices are calculated by taking the difference between the bill for the baseline electricity use and the bill for a candidate standard level and dividing that difference by the change in energy use. This approach requires estimation of monthly consumer electricity use for the baseline and the energy savings associated with each candidate standard level. As both the rate structures and the required energy data differ significantly for residential and commercial consumers, the details of the approach for these two sectors are discussed separately.

Residential Electricity Prices. The calculation methodology provides, for each household in the LCC sample, an average annual price and a monthly marginal price. To compute these prices, the monthly baseline energy consumption must first be estimated. This is done using the monthly billing data from the RECS 2001 dataset; details of the calculation are presented in appendix 8-F.[b] Given the monthly energy use, twelve monthly bills per household are calculated using the tariffs. To increase the effective size of the sample, within a region each household is paired with each utility in its region. The pairing of a household with a utility is referred to as an *account*. The utilities are weighted by the fraction of customers they serve within a region. Taking the weighted sum over accounts provides a single set of prices for each household.

The annual average baseline price is calculated as a simple average over the twelve monthly baseline bills. To calculate monthly marginal prices for each account, the monthly energy use is decremented by seven percent and the bill recalculated. The marginal price in each month is defined as the bill savings divided by the energy savings. Monthly variability in the marginal price is due primarily to seasonal rates. Season definitions vary by utility. The annual cost savings are equal to the monthly marginal price times the monthly energy savings, summed across months. A description of how the monthly energy savings are estimated for each efficiency level is given in chapter 7.

Commercial Electricity Prices. Electricity tariffs for commercial consumers can be very complex, incorporating block rates, seasonal rates, demand charges, time-of-use rates, etc. To calculate commercial electricity bills requires both the monthly consumption and demand; for utilities with mandatory time-of-use (TOU) tariffs, consumption and demand data are required for each TOU period. This monthly data is not available for the CBECS 2003 records used in the LCC sample, so bills cannot be calculated directly. CBECS does provide annual electricity consumption and expenditures for each record, which is used here to estimate the average annual price. For marginal prices, the estimates are based on regional coefficients developed in a previous analysis of commercial buildings.[13] [14]

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[b] There is as yet no monthly data for 2005 RECS.

Monthly billing data, consisting of electricity consumption, demand, and expenditures, are available for the CBECS 1992 and CBECS 1995 survey years. For all CBECS records with sufficient data, interpolation methods were used to define consumption and demand values for twelve calendar months. These monthly data were run through the TAP bill calculation tools to provide the corresponding monthly expenditures for the utilities in the tariff sample. As for the residential analysis, each building is assigned to each utility in its region. As CBECS does not use the "Large State" flag, regions are defined as the nine census divisions, with the climate zone field used to separate the Mountain and Pacific census divisions into north and south subdivisions.[c] Once a building is assigned to a utility, the tariff is assigned automatically based on the annual peak demand and/or energy consumption and the tariff rules.

Monthly marginal prices for this dataset were calculated using the methodology described above, with one modification. Because the customer bill depends on both energy consumption and demand, separate marginal prices were developed to represent the effect of varying these two quantities independently. The monthly marginal energy consumption (or demand) price is calculated simply by decrementing the energy consumption (or demand) and recalculating the bill. In equation form:

- ΔE is the change in electricity consumption
- ΔBE is the resulting change in the bill
- $MPE = \Delta BE/\Delta E$ is the marginal consumption price in units of dollars per kWh.
- ΔD is the change in demand
- ΔBD the resulting change in the bill
- $MPD = \Delta BD/\Delta E$ is the marginal demand price in units of dollars per kW.

It is important to note that the marginal demand price is not the same as the demand charge. It is a more general construct, defined empirically, that combines the impact of ordinary demand charges and so-called hours charges (variable block rates in which the block size depends on demand). Given changes ΔE and ΔD to the baseline energy use, the total change in the bill is:

$$\Delta B = \Delta BD + \Delta BE.$$

In practice it is simpler to estimate the load factor than it is to estimate ΔD directly. The load factor is the ratio of the average hourly electricity use to the peak demand; if this ratio is approximately the same for the load decrements, then

$$LF = \Delta E/(NH*\Delta D)$$

Where:

[c] Region 8.1 corresponds to CBECS climate zone 1, and 8.2 to all other climate zones. Region 9.1 includes CBECS climate zones 1, 2 and 3, while Region 9.2 includes climate zones 4 and 5.

NH = the number of hours in the billing period, here equal to 8760/12, and
LF = the billing period load factor.

Using this expression, the empirical marginal price (EMP) for commercial customers is defined as:

$$EMP = MPE + MPD/(NH * LF)$$

The bill savings are equal to $\Delta B = EMP * \Delta E$.

The load factor is estimated as:

$$LF = \frac{HRS_{avg}}{HRS_{peak}}$$

Where:

HRS_{avg} = average hours of operation, and
HRS_{peak} = peak hours of operation.

The average hours of operation were determined for each product class as described in chapter 7. To determine peak hours of operation, DOE multiplied the number of months with cooling degree-days greater than zero by the average number of hours in a month (730). Monthly cooling degree-data were determined using the aforementioned NOAA weather station match.

To apply this methodology to the CBECS 2003 records used for the current rule-making, DOE used seasonal, regional average values for the marginal energy price and the marginal demand price. The summer season covers the months May through September, and the winter season all other months. Regional weighted averages are calculated by summing over all the buildings in a region, using the CBECS building weights. These values are shown in Table 8.2.36.

The commercial tariff data were last updated in 2004. To convert to 2008 dollars, two datasets were used: the report Average Regulated Retail Price of Electricity[15] for the years 2004 through 2007, and the EEI Typical Bill reports[16] for 2007 to 2008. Based on these data, a weighted-average price escalation factor for each region was calculated using consumer counts as the weights. The consumer counts come from the most recent EIA Form 861 data, which is for 2007.[17] EIA data from 2003 through 2006 were used to determine how much the rate of price escalation differs on average between the publicly vs. privately owned utility companies.

Table 8.2.36 Commercial Sector Marginal Electricity Prices

	Marginal Energy Prices (2008 ¢/kWh)			Marginal Demand Prices (2008 $/kWh)		
Region	Annual	Summer	Winter	Annual	Summer	Winter
1	11.42	11.56	11.22	14.43	16.58	12.91
2	9.47	9.78	9.20	12.73	13.82	11.88
3	6.26	6.34	6.15	12.05	12.73	11.54
4	4.62	4.93	4.39	4.45	5.08	3.99
5	7.34	7.31	7.33	8.24	8.48	8.08
6	6.04	5.90	6.13	6.99	7.37	6.74
7	8.67	9.49	7.69	5.79	6.55	5.22
8	6.99	6.95	7.01	7.69	7.85	7.56
8.1*	4.87	5.00	4.80	3.85	3.86	3.86
8.2*	7.27	7.20	7.30	8.25	8.42	8.10
9.1*	5.76	5.75	5.76	2.69	2.68	2.68
9.2*	11.64	11.82	11.28	6.47	8.92	4.25

* Census divisions 8 and 9 are divided by HDD and CDD into two subdivisions.

8.2.2.4 Energy Price Trends

DOE used price forecasts by the EIA to estimate future trends in natural gas and electricity prices. To arrive at prices in future years, it multiplied the average prices described in the preceding section by the forecast of annual average price changes in EIA's *AEO2010*.[18] To estimate the trend after 2035, DOE followed past guidelines provided to the Federal Energy Management Program (FEMP) by EIA and used the average rate of change during 2020–2035 for electricity, natural gas, and LPG.

DOE calculated LCC and PBP using three separate projections from *AEO2010*: Reference, Low Economic Growth, and High Economic Growth. The high- and low-growth cases show the projected effects of alternative growth assumptions on energy markets. Figure 8.2.1, Figure 8.2.2, and Figure 8.2.3 show the residential and commercial electricity, natural gas, and LPG price trends, respectively, based on the three *AEO2010* projections. For the LCC results presented in section 8.4, DOE used only the energy price forecasts from the AEO reference case.

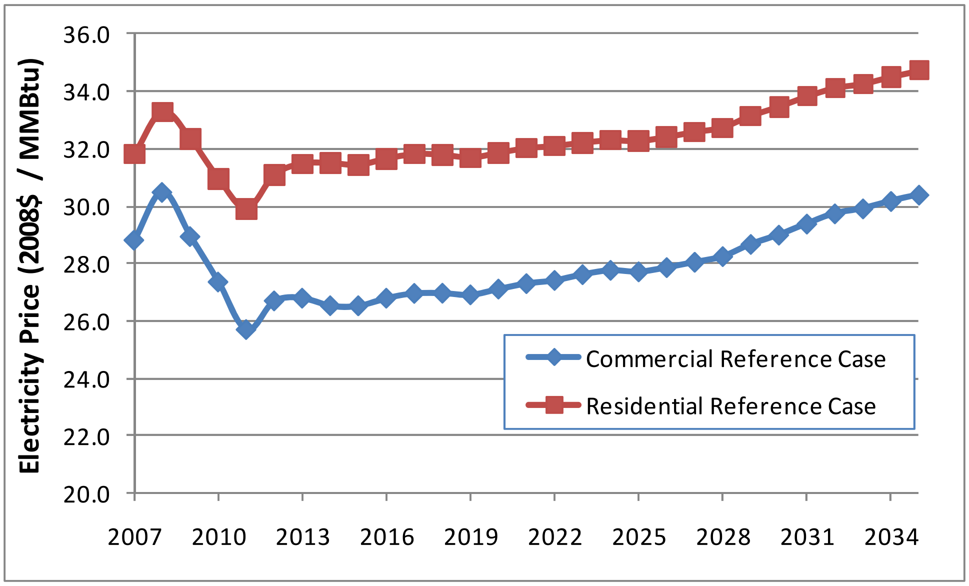

Figure 8.2.1 Residential and Commercial Electricity Price Trends

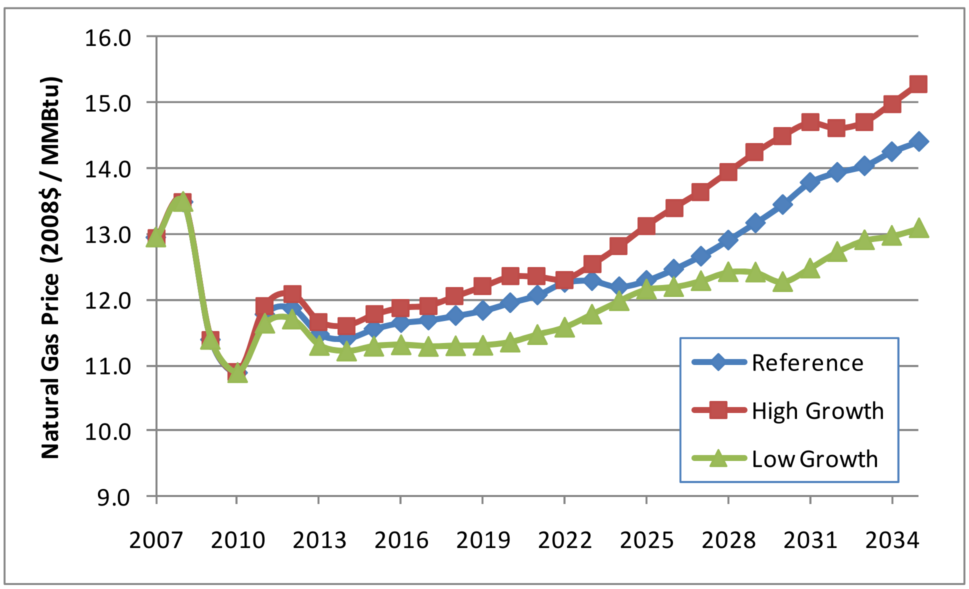

Figure 8.2.2 Residential Natural Gas Price Trend

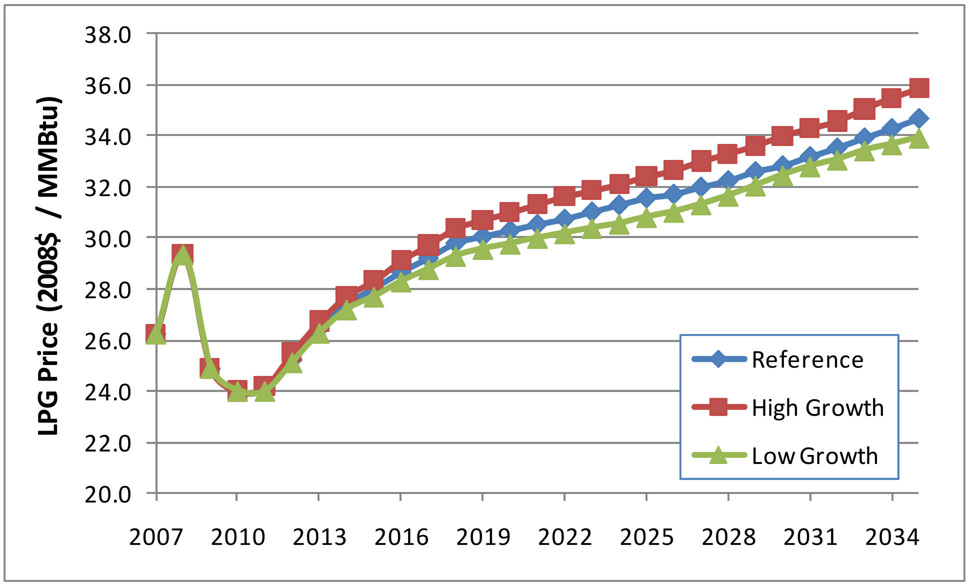

Figure 8.2.3 Residential LPG Price Trend

8.2.2.5 Repair and Maintenance Costs

The maintenance cost is the cost of regular scheduled product maintenance. The repair cost is the cost to repair the product when it fails. Typically, small incremental changes in product efficiency incur no, or only very small, changes in repair and maintenance costs over baseline products.

For clothes dryers, DOE derived annualized maintenance and repair frequencies based on Consumer Reports data on repair and maintenance issues for clothes dryers during the first four years of ownership. DOE estimated that on average 1.5 percent of electric and 1.75 percent of gas clothes dryers are maintained or repaired each year. DOE assumed that an average service call and repair/maintenance takes about 2.5 hours and that the average material cost is equal to one-half of the equipment cost. The values for cost per service call are then annualized by multiplying by the frequencies and dividing by the average equipment lifetime of 16 years.

For room air conditioners, DOE did not find data about repair frequencies. It assumed that repair frequencies are fairly low and increase for the higher-capacity units due to more expensive equipment cost. DOE assumed the 1 percent of small sized units (below 6,000 Btu/hr), 2.5 percent of medium sized units (8,000 to 14,000 Btu/hr), and 5 percent of large sized units (above 20,000 Btu/hr) are maintained or repaired each year. DOE assumed that an average service call and repair/maintenance takes about 1 hour for small and medium-sized units and 2 hours for large units, and that the average material cost is equal to one-fourth of the incremental equipment cost. These values are then annualized by multiplying by the frequencies and dividing by the average equipment lifetime of 10.5 years.

8.2.2.6 Product Lifetime

The product lifetime is the age at which the product is retired from service. *Appliance* magazine provides estimates of the low, high, and average years of an appliance's lifetime. The estimates, which are based on first-owner use of the product, represent the expert judgment of *Appliance* staff based on input obtained from various sources. DOE also identified other sources that give lifetimes for clothes dryers and room air conditioners (see Tables 8.2.37 and 8.2.38). Because the basis for the estimates in the literature was uncertain, DOE developed a method using household survey data to estimate the distribution of room air conditioner and clothes dryer lifetimes in the field.

Table 8.2.37 Clothes Dryers: Product Lifetime Estimates and Sources

Typical Lifetime or Range (years)		**Source**
Original Sources		
Average = 12; Low = 8; High = 15		Appliance Magazine, September 2008[19]
15		CEC 2005[20]
18		CALMAC 2000[21]
Other Sources		
Lifetime	*Source*	
Average = 12; Low = 8; High = 15	Appliance Magazine, 2006	BTS Core Databook, 2007[22]
18	EnerGuide 2005	Natural Resources Canada, 2007[23]
18	DOE Framework Document	Itron, Report to CEC, 2007
18	NA	CEC Consumer Energy Center website
18	See endnote	CEC Flex Your Power website
14	NA	Nebraska Public Power website
18	NA	New Mexico Market Assessment, Itron 2006[8]
12	Nexant, PECI	Questar Gas, Utah, from Deemed Savings Database, 2006
14		RTF (Northwest) CW/CD spreadsheet, 2008

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

Table 8.2.38 Room Air Conditioners: Product Lifetime Estimates and Sources

Typical Lifetime or Range (years)		Source
Original Sources		
Average = 9; Low = 7		Appliance Magazine, September 2008[19]
12.5		ASHRAE 2008[24]
15		CEC 2005[20]
12		European Rulemaking Draft Report[25]
Average = 15; High = 20		NRDC[26]
Other Sources		
Lifetime	*Source*	
9	Appliance Magazine, 1997	ENERGY STAR Savings Calculator[d]
18	EnerGuide 2005	Natural Resources Canada, 2008[27]
15	NA	New Mexico Market Assessment, Itron 2006[28]
18	NA	Nebraska Public Power District[29]
12	See endnote	NYSERDA SBC, 2002[30]
9	NA	RTF (Northwest), 2002[31]
12.5	DOE TSD 1997	NCEP report, LBNL 2004[32]
19	Aspen Memo, 2002	NYSERDA Deemed Savings Database: ENERGY STAR[33]
13 (TTW)	DOE TSD 2005	NYSERDA Deemed Savings Database: ENERGY STAR[13]
Low = 8, High =16		NEMS Residential Demand Module, 2008[34]
13		LBNL 2008[35]
Average = 10–15, Low = 8-12, High = 14-18		LBNL 1994[36]
10		Consortium for Energy Efficiency[37]
10 - 12		American Council for an Energy Efficient Economy, 2007[38]

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

[d] ENERGY STAR Savings Calculator, Products, Room AC. Efficient and conventional models.

Estimation of Survival Function. The Residential Energy Consumption Survey (RECS) records the presence of various appliances in each household, and places the age of each appliance into bins comprising several years. Data from the U.S. Census's American Housing Survey (AHS),[7] which surveys all housing including vacant and second homes, enabled DOE to adjust the RECS data to reflect the presence of appliances outside of primary residences. By combining the results of both surveys with the known history of appliance shipments (collected from *Appliance* magazine or directly from manufacturer trade associations), DOE estimated the percentage of appliances of a given age still in operation. This survival function, which DOE assumed has the form of a cumulative Weibull distribution, provides an average and a median appliance lifetime.

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

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

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

Where:

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

When $\beta = 1$, the failure rate is constant over time, giving the distribution the form of a cumulative exponential distribution. In the case of appliances, β commonly is greater than 1, reflecting an increasing failure rate as appliances age.

RECS is DOE's primary resource for appliance ages. For several appliances, including room air conditioners and clothes dryers, the survey asks respondents to identify the appliance's age as:

- less than 2 years old,
- 2 to 4 years old,
- 5 to 9 years old,

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[e] For reference on the Weibull distribution, see sections 1.3.6.6.8 and 8.4.1.3 of the *NIST/SEMATECH e-Handbook of Statistical Methods*, <www.itl.nist.gov/div898/handbook/>.

- 10 to 19 years old, or
- more than 20 years old.

The RECS has been conducted every three or four years for the past several decades. For this analysis, DOE used the surveys conducted in 1990, 1993, 1997, 2001, and 2005. DOE used the AHS count of housing units that contain room air conditioners or clothes dryers to scale the RECS data to better match the total installed stock. Table 8.2.39 shows the lifetime parameters for room air conditioners and clothes dryers. See appendix 8-C for more details.

Table 8.2.39 Lifetime Parameters

	Calculated Values				Weibull Parameters	
Product Class	**Minimum** *(years)*	**Average** *(years)*	**Maximum** *(years)*	**Maximum percentile** *(%)*	**Alpha (scale)**	**Beta (shape)**
Clothes Dryers	5	16.0	30	94	12.1	1.38
Room Air Conditioners	3	10.5	20	90	7.47	1.00

8.2.2.7 Discount Rates

The discount rate is the rate at which DOE discounted future consumer expenditures to establish their present value. DOE derived the discount rates for the LCC and PBP analyses from estimates of the finance cost of purchasing the considered products. Following financial theory, the finance cost of raising funds to purchase appliances can be interpreted as: (1) the financial cost of any debt incurred to purchase products, or (2) the opportunity cost of any equity used to purchase products. DOE considers both of these interpretations.

The purchase of products installed in new homes entails different finance costs for consumers than the purchase of appliances bought directly by consumers. For room air conditioners and clothes dryers, however, DOE believes that few products are installed by builders in new homes. DOE also estimated discount rates for purchasers of room air conditioners in the commercial sector.

Discount Rates for Residential Consumers. Households use a variety of methods to finance the purchase of major appliances. In principle, one could estimate the interest rates on the actual financing methods used to purchase appliances. However, the shares of different financing methods in total appliance purchases are unknown. DOE's approach involves identifying all possible debt or asset classes that might be used to purchase the considered appliances, including household assets that might be indirectly affected.[f] DOE did not include debt from primary mortgages or assets considered non-liquid (such as retirement accounts), since these would likely not be indirectly affected by appliance purchases. DOE estimated the average

[f] An indirect effect would arise if a household sold some assets in order to pay off a loan or credit card debt that might have been used to finance the actual appliance purchase.

shares of the various debt and equity classes in the average U.S. household equity and debt portfolios using data from the Federal Reserve Board's Survey of Consumer Finances (SCF) for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[39] Table 8.2.40 shows the average shares of each considered class. DOE used the mean share of each class across the seven surveys as a basis for estimating the weight of the classes in the direct or indirect financing of the considered appliances.

Table 8.2.40 Average Shares of Considered Household Debt and Equity Types (%)

Type	1989 SCF	1992 SCF	1995 SCF	1998 SCF	2001 SCF	2004 SCF	2007 SCF	Mean
Home equity loans	4.3	4.5	2.7	2.8	2.8	4.4	4.6	3.7
Credit cards	1.6	2.1	2.6	2.2	1.7	2.0	2.4	2.1
Other installment loans	2.8	1.7	1.4	1.7	1.1	1.3	1.1	1.6
Other residential loans	4.4	6.9	5.2	4.3	3.1	5.8	7.1	5.3
Other line of credit	1.1	0.6	0.4	0.2	0.3	0.5	0.3	0.5
Checking accounts	5.8	4.7	4.9	3.9	3.6	4.2	3.4	4.4
Savings & money market	19.2	18.8	14.0	12.8	14.2	15.1	13.0	15.3
Certificate of deposit (CD)	14.5	11.7	9.4	7.0	5.4	5.9	6.5	8.6
Savings bond	2.2	1.7	2.2	1.1	1.2	0.9	0.7	1.4
Bonds	13.8	12.3	10.5	7.0	7.9	8.4	6.7	9.5
Stocks	22.4	24.0	25.9	36.9	37.5	28.0	28.6	29.0
Mutual funds	8.0	11.1	20.9	20.1	21.3	23.4	25.5	18.6
Total	100	100	100	100	100	100	100	100

DOE estimated interest or return rates associated with each type of equity and debt. The data source for the interest rates for loans, credit cards, and lines of credit is the Federal Reserve Board's SCF in 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Table 8.2.41 shows the average nominal rates in each year, and the inflation rates used to calculate real rates. For home equity loans, DOE calculated effective interest rates in a similar manner as for mortgage rates, since interest on such loans is tax deductible. Table 8.2.42 shows the average effective real rates in each year and the mean rate across the years. Since the interest rates for each debt carried by households in these years were established over a range of time, DOE believes they are representative of rates in the year in which amended standards would take effect.

Table 8.2.41 Average Nominal Interest Rates for Household Debt Classes (%)

	1989 SCF	1992 SCF	1995 SCF	1998 SCF	2001 SCF	2004 SCF	2007 SCF	Mean
Home equity loans	11.5	9.6	9.6	9.8	8.7	5.7	6.3	7.9
Credit cards*	-	-	14.2	14.5	14.2	11.7	7.9	9.0
Other installment loans	9.0	7.8	9.3	7.8	8.7	7.4	12.6	13.4
Other residential loans	8.8	7.6	7.7	7.7	7.5	6.0	10.4	8.6
Other line of credit	14.8	12.7	12.4	11.9	14.7	8.8	6.3	7.4
Inflation rate	4.82	3.01	2.83	1.56	2.85	2.66	2.85	

* No interest rate data available for credit cards in 1989 or 1992.

Table 8.2.42 Average Real Effective Interest Rates for Household Debt Classes (%)

	1989 SCF	1992 SCF	1995 SCF	1998 SCF	2001 SCF	2004 SCF	2007 SCF)	Mean
Home equity loans	3.8	4.3	4.4	5.8	3.8	1.9	3.3	3.9
Credit cards*	-	-	11.0	12.7	11.1	9.1	9.7	10.7
Other installment loans	4.9	5.8	7.0	6.6	6.1	5.4	5.8	6.0
Other residential loans	4.0	4.7	4.8	6.0	4.6	3.3	3.4	4.4
Other line of credit	9.6	9.4	9.3	10.2	7.3	6.0	9.7	8.8

* No interest rate data available for credit cards in 1989 or 1992.

DOE developed a probability distribution of interest rates for each debt class based on the *SCF* data. To account for variation among households, DOE sampled a rate for each household from the distributions for the appropriate debt class. Appendix 8-D presents the probability distribution of interest rates for each debt class that DOE used in the LCC and PBP analyses.

Similar rate data are not available from the *SCF* for the asset classes, so the Department derived data for these classes from national-level historical data. The interest rates associated with certificates of deposit (CDs), [40] savings bonds, [41] and bonds (AAA corporate bonds) [42] are from Federal Reserve Board time-series data covering 1977–2009. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts are from Cost of Savings Index data covering 1984–2009.[43] The rates for stocks are the annual returns on the Standard and Poor's (S&P) 500 in 1977–2009.[44] The mutual fund rates are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year from 1977–2009. DOE adjusted the nominal rates to real rates using an inflation index. Average nominal and real interest rates for the classes of assets are shown in Table 8.2.43. Since the interest and return rates for each asset type cover a range of time, DOE believes they are representative of rates in the year in which amended standards would take effect.

Table 8.2.43 Average Nominal and Real Interest Rates for Household Equity Classes

	Average Nominal Rate (%)	Average Real Rate (%)
Checking accounts	-	0.0
Savings and money market	5.4	2.2
CDs	6.6	2.3
Savings bonds	7.7	3.3
Bonds	8.5	4.1
Stocks	11.6	7.1
Mutual funds	10.3	5.8

DOE developed a normal probability distribution of interest rates for each asset type by using the mean value and standard deviation from the distribution. To account for variation among households, DOE sampled a rate for each household from the distributions for the appropriate asset class. Appendix 8-D presents the probability distribution of interest rates for each asset type that DOE used in the LCC and PBP analyses.

Table 8.2.44 summarizes the average shares of the debt and asset shares over the six years of survey data and the mean real effective rates of each type of equity or debt. The average rate across all types of household debt and equity, weighted by the shares of each class, is 4.8 percent. In its analysis, DOE assigned specific discount rates to each sample household from the distributions discussed above.

Table 8.2.44 Shares and Interest or Return Rates Used for Household Debt and Equity Classes

	Average Share of Household Debt plus Equity (%)*	Mean Effective Real Rate (%)**
Home equity loans	3.7	3.9
Credit cards	2.1	10.7
Other installment loans	1.6	6.0
Other residential loans	5.3	4.4
Other line of credit	0.5	8.8
Checking accounts	4.4	0.0
Savings and money market accounts	15.3	2.2
CDs	8.6	2.3
Savings bonds	1.4	3.3
Bonds	9.5	4.1
Stocks	29.0	7.1
Mutual funds	18.6	5.8
Total/Weighted-average discount rate	100	**4.8**

* Not including primary mortgage or retirement accounts.

** Adjusted for inflation and, for home equity loans, loan interest tax deduction.

Discount Rates for Commercial Sector Purchasers. DOE derived the discount rate for commercial sector purchasers of room air conditioners from the cost of capital of publicly traded firms in the sectors that purchase those products. The firms typically finance equipment purchases through debt and/or equity capital. DOE estimated the cost of the firms' capital as the weighted average of the cost of equity financing and the cost of debt financing for each year between 2001 and 2008. The costs of debt and equity financing usually are publicly available for firms in lodging and other commercial sectors[g] that may purchase room air conditioners.

DOE estimated the cost of equity using the capital asset pricing model (CAPM).[45] The CAPM assumes that the cost of equity (k_e) for a given company is proportional to the systematic risk faced by that company, whereby high risk is associated with a high cost of equity and low risk is associated with a low cost of equity. The systematic risk facing a firm is determined by several variables: the risk coefficient of the firm (β), the expected return on risk-free assets (R_f), and the equity risk premium (*ERP*). The risk coefficient of a firm describes the risk associated with that firm represented by standard deviations in the firm's stock price. The expected return on risk-free assets is defined by the yield on long-term government bonds. The *ERP* represents the difference between the expected stock market return and the risk-free rate. To estimate the expected return on risk-free assets and the equity risk premium, DOE used stock and bond data from Damodaran Online, a widely used source of information about debt and equity financing for most types of firms.[46,47] The Damodaran Online data were adjusted for annual inflation

[g] The "other commercial" sector includes financial institutions and all services other than lodging (SIC 6-8).

using deflator data for the gross domestic product from the Bureau of Economic Analysis' *National Income and Product Accounts Tables*.[48]

The cost of equity financing is estimated using the following equation:

$$k_e = R_f + (\beta ? ERP)$$

Where:

k_e = cost of equity,
R_f = inflation-adjusted expected return on risk-free assets,[h]
β = risk coefficient of the firm, and
ERP = equity risk premium.

The cost of debt financing (k_d) is the interest rate paid on money a company borrows. The cost of debt is estimated by adding a risk adjustment factor (R_a) to the risk-free rate. This risk adjustment factor depends on the variability of stock returns represented by standard deviations in the firm's stock price. Thus for firm *i*, the cost of debt financing is:

$$k_{di} = R_f + R_{ai}$$

Where:

k_d = cost of debt financing for firm *i*,
R_f = expected return on risk-free assets, and
R_{ai} = risk adjustment factor to risk-free rate for firm *i*.

DOE estimates the weighted-average cost of capital using the following equation:

$$WACC = k_e ? w_e + k_d ? w_d$$

Where:

$WACC$ = weighted average cost of capital,
w_e = proportion of equity financing, and
w_d = proportion of debt financing.

The values of the parameters used in the calculations are shown in Table 8.2.45.

[h] Ibbotson Associates argues that the arithmetic mean equates the expected future value with the present value and should be used in calculating the risk-free rate and equity risk premium when using CAPM to estimate discount rates (*Stocks, Bonds, Bills, and Inflation 2009 Yearbook*, Ibbotson Associates, p. 60).

Table 8.2.45 Data for Calculating Weighted-Average Cost of Capital for Commercial Sectors

Sector	Year	β	R_f %	ERP %	R_a %	w_e %	w_d %
Lodging	2001	1.18	3.25	5.17	1.50	88	12
	2002	1.27	3.55	3.66	1.50	89	11
	2003	1.71	3.40	4.70	1.25	93	7
	2004	0.98	3.43	4.34	1.00	89	11
	2005	1.45	3.36	4.08	1.25	93	7
	2006	1.24	3.36	4.13	1.25	93	7
	2007	1.25	3.54	4.33	1.00	96	4
	2008	1.23	4.10	2.33	2.00	86	14
Other Commercial	2001	0.87	3.25	5.17	3.50	77	23
	2002	0.92	3.55	3.66	3.50	77	23
	2003	0.87	3.40	4.70	1.50	81	19
	2004	0.90	3.43	4.34	1.25	84	16
	2005	0.88	3.36	4.08	1.50	82	18
	2006	0.91	3.36	4.13	2.00	84	16
	2007	0.87	3.54	4.33	1.25	79	21
	2008	0.93	4.10	2.33	3.00	68	32

Note: Parameters are defined on the preceding two pages.

Using the procedure described above and the data in Table 8.2.40, DOE developed the real weighted-average cost of capital for the two commercial sectors that purchase room air conditioners. Those costs are listed in Table 8.2.46.

Table 8.2.46 Weighted-Average Cost of Capital for Commercial Sectors

Year	Lodging (%)	Other Commercial (%)
2001	5.69	6.75
2002	5.11	6.21
2003	5.49	6.64
2004	5.82	6.62
2005	5.95	6.24
2006	6.04	6.46
2007	6.42	6.40
2008	5.74	5.60
Sector average	5.78	6.37

DOE generated a distribution of discount rates within each sector. The standard deviation of the distribution for each sector is provided in Table 8.2.47. Weighting each sector's discount rate by its estimated share of room air conditioner purchases, DOE estimated that the average discount rate for companies that purchase room air conditioners is 6.20 percent.

Table 8.2.47 Discount Rates for Commercial Sectors

Sector	Discount Rate				Share of Purchases (%)
	Average (%)	**Max. (%)**	**Min. (%)**	**Standard Deviation (%)**	
Lodging	5.78	11.98	2.35	1.26	29
Other commercial	6.37	15.65	2.48	1.72	71
Weighted average	**6.20**	-	-	-	100

To account for variations in discount rates within each sector, DOE applied a normal probability distribution to the average values and standard deviations in Table 8.2.47. DOE truncated the normal distribution using the maximum and minimum values.

8.2.2.8 Effective Date of Standard

The effective date is the future date when a new standard becomes operative. Based on DOE's implementation report for energy conservation standards activities submitted pursuant to Section 141 of the Energy Policy Act of 2005, a final rule for the home appliances being considered for this standards rulemaking is scheduled for completion in June 2011.[49] Therefore, the effective date of any new energy efficiency standards for these products will be three years after the final rule is published, which is June 2014. DOE calculated the LCC for all consumers as if they each would purchase a new product in the year the standard takes effect.

8.2.3 Product Energy Efficiency in the Base Case

To estimate the percentage of consumers who would be affected by a standard at any of the potential efficiency levels, in its LCC analysis DOE considered the projected distribution of efficiencies for products that consumers purchase under the base case (the case without amended energy efficiency standards). DOE refers to this distribution of product energy 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 sample household and commercial user. If a household is assigned a product efficiency that is greater than or equal to the efficiency of the standard level under consideration, the LCC calculation shows that this household would not be affected by that standard level. The energy efficiency distributions that DOE used in the LCC analysis are described below.

8.2.3.1 Clothes Dryers

To develop a base case energy efficiency distribution for clothes dryers, DOE began with data that AHAM provided showing the distribution of clothes dryer efficiencies sold by product class in 2005–2007. Because there is no evidence of change in average efficiency in recent years, DOE assumed that the shares remain the same in 2014. The market shares in Tables 8.2.48 and 8.2.49 represent the products that households would be expected to purchase in 2014 in the absence of new standards.

Table 8.2.48 Vented Clothes Dryers Energy Efficiency: Base Case Market Shares in 2014

Electric, Standard		Electric, Compact (120V)		Electric, Compact (240V)		Gas	
CEF (lb/kWh)	**Share**	**CEF (lb/kWh)**	**Share**	**CEF (lb/kWh)**	**Share**	**CEF (lb/kWh)**	**Share**
3.55	2.6%	3.43	59.4%	3.12	100.0%	3.14	7.9%
3.56	18.9%	3.48	0.0%	3.16	0.0%	3.16	8.2%
3.61	53.5%	3.61	15.6%	3.27	0.0%	3.20	42.9%
3.73	17.9%	3.72	16.7%	3.36	0.0%	3.30	30.9%
3.81	6.1%	3.80	4.2%	3.48	0.0%	3.41	9.3%
4.08	1.0%	4.08	4.2%	3.60	0.0%	3.61	0.9%
5.42	0.0%	5.41	0.0%	4.89	0.0%	-	-

Table 8.2.49 Vent-less Clothes Dryers Energy Efficiency: Base Case Market Shares in 2014

Electric, Compact (240V)		Electric, Combination Washer/Dryer	
CEF (lb/kWh)	**Share**	**CEF (lb/kWh)**	**Share**
2.55	100.0%	2.08	100.0%
2.59	0.0%	2.35	0.0%
2.69	0.0%	2.38	0.0%
2.71	0.0%	2.46	0.0%
2.80	0.0%	2.56	0.0%
4.03	0.0%	3.69	0.0%

8.2.3.2 Room Air Conditioners

To develop a base-case energy efficiency distribution for room air conditioners, DOE began with data that AHAM provided showing the distribution of room air conditioner efficiencies sold by product class in 2005–2007. Using these data, DOE derived the shares in Tables 8.2.50 and 8.2.51. Regarding change in energy efficiency in coming years, DOE used historical trends from 2005 to 2009, which give a 0.25 percent annual growth trend in energy star levels. Therefore, DOE assumed that the market shares of the efficiency levels in 2014 will be higher than in 2007. The market shares in the following tables represent the products that consumers would be expected to purchase in 2014 in the absence of new standards.

Table 8.2.50 Room Air Conditioners with Louvers: Base Case Market Shares in 2014

Less than 6,000 Btu/h		8,000–13,999 Btu/h		20,000-24,999 Btu/h		Greater than 25,000 Btu/h	
CEER	**Share**	**CEER**	**Share**	**CEER**	**Share**	**CEER**	**Share**
9.52	70.0%	9.69	38.4%	8.47	13.6%	8.48	12.9%
10.10	0.0%	10.20	2.4%	9.00	1.4%	9.00	2.1%
10.60	29.0%	10.70	57.9%	9.40	81.0%	9.40	85.0%
11.10	1.0%	10.90	1.5%	9.80	2.0%	9.80	0.0%
11.38	0.0%	11.50	0.2%	10.15	2.0%	--	--
11.67	0.0%	11.96	0.4%	--	--	--	--

Table 8.2.51 Room Air Conditioners without Louvers: Base Case Market Shares in 2014

8,000-10,999 Btu/h		Greater than 11,000 Btu/h	
CEER	**Share**	**CEER**	**Share**
8.41	10.0%	8.44	10.0%
9.30	65.2%	9.30	60.0%
9.60	19.2%	9.50	12.9%
10.00	3.7%	9.80	17.1%
10.35	1.9%	10.02	0.0%

DOE also assembled data for 2002–2007 on market shares of ENERGY STAR room air conditioners by State and organized them into Census Divisions and four large States. In assigning a product efficiency to each sample household and commercial user, DOE accounted for regional patterns in the efficiency distribution.

8.3 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

This section presents the LCC and PBP results for clothes dryers and room air conditioners . As discussed in section 8.1.1, DOE's approach for conducting the LCC analysis relied on developing samples of consumers that use each of the products. DOE also characterized the uncertainty of many of the inputs to the analysis with probability distributions. DOE used a Monte Carlo simulation technique to perform the LCC calculations on the consumers in the sample. For each set of sample consumers using the product in each product class, DOE calculated the average LCC and LCC savings and the median and average PBP for each of the candidate standard levels (CSLs). At this stage of the rulemaking, the CSLs correspond to the energy efficiency levels presented in the preceding sections.

DOE calculated LCC savings and PBPs relative to the base case products that it assigned to the sample households. As discussed in section 8.2.6, for some consumers DOE assigned a base case product that is more efficient than some of the CSLs. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific standard level and the LCC of the baseline product.

LCC and PBP calculations were performed 10,000 times on the sample of consumers established for each product. Each LCC and PBP calculation was performed on a single consumer that was selected from the sample. The selection of a consumer was based on its weight (i.e., how representative a particular consumer is of other consumers 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.

Based on the Monte Carlo simulations that DOE performed, for each CSL, DOE calculated the share of consumers with a net LCC benefit, with a net LCC cost, and with no impact. DOE considered a consumer to receive no impact at a given standard level if DOE assigned it a base case product that is the same as or has a higher efficiency than the standard level. To illustrate the range of LCC and PBP impacts among the sample consumers, the sections below present figures that provide such information for each product class.

The results presented in section 8.3.2 for room air conditioners combine the results for residential and commercial users, which means that DOE had to give an appropriate weight to the results for each type of user. DOE did not find any room air conditioner shipment data that gives a breakdown between commercial and residential purchasers. It based the shares of shipments in the effective year of each of these purchaser types on the estimated residential and commercial shares of the total national stock of room air conditioners in 2007.

The AHS 2007[7] provides the number of households with a room air conditioner (31.4 million),[i] as well as the total number of residential room air conditioners (53.8 million residential room air conditioners) in 2007. For calculating the stock of commercial room air conditioners, CBECS 2003 gives the total floor area cooled by room air conditioners. Assuming a ton of cooling capacity is adequate to cool 300 sq. ft., an average size of 10,000 Btu/h and a value of 12,000 Btu/h per ton, DOE estimated that an average room air conditioner cools 250 sq. ft. Dividing the total floor area cooled by room air conditioners by 250 sq ft per room air conditioner yields a value close to 7 million room air conditioners in commercial buildings. Using the above values yields shares of the total room air conditioner stock of 88.4 percent for residential units and 11.6 percent for commercial units.

8.3.1 Clothes Dryers

8.3.1.1 Summary of Results

Tables 8.3.1 through 8.3.6 summarize the LCC and payback period results by CSL for each considered clothes dryer product class. With regard to the PBPs shown below, DOE determined the median and average values by excluding the percentage of households not impacted by the standard.

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[i] AHS provides a complete set of all households in the United States (not only households currently in use, but also vacant households and households with seasonal use).

Table 8.3.1 Vented Clothes Dryers, Electric, Standard: LCC and PBP Results

CSL	CEF *lb/kWh*	Life-Cycle Cost: Average Installed Cost	Life-Cycle Cost: Average Lifetime Operating Cost*	Life-Cycle Cost: Average LCC	Life-Cycle Cost Savings: Average Savings	Households with: Net Cost	Households with: No Impact	Households with: Net Benefit	Median Payback Period (years)
Baseline	3.55	$455	$869	$1,324	N/A	0%	100%	0%	N/A
1	3.56	$455	$867	$1,323	$0	1%	98%	2%	3.9
2	3.61	$456	$856	$1,311	$2	0%	79%	21%	0.2
3	3.73	$467	$829	$1,296	$14	19%	25%	56%	5.3
4	3.81	$528	$812	$1,340	-$27	79%	7%	14%	25.4
5	4.08	$583	$761	$1,343	-$30	75%	1%	24%	19.1
6	5.42	$879	$580	$1,459	-$146	81%	0%	19%	22.1

* Discounted

Table 8.3.2 Vented Clothes Dryers, Compact (120V): LCC and PBP Results

CSL	CEF *lb/kWh*	Life-Cycle Cost: Average Installed Cost	Life-Cycle Cost: Average Lifetime Operating Cost*	Life-Cycle Cost: Average LCC	Life-Cycle Cost Savings: Average Savings	Households with: Net Cost	Households with: No Impact	Households with: Net Benefit	Median Payback Period (years)
Baseline	3.43	$470	$384	$854	N/A	0%	100%	0%	N/A
1	3.48	$471	$379	$850	$4	5%	0%	95%	2.7
2	3.61	$471	$369	$840	$14	4%	0%	96%	0.9
3	3.72	$501	$357	$858	-$5	73%	0%	27%	15.0
4	3.80	$560	$350	$910	-$56	96%	0%	4%	34.4
5	4.08	$627	$325	$953	-$99	95%	0%	5%	36.1
6	5.41	$875	$243	$1,118	-$264	95%	0%	5%	40.1

* Discounted

Table 8.3.3 Vented Clothes Dryers, Compact (240V): LCC and PBP Results

CSL	CEF *lb/kWh*	Life-Cycle Cost: Average Installed Cost	Life-Cycle Cost: Average Lifetime Operating Cost*	Life-Cycle Cost: Average LCC	Life-Cycle Cost Savings: Average Savings	Households with: Net Cost	Households with: No Impact	Households with: Net Benefit	Median Payback Period (years)
Baseline	3.12	$470	$427	$896	N/A	0%	100%	0%	N/A
1	3.16	$471	$422	$893	$2	4%	41%	55%	2.8
2	3.27	$471	$411	$882	$8	2%	41%	56%	0.9
3	3.36	$501	$400	$901	-$5	58%	25%	17%	15.7
4	3.48	$560	$386	$946	-$47	87%	8%	5%	33.5
5	3.60	$627	$373	$1,000	-$99	93%	4%	3%	45.1
6	4.89	$875	$272	$1,147	-$246	95%	0%	5%	38.2

* Discounted

Table 8.3.4 Vented Clothes Dryers, Gas: LCC and PBP Results

CSL	CEF *lb/kWh*	Life-Cycle Cost: Average Installed Cost	Life-Cycle Cost: Average Lifetime Operating Cost*	Life-Cycle Cost: Average LCC	Life-Cycle Cost Savings: Average Savings	Households with: Net Cost	Households with: No Impact	Households with: Net Benefit	Median Payback Period (years)
Baseline	3.14	$554	$445	$999	N/A	0%	100%	0%	N/A
1	3.16	$555	$440	$995	$0	1%	93%	7%	2.2
2	3.20	$555	$427	$983	$2	0%	85%	15%	0.5
3	3.30	$567	$416	$983	$2	32%	42%	26%	11.7
4	3.41	$658	$404	$1,062	-$69	88%	11%	2%	73.3
5	3.61	$712	$381	$1,093	-$100	95%	1%	4%	49.5

* Discounted

Table 8.3.5 Vent-less Clothes Dryers, Electric (240V): LCC and PBP Results

CSL	CEF *lb/kWh*	Life-Cycle Cost: Average Installed Cost	Life-Cycle Cost: Average Lifetime Operating Cost*	Life-Cycle Cost: Average LCC	Life-Cycle Cost Savings: Average Savings	Households with: Net Cost	Households with: No Impact	Households with: Net Benefit	Median Payback Period (years)
Baseline	2.55	$1,093	$452	$1,545	N/A	0%	100%	0%	N/A
1	2.59	$1,094	$446	$1,540	$5	0%	0%	100%	2.4
2	2.69	$1,094	$431	$1,525	$20	0%	0%	100%	0.9
3	2.71	$1,131	$427	$1,558	-$13	85%	0%	15%	18.1
4	2.80	$1,176	$411	$1,587	-$42	92%	0%	8%	25.3
5	4.03	$1,462	$261	$1,722	-$177	88%	0%	12%	26.9

* Discounted

Table 8.3.6 Vent-less Clothes Dryers, Electric Combination: LCC and PBP Results

CSL	CEF *lb/kWh*	Life-Cycle Cost			Life-Cycle Cost Savings				Median Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost*	Average LCC	Average Savings	Households with			
						Net Cost	No Impact	Net Benefit	
Baseline	2.08	$1,533	$565	$2,098	N/A	0%	100%	0%	N/A
1	2.35	$1,535	$488	$2,023	$75	2%	0%	98%	0.4
2	2.38	$1,536	$482	$2,019	$79	0%	0%	100%	0.6
3	2.46	$1,537	$468	$2,005	$93	0%	0%	100%	0.5
4	2.56	$1,579	$446	$2,025	$73	21%	0%	79%	5.3
5	3.69	$1,981	$282	$2,263	-$166	82%	0%	18%	22.4

* Discounted

8.3.1.2 Distributions of Impacts

The figures below show the distribution of LCCs in the base case for each product class. Also presented below, for a specific standard level, are figures showing the distribution of LCC impacts and the distribution of PBPs. The figures are presented as frequency charts that show the distribution of LCCs, LCC impacts, and PBPs with their corresponding probability of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples.

Base Case LCC Distributions. Figures 8.3.1 to 8.3.6 show the base case LCC distributions for the six clothes dryer product classes that DOE analyzed for this rulemaking. The figures show the full range of LCCs for the clothes dryer sample.

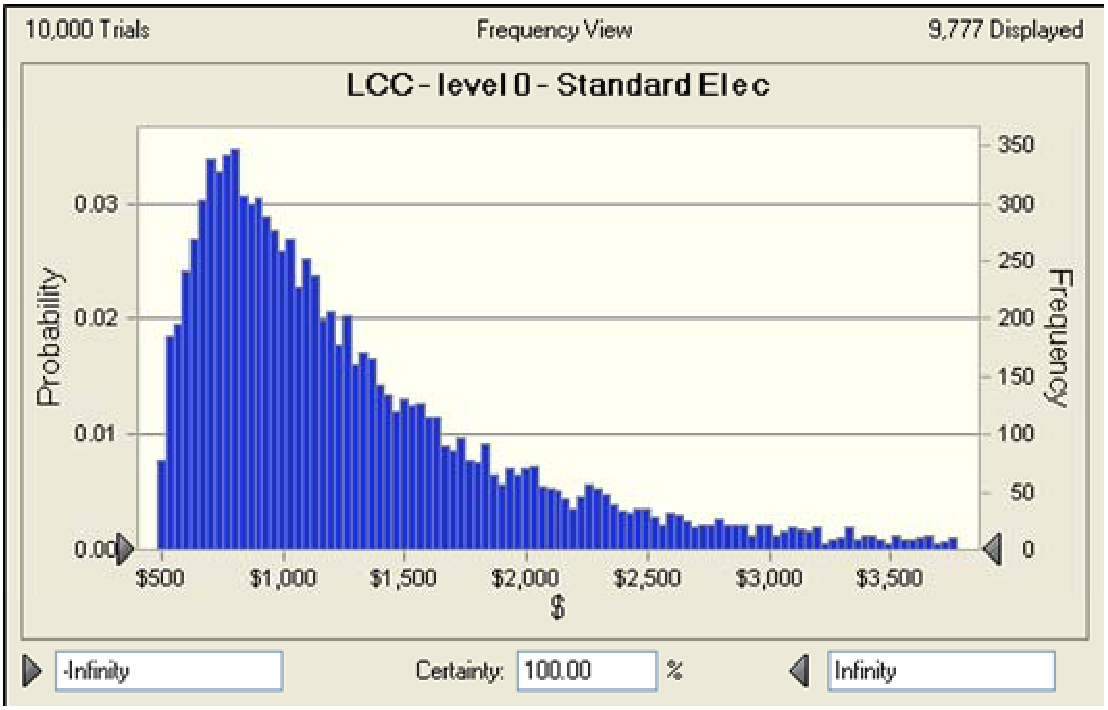

Figure 8.3.1 Clothes Dryers, Electric Standard, Base Case LCC Distribution

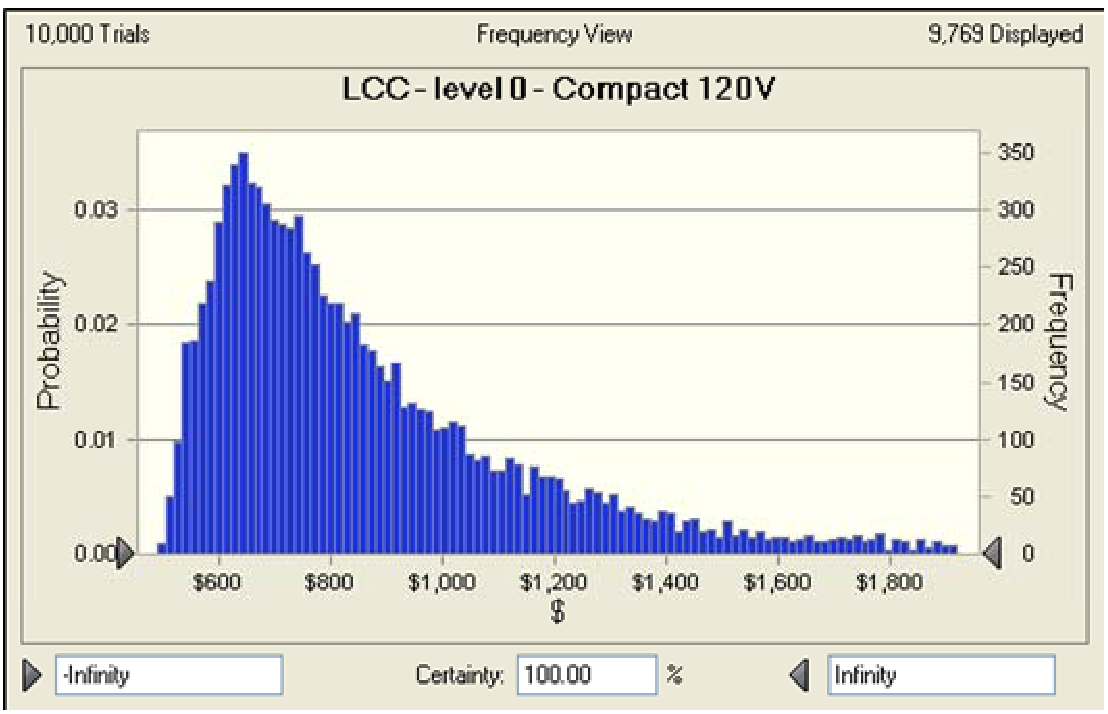

Figure 8.3.2 Clothes Dryers, Electric Compact 120V, Case LCC Distribution

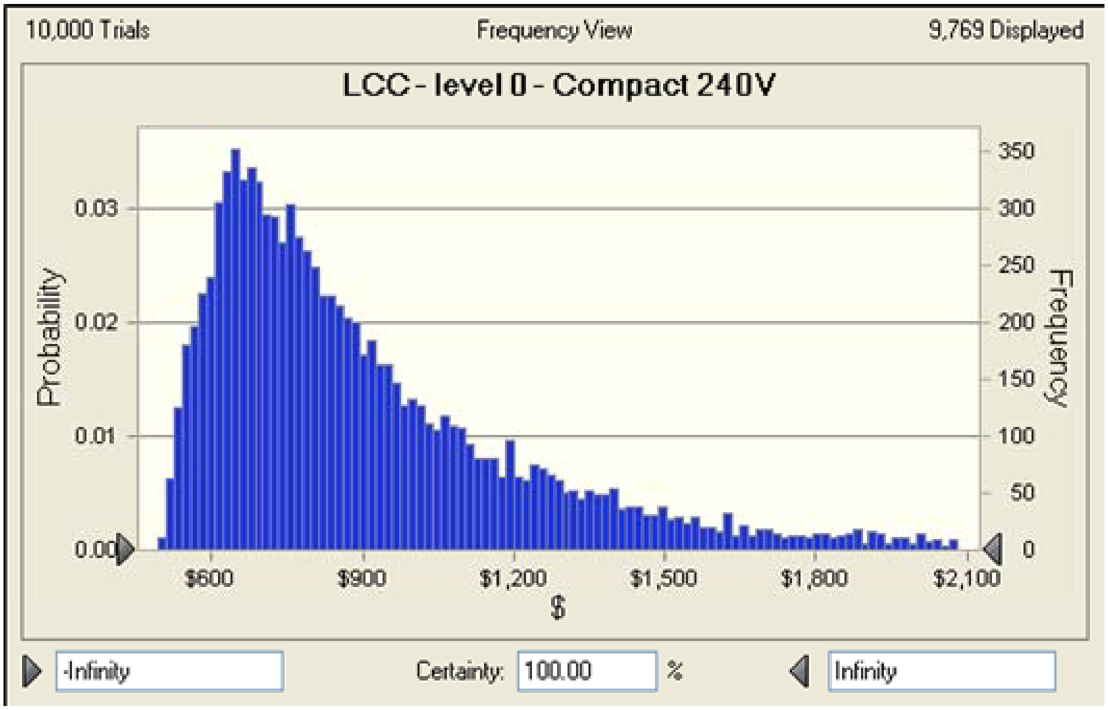

Figure 8.3.3 Clothes Dryers, Electric Compact 240V, Base Case LCC Distribution

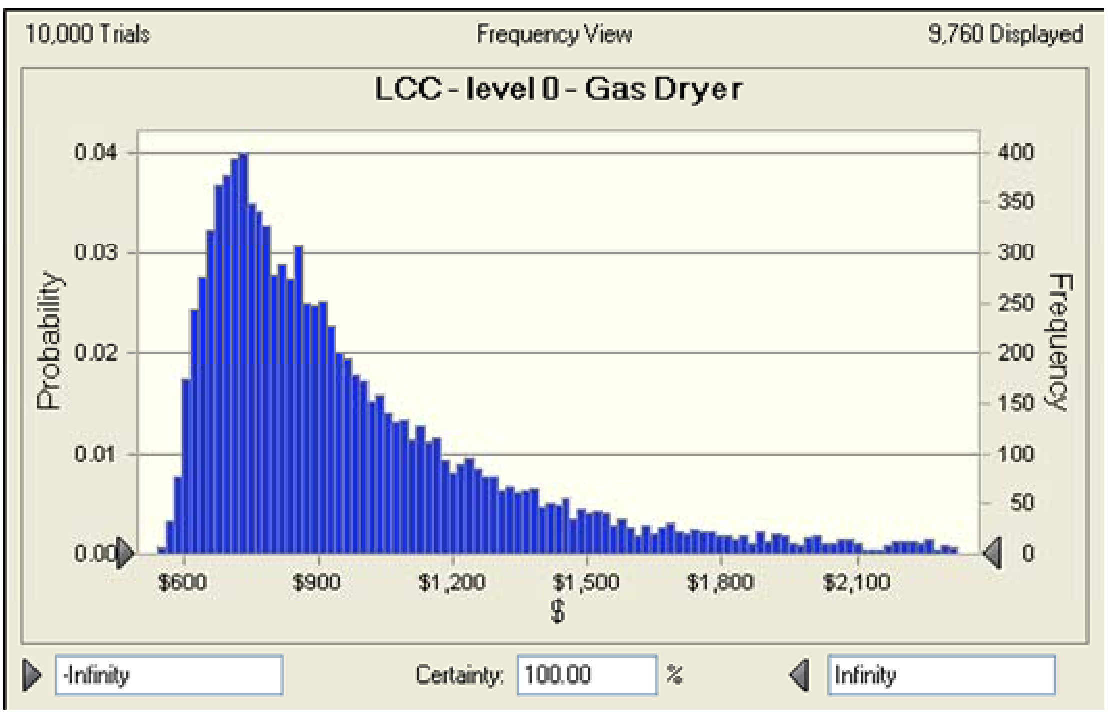

Figure 8.3.4 Clothes Dryers, Gas, Base Case LCC Distribution

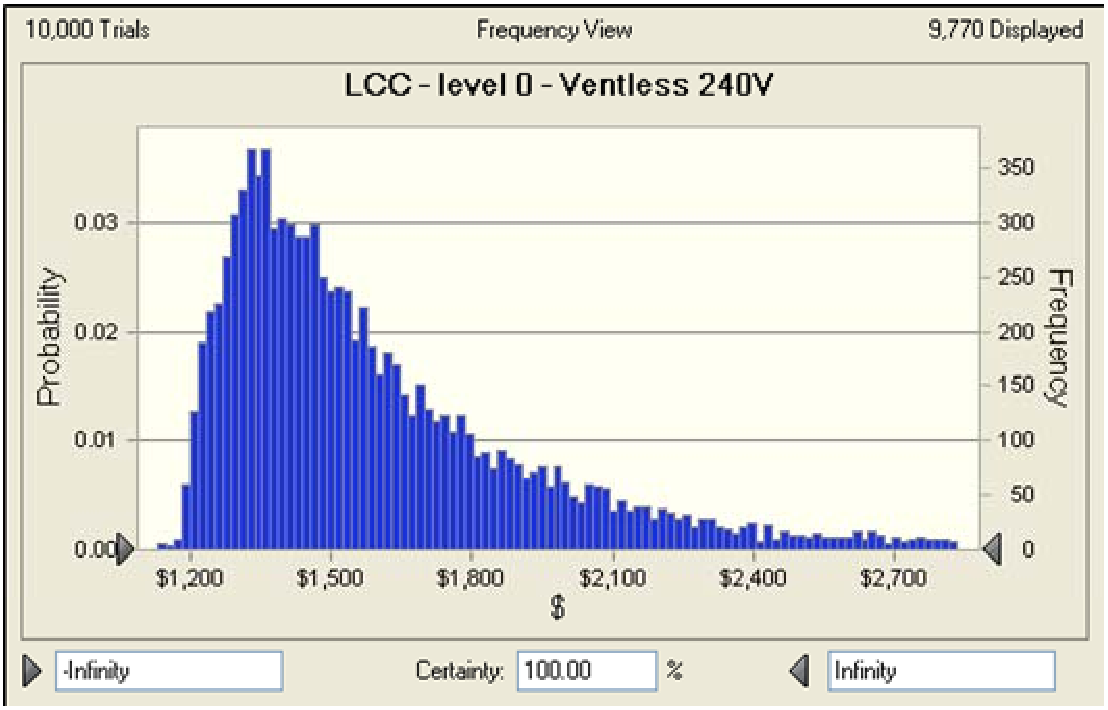

Figure 8.3.5 Clothes Dryers, Vent-less 240V, Standard Base Case LCC Distribution

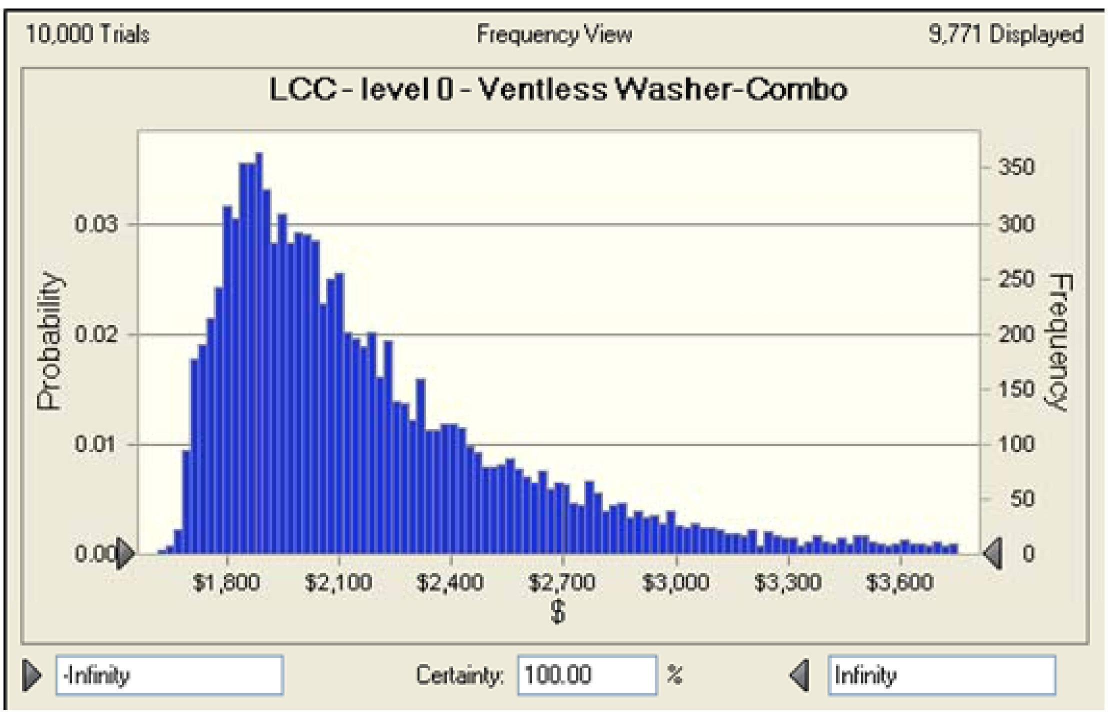

Figure 8.3.6 Clothes Dryers, Vent-less Combination Washer/Dryer, Standard Base Case LCC Distribution

Figure 8.3.7 is an example of a frequency chart showing the distribution of LCC savings for standard level 3 for electric standard clothes dryers. DOE can generate similar frequency charts for every standard level.

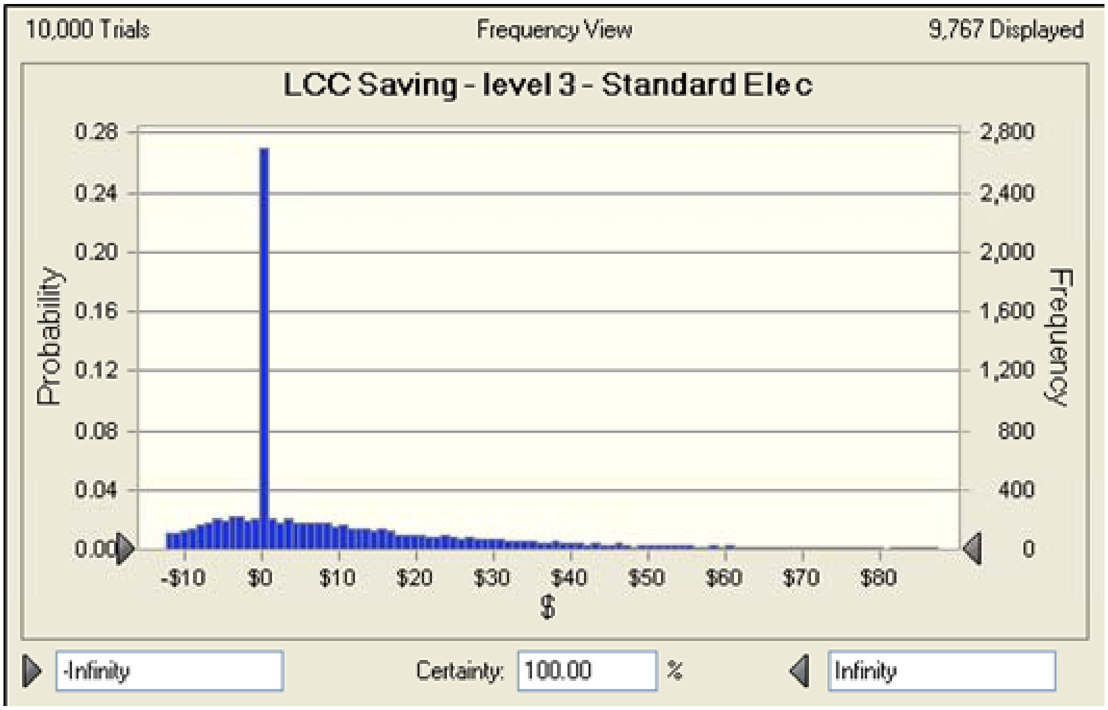

Figure 8.3.7 Clothes Dryers, Electric Standard, Standard Level 3 LCC Savings Distribution

Figure 8.3.8 is an example of a frequency chart showing the distribution of PBPs for standard level 3 for electric standard clothes dryers. DOE can generate similar frequency charts for every standard level.

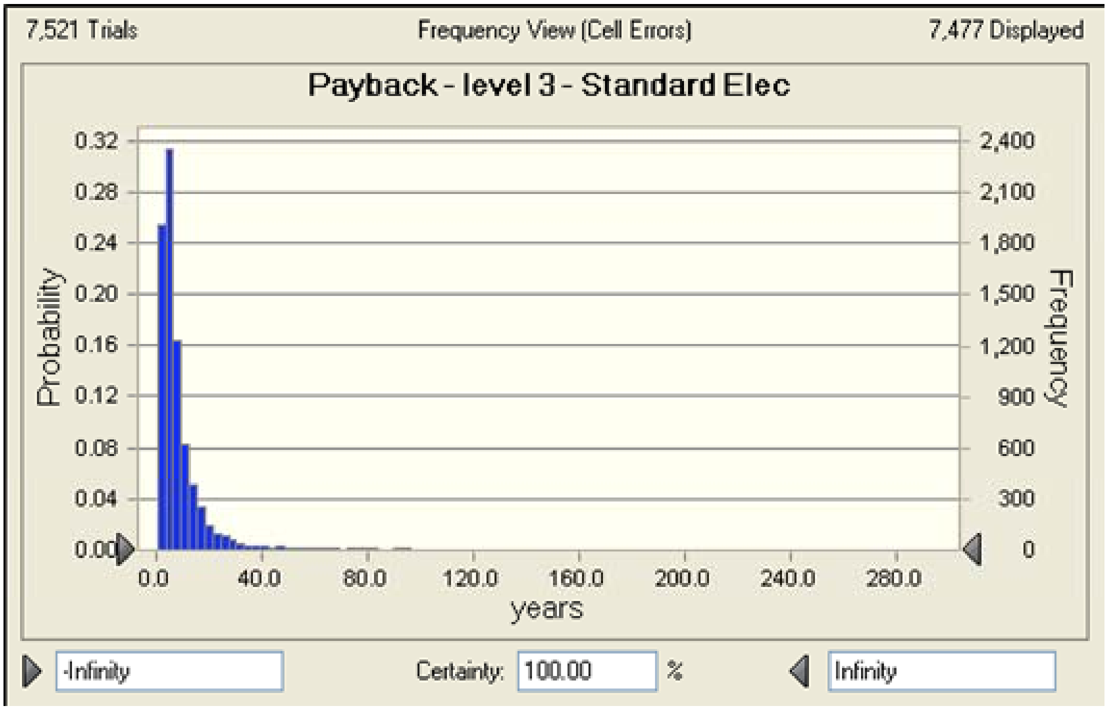

Figure 8.3.8 Clothes Dryers, Electric Standard, Standard Level 3 PBP Distribution

8.3.1.3 Range of Impacts

Figures 8.3.9 through 8.3.14 show the range of LCC savings for all the CSLs considered for each clothes dryer product class. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have lifecycle cost savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level. Negative savings means that the LCC increases relative to the base case.

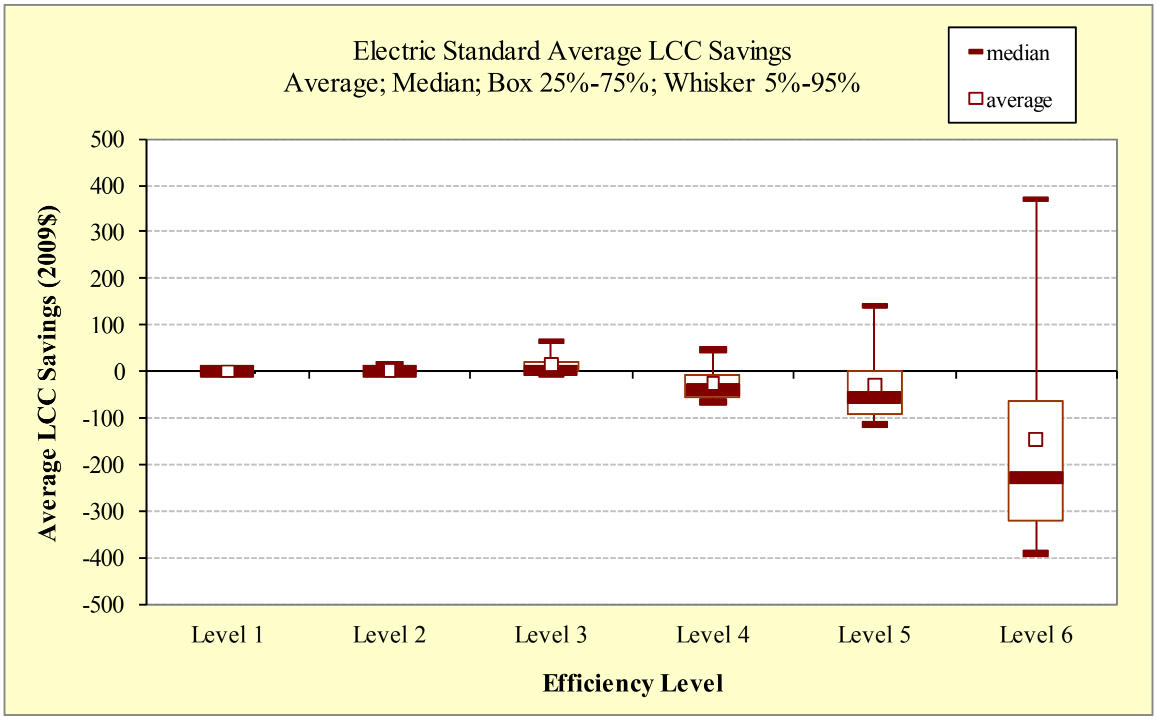

Figure 8.3.9 Clothes Dryers, Electric Standard, Range of LCC Savings

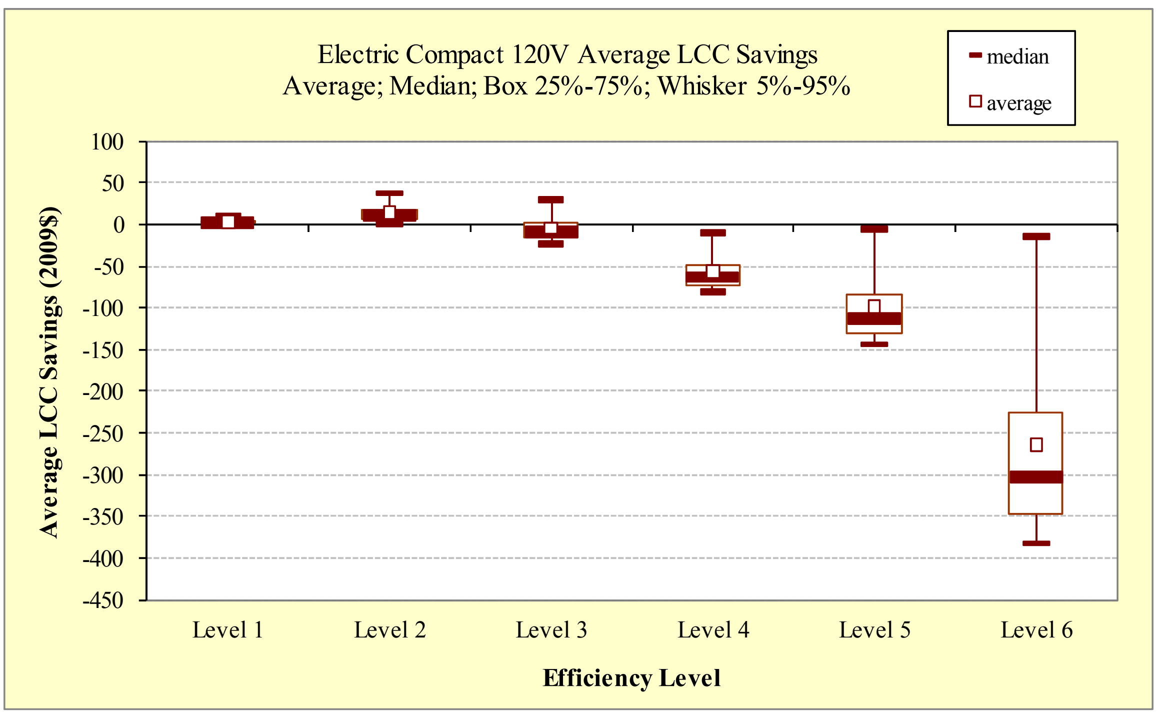

Figure 8.3.10 Clothes Dryers, Electric Compact 120V, Range of LCC Savings

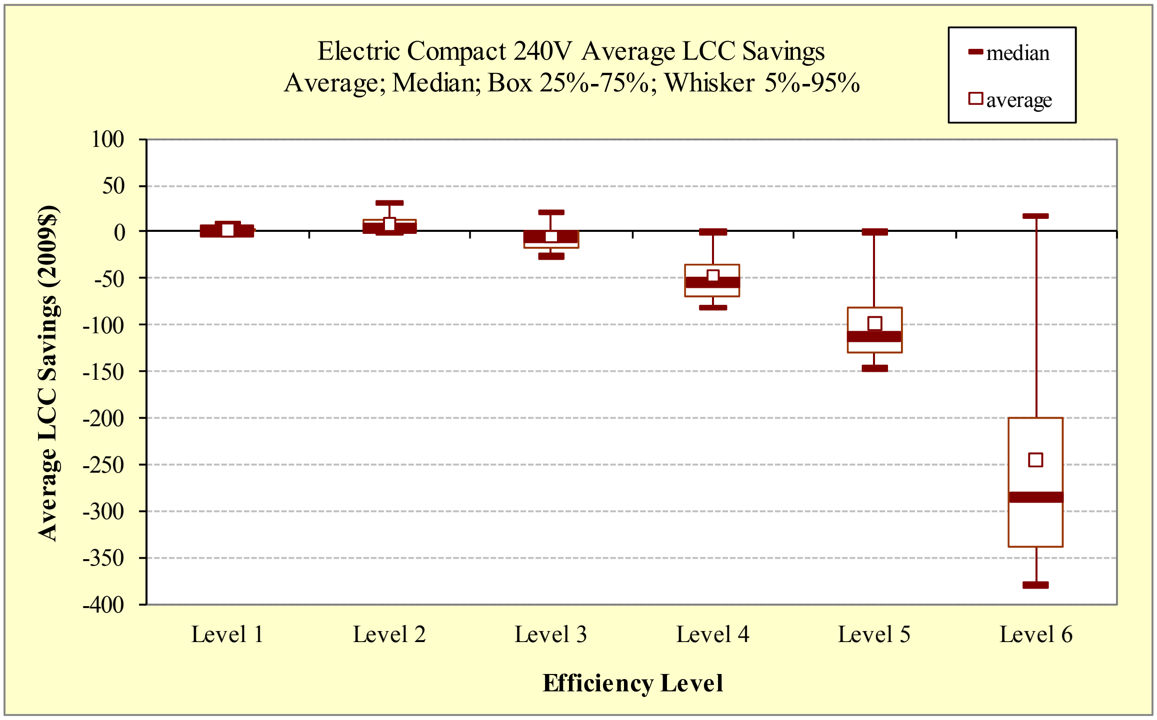

Figure 8.3.11 Clothes Dryers, Electric Compact 240V, Range of LCC Savings

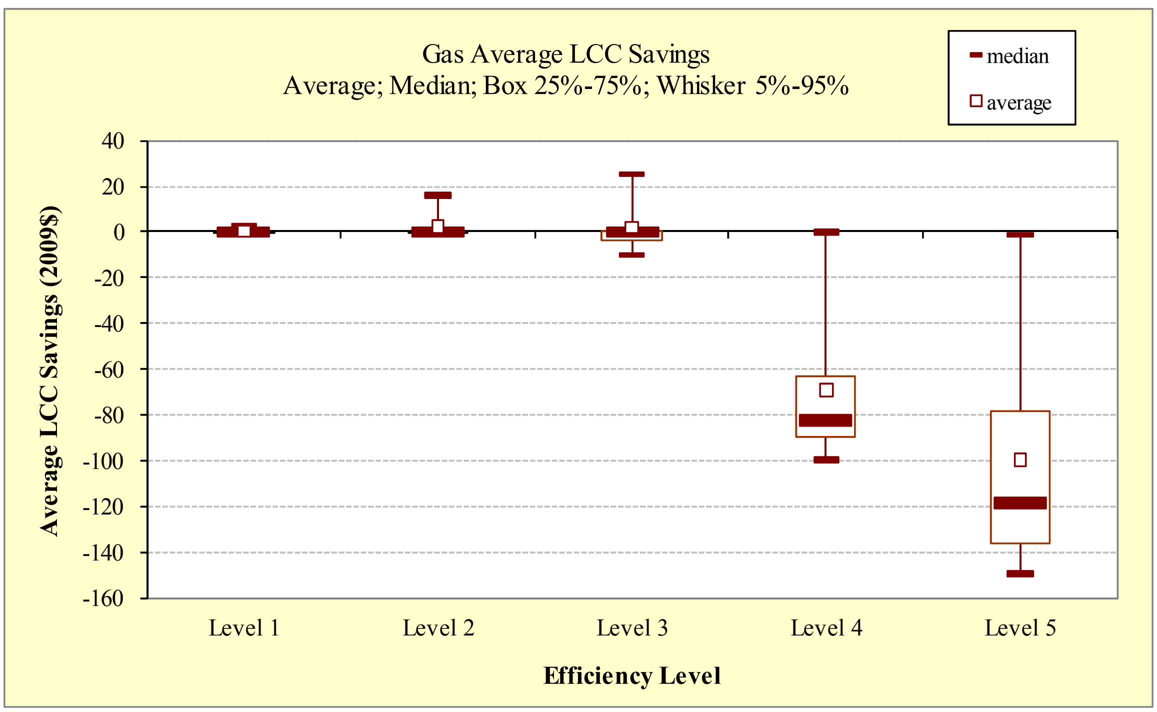

Figure 8.3.12 Clothes Dryers, Gas, Range of LCC Savings

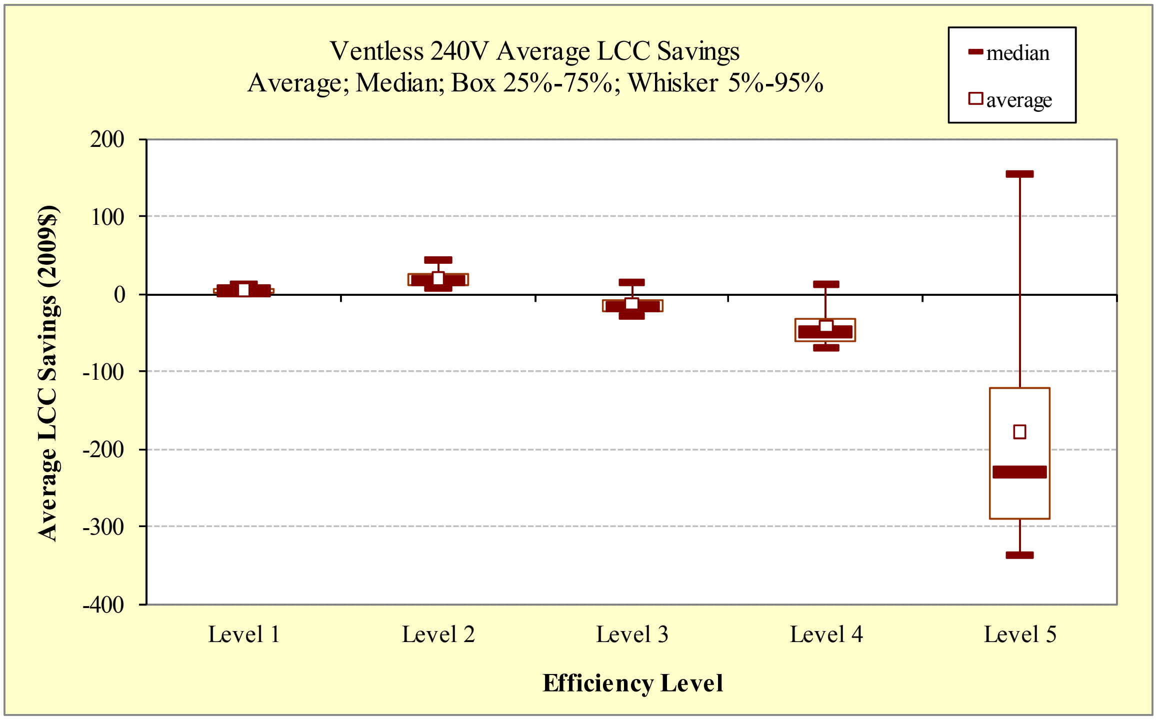

Figure 8.3.13 Clothes Dryers, Vent-less 240V , Range of LCC Savings

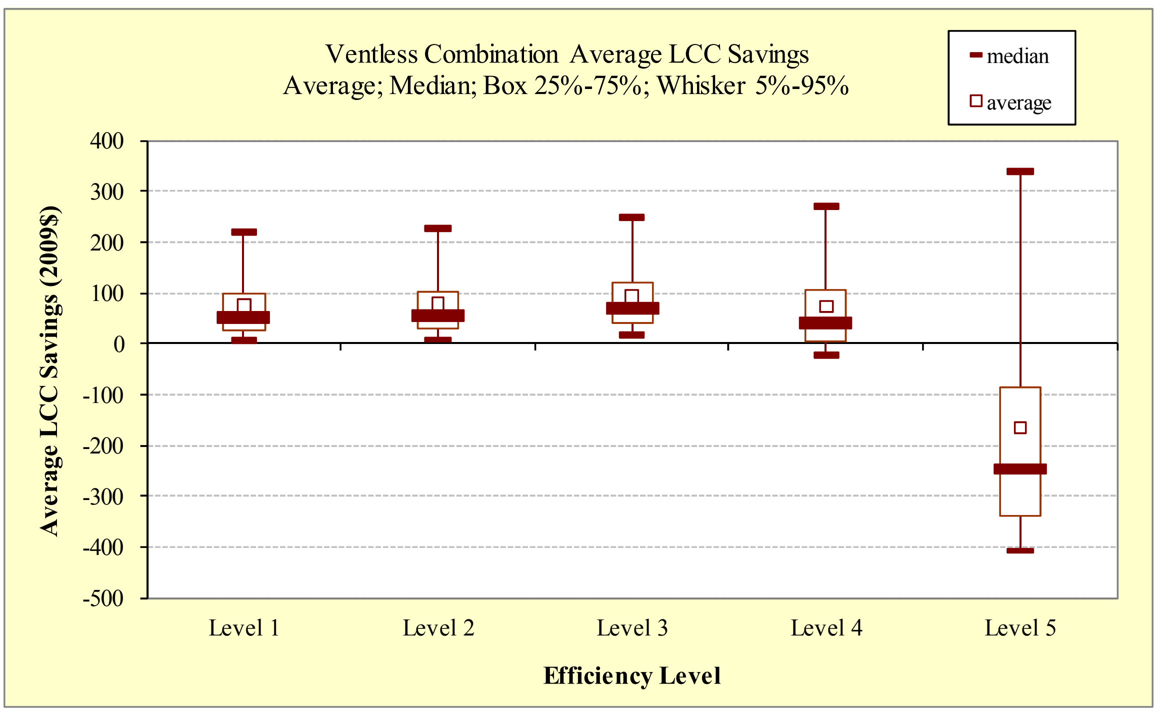

Figure 8.3.14 Clothes Dryers, Vent-less Combination Washer/Dryer, Range of LCC Savings

Figures 8.3.15 through 8.3.20 show the range of PBPs for all CSLs considered for each clothes dryer product class. For each efficiency level, the top and bottom of the box in the figure indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median: 50 percent of the households have a payback period above this value. The horizontal lines above and below each box indicate the 95th and 5th percentiles, respectively. The small box indicates the average PBP for each CSL.

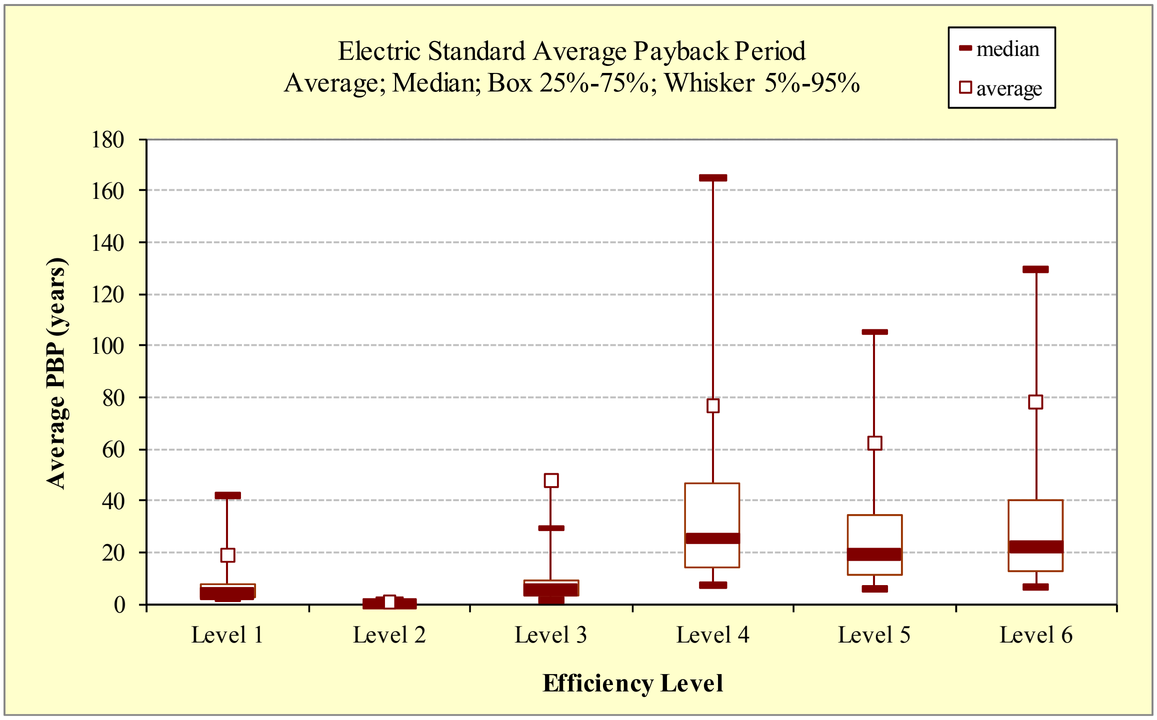

Figure 8.3.15 Clothes Dryers, Vented, Electric Standard, Range of Payback Periods

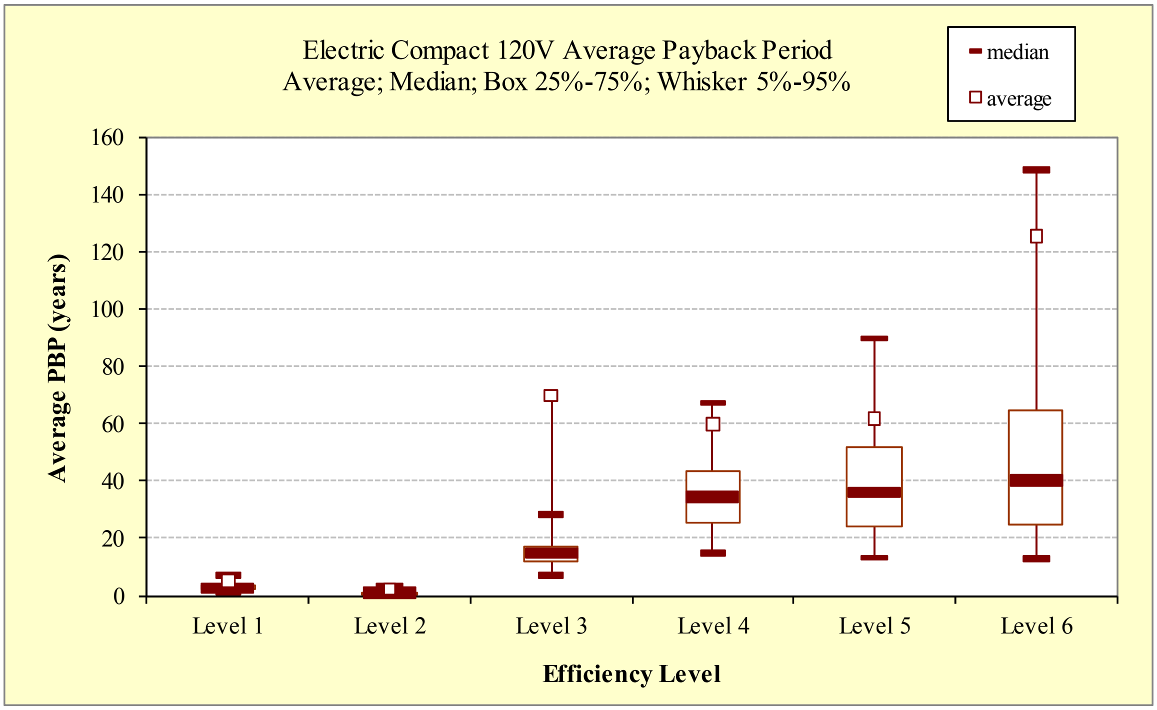

Figure 8.3.16 Clothes Dryers, Vented, Electric Compact 120V, Range of Payback Periods

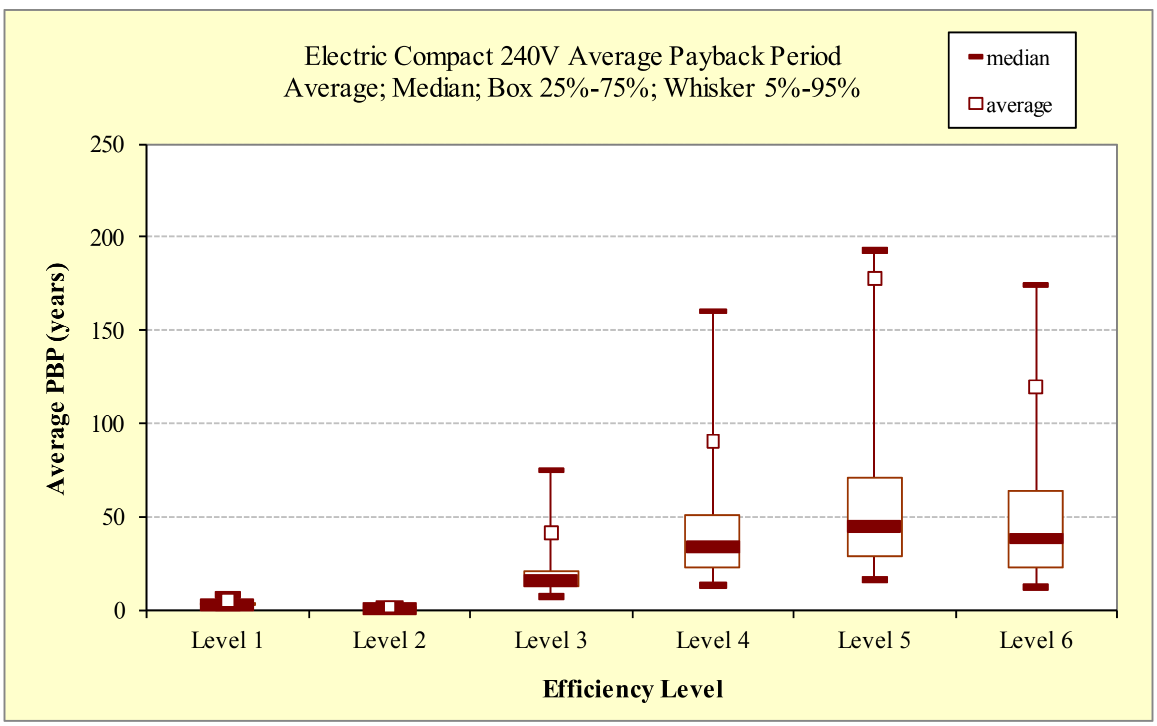

Figure 8.3.17 Clothes Dryers, Vented, Electric Compact 240V, Range of Payback Periods

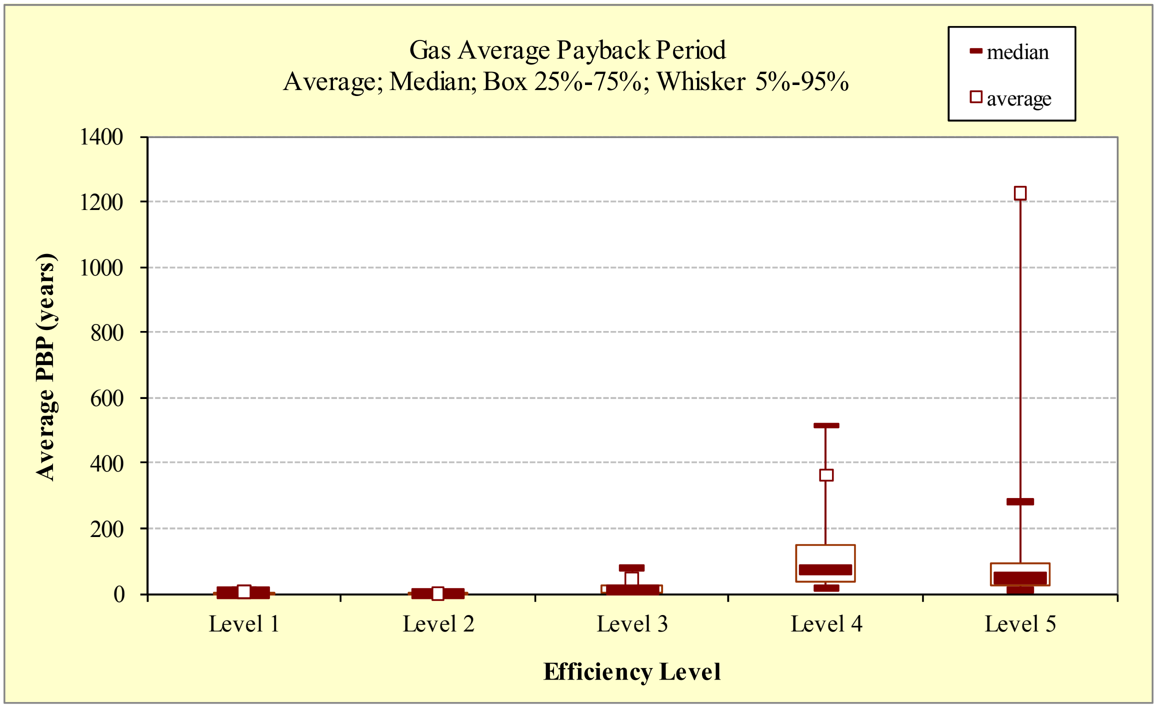

Figure 8.3.18 Clothes Dryers, Vented, Gas, Range of Payback Periods

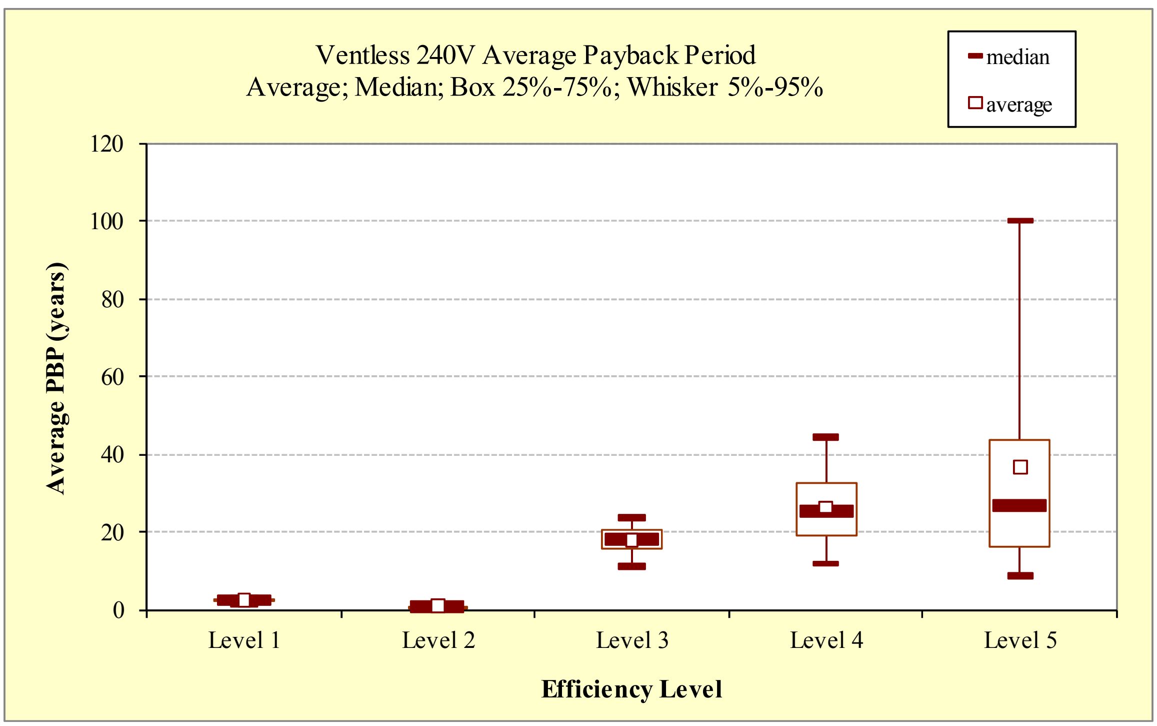

Figure 8.3.19 Clothes Dryers, Vent-less 240V , Range of Payback Periods

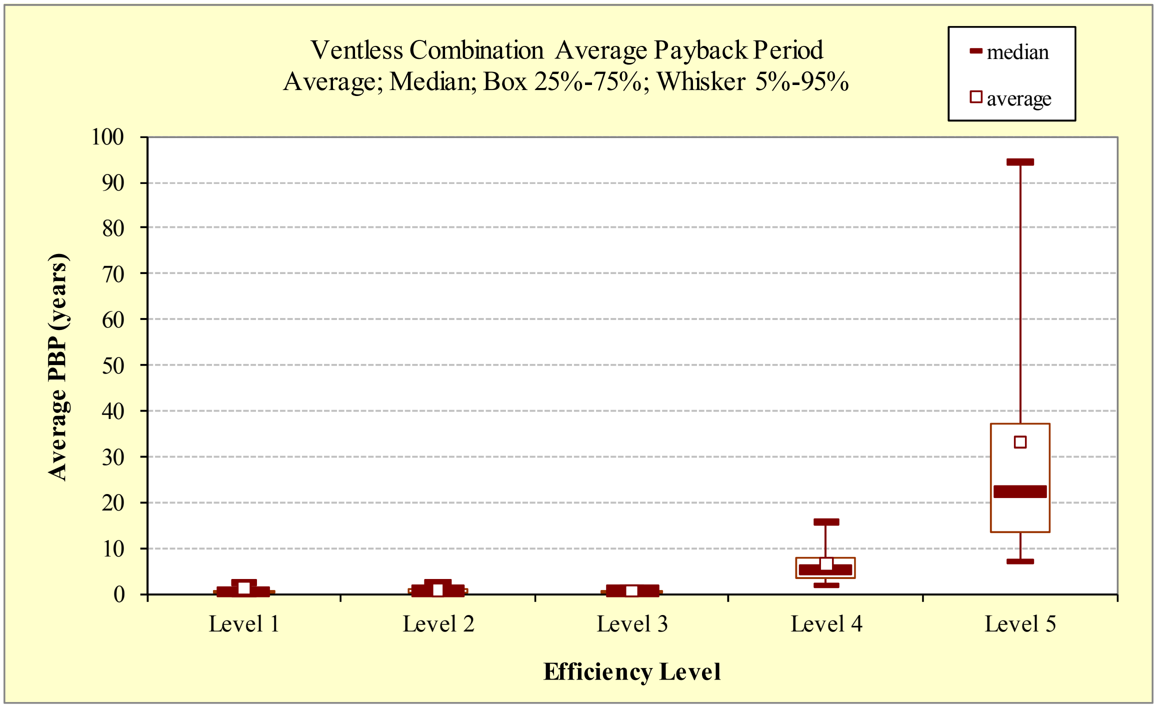

Figure 8.3.20 Clothes Dryers, Vent-less Combination Washer/Dryer, Range of Payback Periods

8.3.2 Room Air Conditioners

8.3.2.1 Summary of Results

Tables 8.3.7 through 8.3.12 show the LCC and PBP results by CSL for each representative room air conditioner product class. The CSLs correspond to the energy efficiency levels included in the engineering analysis. With regard to the PBPs, DOE determined the median and average values by excluding the percentage of users not impacted by the standard.

Table 8.3.7 Room Air Conditioners, less than 6,000 Btu/h, with Louvers: LCC and PBP Results

CSL	CEER	Life-Cycle Cost			Life-Cycle Cost Savings				Median Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost*	Average LCC	Average Savings	Users with Net Cost	Users with No Impact	Users with Net Benefit	
Baseline	9.52	$351	$380	$731	N/A	0%	100%	0%	N/A
1	10.1	$361	$357	$718	$9	21%	31%	48%	4.1
2	10.6	$374	$341	$715	$11	33%	31%	37%	5.8
3	11.1	$393	$326	$719	$7	65%	1%	34%	8.6
4	11.4	$410	$319	$729	-$3	74%	0%	26%	10.9
5	11.7	$472	$311	$784	-$58	90%	0%	10%	20.9

* Discounted

Table 8.3.8 Room Air Conditioners, 8,000–13,999 Btu/h, with Louvers: LCC and PBP Results

CSL	CEER	Life-Cycle Cost			Life-Cycle Cost Savings				Median Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost*	Average LCC	Average Savings	Users with Net Cost	Users with No Impact	Users with Net Benefit	
Baseline	9.69	$477	$614	$1,091	N/A	0%	100%	0%	N/A
1	10.2	$483	$584	$1,067	$9	4%	63%	33%	1.7
2	10.7	$493	$557	$1,050	$16	9%	60%	30%	0.0
3	10.9	$497	$547	$1,045	$22	34%	2%	64%	2.8
4	11.5	$525	$519	$1,044	$22	56%	1%	43%	7.1
5	12.0	$605	$500	$1,104	-$38	77%	0%	22%	14.7

* Discounted

Table 8.3.9 Room Air Conditioners, 20,000–24,999 Btu/h, with Louvers: LCC and PBP Results

CSL	CEER	Life-Cycle Cost			Life-Cycle Cost Savings				Median Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost*	Average LCC	Average Savings	Users with Net Cost	Users with No Impact	Users with Net Benefit	
Baseline	8.47	$857	$750	$1,607	N/A	0%	100%	0%	N/A
1	9.0	$872	$707	$1,579	$3	4%	87%	9%	4.3
2	9.4	$887	$672	$1,559	$6	5%	85%	10%	4.3
3	9.8	$932	$645	$1,577	-$10	87%	4%	9%	22.2
4	10.2	$1,159	$626	$1,785	-$214	98%	2%	0%	73.8

* Discounted

Table 8.3.10 Room Air Conditioners, greater than 25,000 Btu/h, with Louvers: LCC and PBP Results

CSL	CEER	Life-Cycle Cost			Life-Cycle Cost Savings				Median Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost*	Average LCC	Average Savings	Users with Net Cost	Users with No Impact	Users with Net Benefit	
Baseline	8.48	$979	$823	$1,802	N/A	0%	100%	0%	N/A
1	9.00	$1,019	$777	$1,796	$1	9%	88%	4%	10.1
2	9.40	$1,058	$739	$1,797	$1	11%	85%	4%	10.3
3	9.80	$1,313	$712	$2,025	-$227	100%	0%	0%	107.7

* Discounted

Table 8.3.11 Room Air Conditioners, 8,000–10,999 Btu/h, without Louvers: LCC and PBP Results

CSL	CEER	Life-Cycle Cost			Life-Cycle Cost Savings				Median Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost*	Average LCC	Average Savings	Users with Net Cost	Users with No Impact	Users with Net Benefit	
Baseline	8.41	$489	$541	$1,029	N/A	0%	100%	0%	N/A
1	9.3	$495	$490	$986	$4	1%	90%	9%	1.5
2	9.6	$498	$476	$974	$13	12%	25%	62%	2.1
3	10.0	$512	$454	$966	$20	38%	6%	56%	4.9
4	10.4	$615	$440	$1,055	-$66	92%	2%	6%	25.2

* Discounted

Table 8.3.12 Room Air Conditioners, 11,000-13,999 Btu/h, without Louvers: LCC and PBP Results

		Life-Cycle Cost			Life-Cycle Cost Savings				
						Users with			
CSL	**CEER**	**Average Installed Cost**	**Average Lifetime Operating Cost***	**Average LCC**	**Average Savings**	**Net Cost**	**No Impact**	**Net Benefit**	**Median Payback Period (years)**
Baseline	8.44	$574	$767	$1,341	N/A	0%	100%	0%	N/A
1	9.30	$590	$698	$1,288	$5	2%	90%	8%	2.6
2	9.50	$596	$684	$1,279	$11	23%	31%	47%	3.7
3	9.80	$611	$660	$1,271	$18	36%	17%	47%	5.3
4	10.02	$707	$647	$1,354	-$64	93%	0%	7%	25.9

* Discounted

8.3.2.2 Distributions of Impacts

The figures below show the distribution of LCCs in the base case for each product class. Also presented below for a specific standard level are figures showing the distribution of LCC impacts and the distribution of PBPs. The figures are presented as frequency charts that show the distribution of LCCs, LCC impacts, and PBPs with their corresponding probability of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples.

Base Case LCC Distributions. Figures 8.3.21 to 8.3.26 show the base case LCC distributions for the four room air conditioner representative product classes for residential consumers. DOE can generate similar figures for commercial purchasers. The figures show the full range of LCCs for the residential room air conditioner sample.

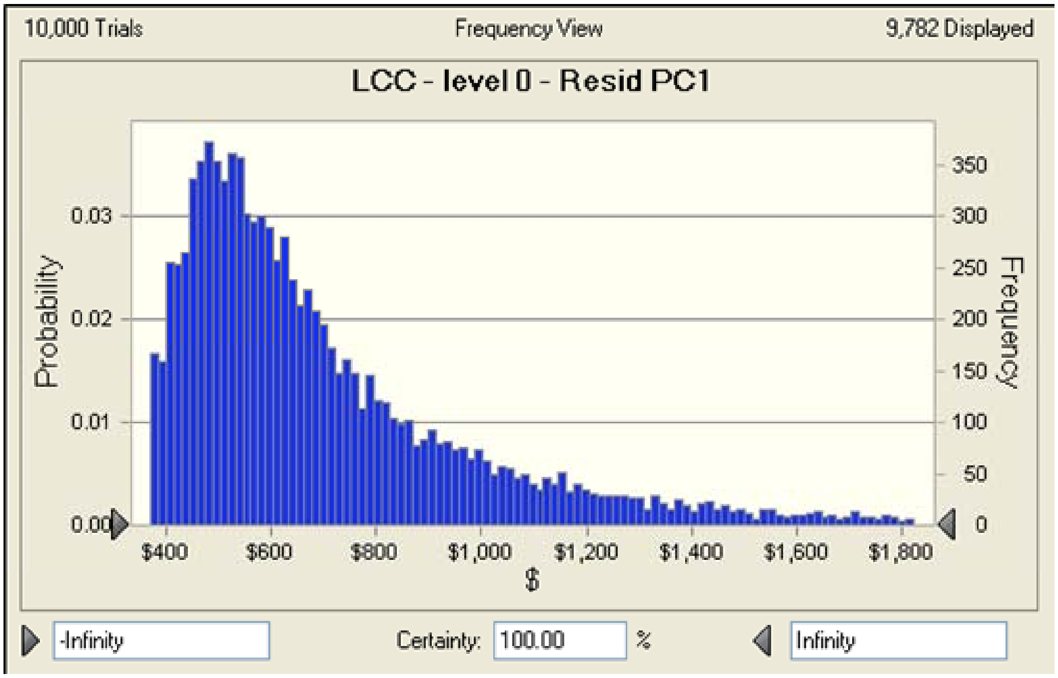

Figure 8.3.21 Room Air Conditioners, Residential <6,000 Btu/h, with Louvers, Base Case LCC Distribution

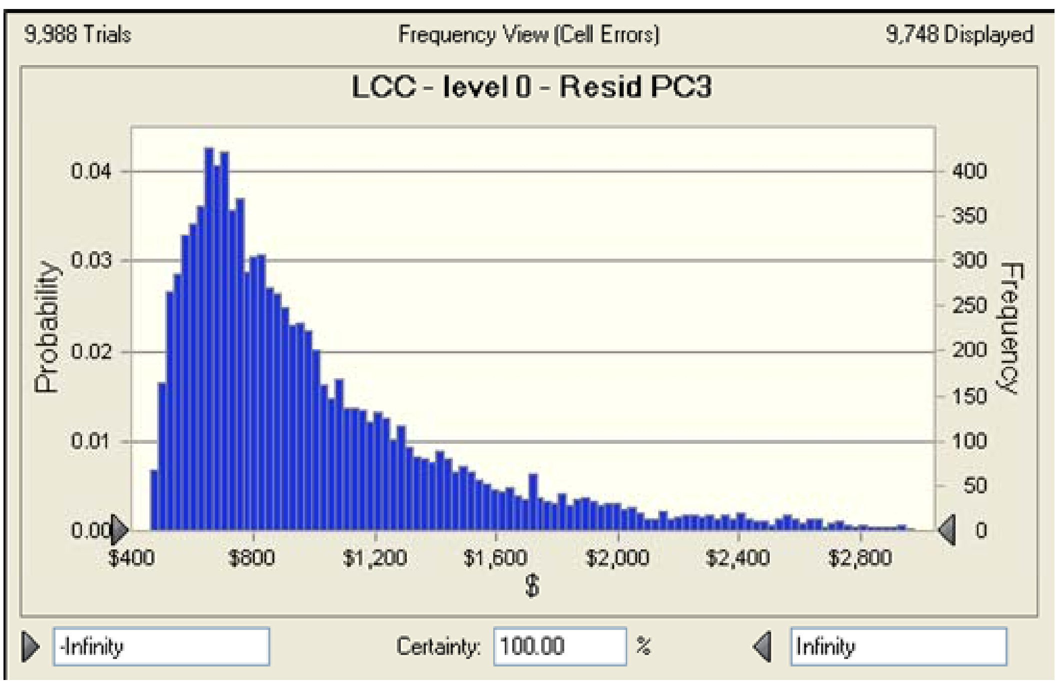

Figure 8.3.22 Room Air Conditioners, Residential 8,000–13,999 Btu/h, with Louvers, Base Case LCC Distribution

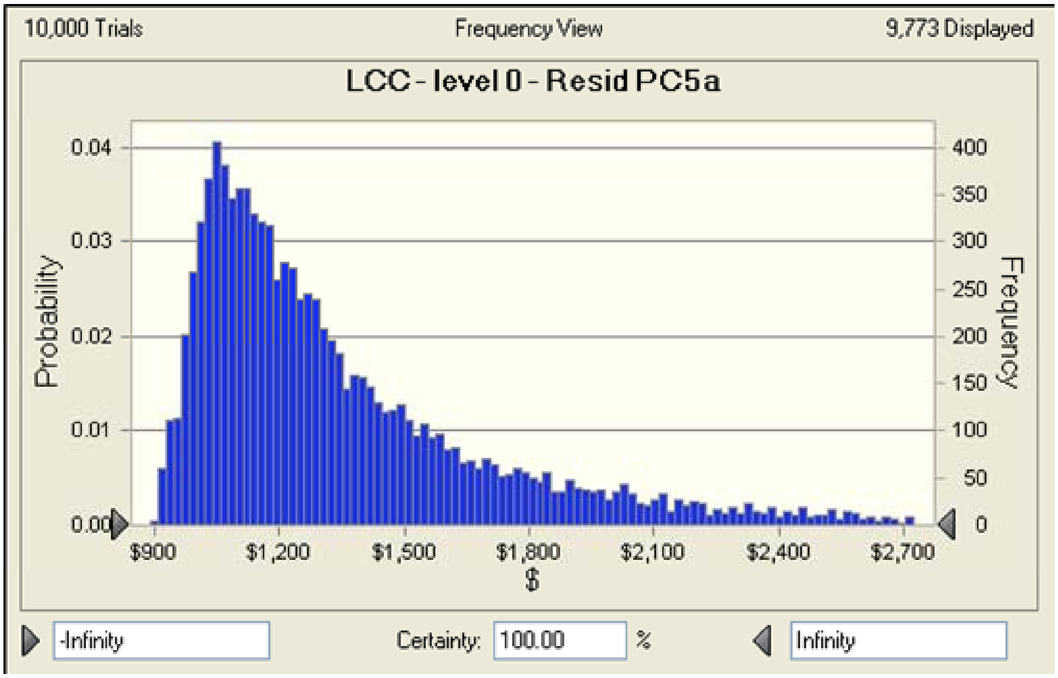

Figure 8.3.23 Room Air Conditioners, Residential 20,000-24,999 Btu/h, with Louvers, Base Case LCC Distribution

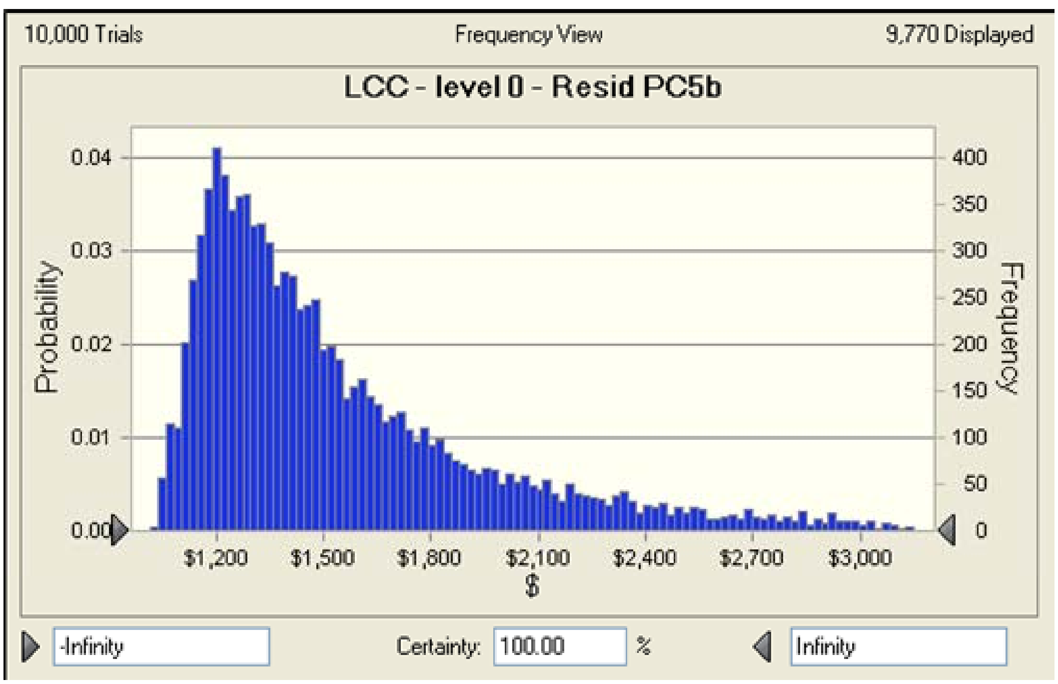

Figure 8.3.24 Room Air Conditioners, Residential ≥25,000 Btu/h, with Louvers, Base Case LCC Distribution

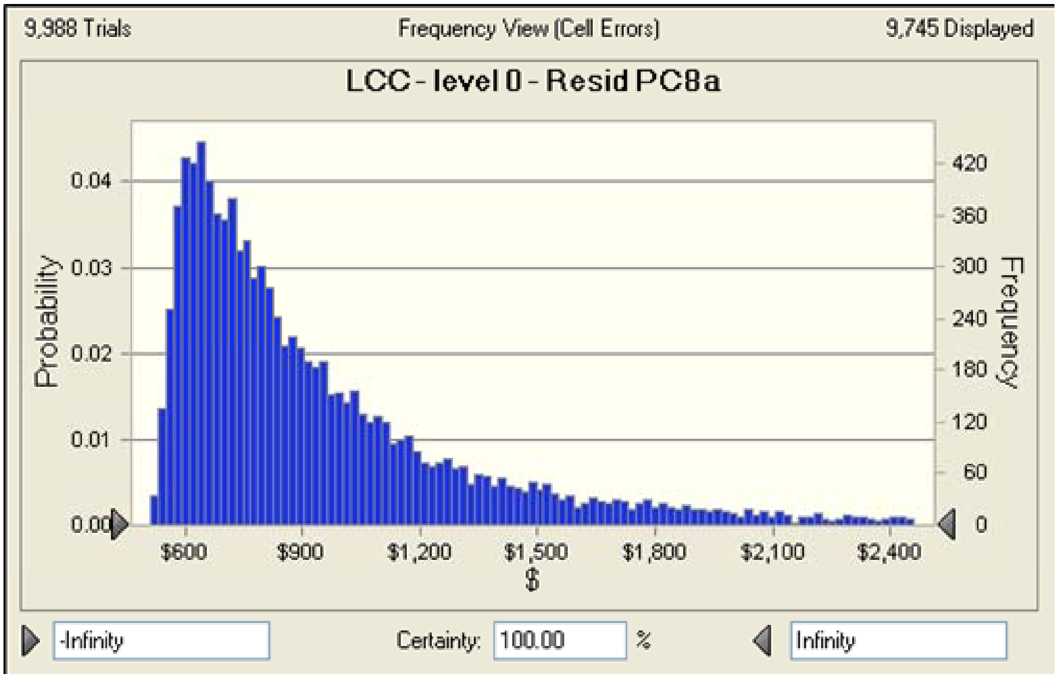

Figure 8.3.25 Room Air Conditioners, Residential 8,000–10,999 Btu/h, without Louvers, Base Case LCC Distribution

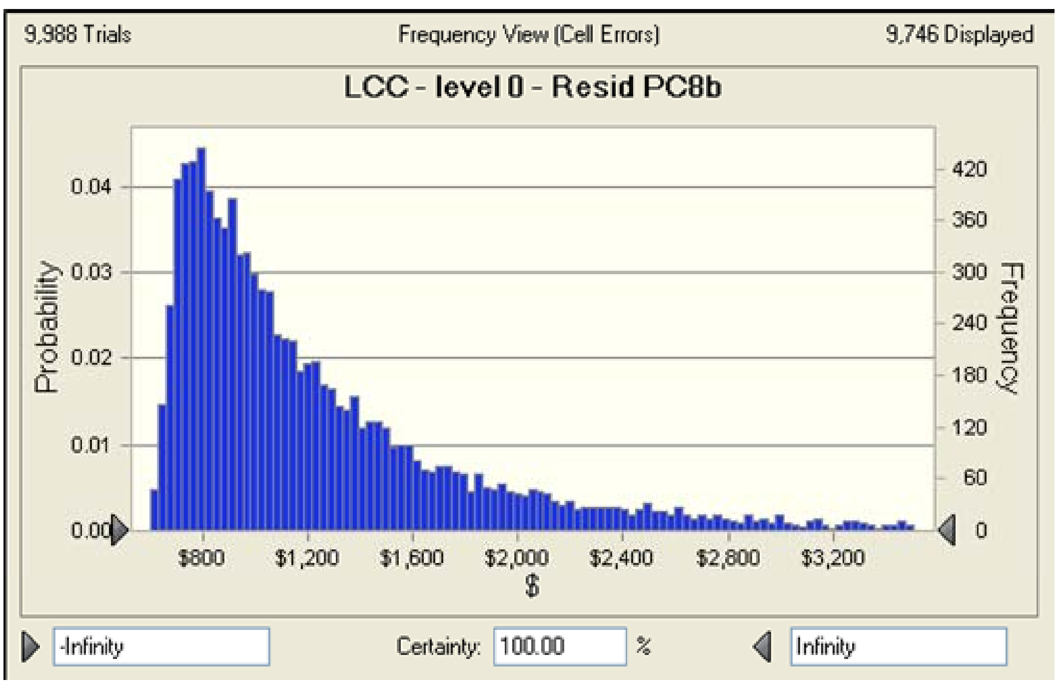

Figure 8.3.26 Room Air Conditioners, Residential 11,000-13,999 Btu/h, without Louvers, Base Case LCC Distribution

Standard-Level Distribution of Impacts. Figures 8.3.27 and 8.3.28 are examples of frequency charts showing the distribution of LCC savings for residential and commercial room air conditioners at CSL 3. DOE can generate frequency charts similar to those shown for every CSL.

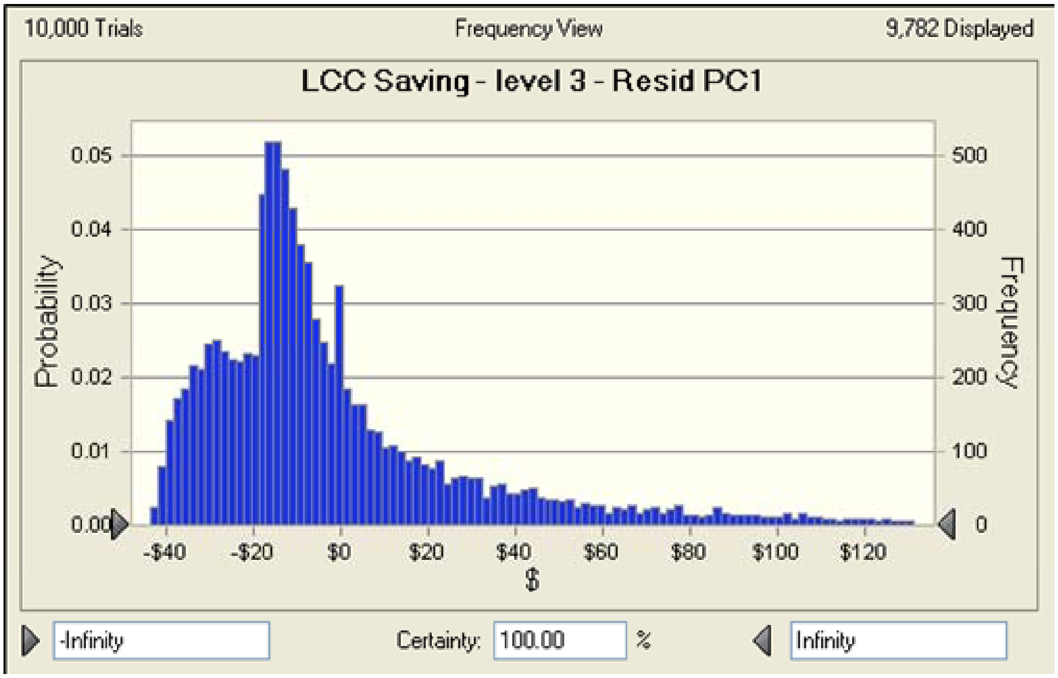

Figure 8.3.27 Room Air Conditioners, Residential <6,000 Btu/h, with Louvers, CSL 3 LCC Savings Distribution

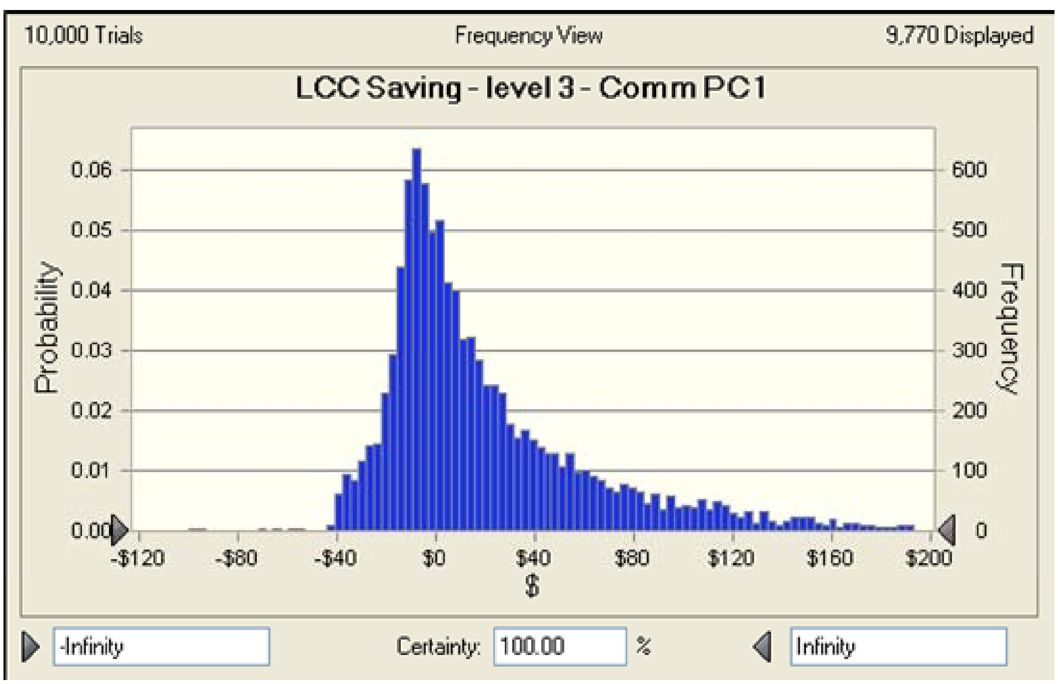

Figure 8.3.28 Room Air Conditioners, Commercial <6,000 Btu/h, with Louvers, CSL 3 LCC Savings Distribution

Figures 8.3.29 and 8.3.30 are examples of frequency charts showing the distribution of PBPs for residential and commercial standard level 3 room air conditioners. DOE can generate frequency charts similar to those shown for every standard level.

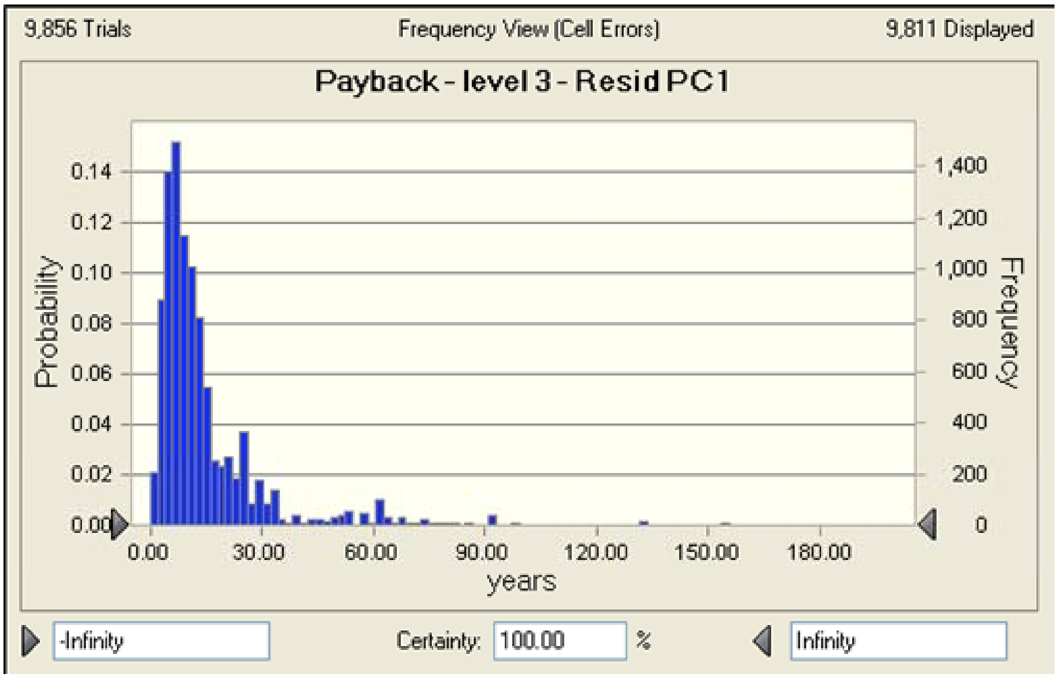

Figure 8.3.29 Room Air Conditioners, Residential <6,000 Btu/h, with Louvers, Standard Level 3 PBP Distribution

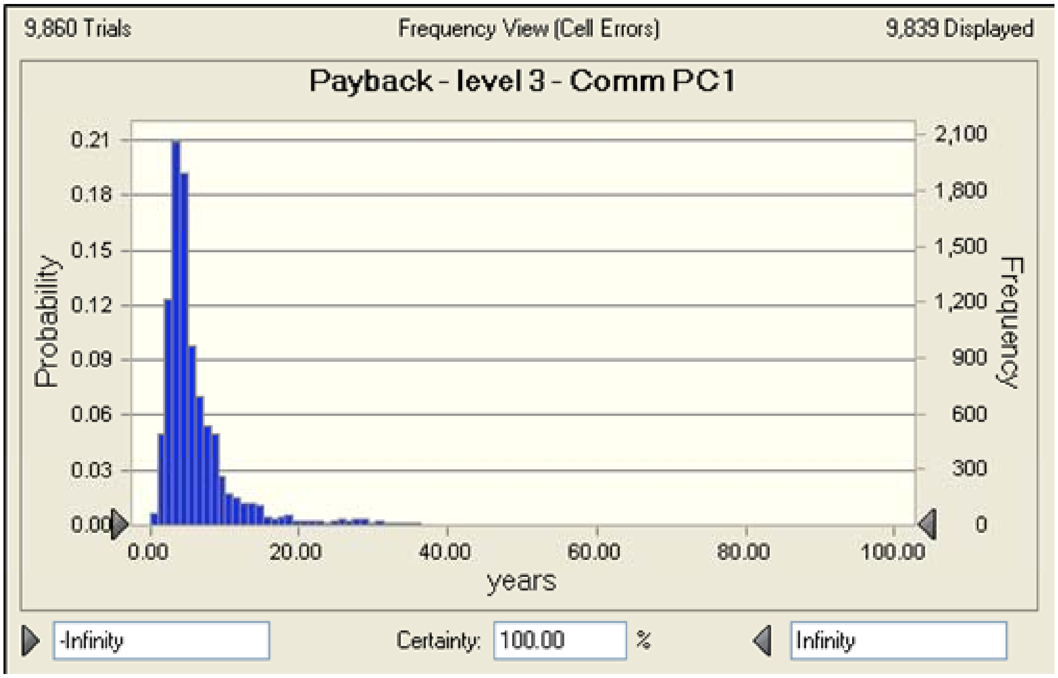

Figure 8.3.30 Room Air Conditioners, Commercial <6,000 Btu/h, with Louvers, Standard Level 3 PBP Distribution

8.3.2.3 Range of Impacts

Figures 8.3.31 through 8.3.42 show the range of LCC savings for the CSLs considered for each room air conditioner product class for residential and commercial users. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have lifecycle cost savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level.

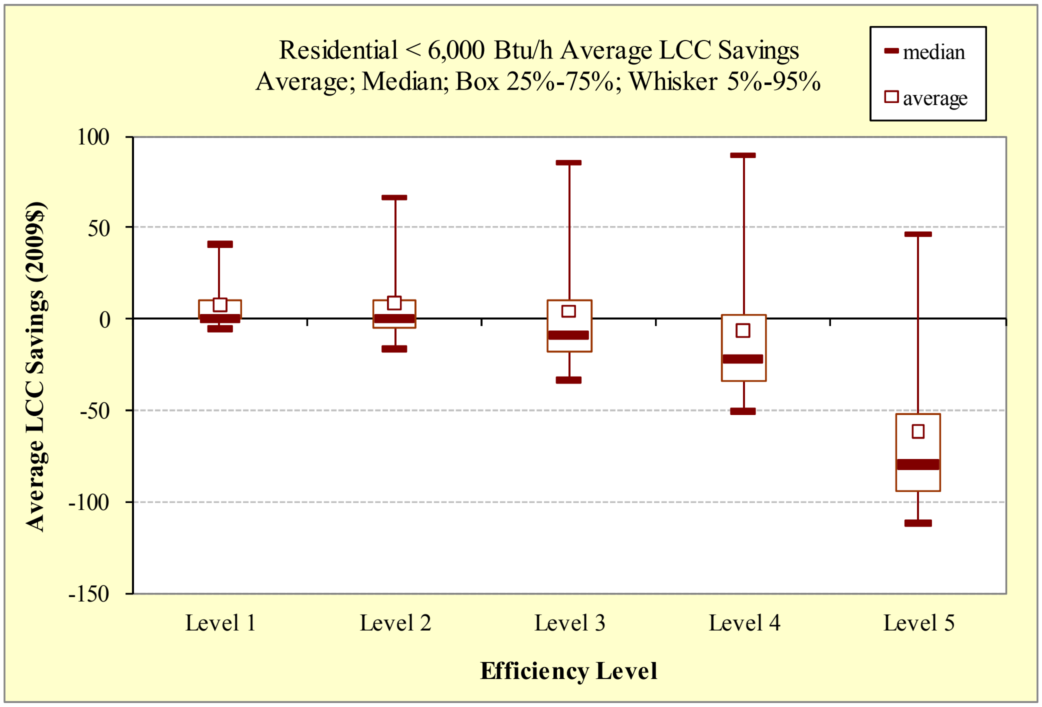

Figure 8.3.31 Room Air Conditioners, Residential <6,000 Btu/h, with Louvers, Range of Average LCC Savings

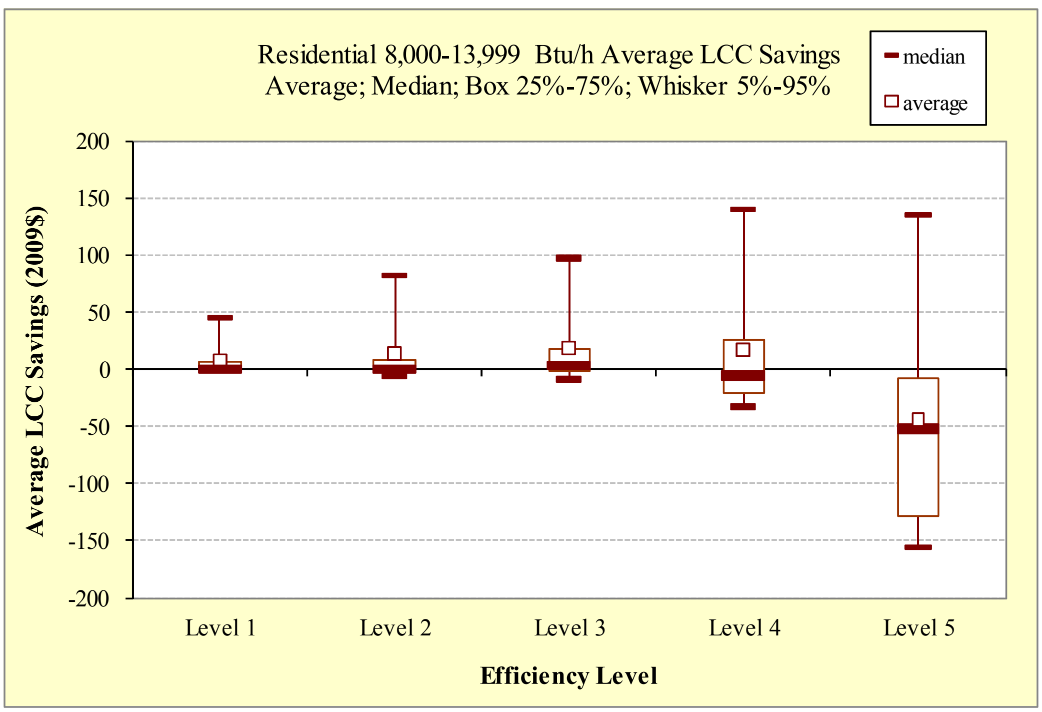

Figure 8.3.32 Room Air Conditioners, Residential 8,000–13,999 Btu/h, with Louvers, Range of Average LCC Savings

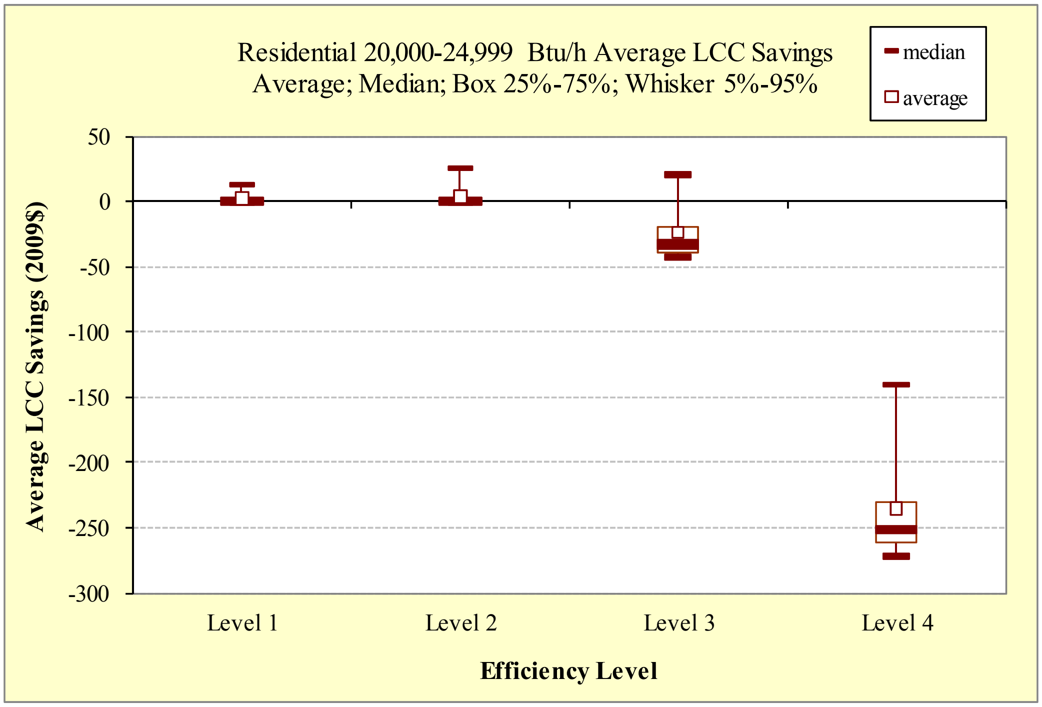

Figure 8.3.33 Room Air Conditioners, Residential 20,000–24,999 Btu/h, with Louvers, Range of Average LCC Savings

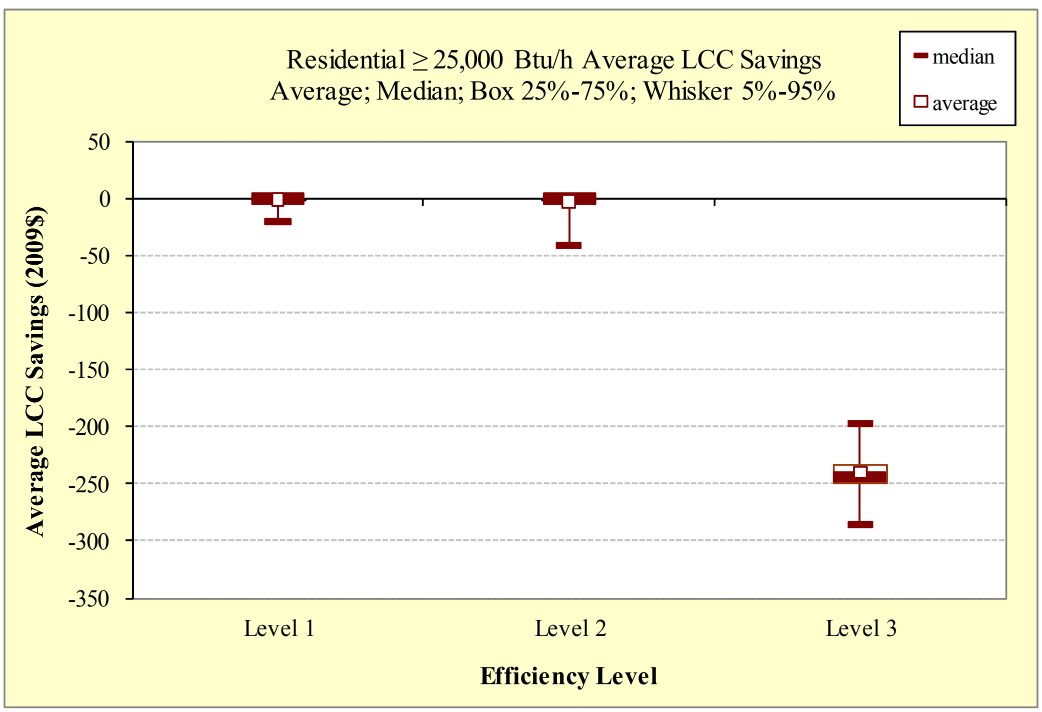

Figure 8.3.34 Room Air Conditioners, Residential ≥25,000 Btu/h, with Louvers, Range of Average LCC Savings

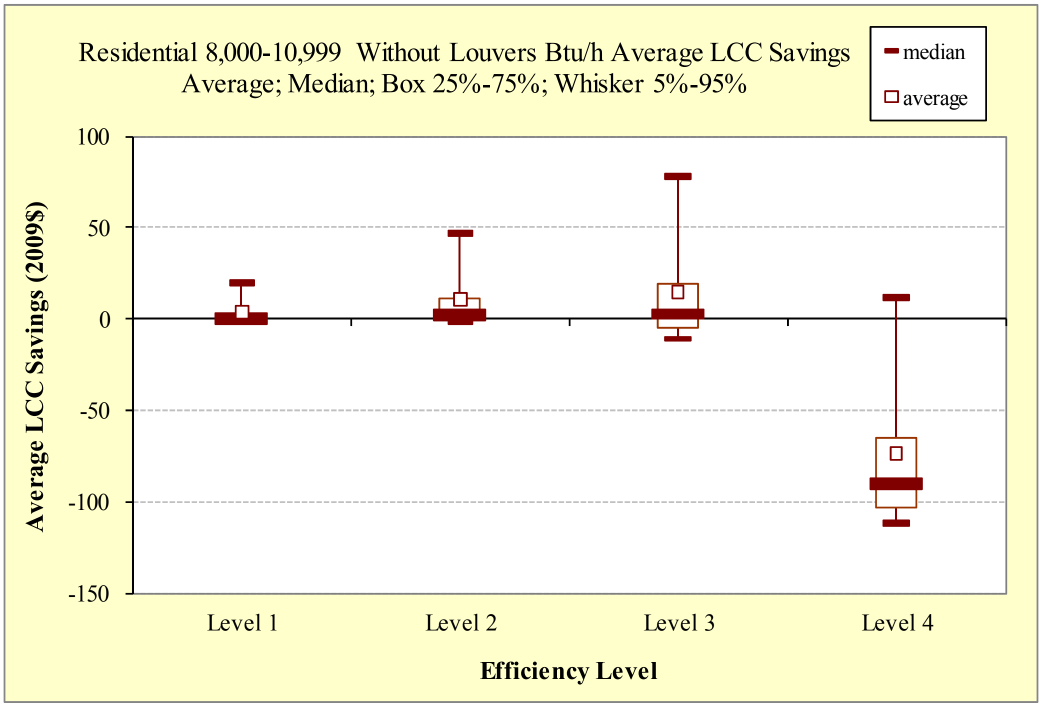

Figure 8.3.35 Room Air Conditioners, Residential 8,000–10,999 Btu/h, without Louvers, Range of Average LCC Savings

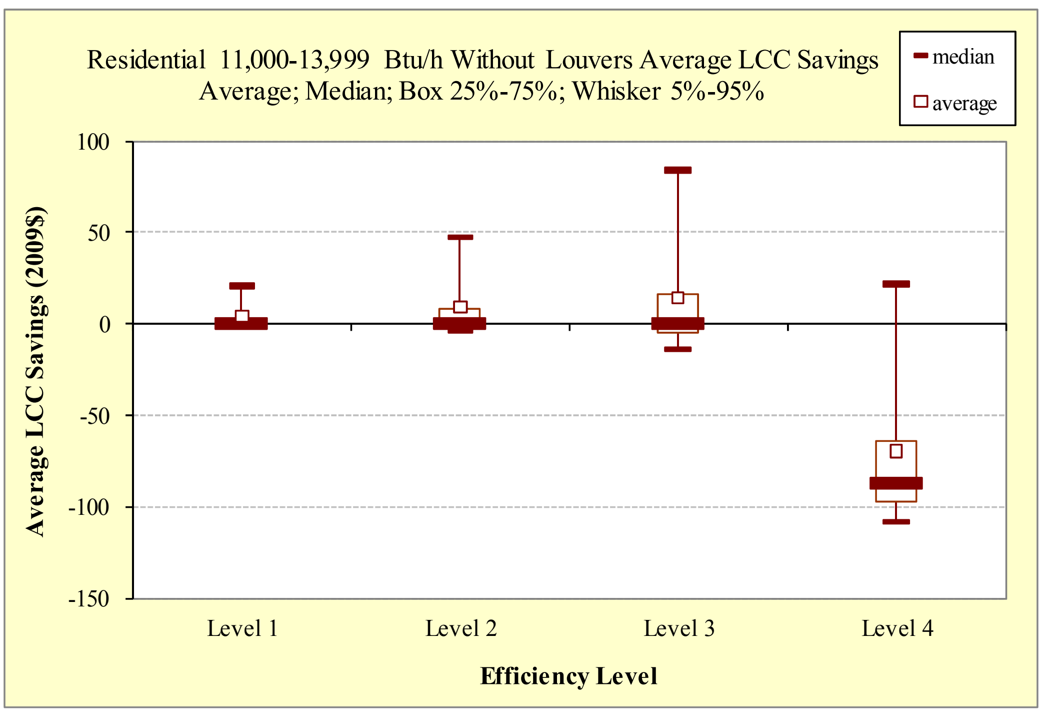

Figure 8.3.36 Room Air Conditioners, Residential 11,000-13,999 Btu/h, without Louvers, Range of Average LCC Savings

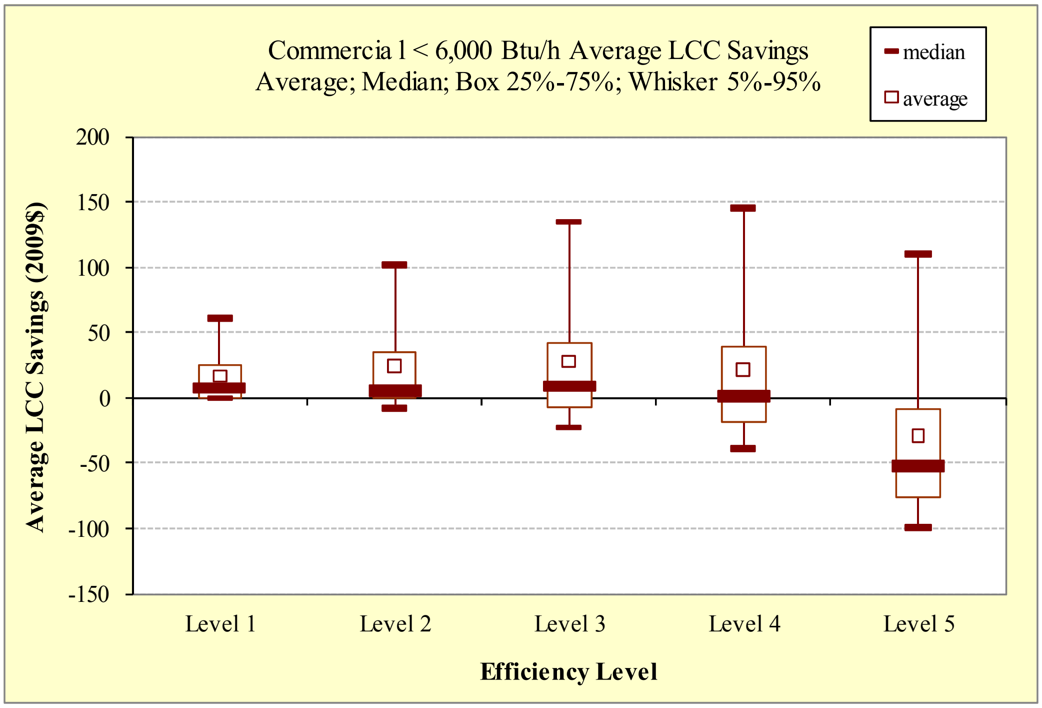

Figure 8.3.37 Room Air Conditioners, Commercial <6,000 Btu/h, with Louvers, Range of Average LCC Savings

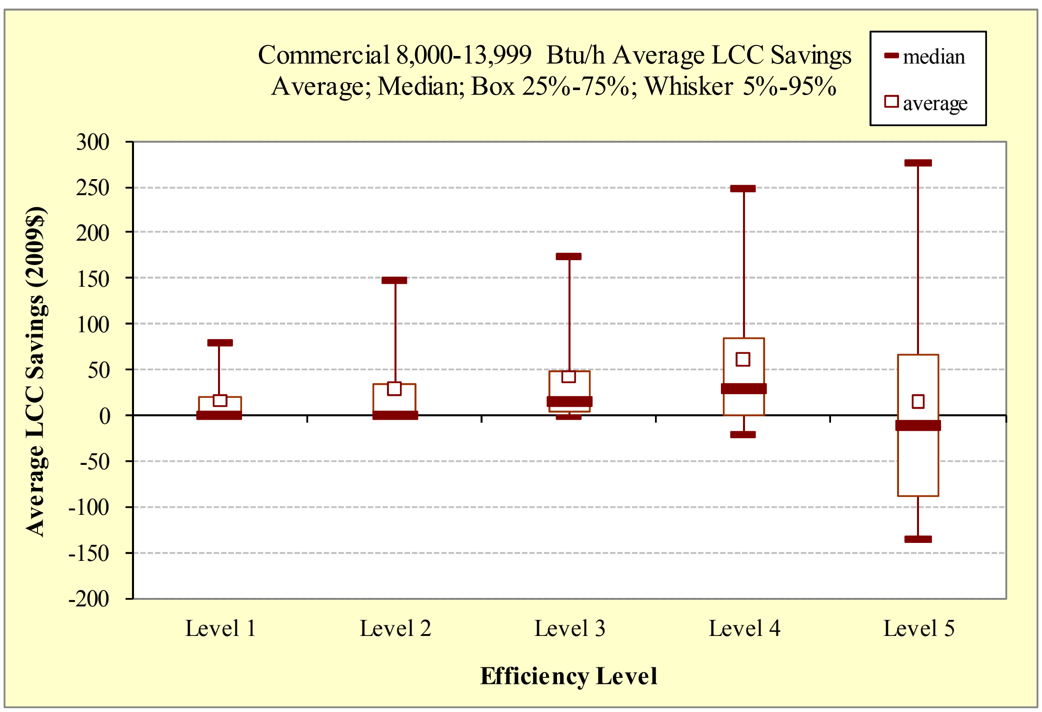

Figure 8.3.38 Room Air Conditioners, Commercial 8,000–13,999 Btu/h, with Louvers, Range of Average LCC Savings

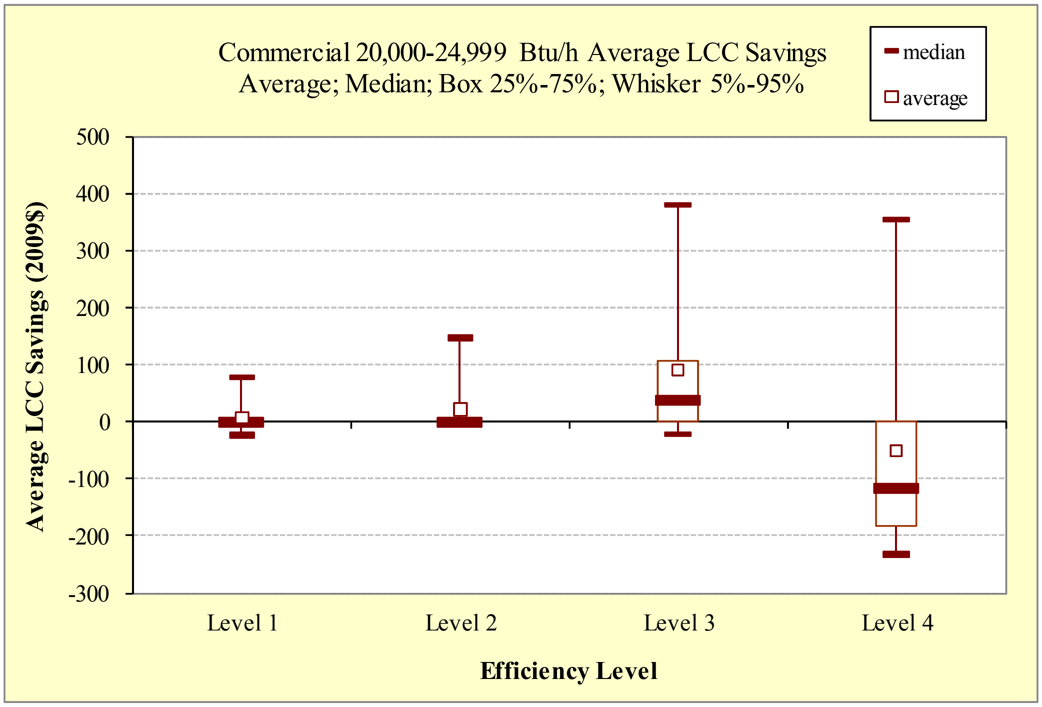

Figure 8.3.39 **Room Air Conditioners, Commercial 20,000–24,999 Btu/h, with Louvers, Range of Average LCC Savings**

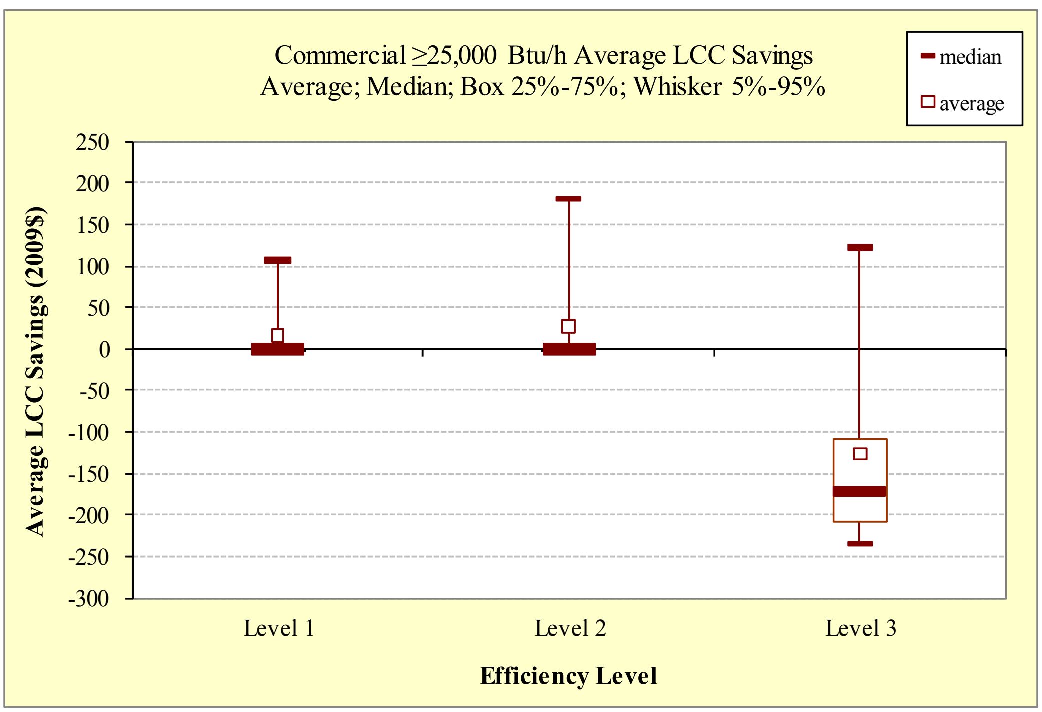

Figure 8.3.40 **Room Air Conditioners, Commercial ≥25,000 Btu/h, with Louvers, Range of Average LCC Savings**

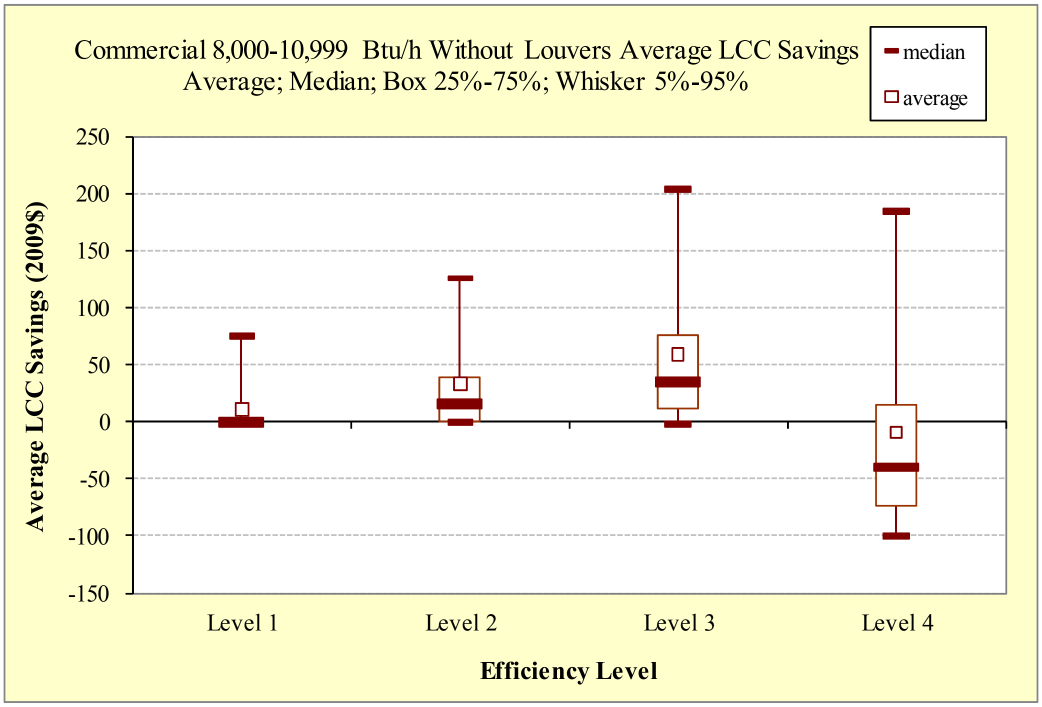

Figure 8.3.41 **Room Air Conditioners, Commercial 8,000–10,999 Btu/h, without Louvers, Range of Average LCC Savings**

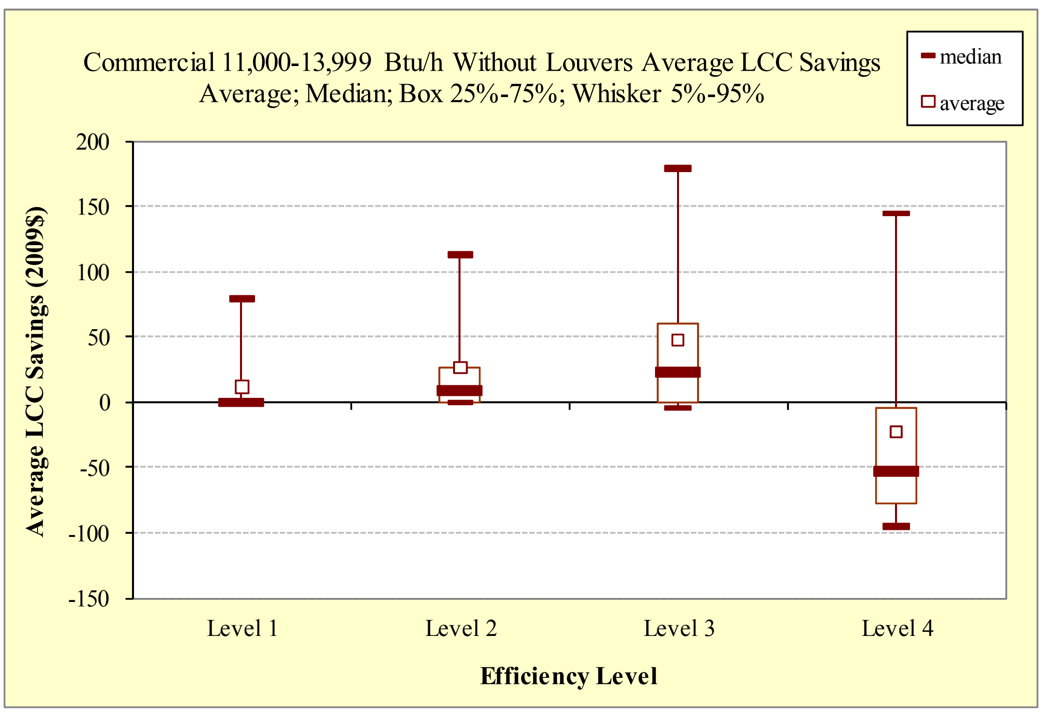

Figure 8.3.42 **Room Air Conditioners, Commercial 11,000-13,999 Btu/h, without Louvers, Range of Average LCC Savings**

Figures 8.3.43 through 8.3.54 show the range of PBPs for all CSLs considered for each room air conditioner product class for residential and commercial users. For each efficiency level, the top and bottom of the box in the figure indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median: 50 percent of the households have a payback period above this value. The horizontal lines above and below each box indicate the 95th and 5th percentiles, respectively. The small box indicates the average PBP for each CSL.

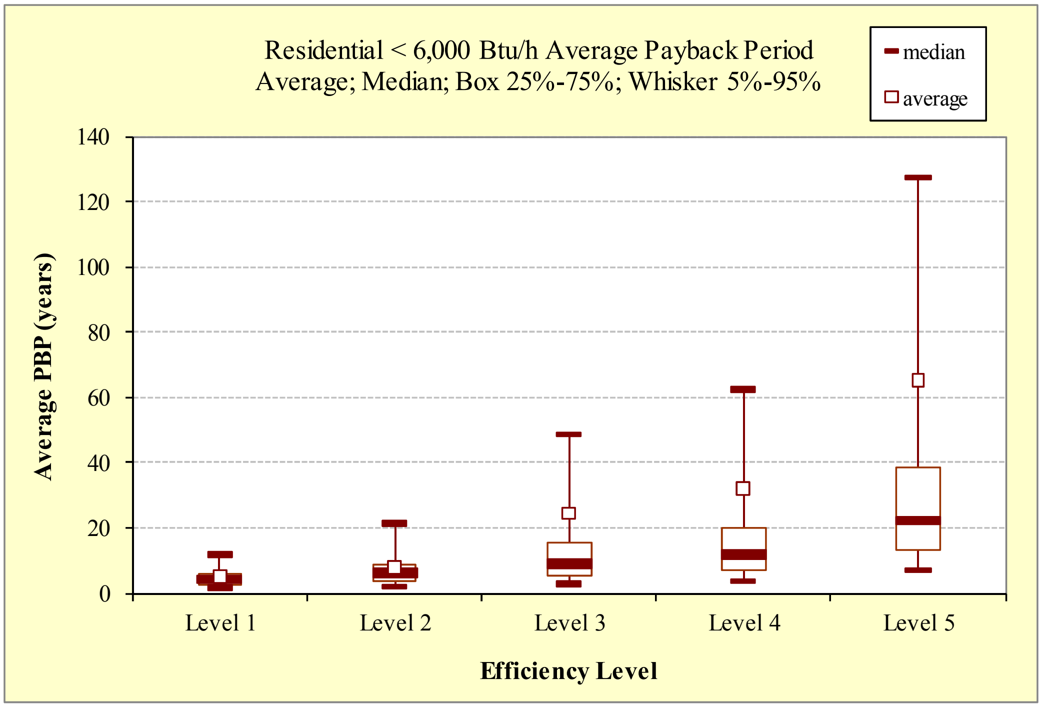

Figure 8.3.43 Room Air Conditioners, Residential < 6,000 Btu/h, with Louvers, Range of Average Payback Period

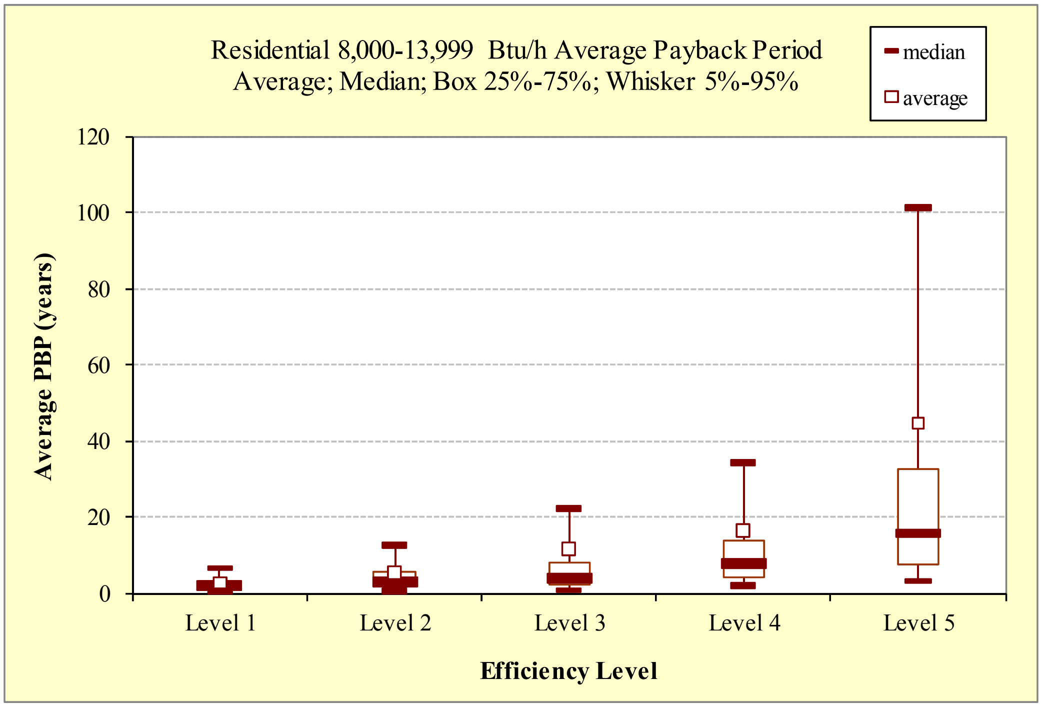

Figure 8.3.44 Room Air Conditioners, Residential 8,000–13,999 Btu/h, with Louvers, Range of Average Payback Period

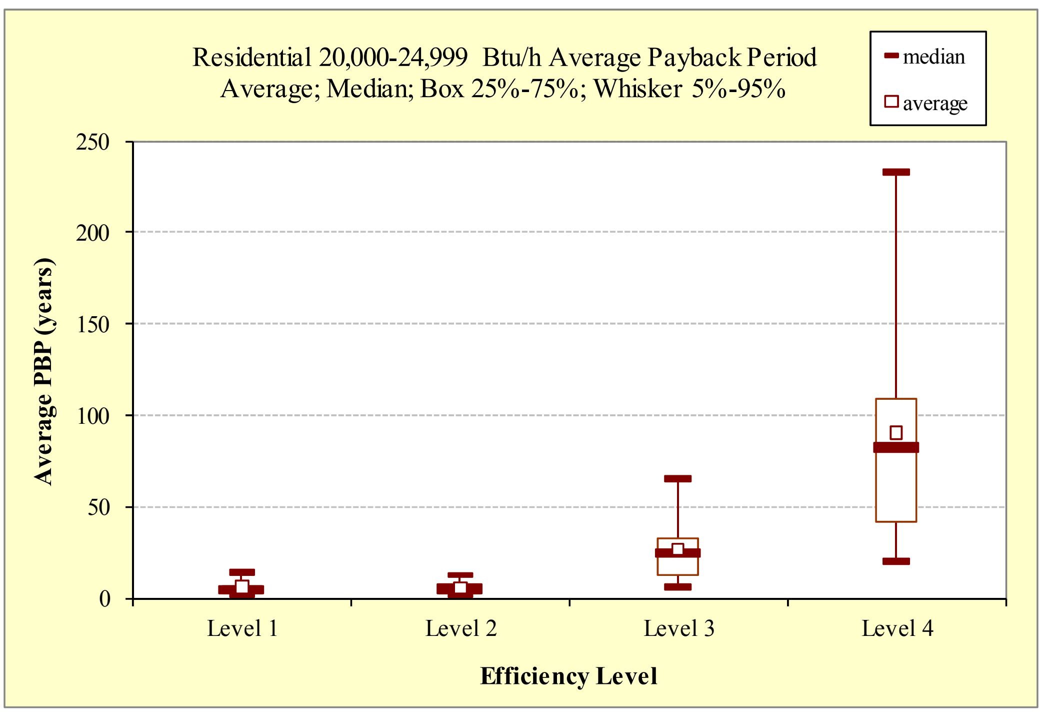

Figure 8.3.45 Room Air Conditioners, Residential 20,000-24,999 Btu/h, with Louvers, Range of Average Payback Period

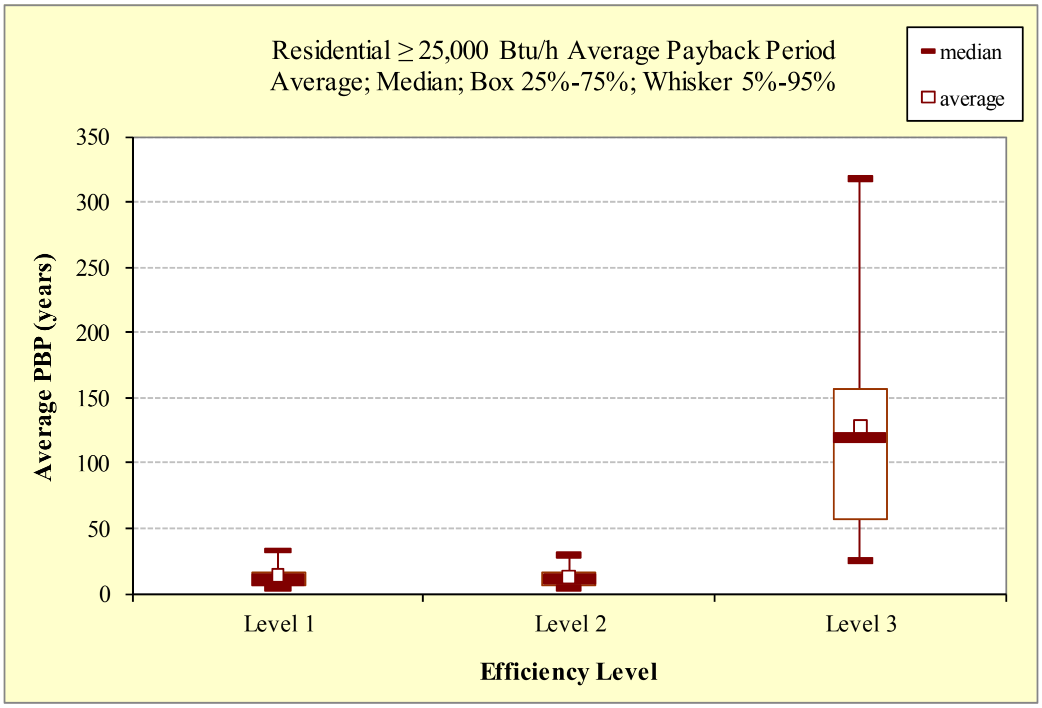

Figure 8.3.46 Room Air Conditioners, Residential ≥25,000 Btu/h, with Louvers, Range of Average Payback Period

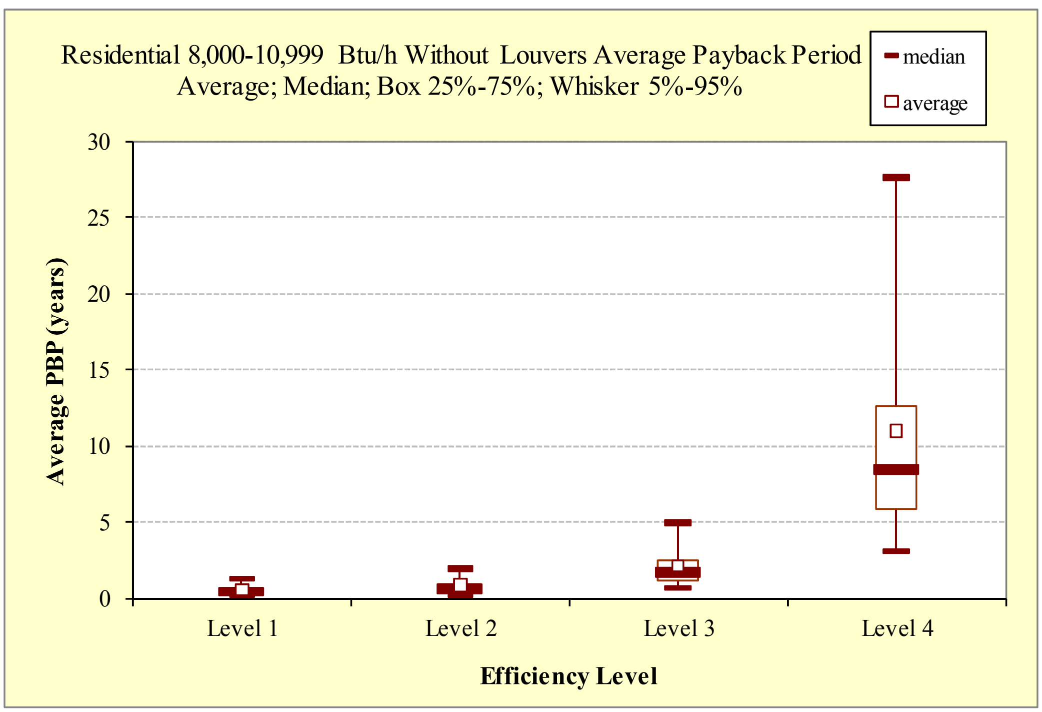

Figure 8.3.47 Room Air Conditioners, Residential 8,000-10,999 Btu/h, without Louvers, Range of Average Payback Period

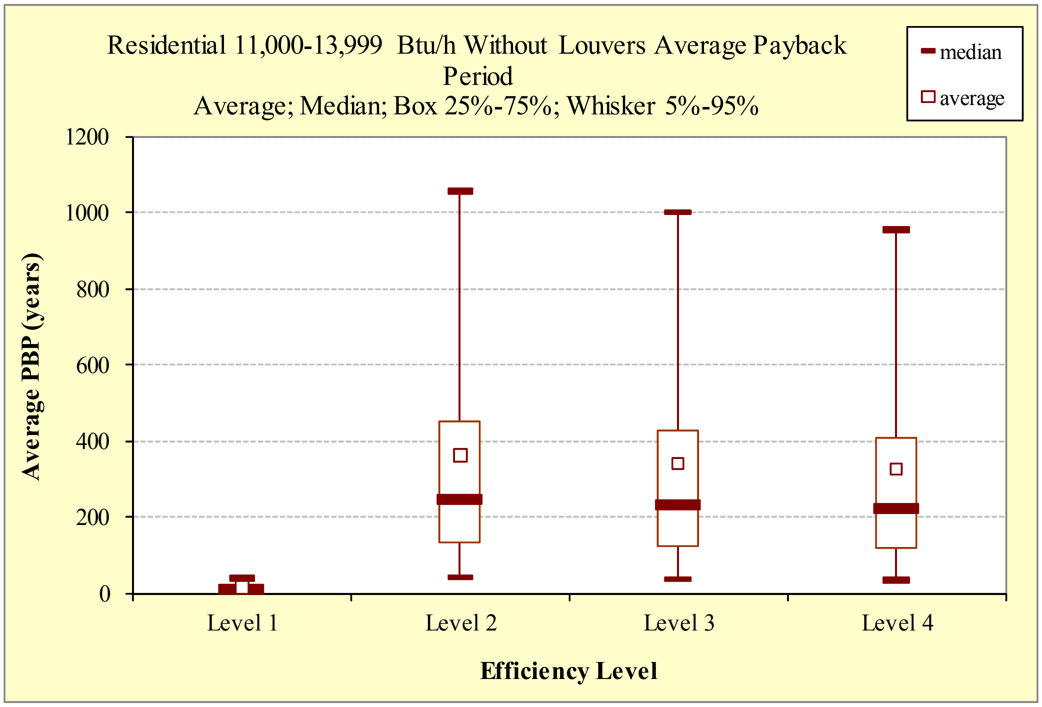

Figure 8.3.48 Room Air Conditioners, Residential 11,000-13,999 Btu/h, without Louvers, Range of Average Payback Period

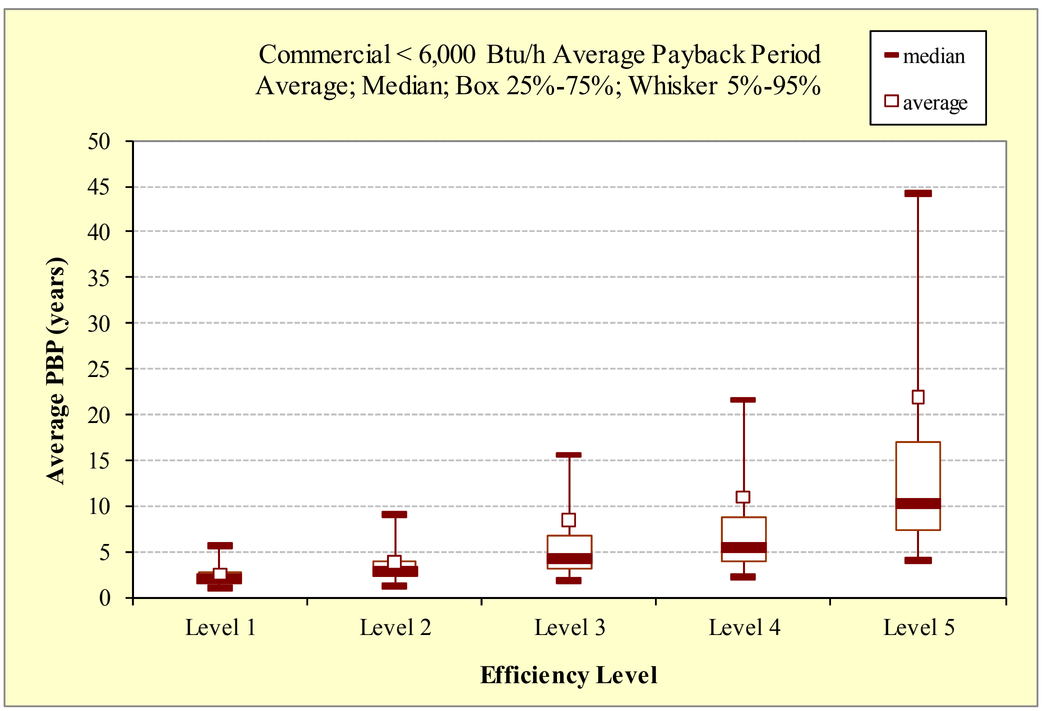

Figure 8.3.49 Room Air Conditioners, Commercial < 6,000 Btu/h, with Louvers, Range of Average Payback Period

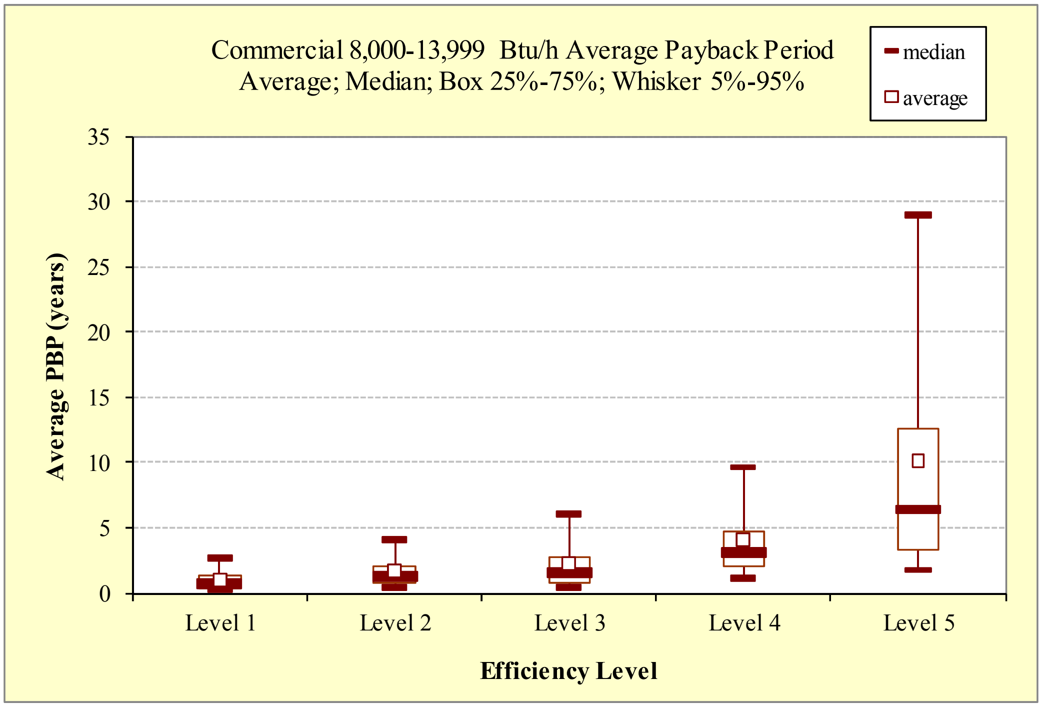

Figure 8.3.50 Room Air Conditioners, Commercial 8,000–13,999 Btu/h, with Louvers, Range of Average Payback Period

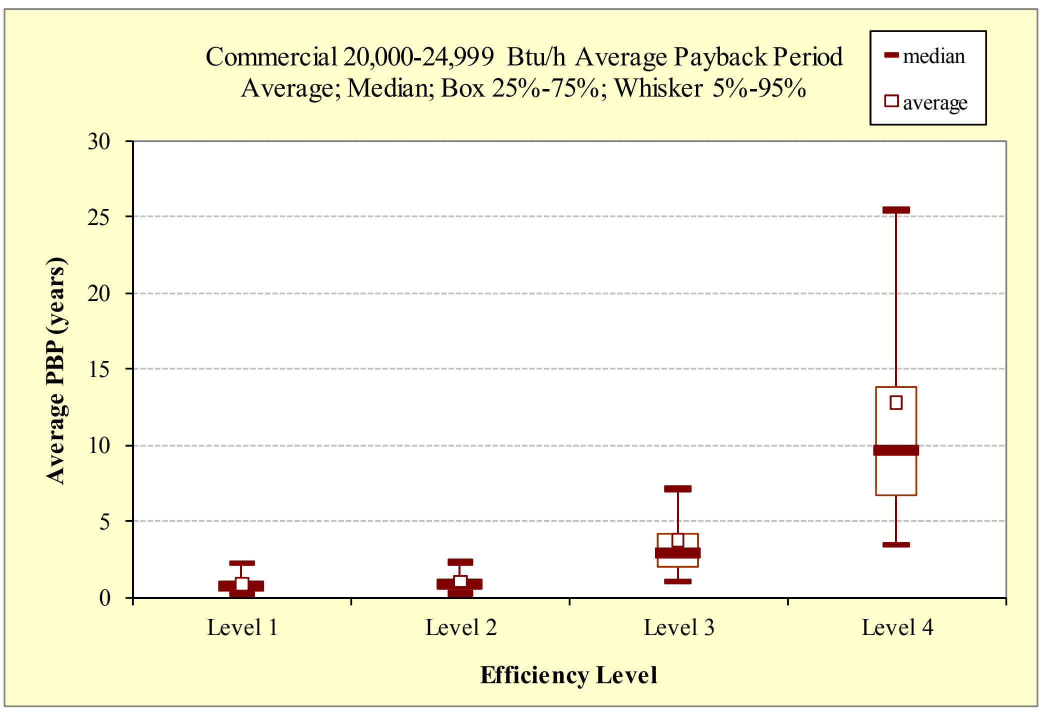

Figure 8.3.51 Room Air Conditioners, Commercial 20,000-24,999 Btu/h, with Louvers, Range of Average Payback Period

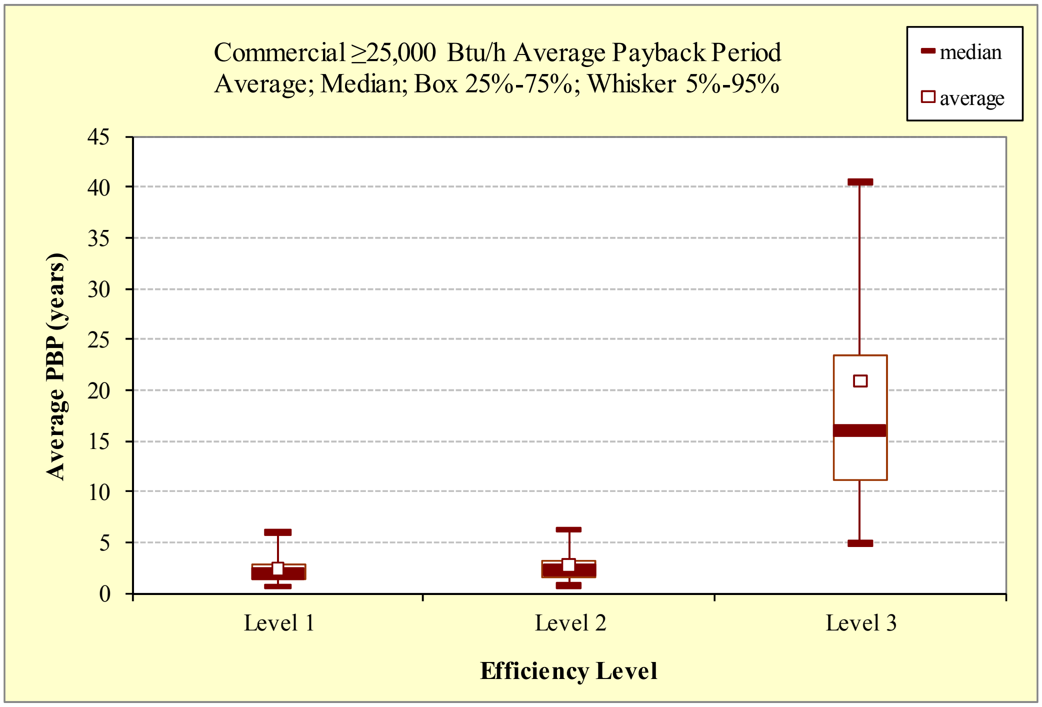

Figure 8.3.52 Room Air Conditioners, Commercial ≥25,000 Btu/h, with Louvers, Range of Average Payback Period

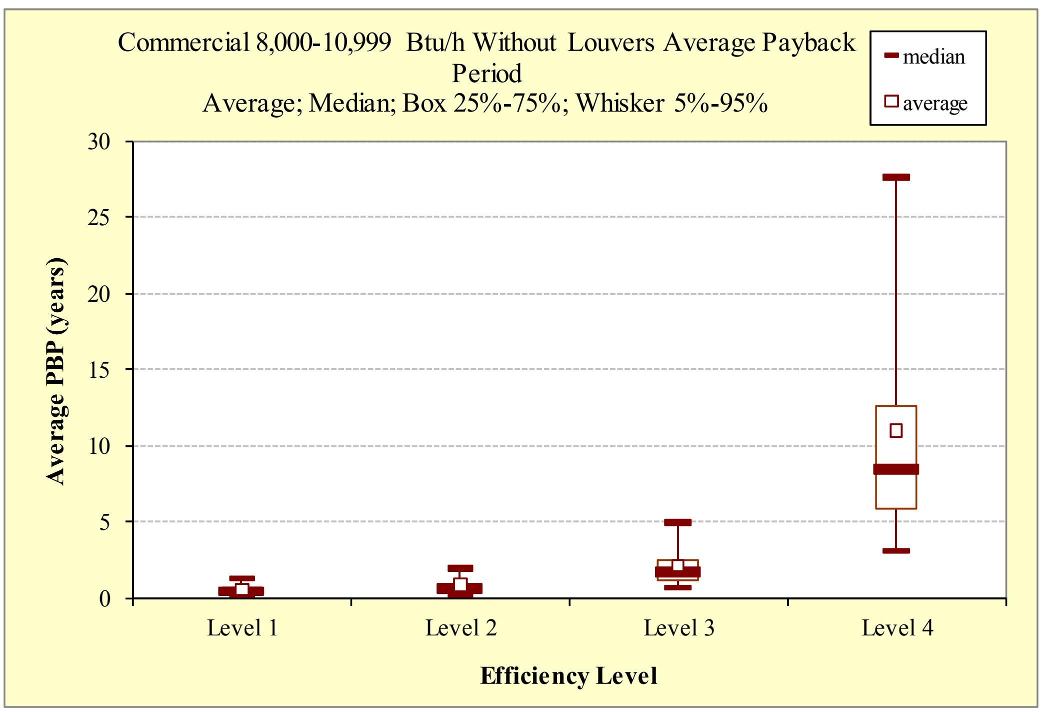

Figure 8.3.53 Room Air Conditioners, Commercial 8,000-10,999 Btu/h, without Louvers, Range of Average Payback Period

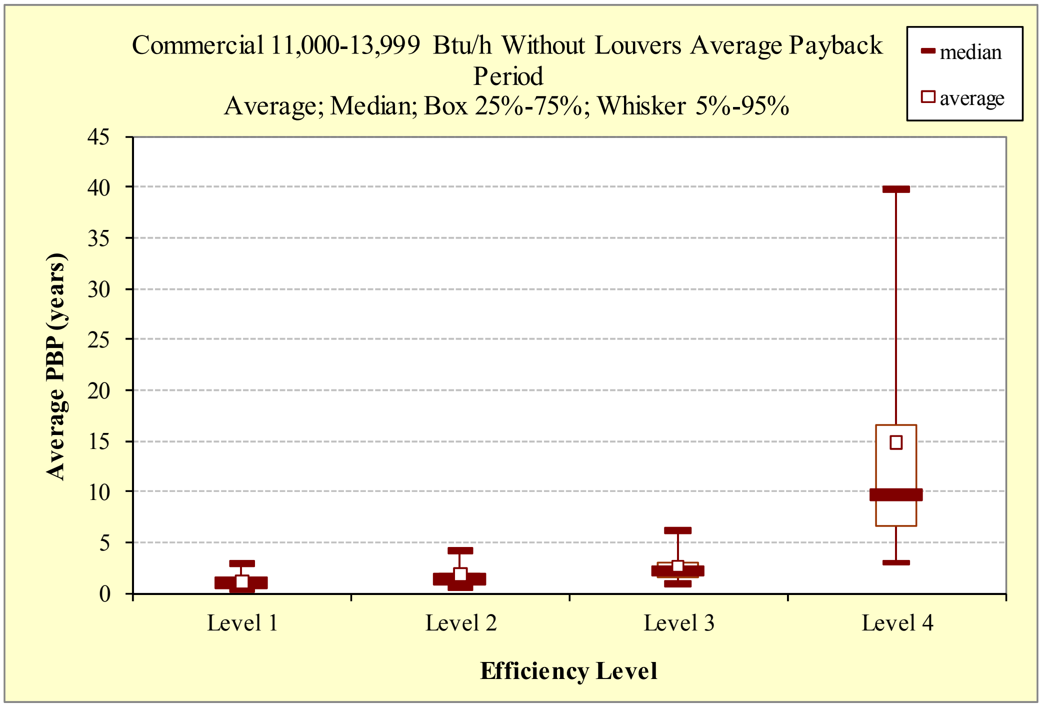

Figure 8.3.54 Room Air Conditioners, Commercial 11,000-13,999 Btu/h, without Louvers, Range of Average Payback Period

8.4 REBUTTABLE PAYBACK PERIOD

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

The basic equation for rebuttable PBP is the same as that shown in section 8.3, Payback Period Inputs. Unlike the analyses described in sections 8.2 and 8.3, however, the rebuttable PBP is not based on the use of household samples and probability distributions. Rather than distributions, the rebuttable PBP is based on discrete single-point values. For example, while DOE uses a probability distribution of regional energy prices in the distributional payback period analysis, it uses only the national average energy price from the probability distribution to determine the rebuttable PBP.

Other than the use of single-point values, the most notable difference between the distribution PBP and the rebuttable PBP is the latter's reliance on the DOE test procedure to determine a product's annual energy consumption. The following sections identify the differences, if any, between the annual energy consumptions determined for the distribution PBP and the rebuttable PBP.

DOE based the annual energy consumption values that it used to determine the rebuttable PBP for room air conditioners on the number of operating hours per year specified in the DOE test procedure.[50]

DOE based the annual energy consumption values that it used to determine the rebuttable PBP for clothes dryers on the number of cycles per year specified in the DOE test procedure.[50]

8.4.1 Inputs

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

- Manufacturing costs, markups, sales taxes, and installation costs were all based on the single-point values used in the distributional LCC and PBP analyses.
- Annual energy consumption is based on the DOE test procedure.
- Energy prices are based on national average values for the year that new standards are assumed to take effect.
- An average discount rate or lifetime is not required in the rebuttable PBP calculation.
- The effective date of the standard is assumed to be 2014.

8.4.2 Results

DOE calculated rebuttable PBPs for each standard level relative to the distribution of product energy efficiencies estimated for the base case. In other words, DOE did not determine the rebuttable PBP relative to the baseline energy efficiency level, but relative to the distribution of product energy efficiencies DOE determined for the base case (i.e., the case without new energy conservation standards).

Tables 8.4.1 though 8.4.3 present the rebuttable PBPs for clothes dryers. Tables 8.4.4 and 8.4.5 present the rebuttable payback periods for room air conditioners.

Table 8.4.1 Clothes Dryers, Electric Vented: Rebuttable Payback Periods

Electric Standard		Electric Compact 120V		Electric Compact 240V	
CEF	PBP	CEF	PBP	CEF	PBP
3.56	4.7	3.48	2.6	3.16	2.5
3.61	1.0	3.61	0.8	3.27	0.9
3.73	3.5	3.72	14.3	3.36	14.4
3.81	14.4	3.80	28.9	3.48	33.7
4.08	13.3	4.08	39.0	3.60	35.9
5.42	16.6	5.41	37.0	4.89	40.2

Table 8.4.2 Clothes Dryers, Gas: Rebuttable Payback Periods

Gas	
CEF	PBP
3.16	4.5
3.20	1.8
3.30	6.7
3.41	34.5
3.61	33.1

Table 8.4.3 Clothes Dryers, Electric Vent-less: Rebuttable Payback Periods

Vent-less Compact 240V		Vent-less Combination	
CEF	PBP	CEF	PBP
2.59	2.3	2.46	0.4
2.69	0.8	2.46	0.7
2.71	17.4	2.46	0.7
2.80	25.2	2.56	6.9
4.03	27.1	3.70	24.9

Table 8.4.4 Room Air Conditioners with Louvers: Rebuttable Payback Periods

<6,000 Btu/h		8,000-13,999 Btu/h		20,000-24,999 Btu/h		≥ 25,000 Btu/h	
CEER	PBP	CEER	PBP	CEER	PBP	CEER	PBP
10.1	3.4	10.2	1.1	9.0	0.9	9.0	2.1
10.6	4.5	10.7	1.6	9.4	1.1	9.4	2.4
11.1	5.8	10.9	1.8	9.8	1.9	9.8	7.4
11.4	7.1	11.5	3.0	10.2	6.4	--	--
11.7	13.0	12.0	6.6	--	--	--	--

Table 8.4.5 Room Air Conditioners without Louvers: Rebuttable Payback Periods

8,000-10,999 Btu/h		≥ 11,000 Btu/h	
CEER	PBP	CEER	PBP
9.3	0.6	9.3	1.3
9.6	0.7	9.5	1.4
10.0	1.3	9.8	1.9
10.4	6.0	10.0	6.0

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CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

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

DOE estimated shipments for each product with a separate shipments model, which is calibrated with historical shipments data. Each shipments model considers specific market segments to estimate shipments, the results for which are then aggregated to estimate total product shipments. To estimate the impacts of potential standard levels on product shipments, each shipments model accounts for the combined effects of changes in purchase price, annual operating cost, and household income on the consumer purchase decision.

The shipments models were developed as Microsoft Excel spreadsheets that are accessible on the Internet (http://www.eere.energy.gov/buildings/appliance_standards/). Appendix 10-A discusses how to access the shipments model spreadsheet and other related spreadsheets, and provides basic instructions for using them.

The rest of this chapter explains the shipments models in more detail. Section 9.2 presents the shipments model methodology for each product; section 9.3 describes the data inputs and the model calibration; section 9.4 discusses impacts on shipments from changes in equipment purchase price, operating cost, and household income; section 9.5 discusses the affected stock; section 9.6 shows the candidate standard levels considered for each product class, and section 9.79.6 presents the results for different energy-efficiency standard-level scenarios.

9.2 SHIPMENTS MODEL METHODOLOGY

DOE developed national stock models for estimating annual shipments for the products considered for this standards rulemaking. The models consider market segments appropriate for the considered products. Typically, the primary market segments are new home installations, replacements, and first-time owners:

$$Ship_p(j) = Rpl_p(j) + NI_p(j) + FTO_p(j)$$

Where:

$Ship_p(j)$ = Total shipments of product p in year j,
$Rpl_p(j)$ = Units of product p retired and replaced in year j,

$NI_p(j)$ = Number of new home installations of product *p* in year *j*, and
$NI_p(j)$ = Number of product *p* going to first-time owners in year *j*.

For room air conditioners, DOE did not consider the new construction market since this product, unlike some major household appliances, is not a standard product for new homes (as opposed to central air conditioners). However, DOE did include a market segment for new purchases of room air conditioners.

DOE's shipments models take an accounting approach, tracking market shares of each product class, the vintage of units in the existing stock, and expected construction trends. The models estimate shipments due to replacements using sales in previous years and assumptions about the lifetime of the equipment. Therefore, estimated sales due to replacements in a given year are equal to the total stock of the appliance minus the sum of the appliances sold in previous years that still remain in the stock. DOE determined the useful service life of each appliance to estimate how long the appliance is likely to remain in stock. The following equation represents how DOE estimated replacement shipments:

$$Rpl_p(j) = Stock_p(j-1) - \sum_{age=0}^{ageMax} \sum_{j=N}^{j-1} Ship_j \times prob_{Rtr}(age)$$

Where:

$Stock_p(j\text{-}1)$ = 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 and provides an estimate of the age distribution of in-service product stocks for all years. The age distribution of in-service product stocks is a key input to both the NES and NPV calculations—the operating costs for any year depend on the age distribution of the stock. The dependence of operating cost on the equipment age distribution occurs under a standards case scenario that produces increasing efficiency over time, where older, less efficient units may have higher operating costs, while younger, more-efficient units will have lower operating costs. Furthermore, in the case of an early replacement scenario, retirements due to early replacement will depend on the age of the units that are subject to early replacement.

DOE estimated replacements using product retirement functions that it developed from product lifetimes. For all products, 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;
α =	scale parameter, which would be the decay length in an exponential distribution;
β =	shape parameter, which determines the way in which the failure rate changes through time; and
θ =	delay parameter, which allows for a delay before any failures occur.

The retirement probability is the difference in the survival function from one year to another.

DOE calculated total in-service stock of equipment by integrating historical shipments data starting from a specific year. The start year depended on the historical data available for the product. As units are added to the in-service stock, some of the older ones retire and exit the stock. To estimate future shipments, DOE developed a series of equations that define the dynamics and accounting of in-service stocks. For new units, the equation is:

$$\boldsymbol{Stock(j, age} = 1\boldsymbol{)} = \boldsymbol{Ship(j} - 1\boldsymbol{)}$$

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:

$$\boldsymbol{Stock(j} + 1\boldsymbol{, age} + 1\boldsymbol{)} = \boldsymbol{Stock(j, age)} ? \left[1 - \boldsymbol{prob_{Rtr}(age)}\right]$$

In the above equation, as the year is incremented from j to $j+1$, the age is also incremented from *age* to *age+1*. With time, a fraction of the in-service stock is removed, and that fraction is determined by a retirement probability function, $prob_{Rtr}(age)$, which is described in section 9.3. Most replacements are made when equipment wears out and fails. Over time, some of the units will be retired and removed from the stock, thus triggering the shipment of a new unit. Because the products considered in this rulemaking are common appliances that have been used by U.S. consumers for a long time, replacements constitute the majority of shipments.

9.3 DATA INPUTS AND MARKET SEGMENTS

The sections below describe the data inputs and market segments considered for each product.

9.3.1 Clothes Dryers

9.3.1.1 Historical Shipments

DOE used historical shipments data (domestic shipments and imports) to calibrate its shipments model. It used three sources to establish historical shipments of electric and gas clothes dryers: (1) data provided by AHAM for the period 1999–2009[1], (2) data from the 2000[2] and 2003[3] AHAM *Factbooks* for the period 1989–1998, and (3) data from *Appliance Magazine*[4, 5, 6] for the period 1972–1988. Figure 9.3.1 shows the historical shipments of electric and gas clothes dryers.

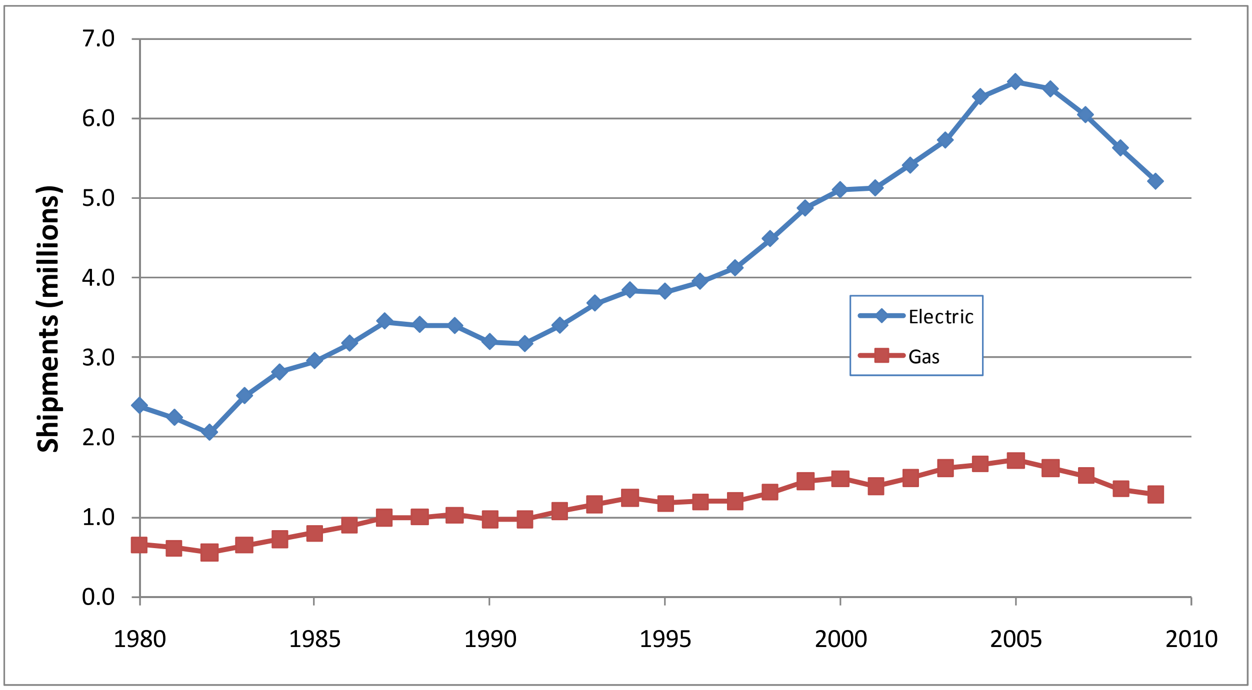

Figure 9.3.1 Historical Shipments of Electric and Gas Clothes Dryers

DOE then disaggregated the shipments of electric clothes dryers based on the market shares for 2007 according to data provided by AHAM (see Table 9.3.1).

Table 9.3.1 Clothes Dryer Product Class Market Shares

Product Class	Market Share (%)
Vented Electric Standard	77.7
Vented Electric Compact (120V)	0.2
Vented Electric Compact (240V)	0.8
Vented Gas	20.9
Vent-less Electric Compact (240V)	0.5
Vent-less Combination Washer/Dryer	0.5

9.3.1.2 Markets and Model Calibration

The shipments market for clothes dryers consists of three main segments: (1) replacement units for equipment that has been retired, (2) units purchased by households in new homes, and (3) households without clothes dryers who purchase the equipment (referred to as first-time owners, or FTOs). Total clothes dryer shipments are represented by the following equation:

$$Ship_{cd}(j) = Rpl_{cd}(j) + NH_{cd}(j) + FTO_{cd}(j)$$

Where:

$Ship_{cd}(j)$ = Total shipments of clothes dryers in year j,
$Rpl_{cd}(j)$ = Replacement shipments in year j,
$NH_{cd}(j)$ = New home shipments in year j, and
$FTO_{cd}(j)$= Shipments to households without clothes dryers in year j.

Replacements. DOE determined shipments for the replacement clothes dryer market segment using an accounting method that tracks the stock of units. Depending on vintage, a certain percentage of clothes dryers will fail and be replaced. To determine when a unit fails, DOE used a survival function based on a product lifetime distribution with an average value of 16 years, and minimum and maximum values of 5 years and 30 years, respectively. For a more complete discussion of clothes dryer lifetimes, refer back to chapter 8. Figure 9.3.2 shows the survival and retirement functions that DOE used to estimate replacement shipments.

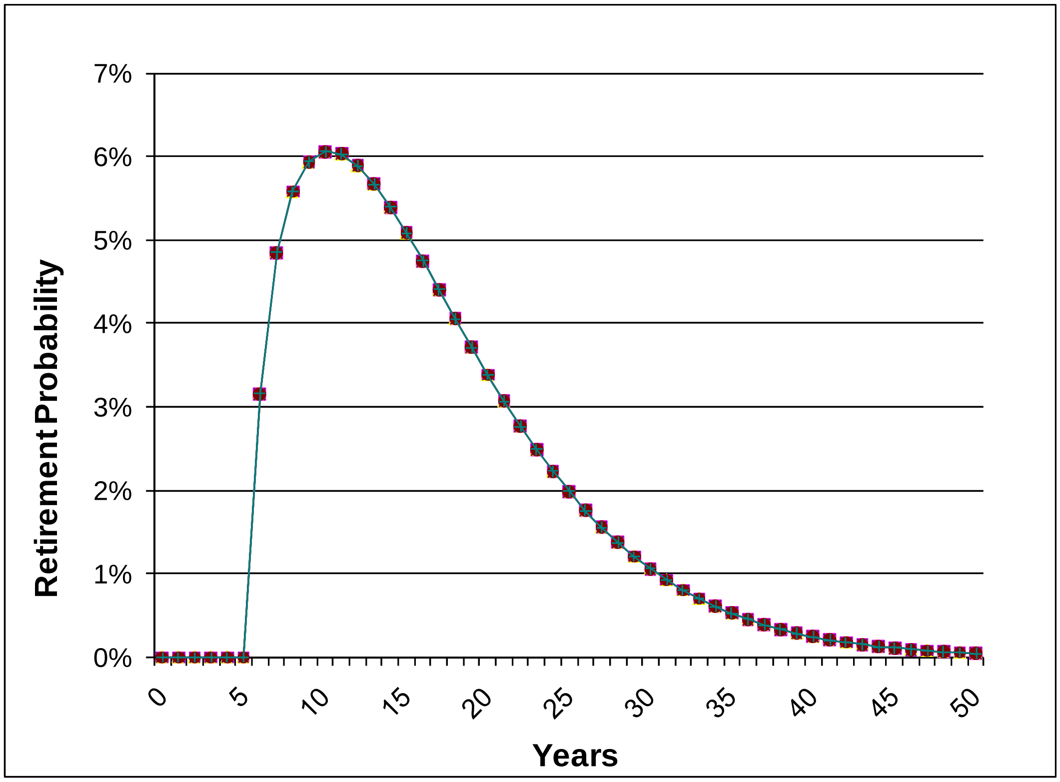

Figure 9.3.2 Clothes Dryers: Retirement Function

New Home Shipments. For clothes dryers, DOE estimated new home shipments using new housing forecasts and product saturation. New housing includes newly constructed single- and multi-family units, referred to as "new housing completions," and mobile home placements. For new housing completions and mobile home placements, DOE used actual data through 2008, and adopted the projections from the DOE Energy Information Administration (EIA)'s *Annual Energy Outlook 2010* (*AEO2010*) for 2009–2035.[7] DOE estimated the fraction of new homes for which the owner or builder purchased an electric or gas clothes dryer based on RECS 2005 data. The saturation over the forecast period is 90 percent. DOE then disaggregated the projected new home shipments of clothes dryers using the market shares in Table 9.3.1.

First-Time Owners. To estimate the number of households without clothes dryers who purchase the equipment, DOE considered the historical percentage of households which purchased a clothes dryer as a first-time owner. DOE derived this rate by dividing historical shipments from 1989-2009 that were not accounted for by replacement or new construction installations by the number of existing households without a clothes dryer. DOE determined that the average first-time owner rate over the past 20 years was 3.3 percent. Taking into account the current economic climate, DOE estimated that this average would be reached by 2013, and would then decrease at a rate of 5 percent annually, as the market becomes saturated with clothes dryers.

9.3.1.3 Base Case Shipments

Figure 9.3.3 shows the forecasted total clothes dryer shipments in the base case (i.e., the case without amended standards), disaggregated into the three market segments, and the historical shipments DOE used to calibrate the forecast. Figure 9.3.4 shows the forecasted clothes dryer shipments in the base case, disaggregated into the considered product classes, and the historical shipments.

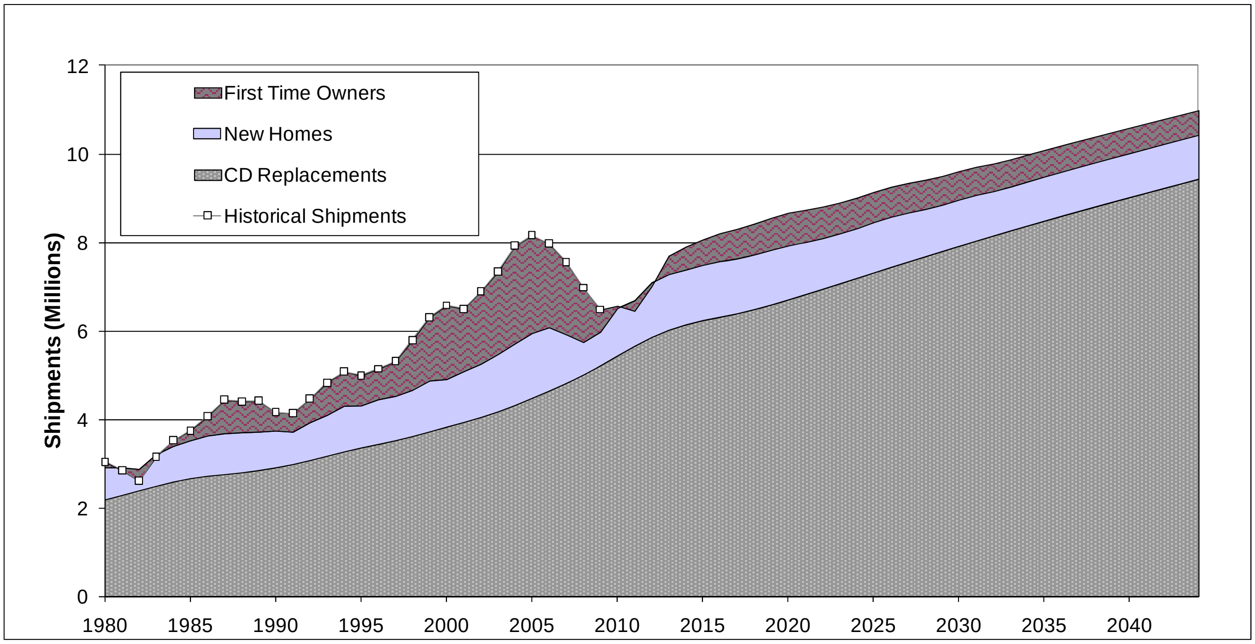

Figure 9.3.3 Clothes Dryers: Base Case Shipments Forecast by Market Segment

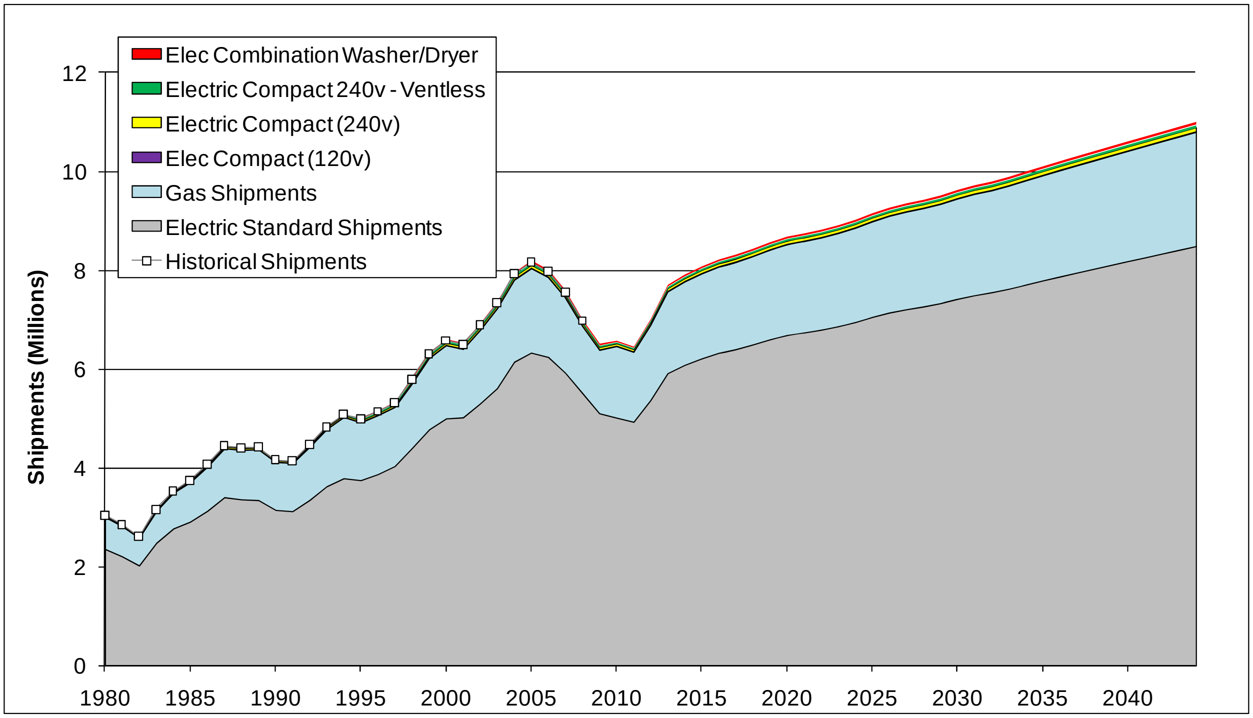

Figure 9.3.4 Clothes Dryers: Base Case Shipments Forecast by Product Class

9.3.2 Room Air Conditioners

9.3.2.1 Historical Shipments

DOE used historical shipments data (domestic shipments and imports) to populate and calibrate its shipments model for room air conditioners. It used three sources to establish historical shipments: (1) data provided by the Association of Home Appliance Manufacturers (AHAM) for the period 1995–2009,[1] (2) data from the 2000 AHAM *Factbook* for the period 1989–1994,[3] and (3) data from *Appliance Magazine*[4,5,6] for the period 1972–1988.[a] The shipments data aggregates all product classes and include units for the residential and commercial sectors.

9.3.2.2 Markets and Model Calibration

The market for room air conditioners primarily consists of replacement units for equipment that has been retired. DOE's shipments model also assumes that some existing

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[a] Shipments estimates from *Appliance Magazine* included exports. Thus, DOE reduced total shipments by 4.1 percent (the average percentage of exports for the years 1989–1993 based on the five-year average difference between the AHAM *Fact Book* 2000 and *Appliance Magazine* data) to estimate total domestic shipments plus imports.

households without room air conditioners as well as households who already own units will purchase the equipment. Total room air conditioner shipments are represented by the following equation:

$$Ship_{rac}(j) = Rpl_{rac}(j) + NP_{rac}(j)$$

Where:

$Ship_{rac}(j)$ =	Total shipments of room air conditioners in year j,
$Rpl_{rac}(j)$ =	Replacement shipments in year j, and
$NP_{rac}(j)$=	Shipments to existing households adding a new room air conditioners in year j.

The sections below discuss these markets in further detail.

Replacements. DOE determined shipments to the replacement market using an accounting method that tracks the total stock of units by vintage. Over time, some units will be retired and removed from stock, thereby 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 unit fails, DOE used a survival function based on a product lifetime distribution with an average value of 10.5 years, and minimum and maximum values of 3 years and 20 years, respectively. For a more complete discussion of room air conditioner lifetimes, refer back to chapter 8. Figure 9.3.5 shows the retirement function that DOE used to estimate replacement shipments.

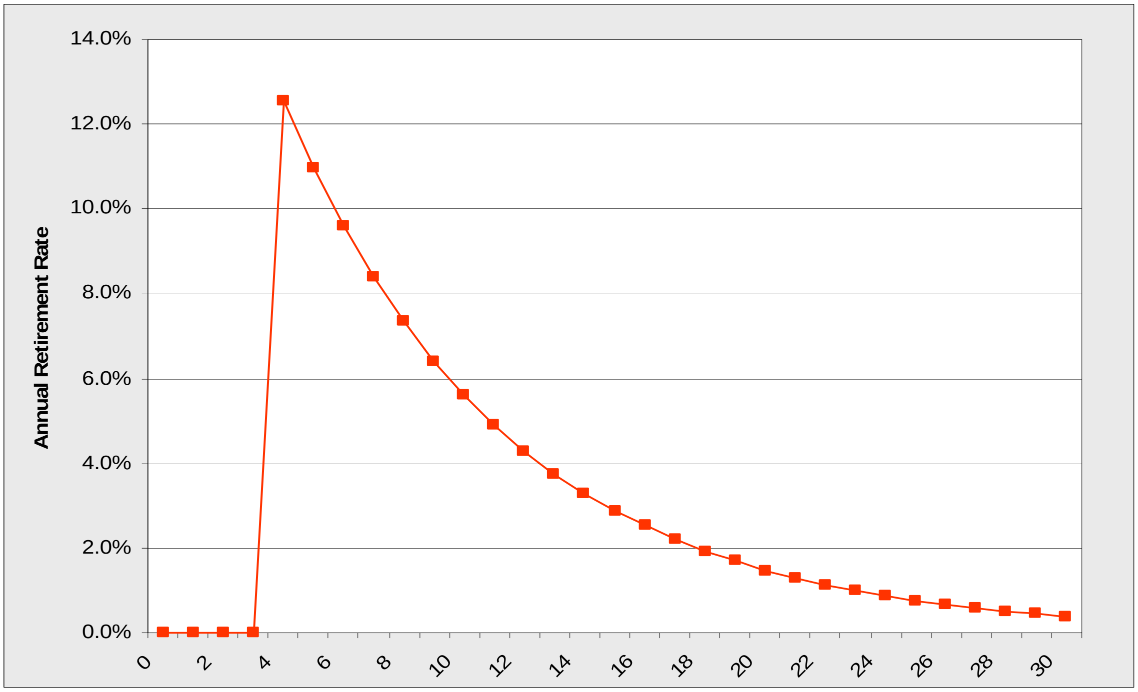

Figure 9.3.5 Room Air Conditioners: Retirement Function

New Purchases. To calibrate the modeled shipments with the historical data, DOE introduced a market segment for new purchases of room air conditioners. These include purchase of additional units by households that already own a room air conditioner, as well as purchases by households without room air conditioners, also referred to as first-time owners (FTOs). Through 2009, DOE derived new purchases as the difference between the historic total shipments and the calculated replacement shipments.

For 2010 and onward, DOE estimated new purchases in the following way. On average, households with room air conditioners own 1.7 units per household, according to the American Housing Survey (AHS) 2007. The AHS indicates that 21 million households did not own a room air conditioner in 2007. Assuming that the households without a room air conditioner would potentially purchase 1.7 units on average, DOE estimated that the total potential for room air conditioner sales in the FTO segment in 2007 was around 36 million. Over time, this pool decreases as some of the households purchase room air conditioners. In 2009, after subtracting the replacement market sales, DOE estimated that the remaining sales imply that less than 1 percent of the FTO potential sales were realized, as opposed to 10 percent over the period 2007-2009. DOE assumed that this would be the case in the next two years until the economy recovers from the economic downturn. In the following years, DOE estimated that 10 percent of the remaining segment in each year in 2012–2044 purchases a unit. DOE based these fractions on the estimated purchases by FTOs in 2009 and in the period 2007–2009 compared to the potential market.

Commercial Sector Shipments. As described in chapter 8, DOE estimated that 12 percent of total room air conditioner shipments go to the commercial sector. DOE used this fraction to estimate shipments to the commercial sector for all years in the forecast period.

9.3.2.3 Base Case Shipments

Figure 9.3.6 presents forecasted room air conditioner shipments in the base case, disaggregated into the considered market segments. The leveling off in shipments forecast by the shipments model reflects the saturation of the potential market for this product.

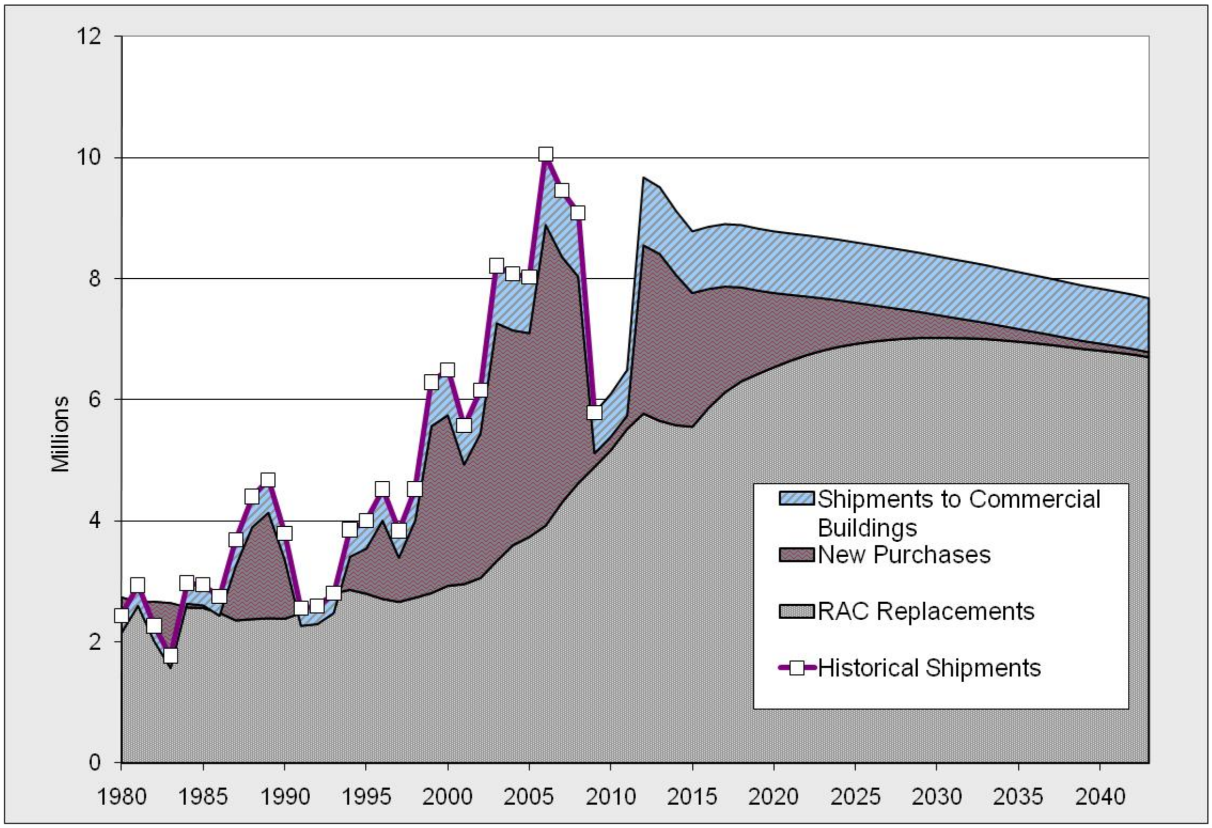

Figure 9.3.6 Room Air Conditioners: Base Case Shipments Forecast by Market Segment

9.3.2.4 Disaggregation into Product Classes

DOE's shipments model for room air conditioners forecasted aggregate shipments. DOE considered 16 product classes for room air conditioners. DOE estimated the market shares for each of the 16 product classes using market share data AHAM provided for 2005–2007.[3] Where AHAM did not disaggregate shipments into all of the product classes, DOE assumed that the distribution of models for the product classes is representative of the distribution of shipments. Table 9.3.2 shows the market shares used for the forecast period, and Figure 9.3.7 shows the shipments forecast by product class.

Table 9.3.2 Room Air Conditioner Product Class Market Shares

Product Class	2005	2006	2007	Share of Models*	Share Used After 2007
1	37.0%	23.0%	32.0%	11.6%	30.7%
2	19.0%	19.0%	16.0%	9.9%	18.0%
3	30.0%	34.0%	36.0%	31.1%	33.4%
4	3.0%	5.5%	6.0%	12.1%	4.8%
5	2.0%	3.9%	2.6%	9.0%	2.8%
6				0.1%	0.1%
7				0.9%	0.4%
8	7.0%	12.0%	7.0%	19.1%	8.0%
9				0.7%	0.3%
10				0.0%	0.0%
11	0.7%	1.0%	NA	0.6%	0.8%
12	0.1%			0.5%	0.1%
13	0.4%	0.6%	NA	0.7%	0.3%
14				0.0%	0.0%
15	0.4%	0.6%	0.4%	1.1%	0.1%
16				2.6%	0.3%

* Based on 2007 CEC directory and AHAM email communication for disaggregation between the product classes 5a and 5b, and 8a and 8b.

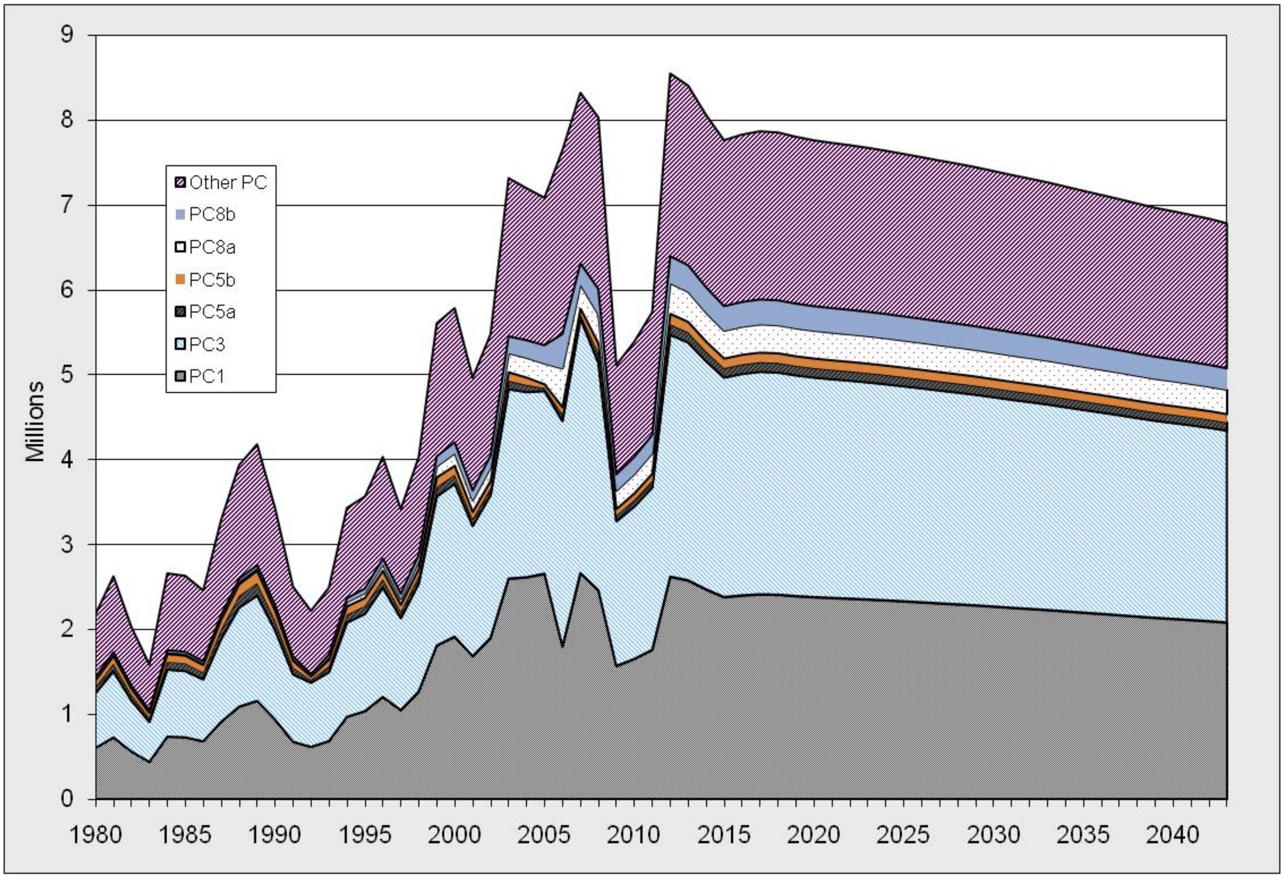

Figure 9.3.7 Room Air Conditioners: Base Case Shipments Forecast by Product Class

9.4 IMPACT OF PURCHASE PRICE INCREASE ON SHIPMENTS

Economic theory suggests that, all else being equal, an increase in the price of a good would lead 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.

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 equipment price and shipments data 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[b] when comparing appliance prices and appliance 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 over the period 1980–2002 to evaluate broad market trends and conduct simple regression analyses. These data indicate that there has been a rise in appliance shipments and a decline in appliance purchase price and operating costs over the time period. Household income has also risen during this time. 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 with the following expression:

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

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 (i.e., under 1.0). DOE's regression analysis suggests that the *relative price* elasticity of demand, averaged over the three appliances, is -0.34. For example, 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 impacts from three effects (i.e., purchase price, operating cost, and household income), the impact from any single effect is mitigated by changes from the other two effects.

The *relative price* elasticity of -0.34 is consistent with estimates in the literature. Nevertheless, DOE stresses that the measure is based on a small data set, using simple statistical analysis. More important, the measure is based on an assumption that economic variables, including purchase price, operating costs, and household income, explain most of the trend in

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[b] 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. In other words, consumers are much more concerned with higher purchase prices.

appliances per household in the United States since 1980. Changes in appliance quality and consumer preferences may have occurred during this period, but DOE did not account for them in this analysis. Despite these uncertainties, DOE believes that its estimate of the relative price elasticity of demand provides a reasonable assessment of the impact that purchase price, operating cost, and household income have on product shipments.

Because DOE's forecasts of shipments and national impacts due to standards are over a 30-year time 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-run value. It was unable to identify sources specific to household durable goods, such as appliances, to indicate how short-run and long-run price elasticities differ. Therefore, to estimate how the *relative price* elasticity changes over time, DOE relied on a study pertaining to automobiles.[8, 9] This study shows that the automobile price elasticity of demand changes in the years following a purchase price change. 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. As shown in the table, 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 the table below, DOE performed a linear interpolation to obtain the *relative price* elasticity.

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

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

Based on the following equation, DOE estimated standards case shipments by incorporating the impact of the *relative price* into the base case shipments forecast. Note that in the equation below, the *relative price* and the *relative price* elasticity are functions of the year because both change with time.

$$\boldsymbol{Ship_{STD\_p}(j) = \left(Rpl_{BASE\_p}(j) + NI_{BASE\_p}(j) + M_{BASE\_p}(j)\right) ? \left(1 - e_{RP}(j) ? \Delta RP(j)\right)}$$

Where:

$Ship_{STD\_p}(j)$ = Total shipments under the standards case of product *p* in year *j*,
$Rpl_{BASE\_p}(j)$ = Units of product *p* under the base case retired and replaced in year *j*,
$NI_{BASE\_p}(j)$ = Number of new home installations under the base case of product *p* in year *j*,
$M_{BASE\_p}(j)$ = 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*.

9.5 AFFECTED STOCK

The affected stock is the in-service stock of the appliance or product that is affected by a standard level. In addition to the forecast of product shipments under both the base case and the standards case, the affected stock (which represents the difference in the appliance stock for the base case and the standards case) is a key output of DOE's shipments models. The affected stock quantifies the impact that new product shipments have on the appliance stock due to a standard level. Therefore, the affected stock consists of those in-service units that are purchased in or after the year the standard has taken effect, as described by the following equation:

$$Aff\ Stock_p(j) = Ship_p(j) + \sum_{age=1}^{j-Std\_yr} Stock_p(age)$$

Where:

Aff Stock$_p$*(j)* =	Affected stock of units of product *p* of all vintages that are operational in year *j*,
Ship$_p$*(j)* =	Shipments of product *p* in year *j*,
Stock$_p$*(j)* =	Stock of units of product *p* of all vintages that are operational in year *j*,
age =	Age of the units (years), and
Std_yr =	Effective date of the standard.

As noted in the above equation, to calculate the affected stock, DOE must define the effective date of the standard. For the NES and NPV results presented in chapter 10, DOE assumed that new energy efficiency standards will become effective in 2014. Thus, all appliances purchased starting in 2014 are affected by the standard level.

9.6 CANDIDATE STANDARD LEVELS

Table 9.6.1 and Table 9.6.2 show the efficiency levels corresponding to each candidate standard level (CSL) for each product class.

Table 9.6.1 Combined Energy Factor (CEF) Levels Corresponding to Candidate Standard Levels for Clothes Dryers

Product Class	Candidate Standard Level					
	1	2	3	4	5	6
Vented Electric Standard	3.56	3.61	3.73	3.81	4.08	5.42
Vented Electric Compact 120V	3.48	3.61	3.72	3.80	4.08	5.41
Vented Electric Compact 240V	3.16	3.27	3.36	3.48	3.60	4.89
Vented Gas	3.16	3.20	3.30	3.41	3.61	
Vent-less Electric 240V	2.59	2.69	2.71	2.80	4.03	
Vent-less Combination Washer/Dryer	2.35	2.38	2.46	2.56	3.69	

Table 9.6.2 Combined Energy Efficiency Rating (CEER) Levels Corresponding to Candidate Standard Levels for Room Air Conditioners

Product Class	Base Case	Candidate Standard Level				
		1	2	3	4	5
Less than 6,000 Btu/h, with Louvers	9.5	10.1	10.6	11.1	11.4	11.7
8,000-13,999 Btu/h, with Louvers	9.7	10.2	10.7	10.9	11.5	12.0
20,000-24,999 Btu/h, with Louvers	8.5	9.0	9.4	9.8	10.2	
25,000 Btu/h or more, with Louvers	8.5	9.0	9.4	9.8		
8,000-10,999 Btu/h, without Louvers	8.4	9.3	9.6	10.0	10.4	
11,000-13,999 Btu/h, without Louvers	8.4	9.3	9.5	9.8	10.0	

9.7 SHIPMENTS FORECASTS

The following sections show the shipments forecasts for the various standard levels that DOE considered for clothes dryers and room air conditioners, as well as for the base case.

9.7.1 Clothes Dryers

Figure 9.7.1 compares the shipments forecasts for the base case and TSLs 1 through 6 for electric standard clothes dryers. In Figure 9.7.1, the difference between the base case and standard level shipments forecasts depicts the annual shipments reductions caused by the standard levels. For all standard levels, shipments are forecasted to decrease compared to the base case —the effects from the increase in product purchase prices offset the effects from decreased operating costs, resulting in a net decrease in shipments. Similar effects are seen for the other clothes dryer product classes.

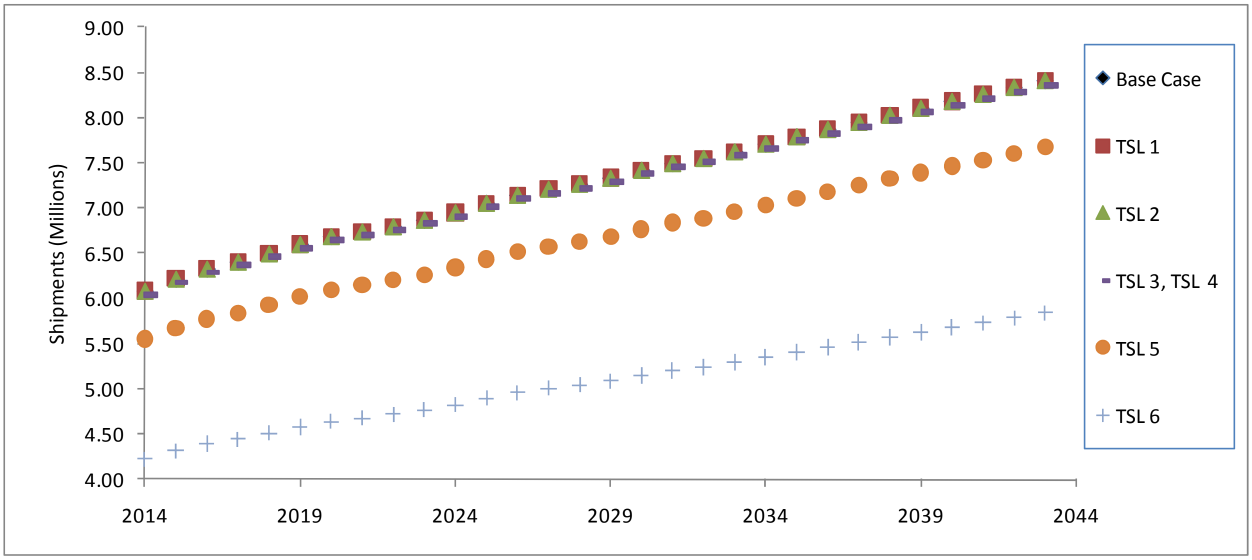

Figure 9.7.1 Clothes Dryers, Electric Standard: Base Case and Standards Case Shipments Forecasts

9.7.2 Room Air Conditioners

Figure 9.7.2 compares the shipments forecasts for the base case and TSL 1 through 6 for units less than 6,000 Btu/h without reverse cycle and with louvered sides. In Figure 9.7.2, the difference between the base case and standard level shipments forecasts depicts the annual shipments reductions caused by the standard levels. For all standard levels, shipments are forecasted to decrease compared to the base case; the effects from the increase in product purchase prices offset the effects from decreased operating costs, resulting in a net decrease in shipments. Similar effects are seen for the other room air conditioner product classes.

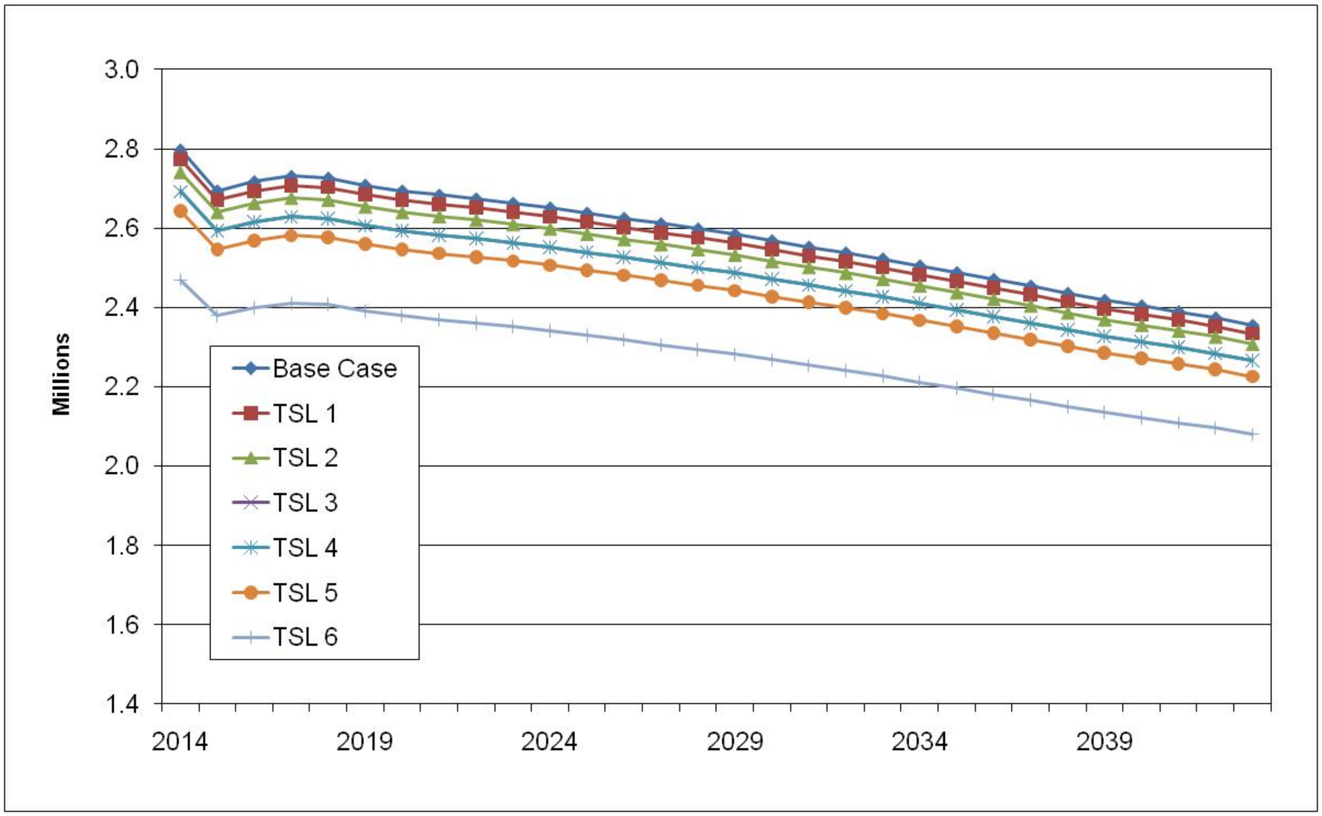

Figure 9.7.2 Room Air Conditioners, < 6,000 Btu/h Without Reverse Cycle and With Louvered Sides: Base Case and Trial Standards Level Shipments Forecasts

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CHAPTER 10: NATIONAL IMPACT ANALYSIS

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

This chapter describes the method the U.S. Department of Energy (DOE) used to conduct a national impacts analysis (NIA) of potential standard levels for room air conditioners and clothes dryers. DOE evaluated the following impacts: (1) national energy savings (NES) attributable to each possible standard, (2) monetary value of the energy savings to consumers of the consider products, (3) increased total installed costs of the products because of standards, and (4) the net present value (NPV) (the difference between the value of energy savings and increased total installed costs).

DOE determined the NES and NPV for all the standard levels considered for room air conditioners and clothes dryers. DOE performed all calculations for each of the considered products using a Microsoft Excel spreadsheet model, which is accessible on the Internet (www.eere.energy.gov/buildings/appliance_standards/). The spreadsheets combine the calculations for determining the NES and NPV for each considered product with input from the appropriate shipments model. As discussed in chapter 16, the NIA model also performs the calculations for the Regulatory Impact Analysis. Details and instructions for using the NIA model are provided in appendix 10-A.

Chapter 9 provides a detailed description of the shipments models that DOE used to forecast future purchases of the considered products. Chapter 9 includes a description of the sensitivity of shipments to total installed cost and operating cost, and how DOE captured those sensitivities within the model.

For room air conditioners, DOE has analyzed four representative product classes in detail. For the NIA, DOE assigned each of the sixteen product classes included in this rulemaking to one of four product class groups, each of which is based on the analyses for the four representative product classes. To estimate the national impacts of amended standards for all the product classes considered in this rulemaking, DOE allocated the product cost and annual energy consumption of each representative product class to all product classes within its group. The following list indicates which product classes are associated with each product class group:

- **Group 1** consists of product class 1: Less than 6,000 Btu/h, Without Reverse Cycle and With Louvers
- **Group 2** consists of product classes 2, 3, 4, 11, and is based on Product class 3: 8,000–13,999 Btu/h, Without Reverse Cycle and With Louvers
- **Group 3** consists of product classes 5a, 9 and 13 and is based on product class5a: 20,000-24,999 Btu/h, Without Reverse Cycle and With Louvers
- **Group 4** consists of product classes 5b and 10 and is based on product class 5b: >25,000 Btu/h, Without Reverse Cycle and With Louvers
- **Group 5** consists of product classes 6, 7, 8a, 12 and is based on product class 8a: 8,000–11,999 Btu/h, Without Reverse Cycle and Without Louvers
- **Group 6** consists of product classes 8b, 14, 15 and 16 and is based on product class 8b: 12,000–13,999 Btu/h, Without Reverse Cycle and Without Louvers

10.2 FORECASTED ENERGY EFFICIENCIES

A key component of DOE's estimates of NES and NPV for each of the two products is the energy efficiencies forecasted for the base case (without amended energy conservation standards) and each of the standards cases (with amended energy conservation standards). The forecasted energy efficiency represents the annual shipments-weighted energy efficiency of the product under consideration during the forecast period (that is, from the assumed effective date of an amended standard to 30 years after that date).

For calculating the NES, per-unit average annual energy consumption is a direct function of product energy efficiency. For the NPV, the per-unit total installed cost is a direct function of energy efficiency; the per-unit annual operating cost, because it is a function of per-unit annual energy consumption, is indirectly dependent on product energy efficiency. The above NES and NPV inputs, as well as all other inputs to the calculation of NES and NPV, are discussed further in sections 10.3 and 10.4.

To forecast the base-case energy efficiency for each product class, DOE used as a starting point the shipments-weighted energy efficiency for 2014. To represent the distribution of product energy efficiencies in 2014, DOE used the same market shares as in the base case for the life-cycle cost (LCC) analysis (see chapter 8). Based on recent trends, DOE assumed no improvement of energy efficiency in the base case for clothes dryers. For room air conditioners, an annual growth rate of 0.25% was applied between 2014 and 2044.

For clothes dryers, in order to forecast standards-case energy efficiencies, DOE used a "roll-up" scenario to establish the shipments-weighted average energy efficiency for the year that energy conservation standards are assumed to become effective (2014). In this approach, product energy efficiencies in the base case that do not meet the standard level under consideration would "roll up" to meet the new standard level. Product energy efficiencies in the base case that exceeded the standard level under consideration would not be affected.

For room air conditioners, 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 SWEER, as it is done in the base case. To develop standards case forecasted SWEERs, DOE developed growth trends for each candidate standard level that maintained the same per-unit average total installed cost difference for the year 2014 between the base case and each standards case over the entire forecast period (2014–2044). DOE's approach for developing standards case SWEERs 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 SWEER growth rate for each standards case is lower than the SWEER growth rate for the base case.

The following sections detail the energy efficiency forecasts that DOE developed for the two products.

10.2.1 Clothes Dryers

Table 10.2.1 through Table 10.2.6 show the distributions for base- and standards-case product energy efficiency in 2014 that DOE used in its NIA for clothes dryers. Also included in the tables are the shipments-weighted energy efficiencies associated with the base case and each considered standard level. DOE assumed that energy efficiencies for all product classes of clothes dryers remain constant at 2014 levels.

Table 10.2.1 Vented Dryer, Electric, Standard: Energy Efficiency Distributions in 2014

Energy Efficiency Level	CEF *(lb/kWh)*	Market Share						
		Base Case	TSL					
			1	2	3	4	5	6
Baseline	3.55	3%						
1	3.56	19%	21%					
2	3.61	54%	54%	75%				
3	3.73	18%	18%	18%	93%	93%		
4	3.81	6%	6%	6%	6%	6%		
5	4.08	1%	1%	1%	1%	1%	100%	
6	5.42	0%	0%	0%	0%	0%	0%	100%
SWEF		3.64	3.64	3.65	3.74	3.74	4.08	5.42

Table 10.2.2 Vented Dryer, Electric, Compact 120V: Energy Efficiency Distributions in 2014

Energy Efficiency Level	CEF *(lb/kWh)*	Market Share						
		Base Case	TSL					
			1	2	3	4	5	6
Baseline	3.43	100%	100%					
1	3.48	0%	0%					
2	3.61	0%	0%	100%	100%	100%		
3	3.72	0%	0%	0%	0%	0%		
4	3.80	0%	0%	0%	0%	0%		
5	4.08	0%	0%	0%	0%	0%	100%	
6	5.41	0%	0%	0%	0%	0%	0%	100%
SWEF		3.43	3.43	3.61	3.61	3.61	4.08	5.41

Table 10.2.3 Vented Dryer, Electric, Compact 240V: Energy Efficiency Distributions in 2014

Energy Efficiency Level	CEF *(lb/kWh)*	Market Share						
		Base Case	TSL					
			1	2	3	4	5	6
Baseline	3.12	59%	59%					
1	3.16	0%	0%					
2	3.27	16%	16%	75%	75%	75%		
3	3.36	17%	17%	17%	17%	17%		
4	3.48	4%	4%	4%	4%	4%		
5	3.60	4%	4%	4%	4%	4%	100%	
6	4.89	0%	0%	0%	0%	0%	0%	100%
SWEF		3.22	3.22	3.31	3.31	3.31	3.60	4.89

Table 10.2.4 Vented Dryer, Gas: Energy Efficiency Distributions in 2014

Energy Efficiency Level	CEF *(lb/kWh)*	Market Share						
		Base Case	TSL					
			1	2	3	4	5	6
Baseline	3.14	8%						
1	3.16	8%	16%					
2	3.20	43%	43%	59%	59%			
3	3.30	31%	31%	31%	31%	90%		
4	3.41	9%	9%	9%	9%	9%		
5	3.61	1%	1%	1%	1%	1%	100%	100%
SWEF		3.25	3.25	3.25	3.25	3.31	3.61	3.61

Table 10.2.5 Vent-less Dryer, Electric, Compact 240V: Energy Efficiency Distributions in 2014

Energy Efficiency Level	CEF *(lb/kWh)*	Market Share						
		Base Case	TSL					
			1	2	3	4	5	6
Baseline	2.55	100%	100%			100%		
1	2.59	0%	0%			0%		
2	2.69	0%	0%	100%	100%	0%		
3	2.71	0%	0%	0%	0%	0%		
4	2.80	0%	0%	0%	0%	0%	100%	
5	4.03	0%	0%	0%	0%	0%	0%	100%
SWEF		2.55	2.55	2.69	2.69	2.55	2.80	4.03

Table 10.2.6 Vent-less Dryer, Electric, Combination Washer/Dryer: Energy Efficiency Distributions in 2014

Energy Efficiency Level	CEF *(lb/kWh)*	Market Share						
		Base Case	TSL					
			1	2	3	4	5	6
Baseline	2.08	100%	100%			100%		
1	2.35	0%	0%			0%		
2	2.38	0%	0%			0%		
3	2.46	0%	0%			0%		
4	2.56	0%	0%	100%	100%	0%	100%	
5	3.69	0%	0%	0%	0%	0%	0%	100%
SWEF		2.08	2.08	2.56	2.56	2.08	2.56	3.69

10.2.2 Room Air Conditioners

Table 10.2.7 through Table 10.2.12 show the distributions for base- and standards-case product energy efficiency in 2014 that DOE used in its NIA for room air conditioners, as well as the shipments-weighted energy efficiency ratio (SWEER) for each considered candidate standard level (CSL). DOE assumed that energy efficiencies for all room air conditioner product classes will increase at a rate of 0.25% per year in absence of standard.

Table 10.2.7 Room Air Conditioners, Without Reverse Cycle and With Louvers, Less than 6,000 Btu/h: Energy Efficiency Distributions in 2014

Energy Efficiency Level	CEER	Market Shares						
		Base Case	Trial Standard Level					
			1	2	3	4	5	6
Baseline	9.5	69%						
1	10.1	0%	69%		69%			
2	10.6	30%	30%	100%	30%			
3	11.1	1%	1%	1%	1%	100%	100%	
4	11.4	0%	0%	0%	0%	0%	0%	
5	11.7	0%	0%	0%	0%	0%	0%	100%
SWEER		9.9	10.3	10.7	10.3	11.1	11.1	11.7

Table 10.2.8 Room Air Conditioners, Without Reverse Cycle and With Louvers, 8,000–13,999 Btu/h: Energy Efficiency Distributions in 2014

Energy Efficiency Level		Market Shares						
	CEER	Base Case	Trial Standard Level					
			1	2	3	4	5	6
Baseline	9.7	37%						
1	10.2	2%						
2	10.7	58%	98%	98%				
3	10.9	1%	1%	1%	99%	99%		
4	11.5	0%	0%	0%	0%	0%	100%	
5	12.0	0%	0%	0%	0%	0%	0%	100%
SWEER		10.3	10.7	10.7	10.9	10.9	11.4	12.0

Table 10.2.9 Room Air Conditioners, Without Reverse Cycle and With Louvers, 20,000-24,999 Btu/h: Energy Efficiency Distributions in 2014

Energy Efficiency Level		Market Shares						
	CEER	Base Case	Trial Standard Level					
			1	2	3	4	5	6
Baseline	8.5	13%			13%		13%	
1	9	2%			2%		2%	
2	9.4	81%	96%	96%	81%	96%	81%	
3	9.8	2%	2%	2%	2%	2%	2%	
4	10.2	2%	2%	2%	2%	2%	2%	100%
SWEER		9.3	9.4	9.4	9.3	9.4	9.3	10.2

Table 10.2.10 Room Air Conditioners, Without Reverse Cycle and With Louvers, 25,000 Btu/h or more: Energy Efficiency Distributions in 2014

Energy Efficiency Level		Market Shares						
	CEER	Base Case	Trial Standard Level					
			1	2	3	4	5	6
Baseline	8.5	12%			12%		12%	
1	9	2%			2%	15%	2%	
2	9.4	85%	100%	100%	85%	85%	85%	
3	9.8	0%	0%	0%	0%	0%	0%	100%
SWEER		9.3	9.4	9.4	9.3	9.3	9.3	9.8

Table 10.2.11 Room Air Conditioners, Without Reverse Cycle and Without Louvers, 8,000–11,999 Btu/h: Energy Efficiency Distributions in 2014

Energy Efficiency Level	CEER	Market Shares						
		Base Case	Trial Standard Level					
			1	2	3	4	5	6
Baseline	8.4	10%						
1	9.3	65%	75%	75%				
2	9.6	20%	20%	20%	94%	94%		
3	10.0	4%	4%	4%	4%	4%	98%	
4	10.4	2%	2%	2%	2%	2%	2%	100%
SWEER		9.3	9.4	9.4	9.6	9.6	10.0	10.4

Table 10.2.12 Room Air Conditioners, Without Reverse Cycle and Without Louvers, 12,000–13,999 Btu/h: Energy Efficiency Distributions in 2014

Energy Efficiency Level	CEER	Market Shares						
		Base Case	Trial Standard Level					
			1	2	3	4	5	6
Baseline	8.4	10%						
1	9.3	59%	69%	69%				
2	9.5	13%	13%	13%	83%	83%	83%	
3	9.8	17%	17%	17%	17%	17%	17%	
4	10.0	0%	0%	0%	0%	0%	0%	100%
SWEER		9.3	9.4	9.4	9.6	9.6	9.6	10.0

Figure 10.2.1 illustrates the approach used by DOE for room air conditioners without reverse cycle and with louvers, less than 6,000 Btu/h. The figure shows the CEER-based base case historical SWEERs, the base case forecasted energy efficiency trend and each standard case forecasted energy efficiency trend for room air conditioners, without reverse cycle and with louvers, less than 6,000 Btu/h. As shown on the figure, 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.

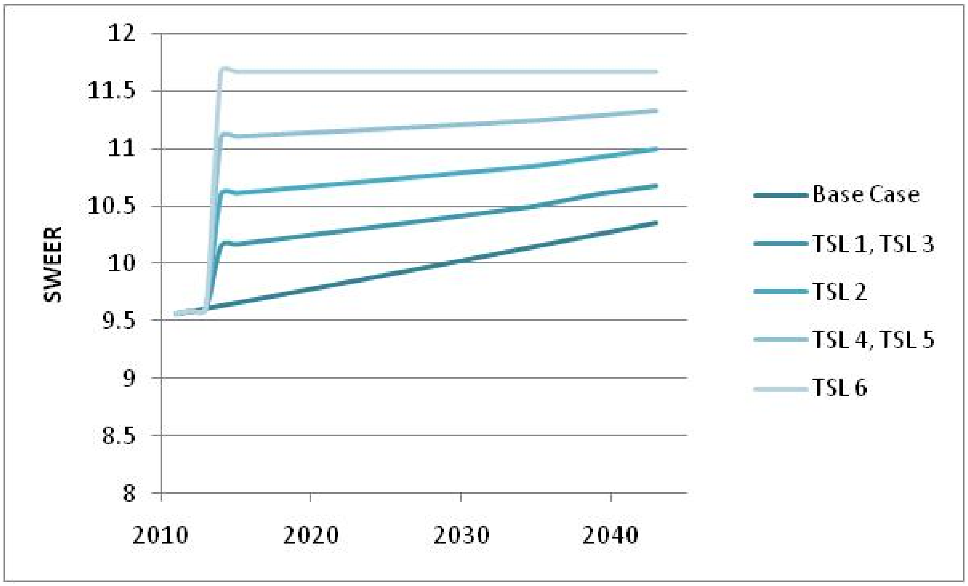

Figure 10.2.1 Room Air Conditioners, Without Reverse Cycle and With Louvers, Less than 6,000 Btu/h: SWEER Forecast for the Base Case and Standard Cases

10.3 NATIONAL ENERGY SAVINGS

DOE calculated the national energy savings associated with the difference between the base case and the case associated with each potential standard for room air conditioners and clothes dryers. DOE calculated cumulative energy savings throughout the forecast period, which extends from 2014 through 2043.

10.3.1 Definition of National Energy Savings

The following equation shows that DOE calculated annual national energy savings (NES) as the difference between two projections: a base case (without new standards) and a standards case. Positive values of NES represent energy savings (that is, national annual energy consumption (AEC) under a standard is less than in the base case).

$$NES_y = AEC_{BASE} - AEC_{STD}$$

Cumulative energy savings are the sum of annual national energy savings throughout the forecast period, which extends from the assumed effective date of new standards (2014) to 30 years after that date (through 2043).

DOE calculated the national annual site energy consumption by multiplying the number or stock of each product class (by vintage) by its unit energy consumption (UEC; also by vintage). The calculation of national annual energy consumption is represented by the following equation.

$$AEC_y = \sum STOCK_V \times UEC_V$$

Where:

AEC =	national annual energy consumption each year in quadrillion British thermal units (quads), summed over vintages of the product stock, $STOCK_V$,
NES =	annual national energy savings (quads),
$STOCK_V$ =	stock of product (millions of units) of vintage *V* that survive in the year for which DOE calculated annual energy consumption,
UEC_V =	annual energy consumption per product in kilowatt-hours (kWh),
V =	year in which the product was purchased as a new unit, and
y =	year in the forecast.

Electricity consumption is converted from site energy to source energy (quads) by applying a time-dependent conversion factor.

The stock of a product depends on annual shipments and the lifetime of the product. As described in chapter 9, DOE projected product shipments under the base case and the standards cases. DOE projected that shipments under the standards cases would be slightly lower than under the base case, because DOE believes that the higher purchase cost of more efficient products would cause some consumers to forego purchasing new products.

To avoid including savings attributable to shipments displaced because of standards, DOE used the projected standards-case shipments and, in turn, the standards-case stock, to calculate the annual energy consumption for the base case.

10.3.2 Inputs to National Energy Savings

The inputs for determining NES are:

- annual energy consumption per unit (*UEC)*
- shipments
- product stock ($STOCK_V$)
- national annual energy consumption (AEC)
- site- to-source conversion factor (*src_conv)*

10.3.2.1 **Annual Energy Consumption per Unit**

DOE developed per-unit annual energy consumption as a function of product energy efficiency for each of the considered products (chapter 7, Energy Use Characterization, and chapter 8, Life-Cycle Cost and Payback Period Analyses). Because per-unit annual energy consumption is directly dependent on energy efficiency, DOE used the shipments-weighted energy efficiencies for the base and standards cases (presented in section 10.2), along with the annual energy use data presented in chapter 8, to estimate the shipments-weighted average annual per-unit energy consumption under the base and standards cases.

Clothes Dryers. Using the relationship between the CEF of clothes dryers and the annual energy consumption described in chapter 8, DOE calculated the per-unit annual energy consumption of clothes dryers. The calculation was based on the shipments-weighted energy efficiencies that correspond to the base case and each standards case for each clothes dryer product class (Table 10.3.1).

Table 10.3.1 Clothes Dryers: Shipments-Weighted Average per-Unit Annual Energy Consumption

Product Class		Base Case	Standard at Efficiency Level					
			1	2	3	4	5	6
Vented Electric Standard	CEF (lbs/kWh)	3.55	3.56	3.61	3.73	3.81	4.08	5.42
	Annual Energy Use (kWh/yr)	718	716	707	684	670	627	476
Vented Electric Compact 120V	CEF (lbs/kWh)	3.43	3.48	3.61	3.72	3.80	4.08	5.41
	Annual Energy Use (kWh/yr)	317	314	305	295	289	268	198
Vented Electric Compact 240V	CEF (lbs/kWh)	3.12	3.16	3.27	3.36	3.48	3.60	4.89
	Annual Energy Use (kWh/yr)	353	349	340	331	319	308	223
Vented Gas	CEF (lbs/kWh)	3.14	3.16	3.20	3.30	3.41	3.61	
	Annual Gas Use (MMBtu/yr)	2.53	2.53	2.53	2.45	2.37	2.25	
	Annual Elec. Use (kWh/yr)	42	39	30	30	30	25	
Vent-less Electric Compact 240V	CEF (lbs/kWh)	2.55	2.59	2.69	2.71	2.80	4.03	
	Annual Energy Use (kWh/yr)	372	366	354	351	337	210	
Vent-less Electric Combination Washer/Dryer	CEF (lbs/kWh)	2.08	2.35	2.38	2.46	2.56	3.69	
	Annual Energy Use (kWh/yr)	463	399	394	383	365	226	

As noted in section 10.2, DOE assumed that forecasted energy efficiencies in the base and standards cases remain constant at 2014 levels. Because per-unit annual energy consumption is a function of energy efficiency, DOE held the values shown in Table 10.3.1 constant throughout the forecast period.

Room Air Conditioners. Using the relationship between EER and annual energy consumption described in chapter 8, DOE calculated the per-unit annual energy consumption based on the shipments-weighted average energy efficiencies that correspond to the base case and each considered standard case for each room air conditioner product class. Table 10.3.2 and Table 10.3.3 show the values used for shipments to the residential and commercial sector, respectively.

Table 10.3.2 Room Air Conditioners: Shipments-Weighted Average per-Unit Annual Energy Consumption in 2014, Residential Sector

Product Class		Base Case	Trial Standard Level 1	2	3	4	5	6
Less than 6,000 Btu/h, with Louvers	**CEER**	9.5	10.1	10.6	10.1	11.1	11.1	11.7
	Annual Energy Use *(kWh/yr)*	389	375	365	375	351	351	337
8,000-13,999 Btu/h, with Louvers	CEER	9.7	10.6	10.6	11.1	11.1	11.4	11.7
	Annual Energy Use *(kWh/yr)*	604	584	584	576	576	550	532
20,000-24,999 Btu/h, with Louvers	CEER	8.5	9.4	9.4	8.5	9.4	8.5	10.2
	Annual Energy Use *(kWh/yr)*	466	459	459	466	459	466	432
25,000 Btu/h or more, with Louvers	CEER	8.5	9.4	9.4	8.5	9.0	8.5	9.8
	Annual Energy Use *(kWh/yr)*	543	536	536	543	539	543	518
8,000-10,999 Btu/h, without Louvers	CEER	8.4	9.3	9.3	9.6	9.6	10.0	10.4
	Annual Energy Use *(kWh/yr)*	481	477	477	467	467	450	438
11,000-13,999 Btu/h, without Louvers	CEER	8.4	9.3	9.3	9.5	9.5	9.5	10.0
	Annual Energy Use *(kWh/yr)*	717	711	711	702	702	702	673

Table 10.3.3 Room Air Conditioners: Shipments-Weighted Average per-Unit Annual Energy Consumption in 2014, Commercial Sector

Product Class		Base Case	Trial Standard Level					
			1	2	3	4	5	6
Less than 6,000 Btu/h, with Louvers	CEER	9.5	10.1	10.6	10.1	11.1	11.1	11.7
	Annual Energy Use *(kWh/yr)*	583	563	548	563	527	527	506
8,000-13,999 Btu/h, with Louvers	CEER	9.7	10.6	10.6	11.1	11.1	11.4	11.7
	Annual Energy Use *(kWh/yr)*	1034	1001	1001	986	986	943	913
20,000-24,999 Btu/h, with Louvers	CEER	8.5	9.4	9.4	8.5	9.4	8.5	10.2
	Annual Energy Use *(kWh/yr)*	2919	2883	2883	2919	2883	2919	2709
25,000 Btu/h or more, with Louvers	CEER	8.5	9.4	9.4	8.5	9.0	8.5	9.8
	Annual Energy Use *(kWh/yr)*	2924	2889	2889	2924	2905	2924	2790
8,000-10,999 Btu/h, without Louvers	CEER	8.4	9.3	9.3	9.6	9.6	10.0	10.4
	Annual Energy Use *(kWh/yr)*	1151	1141	1141	1118	1118	1084	1053
11,000-13,999 Btu/h, without Louvers	CEER	8.4	9.3	9.3	9.5	9.5	9.5	10.0
	Annual Energy Use *(kWh/yr)*	1379	1368	1368	1351	1351	1351	1298

As noted in section 10.2, DOE applied a growth rate to the SWEER to forecast energy efficiencies in the base and standards cases. Because per-unit annual energy consumption is a function of energy efficiency, values shown in Table 10.3.2 and Table 10.3.3 scale with the average SWEER throughout the forecast period.

Figure 10.3.1 shows the evolution of the UEC for room air conditioners less than 6,000 Btu/h, with Louvers (residential sector) in the base case, TSL4 and TSL6.

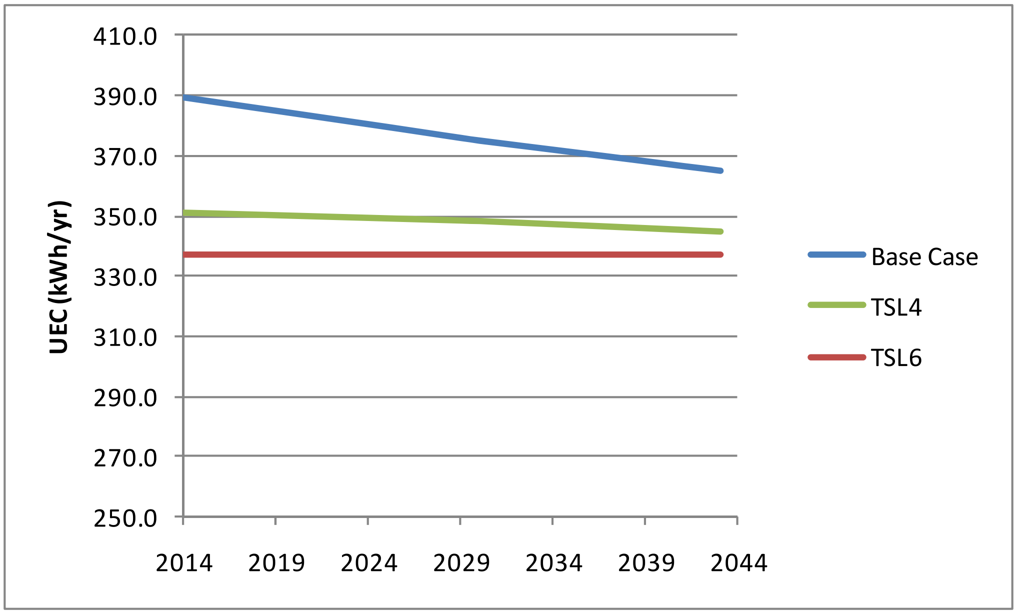

Figure 10.3.1 Room Air Conditioners, Without Reverse Cycle and With Louvers, Less than 6,000 Btu/h: Unit Energy Consumption Forecast for the Base Case and Selected Standard Cases

As shown on the figure, because the efficiency trend in the standard cases does not increase past the max tech level, the unit energy consumption stays constant and equal to the max tech level in TSL6.

When calculating energy consumption at each considered efficiency level for room air conditioner, DOE applied a rebound effect of 15 percent. When the rebound effect is incorporated, calculated energy savings are lower than if no rebound effect were considered

10.3.2.2 **Shipments and Equipment Stock**

The methodology for conducting and generating shipments forecasts for each considered product is described in detail in chapter 9. The product stock in a given year is the number of products shipped from earlier years that survive in the given year. The NIA models keep track of the number of units shipped each year. DOE assumes that the products have an increasing probability of retiring as they age. The survival function represents the probability of survival as a function of years since purchase. The sections in chapter 9 that concern with specific products present further details on the survival functions that DOE used in its analyses.

10.3.2.3 **National Annual Energy Consumption**

The national annual energy consumption (AEC) is the product of the annual energy consumption per unit and the number of units of each vintage. This method of calculation accounts for differences in unit energy consumption from year to year. In determining national annual energy consumption, DOE first calculated annual energy consumption at the site, then applied a conversion factor, described below, to calculate primary energy consumption.

10.3.2.4 Site-to-Source Energy Conversion Factors

In determining annual NES, DOE initially considered the annual energy consumption at a residence (for electricity, the energy in kWh consumed by the household). DOE then calculated primary (source) energy savings from site energy consumption by applying a conversion factor to account for losses associated with the generation, transmission, and distribution of electricity and natural gas. The site-to-source conversion factor is a multiplicative factor used for converting site energy consumption into primary or source energy consumption, expressed in quadrillion Btu (quads).

DOE used annual site-to-source conversion factors based on the version of the national energy modeling system (NEMS) that corresponds to the DOE Energy Information Administration's (EIA's) Annual Energy Outlook 2010 (*AEO2010*).[1] The factors are marginal values, which represent the response of the system to an incremental decrease in consumption. For electricity, the conversion factors change over time in response to projected changes in generation sources (*i.e.*, the types of power plant projected to provide electricity).

Figure 10.3.2 shows the site-to-source conversion factors for electricity between 2005 and 2035 for clothes dryers. NEMS outputs stop in 2035; DOE assumed that conversion factors remain constant at 2035 values throughout the rest of the forecast.

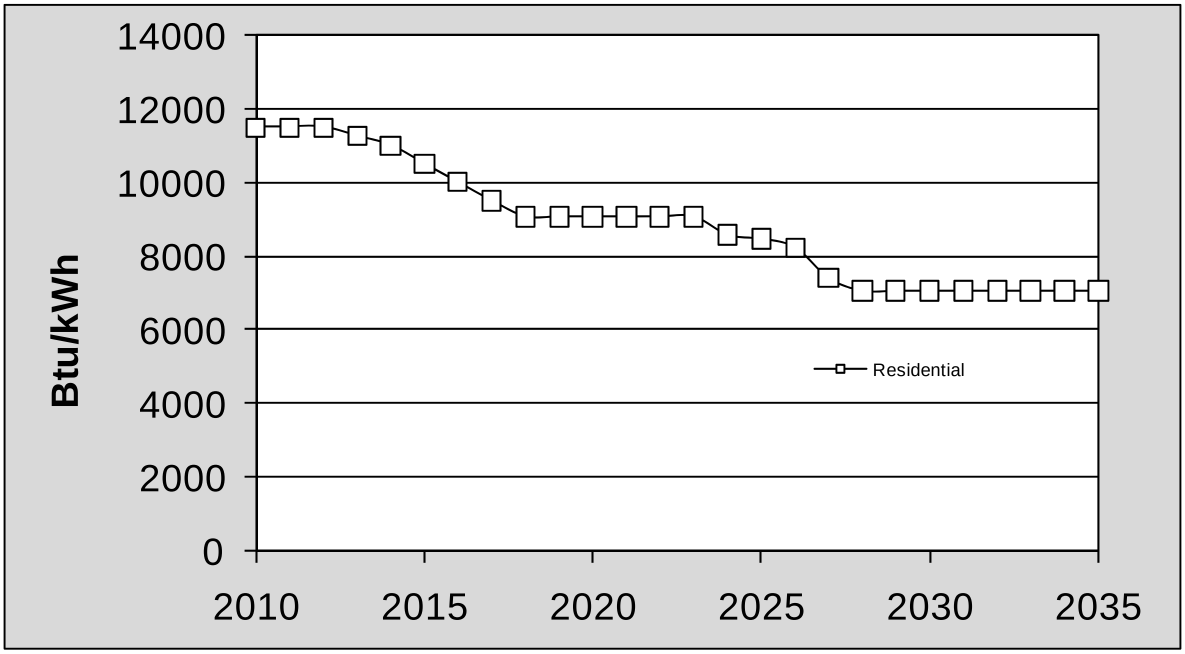

Figure 10.3.2 Site-to-Source Conversion Factors for Electricity – Clothes Dryers

Figure 10.3.3 shows the site-to-source conversion factors for electricity between 2005 and 2035 for room air conditioners, which were generated by NEMS based on the load shape for room air conditioners. NEMS outputs stop in 2030; DOE assumed that conversion factors remain constant at 2030 values throughout the rest of the forecast.

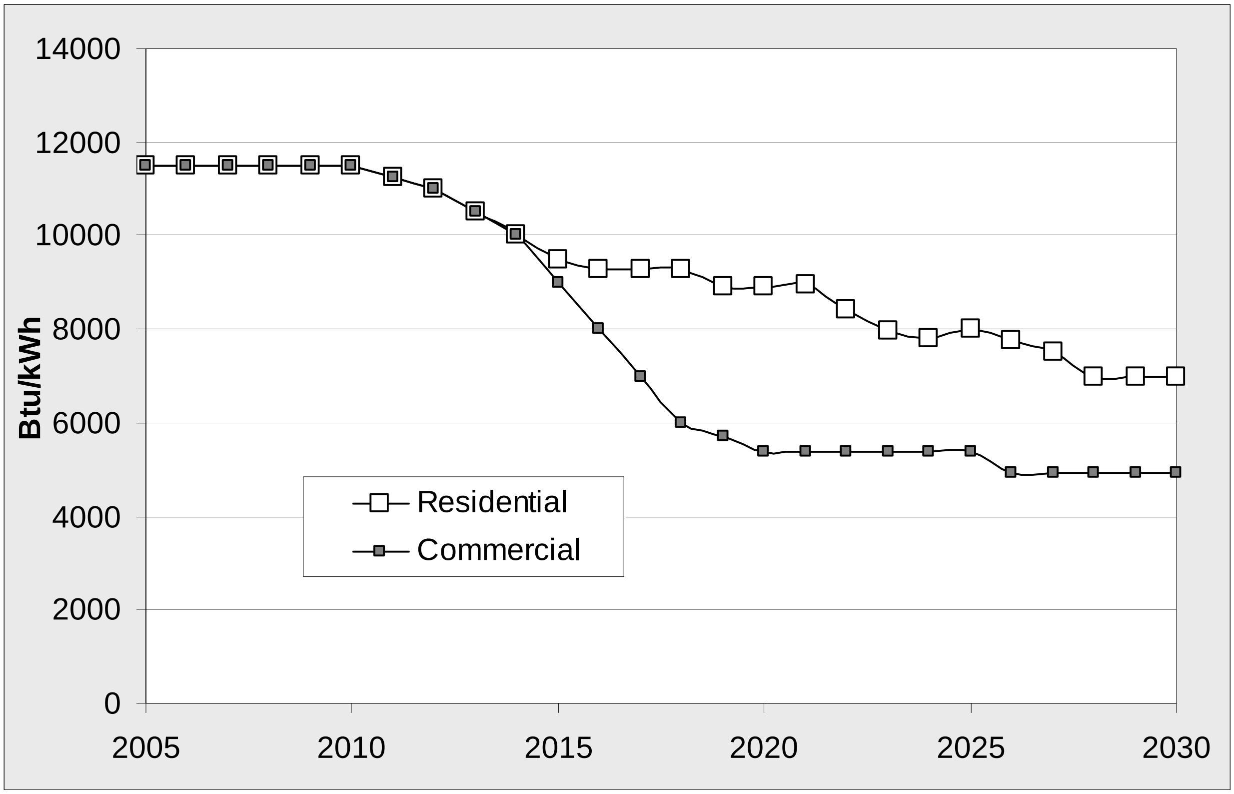

Figure 10.3.3 Site-to-Source Conversion Factors for Electricity – Room Air Conditioners

10.4 NET PRESENT VALUE

DOE calculated the net present value (NPV) of the increased product cost and reduced operating cost associated with the difference between the base case and each potential standards case for the considered products.

10.4.1 Definition of Net Present Value

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

$$NPV = \sum_{y} \left(S(y) - C(y) \right) \times DF(y)$$

Where:

S(y) = value of operating cost savings (including energy, repair, and maintenance costs) in year *y*,

C(y) = value of increased total installed costs (including products and installation), and
DF(y)= discount factor in each year.

DOE calculated the total annual savings in operating costs by multiplying the number or stock of a given product (by vintage) by its per-unit savings on operating costs (also by vintage). DOE calculated the total annual increases in installed costs by multiplying the number or stock of the given product (by vintage) by its per-unit total increase in installed costs (also by vintage). The calculation of the annual savings in operating costs and total annual increases in installed cost is represented by the following equations.

$$OCS(y) = \sum UOCS(y) \times AffStock(y)$$

$$TIC\ (y) = \sum UTIC(y) x S(y)$$

Where:

OCS = total annual savings in operating costs each year summed over vintages of the product stock considered, *AffStock(y)*,
TIC = total annual increase in installed cost each year summed over vintages of the product stock considered, *AffStock(y)*,
S(y) = stock of product (millions of units) of vintage *V* that survive in the year for which DOE calculated annual energy consumption,
UOCS(y) = annual savings in operating cost per unit in year *y*,
UTIC(y) = annual increase in total installed cost per unit in year *y*, and
y = year in forecast.

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

10.4.2 Inputs to Calculation of Net Present Value

The inputs to calculations of NPV are:

- total installed cost per unit,
- annual savings in operating cost per unit,
- total annual increases in installed cost,
- total annual operating costs,
- discount factor,
- present value of costs, and
- present value of savings.

The increase in total annual installed cost is equal to the annual change in the per-unit total installed cost (difference between base case and standards cases) multiplied by the shipments forecasted for the standards case. As when calculating the NES, DOE did not use base case shipments to calculate total annual installed costs for all of the products.

The total annual savings in operating costs are equal to the change in annual operating costs (difference between base case and standards case) per unit multiplied by the shipments forecasted in the standards case. The annual operating cost includes energy, repair, and maintenance costs, as described in chapter 8.

10.4.2.1 **Total Installed Cost per Unit**

The per-unit total installed cost of each considered product is described in chapter 8 as a function of product energy efficiency. Because the per-unit total annual installed cost is directly dependent on energy efficiency, DOE used the shipments-weighted energy efficiencies of the base and standards cases described in section 10.2, in combination with the total installed costs developed in chapter 8, to estimate the shipments-weighted average annual per-unit total installed cost under the base and standards cases.

In the preliminary analysis, DOE followed its past practice and assumed that the manufacturer costs and retail prices of products meeting various efficiency levels remain fixed, in real terms, after 2009 (the year for which the engineering analysis estimated costs) and throughout the period of the analysis. As discussed in chapter 8, examination of historical price data for certain appliances and equipment that have been subject to energy conservation standards indicates that the assumption of constant real prices and costs may, in many cases, over-estimate long-term appliance and equipment price trends.

For the direct final rule, DOE applied the learning rate described in chapter 8 to forecast the prices of clothes dryers and room air conditioners sold in each year in the forecast period (2014-2043). The price in each year is a function of the cumulative production of clothes dryers or room air conditioners forecast in each year. For each of the two products, DOE applied the same values to forecast prices for each product class at each considered efficiency level.

For household laundry equipment, the estimated learning rate (defined as the fractional reduction in price expected from each doubling of cumulative production) is 41.6 percent. With cumulative clothes dryer shipments through 2043 projected to reach 1,197 million (compared with 537 million in 2010), the price is projected to drop to 0.53 times the 2010 value.

For room air conditioners, the estimated learning is 38.9 percent. With cumulative shipments through 2043 projected to reach 503 million (compared with 225 million in 2010), the price is projected to drop to 0.57 times the 2010 value.

Clothes Dryers. Total installed cost for clothes dryers includes costs for both the product and the installation. DOE based average consumer product costs on average manufacturer costs multiplied by average overall markup values. Using the relationship between the efficiency of clothes dryers and total installed cost presented in chapter 8, DOE calculated the per-unit total installed cost for clothes dryers, based on the shipments-weighted energy efficiencies that correspond to the base case and each standards case. Table 10.4.1 shows the costs in 2014.

Table 10.4.1 Clothes Dryers: Shipments-Weighted Average Total Installed Costs in 2014

Product Class		**Base Case**	**Standard at Efficiency Level**					
			1	**2**	**3**	**4**	**5**	**6**
Vented Electric Standard	CEF *(lb/kWh)*	3.55	3.56	3.61	3.73	3.81	4.08	5.42
	Total Installed Cost (*2009$*)	455	455	456	467	528	583	879
Vented Electric Compact 120V	CEF *(lb/kWh)*	3.43	3.48	3.61	3.72	3.80	4.08	5.41
	Total Installed Cost (*2009$*)	470	471	471	501	560	627	875
Vented Electric Compact 240V	CEF *(lb/kWh)*	3.12	3.16	3.27	3.36	3.48	3.60	4.89
	Total Installed Cost (*2009$*)	470	471	471	501	560	627	875
Vented Gas	CEF *(lb/kWh)*	3.14	3.16	3.20	3.30	3.41	3.61	
	Total Installed Cost (*2009$*)	554	555	555	567	658	712	
Vent-less Electric Compact 240V	CEF *(lb/kWh)*	2.55	2.59	2.69	2.71	2.8	2.55	
	Total Installed Cost (*2009$*)	1093	1094	1094	1131	1176	1462	
Vent-less Electric Combination Washer/Dryer	CEF *(lb/kWh)*	2.08	2.35	2.38	2.46	2.56	2.08	
	Total Installed Cost (*2009$*)	1533	1535	1536	1537	1579	1981	

Figure 10.4.1 shows the forecast trend in installed cost for electric standard clothes dryers. The trend is similar for other product classes.

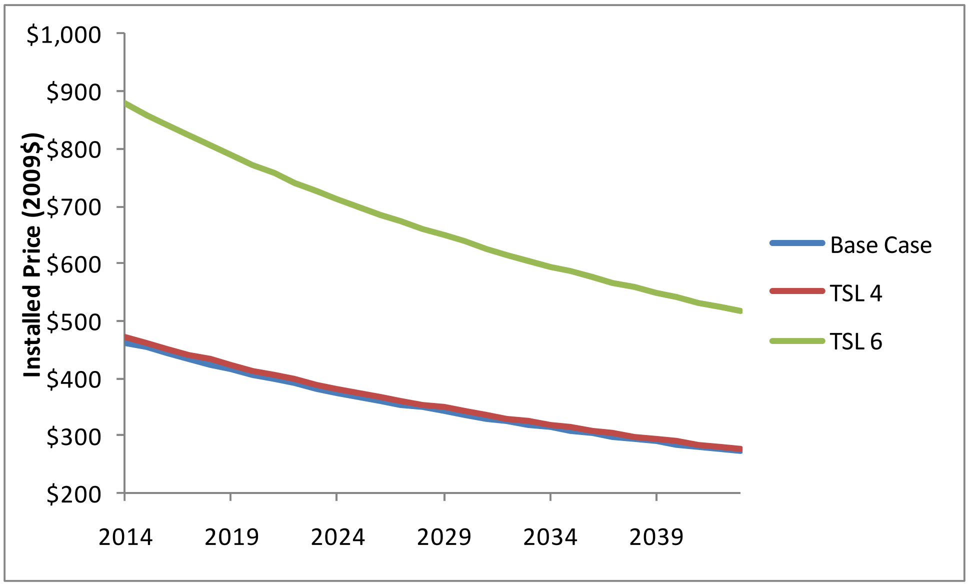

Figure 10.4.1 Electric Standard Clothes Dryers: Installed Cost Forecast for the Base Case and Selected Standard Cases

Room Air Conditioners. DOE based average room air conditioner consumer product costs on average manufacturer costs plus average overall markup values. Using the relationship between room air conditioner CEER and total installed cost presented in chapter 8, DOE derived the per-unit total installed cost based on the shipments-weighted energy efficiencies that correspond to the base case and each standards case for the representative room air conditioner product classes. Table 10.4.2 shows the costs in 2014.

Table 10.4.2 Room Air Conditioners: Shipments-Weighted Average Total Installed Cost in 2014

Product Class		Base Case	Trial Standard Level 1	2	3	4	5	6
Less than 6,000 Btu/h, with Louvers	CEER	9.5	10.1	10.6	10.1	11.1	11.1	11.7
	Total Installed Cost (2009$)	$359	$366	$375	$366	$393	$393	$473
8,000-13,999 Btu/h, with Louvers	CEER	9.7	10.6	10.6	11.1	11.1	11.4	11.7
	Total Installed Cost (2009$)	$488	$494	$494	$498	$498	$526	$605
20,000-24,999 Btu/h, with Louvers	CEER	8.5	9.4	9.4	8.5	9.4	8.5	10.2
	Total Installed Cost (2009$)	$893	$897	$897	$893	$897	$893	$1,163
25,000 Btu/h or more, with Louvers	CEER	8.5	8.5	8.5	8.5	8.5	8.5	8.5
	Total Installed Cost (2009$)	$1,051	$1,062	$1,062	$1,051	$1,056	$1,051	$1,317
8,000-10,999 Btu/h, without Louvers	CEER	8.4	9.3	9.3	9.6	9.6	10.0	10.4
	Total Installed Cost (2009$)	$498	$499	$499	$501	$501	$515	$615
11,000-13,999 Btu/h, without Louvers	CEER	8.4	9.3	9.3	9.5	9.5	9.5	10.0
	Total Installed Cost (2009$)	$594	$595	$595	$599	$599	$599	$708

Figure 10.4.2 shows the forecast trend in installed cost for units without reverse cycle and with louvers, less than 6,000 Btu/h. The trend is similar for other product classes.

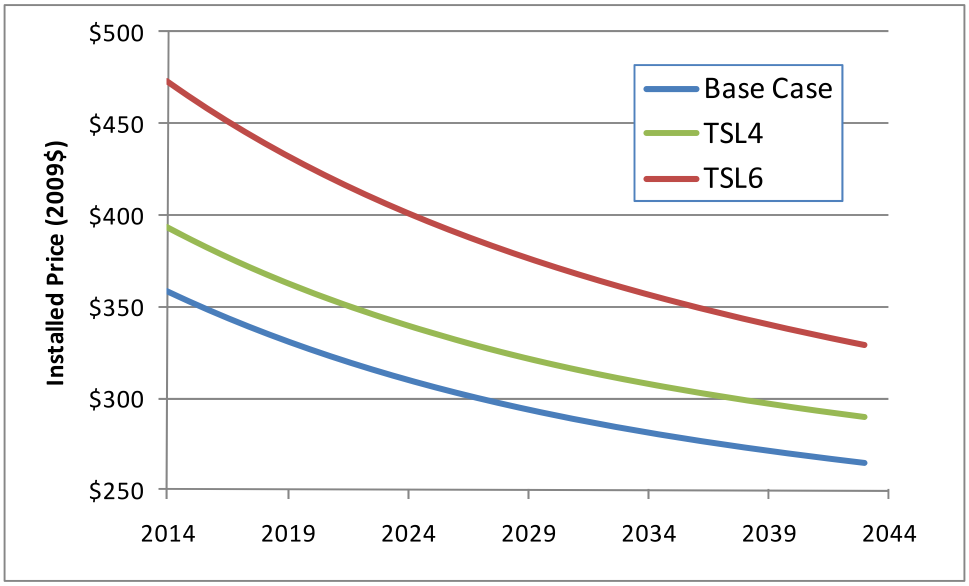

Figure 10.4.2 Room Air Conditioners, Without Reverse Cycle and With Louvers, Less than 6,000 Btu/h: Installed Cost Forecast for the Base Case and Selected Standard Cases

10.4.2.2 Annual Operating Cost Savings per Unit

Per-unit annual operating cost represents the annual cost for energy. DOE determined the savings in per-unit annual energy cost for each product by multiplying the savings in per-unit annual energy consumption by the appropriate energy price.

Estimates of per-unit annual energy consumption for the base case and each standards case were presented in section 10.3.2.1. DOE forecasted energy prices based on EIA's *AEO2010*. The energy prices and price trends are described in chapter 8.

10.4.2.3 Total Increases in Annual Installed Cost

The increase in total annual installed cost for any given standards case is the product of the total installed cost increase per unit 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. DOE used the following equation (also presented in section 10.4.1) to determine the increase in total annual installed cost for a given standards case.

$$TIC\ (y) = \sum UTIC(y) \times S(y)$$

10.4.2.4 Total Savings in Annual Operating Cost

The total savings in annual operating cost for any given standards case is the product of the annual operating cost savings per unit due to the standard and the number of units of each vintage. This approach accounts for differences in savings in annual operating cost from year to year. DOE used the following equation (also presented in section 10.4.1) to determine the total savings in annual operating cost for a given standards case.

$$OCS(y) = \sum UOCS(y) \times AffStock(y)$$

As discussed in chapter 8, the take-back in energy consumption associated with the rebound effect provides increased value to consumers (*e.g.*, a more comfortable indoor environment). The net impact is the sum of the change in the cost of owning the product (that is, national consumer expenditures for total installed and operating costs) and the increased value of the enhanced service from the product. DOE believes that, if the increased national value (to consumers) produced by the rebound effect could be monetized, it would be similar to the monetary value of the foregone energy savings. For this analysis, DOE estimated that this increased value to consumers is equivalent to the monetary value of the energy savings that would have occurred without the rebound effect. The national economic impacts on consumers with or without the rebound effect, as measured by the NPV analysis, therefore are the same.

10.4.2.5 **Discount Factors**

DOE multiplies monetary values in future years by a discount factor to determine present values. The discount factor (*DF*) is described by the equation:

$$DF = \frac{1}{(1+r)^{(y-y_P)}}$$

Where:

r = discount rate,
y = year of the monetary value, and
y_P = year in which the present value is being determined.

DOE used both a 3-percent and a 7-percent real discount rate when estimating national impacts. These discount rates were applied in accordance with the Office of Management and Budget (OMB)'s guidance to Federal agencies on developing regulatory analyses (OMB Circular A-4, September 17, 2003, and section E., "Identifying and Measuring Benefits and Costs," therein).

DOE defines the present year as 2011, which is when it expects the final rule for this rulemaking to be published.

10.4.2.6 **Present Value of Costs**

The present value of increased installed costs is the annual increase in installed cost for each year (*i.e.*, the difference between the standards case and base case), discounted to the present and summed over the period for which DOE is considering the installed products (from the effective date of energy conservation standards through 30 years later).

The increase in total installed cost refers to both product and installation costs associated with the higher energy efficiency of products purchased in the standards case compared to the base case. DOE calculated annual increases in installed cost as the difference in total cost of new products installed each year, multiplied by the shipments in the standards case.

10.4.2.7 **Present Value of Savings**

The present value of savings in operating cost is the annual savings in operating cost (*i.e.*, the difference between the base case and standards case), discounted to the present and summed over the period that begins with the effective date of standards and ends when the last installed unit is retired from service.

Savings represent decreases in operating cost (including costs for energy, repair, and maintenance) associated with the higher energy efficiency of products purchased in a standards case compared to the base case. Total annual savings in operating cost are the savings per unit multiplied by the number of units of each vintage that survive in a particular year. Because equipment consumes energy throughout its lifetime, the energy consumption for units installed in the past year includes energy consumed until the unit is retired from service.

10.5 NES AND NPV RESULTS

The NIA model provides estimates of the NES and NPV that would result from standards at various efficiency levels. 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 (www.eere.energy.gov/buildings/appliance_standards/). Details and instructions for using the spreadsheet are provided in appendix 9-A, User Instructions for Shipments and National Energy Savings Spreadsheet Model, in the section titled, "NES and NPV Input Summary."

Table 10.5.1 summarizes inputs to the NIA model.

Table 10.5.1 Inputs to National Energy Savings and Net Present Value

Input	Data Description
Shipments	Annual shipments from shipments model (see chapter 9).
Effective Date of Standard	2014.
Energy Efficiency in Base Case	Shipments-weighted unit energy consumption (UEC) determined for each year.
Energy Efficiency in Standards Cases	For clothes dryers, “Roll-up” scenario assumed for determining shipments-weighted UEC for each standards case For room air conditioners, “Roll-up + shift” scenario assumed for determining shipments-weighted UEC for each standards case (see section 10.2.).
Annual Energy Consumption per Unit	Annual weighted-average values are a function of shipments-weighted UEC.
Total Installed Cost per Unit	Annual weighted-average values are a function of efficiency level.
Energy Cost per Unit	Annual weighted-average values are a function of the annual UEC and energy prices (see chapter 8 for energy prices).
Repair Cost and Maintenance Cost per Unit	Annual values are a function of efficiency level (see chapter 8).
Escalation of Energy Prices	Based on EIA *AEO2010* forecasts (to 2035) and on extrapolation after 2035 (see chapter 8).
Energy Site-to-Source Conversion Factor	Conversion, which differs yearly, is generated by DOE/EIA’s NEMS program (a time-series conversion factor that includes electric generation, transmission, and distribution losses).
Discount Rate	3 percent and 7 percent real.
Present Year	2011.

10.5.2 National Energy Savings Results by Efficiency Level

The following section provides results of calculating NES for standards at each of the efficiency levels analyzed for the considered products. NES results, which are cumulative to 2044, are shown as primary energy savings. Because DOE based the inputs to the NIA model on weighted-average values, results are discrete point values, rather than a distribution of values as produced by the LCC and PBP analyses. DOE reports both undiscounted and discounted values of energy savings. Discounted energy savings represent a policy perspective where energy savings farther in the future are less significant than energy savings closer to the present.

10.5.2.1 **Clothes Dryers**

Table 10.5.2 through Table 10.5.4 show the results of calculating NES for the CSLs analyzed for clothes dryers.

Table 10.5.2 Clothes Dryers: Cumulative National Energy Savings in Quads

Product Class	Candidate Standard Level					
	1	2	3	4	5	6
Vented Electric Standard	0.001	0.038	0.347	0.564	1.268	2.923
Vented Electric Compact 120V	0.000	0.000	0.001	0.001	0.002	0.003
Vented Electric Compact 240V	0.000	0.001	0.003	0.004	0.006	0.016
Vented Gas	0.002	0.009	0.038	0.079	0.164	
Vent-less Electric Compact 240V	0.001	0.002	0.002	0.004	0.016	
Vent-less Electric Combination Washer/Dryer	0.007	0.008	0.009	0.011	0.023	

Table 10.5.3 Clothes Dryers: Cumulative National Energy Savings in Quads, Discounted at 3 Percent

Product Class	Candidate Standard Level					
	1	2	3	4	5	6
Vented Electric Standard	0.000	0.021	0.190	0.309	0.696	1.605
Vented Electric Compact 120V	0.000	0.000	0.000	0.001	0.001	0.002
Vented Electric Compact 240V	0.000	0.001	0.001	0.002	0.003	0.009
Vented Gas	0.001	0.005	0.020	0.043	0.089	
Vent-less Electric Compact 240V	0.000	0.001	0.001	0.002	0.009	
Vent-less Electric Combination Washer/Dryer	0.004	0.004	0.005	0.006	0.013	

Table 10.5.4 Clothes Dryers: Cumulative National Energy Savings in Quads, Discounted at 7 Percent

Product Class	Candidate Standard Level					
	1	2	3	4	5	6
Vented Electric Standard	0.000	0.011	0.095	0.155	0.349	0.805
Vented Electric Compact 120V	0.000	0.000	0.000	0.000	0.000	0.001
Vented Electric Compact 240V	0.000	0.000	0.001	0.001	0.002	0.004
Vented Gas	0.000	0.003	0.010	0.021	0.043	
Vent-less Electric Compact 240V	0.000	0.001	0.001	0.001	0.004	
Vent-less Electric Combination Washer/Dryer	0.002	0.002	0.002	0.003	0.006	

10.5.2.2

10.5.2.3 Room Air Conditioners

Table 10.5.5 through Table 10.5.7 show the NES results for the CSLs analyzed for each room air conditioner product class group. See section 10.1 for description of the product classes contained in each group.

Table 10.5.5 Room Air Conditioners: Cumulative National Energy Savings in Quads

Groups	Candidate Standard Level				
	1	2	3	4	5
Group 1 - based on Less than 6,000 Btu/h, with Louvers	0.05	0.08	0.13	0.15	0.17
Group 2 - based on 8,000-13,999 Btu/h, with Louvers	0.05	0.14	0.23	0.26	0.29
Group 3 - based on 20,000-24,999 Btu/h, with Louvers	0.00	0.11	0.18	0.21	
Group 4 - based on 25,000 Btu/h or more, with Louvers	0.00	0.08	0.13		
Group 5 - based on 8,000-10,999 Btu/h, without Louvers	0.00	0.09	0.15	0.17	
Group 6 - based on 11,000-13,999 Btu/h, without Louvers	0.00	0.09	0.15	0.17	

Table 10.5.6 Room Air Conditioners: Cumulative National Energy Savings in Quads, Discounted at 3 Percent

Groups	Candidate Standard Level				
	1	2	3	4	5
Group 1 - based on Less than 6,000 Btu/h, with Louvers	0.028	0.051	0.080	0.093	0.103
Group 2 - based on 8,000-13,999 Btu/h, with Louvers	0.032	0.086	0.137	0.159	0.176
Group 3 - based on 20,000-24,999 Btu/h, with Louvers	0.001	0.069	0.110	0.128	
Group 4 - based on 25,000 Btu/h or more, with Louvers	0.000	0.051	0.080		
Group 5 - based on 8,000-10,999 Btu/h, without Louvers	0.003	0.057	0.090	0.105	
Group 6 - based on 11,000-13,999 Btu/h, without Louvers	0.001	0.057	0.090	0.105	

Table 10.5.7 Room Air Conditioners: Cumulative National Energy Savings in Quads, Discounted at 7 Percent

Groups	Candidate Standard Level				
	1	**2**	**3**	**4**	**5**
Group 1 - based on Less than 6,000 Btu/h, with Louvers	0.016	0.029	0.045	0.053	0.058
Group 2 - based on 8,000-13,999 Btu/h, with Louvers	0.018	0.049	0.077	0.090	0.099
Group 3 - based on 20,000-24,999 Btu/h, with Louvers	0.000	0.039	0.062	0.072	
Group 4 - based on 25,000 Btu/h or more, with Louvers	0.000	0.029	0.045		
Group 5 - based on 8,000-10,999 Btu/h, without Louvers	0.002	0.032	0.051	0.059	
Group 6 - based on 11,000-13,999 Btu/h, without Louvers	0.001	0.032	0.051	0.059	

10.5.3 Annual Costs and Savings

Figure 10.5.1 illustrates the basic inputs to calculations of the NPV for the example of the non-discounted annual increases in installed cost and annual savings in operating cost for room air conditioner product class 3 under CSL 1. The figure also shows net savings, which is the difference between the savings and costs for each year. The annual product cost is the sum of the increase in the total installed cost for products purchased each year during the forecast period. The annual savings in operating cost is the savings for products operating in each year. The NPV is the difference between the cumulative annual discounted savings and the cumulative annual discounted costs. Figures similar to the one presented below could be created from analysis data for each of the considered products' standard cases.

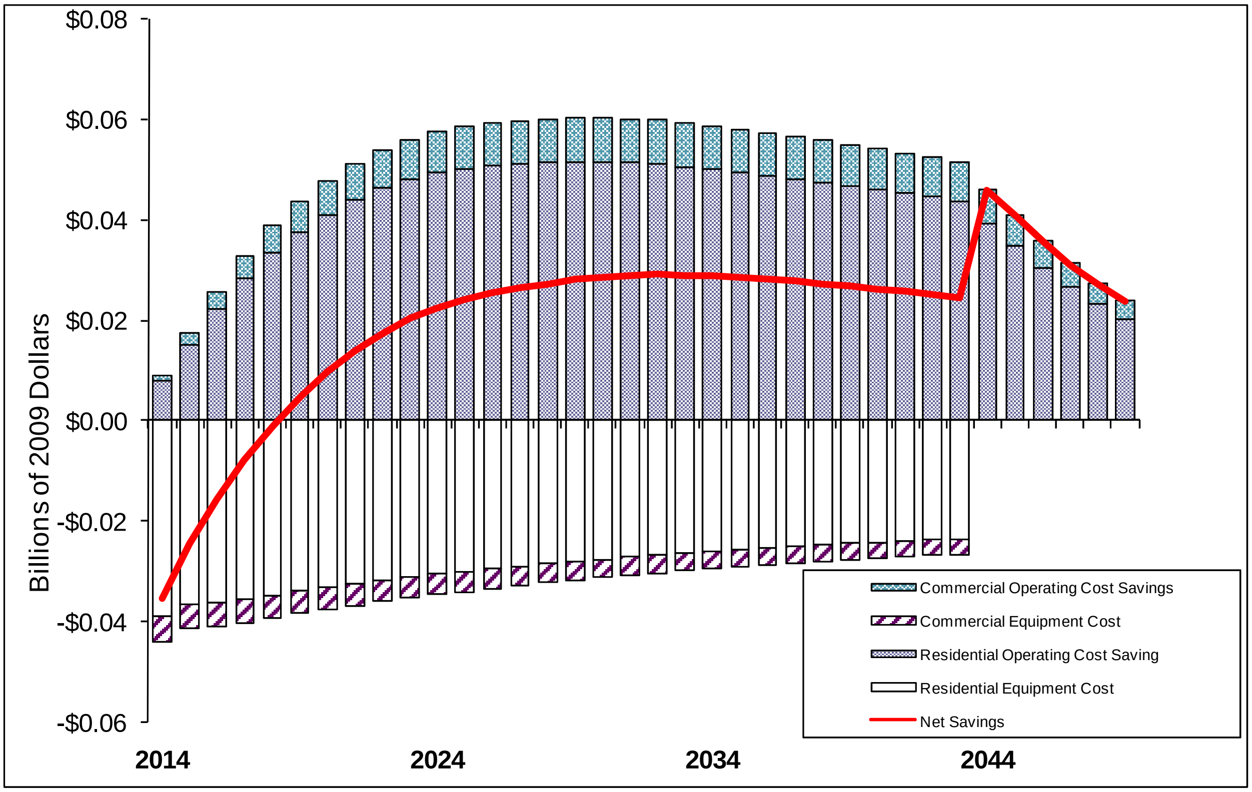

Figure 10.5.2 Non-Discounted Changes in Annual Installed Cost and Operating Cost for Room Air Conditioner Product Class 3 at CSL 1

10.5.4 Consumer Net Present Value Results by Efficiency Level

This section provides results of calculating net present value (NPV) of consumer benefit for standards at each of the considered efficiency levels for the considered refrigeration products. Results, which are cumulative, are shown as the discounted value of the net savings in dollar terms. DOE based the inputs to the NIA model on weighted-average values, yielding results that are discrete point values, rather than a distribution of values as in the life-cycle cost and payback period analysis.

The present value of increased total installed cost is the total annual increase in installed cost (the difference between the standards case and base case), discounted to the present and summed throughout the period for which DOE evaluated the impact of standards.

Savings are decreases in operating cost associated with the higher energy efficiency of products purchased in the standards case compared to the base case. Total savings in operating cost are the savings per unit multiplied by the number of units of each vintage (*i.e.*, year of manufacture) that survive in a particular year. The operating cost includes expenditures until the last unit purchased during the forecast period is retired from service. .

10.5.4.1 Clothes Dryers

Table 10.5.8 and Table 10.5.9 show the consumer NPV results for the CSLs analyzed for each clothes dryer product class. A negative NPV indicates that the costs of a standard at a given efficiency level exceed the savings.

Table 10.5.8 Clothes Dryers: Cumulative Consumer Net Present Value, Discounted at 3 Percent

Product Class	Candidate Standard Level					
	1	2	3	4	5	6
	Billion 2009$					
Vented Electric Standard	0.01	0.40	2.78	-0.44	2.13	0.56
Vented Electric Compact 120V	0.00	0.01	0.00	-0.01	-0.01	-0.03
Vented Electric Compact 240V	0.00	0.01	0.00	-0.03	-0.07	-0.12
Vented Gas	0.01	0.09	0.21	-1.52	-1.91	
Vent-less Electric Compact 240V	0.01	0.02	0.00	-0.01	-0.04	
Vent-less Electric Combination Washer/Dryer	0.07	0.08	0.09	0.09	0.00	

Table 10.5.9 Clothes Dryers: Cumulative Consumer Net Present Value, Discounted at 7 Percent

Product Class	Candidate Standard Level					
	1	2	3	4	5	6
	Billion 2009$					
Vented Electric Standard	0.00	0.17	1.02	-1.30	-1.08	-5.02
Vented Electric Compact 120V	0.00	0.00	0.00	-0.01	-0.01	-0.02
Vented Electric Compact 240V	0.00	0.01	0.00	-0.02	-0.05	-0.10
Vented Gas	0.01	0.04	0.05	-1.07	-1.47	
Vent-less Electric Compact 240V	0.00	0.01	0.00	-0.01	-0.05	
Vent-less Electric Combination Washer/Dryer	0.03	0.03	0.04	0.03	-0.04	

10.5.4.2 Room Air Conditioners

Table 10.5.10 through Table 10.5.11 show the results of calculating the NPV for the CSLs analyzed for each room air conditioner product class group. See section 10.1 for description of the product classes contained in each group. A negative NPV indicates that the costs of a standard at a given efficiency level exceed the savings.

Table 10.5.10 Room Air Conditioners: Cumulative Consumer Net Present Value, Discounted at 3 Percent

Groups	Candidate Standard Level				
	1	**2**	**3**	**4**	**5**
	Billion 2009$				
Group 1 - based on Less than 6,000 Btu/h, with Louvers	0.28	0.36	0.25	-0.14	-1.84
Group 2 - based on 8,000-13,999 Btu/h, with Louvers	0.43	0.62	0.42	-0.25	-3.14
Group 3 - based on 20,000-24,999 Btu/h, with Louvers	0.00	0.50	0.34	-0.20	
Group 4 - based on 25,000 Btu/h or more, with Louvers	0.00	0.36	0.25		
Group 5 - based on 8,000-10,999 Btu/h, without Louvers	0.04	0.41	0.28	-0.16	
Group 6 - based on 11,000-13,999 Btu/h, without Louvers	0.01	0.41	0.28	-0.16	

Table 10.5.11 Room Air Conditioners: Cumulative Consumer Net Present Value, Discounted at 7 Percent

Groups	Candidate Standard Level				
	1	**2**	**3**	**4**	**5**
	Billion 2009$				
Group 1 - based on Less than 6,000 Btu/h, with Louvers	0.12	0.12	-0.02	-0.29	-1.39
Group 2 - based on 8,000-13,999 Btu/h, with Louvers	0.21	0.21	-0.03	-0.49	-2.37
Group 3 - based on 20,000-24,999 Btu/h, with Louvers	0.00	0.16	-0.03	-0.39	
Group 4 - based on 25,000 Btu/h or more, with Louvers	0.00	0.12	-0.02		
Group 5 - based on 8,000-10,999 Btu/h, without Louvers	0.02	0.13	-0.02	-0.32	
Group 6 - based on 11,000-13,999 Btu/h, without Louvers	0.01	0.14	-0.02	-0.32	

10.6 NES AND NPV RESULTS BY TRIAL STANDARD LEVEL

10.6.1 Trial Standard Levels

In considering amended standards for the direct final rule, DOE created trial standard levels (TSLs) that combine specific efficiency levels across product classes. DOE analyzed the benefits and burdens of a number of TSLs for the products considered in this rulemaking. A description of each TSL DOE analyzed is provided below. DOE attempted to limit the number of

TSLs considered by excluding efficiency levels that do not exhibit significantly different economic and/or engineering characteristics from the efficiency levels already selected as a TSL.

Table 10.6.1 shows the TSLs DOE analyzed for clothes dryers. TSL 1 consists of the efficiency levels with the largest market share with a positive NPV (at a 3% discount rate). TSL 2 consists of the efficiency levels with the highest NPV (at a 3% discount rate). TSL 3 consists of the efficiency levels with the highest energy savings and a positive NPV (at a 3% discount rate). TSL 2 consists of the efficiency levels that reflect 5% efficiency increase above the baseline. TSL 5 consists of non heat pump design efficiency levels with the highest energy savings. TSL 6 consists of the max-tech efficiency levels.

Table 10.6.1 Trial Standard Levels for Clothes Dryers

Product Class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
	CEF					
Vented Electric Standard	3.56	3.61	3.73	3.73	4.08	5.42
Vented Electric Compact 120V	3.43	3.61	3.61	3.61	4.08	5.41
Vented Electric Compact 240V	3.12	3.27	3.27	3.27	3.60	4.89
Vented Gas	3.16	3.20	3.20	3.30	3.61	3.61
Vent-less Electric Compact 240V	2.55	2.69	2.69	2.55	2.80	4.03
Vent-less Electric Combination Washer/Dryer	2.08	2.56	2.56	2.08	2.56	3.69

Table 10.6.2 shows the TSLs DOE analyzed for room air conditioners. TSL 1 consists of the efficiency levels with the largest market share with a positive NPV (at a 3% discount rate). TSL 2 consists of the ENERGY STAR levels for each product class. TSL 3 consists of the efficiency levels with the highest NPV (at a 3% discount rate). TSL 4 consists of the efficiency levels included in the Consensus Agreement presented to DOE by several interested parties. TSL 5 consists of the efficiency levels with the highest energy savings and a positive NPV (at a 7% discount rate). TSL 6 consists of the max-tech efficiency levels.

Table 10.6.2 Trial Standard Levels for Room Air Conditioners

Product Class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
	CEER					
Group 1 – includes PC 1	10.10	10.60	10.10	11.10	11.10	11.67
Group 2 – includes PC 2, 3, 4, 11	10.70	10.70	10.90	10.90	11.50	11.96
Group 3 – includes PC 5a, 9, 13	9.40	9.40	8.47	9.40	8.47	10.15
Group 4 – includes PC 5b, 10	9.40	9.40	8.48	9.00	8.48	9.80
Group 5 – includes PC 6, 7, 8a, 12	9.30	9.30	9.60	9.60	10.00	10.35
Group 6 – includes PC 8b, 14, 15, 16	9.30	9.30	9.50	9.50	9.50	10.02

10.6.2 National Energy Savings Results by Trial Standard Level

10.6.2.1 Clothes Dryers

Table 10.6.3 through Table 10.6.5 show the cumulative national energy savings in 2014-2043 associated with standards at the considered TSLs for clothes dryers.

Table 10.6.3 Clothes Dryers: Cumulative National Energy Savings in Quads

Product Class	Trial Standard Level					
	1	**2**	**3**	**4**	**5**	**6**
Vented Electric Standard	0.001	0.038	0.347	0.347	1.268	2.923
Vented Electric Compact 120V	0.000	0.000	0.000	0.000	0.002	0.003
Vented Electric Compact 240V	0.000	0.001	0.001	0.001	0.006	0.016
Vented Gas	0.002	0.009	0.009	0.038	0.164	0.164
Vent-less Electric Compact 240V	0.000	0.002	0.002	0.000	0.004	0.016
Vent-less Electric Combination Washer/Dryer	0.000	0.011	0.011	0.000	0.011	0.023
Total	0.002	0.062	0.370	0.386	1.455	3.145

Table 10.6.4 Clothes Dryers: Cumulative National Energy Savings in Quads, Discounted at 3 Percent

Product Class	Trial Standard Level					
	1	**2**	**3**	**4**	**5**	**6**
Vented Electric Standard	0.000	0.021	0.190	0.190	0.696	1.605
Vented Electric Compact 120V	0.000	0.000	0.000	0.000	0.001	0.002
Vented Electric Compact 240V	0.000	0.001	0.001	0.001	0.003	0.009
Vented Gas	0.001	0.005	0.005	0.020	0.089	0.089
Vent-less Electric Compact 240V	0.000	0.001	0.001	0.000	0.002	0.009
Vent-less Electric Combination Washer/Dryer	0.000	0.006	0.006	0.000	0.006	0.013
Total	0.001	0.034	0.203	0.212	0.797	1.725

Table 10.6.5 Clothes Dryers: Cumulative National Energy Savings in Quads, Discounted at 7 Percent

Product Class	Trial Standard Level					
	1	**2**	**3**	**4**	**5**	**6**
Vented Electric Standard	0.000	0.011	0.095	0.095	0.349	0.805
Vented Electric Compact 120V	0.000	0.000	0.000	0.000	0.000	0.001
Vented Electric Compact 240V	0.000	0.000	0.000	0.000	0.002	0.004
Vented Gas	0.000	0.003	0.003	0.010	0.043	0.043
Vent-less Electric Compact 240V	0.000	0.001	0.001	0.000	0.001	0.004
Vent-less Electric Combination Washer/Dryer	0.000	0.003	0.003	0.000	0.003	0.006
Total	0.001	0.017	0.102	0.106	0.399	0.864

10.6.2.2

10.6.2.3 **Room Air Conditioners**

Table 10.6.6 through Table 10.6.8 show the cumulative national energy savings in 2014-2043 associated with standards at the considered TSLs for room air conditioners.

Table 10.6.6 Room Air Conditioners: Cumulative National Energy Savings in Quads

Product Class	Trial Standard Level					
	1	**2**	**3**	**4**	**5**	**6**
Group 1 – includes PC 1	0.05	0.08	0.05	0.13	0.13	0.17
Group 2 – includes PC 2, 3, 4, 11	0.05	0.14	0.08	0.23	0.23	0.29
Group 3 – includes PC 5a, 9, 13	0.00	0.11	0.06	0.18	0.18	0.23
Group 4 – includes PC 5b, 10	0.00	0.08	0.05	0.13	0.13	0.17
Group 5 – includes PC 6, 7, 8a, 12	0.00	0.09	0.05	0.15	0.15	0.19
Group 6 – includes PC 8b, 14, 15, 16	0.00	0.09	0.05	0.15	0.15	0.19
Total	0.10	0.61	0.34	0.97	0.97	1.25

Table 10.6.7 Room Air Conditioners: Cumulative National Energy Savings in Quads, Discounted at 3 Percent

Product Class	Trial Standard Level					
	1	**2**	**3**	**4**	**5**	**6**
Group 1 – includes PC 1	0.03	0.05	0.03	0.08	0.08	0.10
Group 2 – includes PC 2, 3, 4, 11	0.03	0.09	0.05	0.14	0.14	0.18
Group 3 – includes PC 5a, 9, 13	0.00	0.07	0.04	0.11	0.11	0.14
Group 4 – includes PC 5b, 10	0.00	0.05	0.03	0.08	0.08	0.10
Group 5 – includes PC 6, 7, 8a, 12	0.00	0.06	0.03	0.09	0.09	0.12
Group 6 – includes PC 8b, 14, 15, 16	0.00	0.06	0.03	0.09	0.09	0.12
Total	0.06	0.37	0.21	0.59	0.59	0.76

Table 10.6.8 Room Air Conditioners: Cumulative National Energy Savings in Quads, Discounted at 7 Percent

Product Class	Trial Standard Level					
	1	2	3	4	5	6
Group 1 – includes PC 1	0.02	0.03	0.02	0.05	0.05	0.06
Group 2 – includes PC 2, 3, 4, 11	0.02	0.05	0.03	0.08	0.08	0.10
Group 3 – includes PC 5a, 9, 13	0.00	0.04	0.02	0.06	0.06	0.08
Group 4 – includes PC 5b, 10	0.00	0.03	0.02	0.05	0.05	0.06
Group 5 – includes PC 6, 7, 8a, 12	0.00	0.03	0.02	0.05	0.05	0.06
Group 6 – includes PC 8b, 14, 15, 16	0.00	0.03	0.02	0.05	0.05	0.07
Total	0.04	0.21	0.12	0.33	0.33	0.42

10.6.3 Consumer Net Present Value Results by Trial Standard Level

10.6.3.1 Clothes Dryers

Table 10.6.9 and Table 10.6.10 show the consumer NPV results associated with standards at the considered TSLs for each clothes dryer product class. A negative NPV indicates that the costs of a standard at a given efficiency level exceed the savings.

Table 10.6.9 Clothes Dryers: Cumulative Consumer Net Present Value, Discounted at 3 Percent

Product Class	Trial Standard Level					
	1	2	3	4	5	6
	Billion 2009$					
Vented Electric Standard	0.01	0.40	2.78	2.78	2.13	0.56
Vented Electric Compact 120V	0.00	0.01	0.01	0.01	-0.01	-0.03
Vented Electric Compact 240V	0.00	0.01	0.01	0.01	-0.07	-0.12
Vented Gas	0.01	0.09	0.09	0.21	-1.91	-1.91
Vent-less Electric Compact 240V	0.00	0.02	0.02	0.00	-0.01	-0.04
Vent-less Electric Combination Washer/Dryer	0.00	0.09	0.09	0.00	0.09	0.00
Total	0.02	0.62	3.00	3.01	0.22	-1.53

Table 10.6.10 Clothes Dryers: Cumulative Consumer Net Present Value, Discounted at 7 Percent

Product Class	Trial Standard Level					
	1	2	3	4	5	6
	Billion 2009$					
Vented Electric Standard	0.00	0.17	1.02	1.02	-1.08	-5.02
Vented Electric Compact 120V	0.00	0.00	0.00	0.00	-0.01	-0.02
Vented Electric Compact 240V	0.00	0.01	0.01	0.01	-0.05	-0.10
Vented Gas	0.01	0.04	0.04	0.05	-1.47	-1.47
Vent-less Electric Compact 240V	0.00	0.01	0.01	0.00	-0.01	-0.05
Vent-less Electric Combination Washer/Dryer	0.00	0.03	0.03	0.00	0.03	-0.04
Total	0.01	0.25	1.10	1.08	-2.60	-6.72

10.6.3.2 **Room Air Conditioners**

Table 10.6.11 and Table 10.6.12 show the consumer NPV results associated with standards at the considered TSLs for each room air conditioner product class group. A negative NPV indicates that the costs of a standard at a given efficiency level exceed the savings.

Table 10.6.11 Room Air Conditioners: Cumulative Consumer Net Present Value, Discounted at 3 Percent

Product Class	Trial Standard Level					
	1	2	3	4	5	6
	Billion 2009$					
Group 1 – includes PC 1	0.28	0.36	0.28	0.25	0.25	-1.84
Group 2 – includes PC 2, 3, 4, 11	0.43	0.62	0.47	0.42	0.42	-3.14
Group 3 – includes PC 5a, 9, 13	0.00	0.50	0.38	0.34	0.34	-2.52
Group 4 – includes PC 5b, 10	0.00	0.36	0.28	0.25	0.25	-1.84
Group 5 – includes PC 6, 7, 8a, 12	0.04	0.41	0.31	0.28	0.28	-2.06
Group 6 – includes PC 8b, 14, 15, 16	0.01	0.41	0.31	0.28	0.28	-2.07
Total	0.75	2.66	2.02	1.80	1.80	-13.47

Table 10.6.12 Room Air Conditioners: Cumulative Consumer Net Present Value, Discounted at 7 Percent

Product Class	Trial Standard Level					
	1	2	3	4	5	6
	Billion 2009$					
Group 1 – includes PC 1	0.12	0.12	0.12	-0.02	-0.02	-1.39
Group 2 – includes PC 2, 3, 4, 11	0.21	0.21	0.20	-0.03	-0.03	-2.37
Group 3 – includes PC 5a, 9, 13	0.00	0.16	0.16	-0.03	-0.03	-1.90
Group 4 – includes PC 5b, 10	0.00	0.12	0.12	-0.02	-0.02	-1.39
Group 5 – includes PC 6, 7, 8a, 12	0.02	0.13	0.13	-0.02	-0.02	-1.56
Group 6 – includes PC 8b, 14, 15, 16	0.01	0.14	0.13	-0.02	-0.02	-1.56
Total	0.35	0.88	0.86	-0.15	-0.15	-10.15

REFERENCES

1. Energy Information Administration, *Annual Energy Outlook 2010 with Projections to 2035*, 2010. Washington, DC. Report No. DOE/EIA-0383(2010). <http://www.eia.doe.gov/oiaf/aeo/>

CHAPTER 11. LIFE-CYCLE COST SUBGROUP ANALYSIS

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CHAPTER 11. LIFE-CYCLE COST SUBGROUP ANALYSIS

11.1 INTRODUCTION

Chapter 8 describes the life-cycle cost (LCC) and payback period (PBP) analyses that examine impacts of energy conservation standards on the U.S. population. In analyzing the potential impact of new or amended standards on residential consumers, DOE further evaluates the impact on identifiable groups of consumers (i.e., subgroups) that may be disproportionately affected by a national standard level. The LCC subgroup analysis evaluates impacts by analyzing the LCC and PBPs for subgroups of residential consumers.

For both clothes dryers and room air conditioners, DOE identified two consumer subgroups that warranted further study: (a) households composed of people 65 years of age or older (senior-only); and (b) households at or below the poverty line (low-income).

DOE determined the impact on consumer subgroups for clothes dryers and room air conditioners using the LCC Spreadsheet Model, which allows for the examination of particular consumer subgroups. DOE has the ability to use the LCC Spreadsheet Model to analyze the LCC for any subgroup by sampling only the data that apply to that subgroup (Chapter 8 explains in detail the inputs to the model used in determining LCC and PBPs). As described in section 11.3, the energy use and energy price characteristics of the two subgroups (senior-only and low-income) are different than that for the general population.

This chapter describes the subgroup identification in further detail and gives the results of the LCC and PBP analyses for the considered subgroups.

11.2 SUBGROUPS DEFINITION

11.2.1 Senior-Only Households

Senior-only households have occupants who are all at least 65 years of age. Based on the DOE Energy Information Administration (EIA)'s Residential Energy Consumption Survey of 2005 (RECS), senior-only households comprise 17 percent of the country's households.[1]

11.2.2 Low-Income Households

As defined in the RECS survey, low-income households are considered to be those at or below the "poverty line." The "poverty line" varies with household size, head of household age, and family income. Table 11.2.1 summarizes the income level baselines for selecting low-income households from the RECS sample. The RECS survey classifies 15 percent of the country's households as low-income.

Table 11.2.1 RECS 2005 Definitions of Low-Income Households by Yearly Income

	Average Income in $		
Household Size	**48 Contiguous States and D.C.**	**Alaska**	**Hawaii**
1	9,570	11,950	11,010
2	12,830	16,030	14,760
3	16,090	20,100	18,510
4	19,350	24,190	22,260
5	22,610	28,270	26,010
6	25,870	32,350	29,760
7	29,130	36,430	33,510
8	32,390	40,510	37,260
9	35,650	44,590	41,010
10	38,910	48,670	44,760
11	42,170	52,750	48,510
12	45,430	56,830	52,260
13	48,690	60,910	56,010
14	51,950	64,990	59,760
15	55,210	69,070	63,510

11.3 INPUTS TO THE LIFE-CYCLE COST AND PAYBACK PERIOD SUBGROUP ANALYSIS

DOE performed the consumer subgroup analysis by analyzing the LCC and PBP of senior-only, low-income, multi-family, and manufactured households with the spreadsheet models used for the LCC and PBP analysis.

Tables 11.3.1 and 11.3.2 summarize the household populations for clothes dryers and room air conditioners, while Tables 11.3.3 and 11.3.4 summarize the weighted-average annual energy use for the households analyzed in the consumer subgroup analyses. These values are compared against the weighted-average values for the national sample.

Table 11.3.1 Household Population Data for Clothes Dryers

	Electric Vented		**Gas**		**Electric Ventless**	
	Count	Weight	Count	Weight	Count	Weight
National	2655	66,957,265	756	20,262,441	570	14,370,518
Senior-Only	423	11,464,456	110	3,127,121	71	2,050,730
Senior-Only %	15.9%	17.1%	14.6%	15.4%	2.7%	14.3%
Low-Income	360	7,479,458	56	1,211,394	142	3,132,148
Low-Income %	13.6%	11.2%	7.4%	6.0%	5.3%	21.8%

Table 11.3.2 Household Population Data for Room Air Conditioners

	<6,000 Btu/h		8,000-13,999 Btu/h		>20,000 Btu/h	
	Count	Weight	Count	Weight	Count	Weight
National	266	9,187,800	890	38,903,667	66	2,484,502
Senior-Only	60	2,234,642	129	5,907,794	12	345,448
Senior-Only %	22.6%	24.3%	14.5%	15.2%	18.2%	13.9%
Low-Income	64	1,592,070	242	9,749,578	11	211,186
Low-Income %	24.1%	17.3%	27.2%	25.1%	16.7%	8.5%

Table 11.3.3 Weighted-Average Annual Energy Use for Baseline Clothes Dryers

kWh/year	**All Households**	**Senior -Only**	**Low-Income**
Electric Standard	718	467	674
Compact 120V	353	234	368
Compact 240V	317	211	330
Gas	785	488	834
Ventless 240V	372	248	387
Combination	463	307	482

Table 11.3.4 Weighted-Average Annual Energy Use for Baseline for Room Air Conditioners

kWh/year	**All Households**	**Senior-Only**	**Low-Income**
<6,000 Btu/h, with Louvers	401	242	526
8,000-13,999 Btu/h, with Louvers	636	535	729
20,000-24,999 Btu/h, with Louvers	506	325	844
>25,000 Btu/h, with Louvers	589	377	983
8,000-10,999 Btu/h, without Louvers	523	446	600
>11,000 Btu/h, without Louvers	779	664	894

11.4 RESULTS

11.4.1 Clothes Dryers

Tables 11.4.1 through 11.4.12 below summarize the LCC results for clothes dryers. The LCC results provide the average installed price, average lifetime operating cost (discounted), average life-cycle cost, average life-cycle cost savings, the percentage of consumers that are burdened with net costs, realize net savings, or are not impacted, and the median payback period.

11.4.1.1 Senior-Only

Table 11.4.1 Electric Standard Dryers: LCC and PBP Results for Senior-Only Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
3.55	$455	$558	$1,014	N/A	0%	100%	0%	N/A
3.56	$456	$555	$1,012	$0	1%	98%	2%	3.8
3.61	$457	$544	$1,001	$2	0%	79%	21%	0.2
3.73	$468	$527	$995	$7	31%	25%	45%	7.7
3.81	$528	$517	$1,045	-$40	86%	7%	7%	38.4
4.08	$583	$484	$1,068	-$62	88%	1%	11%	30.2
5.42	$880	$370	$1,250	-$245	92%	0%	8%	35.5

* “No impact” means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.2 Compact 120V Dryers: LCC and PBP Results for Senior-Only Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
3.43	$470	$264	$734	N/A	0%	100%	0%	N/A
3.48	$471	$259	$730	$3	5%	0%	95%	2.6
3.61	$471	$248	$719	$14	2%	0%	98%	0.9
3.72	$501	$241	$742	-$8	79%	0%	21%	16.2
3.80	$560	$236	$796	-$63	98%	0%	2%	40.1
4.08	$628	$219	$847	-$113	98%	0%	2%	46.3
5.41	$875	$164	$1,040	-$306	98%	0%	2%	56.0

* “No impact” means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.3 Compact 240V Dryers: LCC and PBP Results for Senior-Only Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
3.12	$470	$292	$762	N/A	0%	100%	0%	N/A
3.16	$471	$288	$759	$2	3%	41%	55%	2.6
3.27	$471	$277	$748	$9	1%	41%	57%	0.8
3.36	$501	$269	$770	-$8	62%	25%	13%	17.1
3.48	$560	$260	$820	-$54	89%	8%	2%	41.8
3.60	$628	$251	$879	-$110	95%	4%	1%	59.0
4.89	$875	$184	$1,060	-$291	98%	0%	2%	54.6

* “No impact” means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.4 Gas Dryers: LCC and PBP Results for Senior-Only Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
3.14	$555	$288	$843	N/A	0%	100%	0%	N/A
3.16	$556	$283	$839	$0	1%	93%	6%	2.3
3.20	$556	$271	$827	$2	0%	85%	15%	0.5
3.30	$568	$264	$832	-$1	40%	42%	18%	18.2
3.41	$659	$257	$916	-$76	89%	11%	0%	110.2
3.61	$713	$242	$956	-$115	98%	1%	1%	74.6

* “No impact” means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.5 Vent-less Compact 240V Dryers: LCC and PBP Results for Senior-Only Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
2.55	$1,093	$313	$1,405	N/A	0%	100%	0%	N/A
2.59	$1,094	$306	$1,400	$5	0%	0%	100%	2.6
2.69	$1,094	$291	$1,385	$20	0%	0%	100%	0.9
2.71	$1,131	$289	$1,420	-$14	87%	0%	13%	19.3
2.80	$1,176	$278	$1,454	-$49	96%	0%	4%	30.1
4.03	$1,462	$178	$1,640	-$234	95%	0%	5%	37.7

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.6 Vent-less Combination Washer-Dryers: LCC and PBP Results for Senior-Only Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
2.08	$1,533	$389	$1,922	N/A	0%	100%	0%	N/A
2.35	$1,535	$337	$1,872	$49	5%	0%	95%	0.6
2.38	$1,537	$332	$1,868	$54	1%	0%	99%	0.9
2.46	$1,537	$317	$1,854	$68	0%	0%	100%	0.7
2.56	$1,579	$302	$1,881	$41	34%	0%	66%	7.1
3.69	$1,982	$193	$2,175	-$253	92%	0%	8%	31.8

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

11.4.1.2 Low-Income

Table 11.4.7 Electric Standard Dryers: LCC and PBP Results for Low-Income Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
3.55	$451	$792	$1,242	N/A	0%	100%	0%	N/A
3.56	$452	$789	$1,241	$0	1%	98%	2%	3.6
3.61	$452	$778	$1,230	$2	0%	79%	21%	0.2
3.73	$463	$754	$1,217	$12	24%	25%	51%	6.3
3.81	$524	$739	$1,263	-$30	80%	7%	13%	30.4
4.08	$579	$692	$1,271	-$38	79%	1%	20%	23.8
5.42	$874	$528	$1,402	-$170	83%	0%	17%	27.9

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.8 Compact 120V Dryers: LCC and PBP Results for Low-Income Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
3.43	$464	$388	$852	N/A	0%	100%	0%	N/A
3.48	$465	$383	$849	$3	7%	0%	93%	2.8
3.61	$466	$373	$839	$13	6%	0%	94%	0.9
3.72	$495	$362	$857	-$5	75%	0%	25%	15.4
3.80	$555	$354	$909	-$57	96%	0%	4%	36.0
4.08	$622	$329	$951	-$99	95%	0%	5%	38.2
5.41	$868	$245	$1,114	-$262	95%	0%	5%	42.5

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.9 Compact 240V Dryers: LCC and PBP Results for Low-Income Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact*	Households with Net Benefit	Median (years)**
3.12	$464	$431	$895	N/A	0%	100%	0%	N/A
3.16	$465	$427	$892	$2	5%	41%	54%	2.8
3.27	$466	$416	$882	$8	3%	41%	55%	0.9
3.36	$495	$405	$900	-$6	59%	25%	16%	16.0
3.48	$555	$391	$945	-$47	86%	8%	5%	34.8
3.60	$622	$377	$999	-$99	93%	4%	3%	47.2
4.89	$868	$275	$1,144	-$243	94%	0%	6%	40.6

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.10 Gas Dryers: LCC and PBP Results for Low-Income Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact*	Households with Net Benefit	Median (years)**
3.14	$546	$439	$985	N/A	0%	100%	0%	N/A
3.16	$547	$434	$981	$0	1%	93%	7%	2.3
3.20	$548	$423	$970	$2	0%	85%	15%	0.5
3.30	$560	$411	$971	$2	33%	42%	25%	12.1
3.41	$651	$400	$1,050	-$69	88%	11%	2%	73.8
3.61	$705	$377	$1,082	-$100	95%	1%	4%	51.4

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.11 Vent-less Compact 240V Dryers: LCC and PBP Results for Low-Income Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact*	Households with Net Benefit	Median (years)**
2.55	$1,087	$457	$1,544	N/A	0%	100%	0%	N/A
2.59	$1,088	$450	$1,539	$5	0%	0%	100%	2.5
2.69	$1,089	$436	$1,525	$19	0%	0%	100%	0.9
2.71	$1,125	$432	$1,557	-$14	87%	0%	13%	18.6
2.80	$1,170	$416	$1,586	-$42	93%	0%	7%	26.7
4.03	$1,455	$264	$1,719	-$175	88%	0%	12%	28.6

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.12 Vent-less Combination Washer-Dryers: LCC and PBP Results for Low-Income Households

CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact*	Households with Net Benefit	Median (years)**
2.08	$1,527	$570	$2,098	N/A	0%	100%	0%	N/A
2.35	$1,529	$493	$2,022	$76	2%	0%	98%	0.4
2.38	$1,531	$487	$2,018	$80	1%	0%	100%	0.6
2.46	$1,531	$474	$2,005	$93	0%	0%	100%	0.6
2.56	$1,573	$452	$2,025	$73	23%	0%	77%	5.6
3.69	$1,975	$285	$2,260	-$162	83%	0%	17%	23.8

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

11.4.2 Room Air Conditioners

Tables 11.4.13 through 11.4.24 below summarize the LCC results for room air conditioners. The LCC results provide the average installed price, average lifetime operating cost (discounted), average life-cycle cost, average life-cycle savings, the percentage of consumers that are burdened with net costs, realize net savings, or are not impacted, and the median payback period.

11.4.2.1 Senior-Only

Table 11.4.13 Room Air Conditioners, <6,000 Btu/h, with Louvers: LCC and PBP Results for Senior-Only Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact*	Households with Net Benefit	Median (years)**
9.52	$354	$283	$637	N/A	0%	100%	0%	N/A
10.1	$364	$265	$630	$5	30%	31%	39%	5.3
10.6	$377	$254	$632	$4	45%	31%	24%	8.0
11.1	$396	$244	$640	-$5	81%	1%	18%	11.8
11.4	$414	$239	$653	-$17	88%	0%	12%	15.2
11.7	$476	$234	$710	-$75	96%	0%	4%	28.1

* “No impact” means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.14 Room Air Conditioners, 8,000-13,999 Btu/h, with Louvers: LCC and PBP Results for Senior-Only Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact*	Households with Net Benefit	Median (years)**
9.69	$472	$529	$1,001	N/A	0%	100%	0%	N/A
10.2	$478	$503	$981	$8	5%	62%	33%	2.2
10.7	$488	$481	$969	$13	12%	59%	28%	0.0
10.9	$492	$473	$965	$17	41%	2%	57%	3.3
11.5	$520	$448	$968	$14	64%	1%	36%	8.2
12.0	$599	$432	$1,031	-$49	83%	0%	17%	18.2

* “No impact” means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.15 Room Air Conditioners, 20,000-24,999 Btu/h, with Louvers: LCC and PBP Results for Senior-Only Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
8.47	$838	$615	$1,453	N/A	0%	100%	0%	N/A
9.0	$854	$580	$1,433	$1	8%	87%	6%	6.3
9.4	$868	$551	$1,419	$3	8%	85%	6%	6.4
9.8	$913	$529	$1,442	-$17	92%	4%	4%	29.6
10.2	$1,139	$514	$1,653	-$223	98%	2%	0%	97.3

* “No impact” means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.16 Room Air Conditioners, >25,000 Btu/h, with Louvers: LCC and PBP Results for Senior-Only Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
8.48	$957	$665	$1,622	N/A	0%	100%	0%	N/A
9.00	$998	$628	$1,626	$0	11%	87%	1%	14.6
9.40	$1,036	$597	$1,634	-$1	13%	85%	2%	14.9
9.80	$1,290	$576	$1,866	-$234	100%	0%	0%	143.8

* “No impact” means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.17 Room Air Conditioners, 8,000-10,999 Btu/h, without Louvers: LCC and PBP Results for Senior-Only Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
8.41	$484	$476	$960	N/A	0%	100%	0%	N/A
9.3	$491	$432	$923	$4	1%	90%	9%	1.9
9.6	$494	$419	$913	$11	17%	25%	58%	2.6
10.0	$508	$400	$908	$16	45%	6%	49%	5.6
10.4	$610	$388	$998	-$73	94%	2%	4%	28.8

* “No impact” means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.18 Room Air Conditioners, >11,000 Btu/h, without Louvers: LCC and PBP Results for Senior-Only Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact*	Households with Net Benefit	Median (years)**
8.44	$567	$669	$1,237	N/A	0%	100%	0%	N/A
9.30	$584	$610	$1,194	$4	3%	90%	7%	3.4
9.50	$589	$598	$1,187	$9	28%	31%	41%	4.5
9.80	$605	$577	$1,182	$13	43%	17%	40%	6.3
10.02	$700	$566	$1,267	-$71	95%	0%	5%	31.9

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

11.4.2.2 Low-Income

Table 11.4.19 Room Air Conditioners, <6,000 Btu/h, with Louvers: LCC and PBP Results for Low-Income Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact*	Households with Net Benefit	Median (years)**
9.52	$346	$480	$826					
10.1	$356	$454	$809	$12	19%	30%	51%	3.3
10.6	$369	$433	$802	$17	28%	30%	42%	4.5
11.1	$387	$415	$802	$17	54%	1%	45%	6.6
11.4	$405	$406	$810	$9	64%	0%	36%	8.2
11.7	$467	$397	$863	-$44	84%	0%	16%	16.2

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.20 Room Air Conditioners, 8,000-13,999 Btu/h, with Louvers: LCC and PBP Results for Low-Income Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
9.69	$474	$684	$1,159	N/A	0%	100%	0%	N/A
10.2	$480	$652	$1,132	$10	3%	62%	35%	1.6
10.7	$490	$623	$1,113	$18	8%	59%	33%	0.0
10.9	$494	$612	$1,106	$24	27%	2%	69%	2.5
11.5	$522	$580	$1,103	$27	50%	1%	48%	6.1
12.0	$601	$560	$1,161	-$31	74%	0%	25%	12.9

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.21 Room Air Conditioners, 20,000-24,999 Btu/h, with Louvers: LCC and PBP Results for Low-Income Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
8.47	$846	$1,034	$1,880	N/A	0%	100%	0%	N/A
9.0	$862	$973	$1,835	$7	2%	82%	16%	2.1
9.4	$876	$928	$1,804	$13	3%	80%	17%	2.3
9.8	$921	$890	$1,812	$8	71%	4%	25%	10.0
10.2	$1,149	$862	$2,010	-$187	96%	2%	2%	33.2

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.22 Room Air Conditioners, >25,000 Btu/h, with Louvers: LCC and PBP Results for Low-Income Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median (years)**
					Net Cost	No Impact*	Net Benefit	
8.48	$967	$1,152	$2,119	N/A	0%	100%	0%	N/A
9.00	$1,007	$1,086	$2,093	$4	7%	83%	10%	5.0
9.40	$1,046	$1,036	$2,082	$7	10%	80%	10%	5.4
9.80	$1,301	$996	$2,297	-$209	99%	0%	1%	48.6

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.23 Room Air Conditioners, 8,000-10,999 Btu/h, without Louvers: LCC and PBP Results for Low-Income Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact*	Households with Net Benefit	Median (years)**
8.41	$486	$600	$1,086	N/A	0%	100%	0%	N/A
9.3	$492	$545	$1,038	$5	1%	90%	10%	1.2
9.6	$495	$528	$1,024	$15	8%	25%	66%	1.8
10.0	$510	$506	$1,016	$23	33%	6%	60%	4.3
10.4	$612	$490	$1,103	-$62	90%	2%	7%	22.1

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

Table 11.4.24 Room Air Conditioners, >11,000 Btu/h, without Louvers: LCC and PBP Results for Low-Income Households

CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period
	Average Installed Price	Average Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact*	Households with Net Benefit	Median (years)**
8.44	$570	$855	$1,425	N/A	0%	100%	0%	N/A
9.30	$587	$779	$1,366	$6	1%	90%	9%	2.1
9.50	$592	$764	$1,356	$13	18%	31%	51%	3.1
9.80	$607	$739	$1,346	$21	32%	17%	50%	4.7
10.02	$703	$724	$1,428	-$60	91%	0%	8%	22.8

* "No impact" means that the base case product assigned to the household has greater efficiency than the level indicated, so the household is not affected.

REFERENCES

1. U.S. Department of Energy - Energy Information Administration, *Residential Energy Consumption Survey: 2005 Public Use Data Files,* 2005. <http://www.eia.doe.gov/emeu/recs/recspubuse05/pubuse05.html>

CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

12.1 INTRODUCTION

In determining whether a standard is economically justified, the U.S. Department of Energy (DOE) is required to consider "the economic impact of the standard on the manufacturers and on the consumers of the products subject to such a standard." (42 U.S.C. 6313(a)(6)(B)(i)) The law also calls for an assessment of the impact of any lessening of competition as determined in writing by the Attorney General. *Id*. DOE conducted a manufacturer impact analysis (MIA) to estimate the financial impact of more stringent energy conservation standards on manufacturers of residential clothes dryers and room air conditioners, and assessed the impact of such standards on direct employment and manufacturing capacity.

The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA primarily relies on the Government Regulatory Impact Model (GRIM), an industry cash-flow model adapted for each product in this rulemaking. The GRIM inputs include information on industry cost structure, shipments, and pricing strategies. The GRIM's key output is the industry net present value (INPV). The model estimates the financial impact of more stringent energy conservation standards for each product by comparing changes in INPV between a base case and the various trial standard levels (TSLs) in the standards case. The qualitative part of the MIA addresses product characteristics, manufacturer characteristics, market and product trends, as well as the impact of standards on subgroups of manufacturers.

12.2 METHODOLOGY

DOE conducted the MIA in three phases. Phase I, "Industry Profile," consisted of preparing an industry characterization for the residential clothes dryer and room air conditioner industries, including data on market share, sales volumes and trends, pricing, employment, and financial structure. In Phase II, "Industry Cash Flow," DOE used the GRIM to assess the impacts of amended energy conservation standards on the products in this rulemaking.

In Phase II, DOE created a separate GRIM for residential clothes dryers and room air conditioners and separate interview guides to gather information on the potential impacts on manufacturers. In the MIA, DOE aggregated the results for similar product classes made by the same manufacturers and in the same production facilities to allow DOE to better assess the impacts of amended energy conservation standards on manufacturers.

In Phase III, "Subgroup Impact Analysis," DOE interviewed manufacturers representing over 90 percent of clothes dryer sales and approximately 50 percent of room air conditioner sales. Interviewees included manufacturers with various market shares and product focus, providing a representative cross-section of the industries. During interviews, DOE discussed financial topics specific to each manufacturer and obtained each manufacturer's view of the industry. The interviews provided DOE with valuable information for evaluating the impacts of amended energy conservation standards on manufacturer cash flows, investment requirements, and employment.

DOE groups the MIA results by product classes that are made by the same manufacturers. DOE presents results for residential clothes dryers and room air conditioners separately.

12.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the residential clothes dryer and room air conditioner industries that built upon the market and technology assessment prepared for this rulemaking. (See chapter 3 of this Technical Support Document (TSD).) Before initiating the detailed impact studies, DOE collected information on the present and past structure and market characteristics of each industry. This information included market share data, product shipments, manufacturer markups, and the cost structure for various manufacturers. The industry profile includes: (1) further detail on the overall market and product characteristics; (2) estimated manufacturer market shares; (3) financial parameters such as net plant, property, and equipment; selling, general and administrative (SG&A) expenses; cost of goods sold, *etc.;* and (4) trends in the number of firms, market, and product characteristics. The industry profile included a top-down cost analysis of manufacturers in each industry that DOE used to derive preliminary financial inputs for the GRIM (e.g., revenues, depreciation, SG&A, and research and development (R&D) expenses).

DOE also used public information to further calibrate its initial characterization of each industry, including Securities and Exchange Commission (SEC) 10–K reports,[1] Standard & Poor's (S&P) stock reports,[2] and corporate annual reports. DOE supplemented this public information with data released by privately held companies.

12.2.2 Phase II: Industry Cash-Flow Analysis and Interview Guide

Phase II focused on the financial impacts of amended energy conservation standards on each industry as a whole. More stringent 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. In Phase II, DOE performed preliminary industry cash-flow analyses and prepared written guides for manufacturer interviews. DOE used the GRIMs to perform two cash-flow analyses: one for the clothes dryers industry and one for room air conditioners. In performing these analyses, DOE used the financial values derived during Phase 1 and the shipment assumptions from the NIA.

12.2.2.1 Industry Cash-Flow Analysis

The GRIM uses several factors to determine a series of annual cash flows from the announcement year of amended energy conservation standards until several years after the standards' compliance date. These factors include annual expected revenues, costs of sales, SG&A, taxes, and capital expenditures related to the amended standards. Inputs to the GRIM include manufacturing costs and selling prices and shipments forecasts developed in other analyses. DOE derived the manufacturing costs from the engineering analysis and information provided by the industry and estimated typical manufacturer markups from public financial reports and interviews with manufacturers. DOE developed alternative markup scenarios for each GRIM based on discussions with manufacturers. DOE's shipments analysis, presented in chapter 10 of this TSD, provided the basis for the shipment projections in each GRIM. The financial parameters were developed using publicly available manufacturer data and were revised with information submitted confidentially during manufacturer interviews. The GRIM results are compared to base case projections for each industry. The financial impact of amended energy conservation standards is the difference between the base-case and standards-case at each TSL discounted annual cash flows.

12.2.2.2 Interview Guides

During Phase III of the MIA, DOE interviewed manufacturers to gather information on the effects of amended energy conservation on revenues and finances, direct employment, capital assets, and industry competitiveness. Before the interviews, DOE distributed interview guides for clothes dryers and room air conditioners. The interview guides provided a starting point to identify relevant issues and help identify the impacts of amended energy conservation standards on individual manufacturers or subgroups of manufacturers. Most of the information DOE received from these meetings is protected by non-disclosure agreements and resides with DOE's contractors. Before each telephone interview or site visit, DOE provided company representatives with an interview guide that included the topics for which DOE sought input. The MIA interview topics included (1) key issues to this rulemaking; (2) a company overview and organizational characteristics; (3) engineering and life cycle cost follow-up; (4) manufacturer markups and profitability; (5) shipment projections; (6) financial parameters; (7) conversion costs; (8) cumulative regulatory burden; (9) direct employment impact assessment; (10) manufacturing capacity and non-US sales; (11) impact on competition; and (12) impacts on small business. The interview guides are presented in Appendix 12-A.

12.2.3 Phase III: Subgroup Analysis

For its analysis, DOE presented the impacts on clothes dryers and room air conditioners separately. While conducting the MIA, DOE interviewed a representative cross-section of residential clothes dryer and room air conditioner manufacturers. The MIA interviews broadened the discussion to include business-related topics. DOE sought to obtain feedback from industry on the approaches used in the GRIMs and to isolate key issues and concerns. During interviews, DOE defined no manufacturer subgroups that could be disproportionately impacted by amended energy conservation standards.

12.2.3.1 Manufacturing Interviews

The information gathered in Phase I and the cash-flow analysis performed in Phase II are supplemented with information gathered from manufacturer interviews in Phase III. The interview process provides an opportunity for interested parties to express their views on important issues privately, allowing confidential or sensitive information to be considered in the rulemaking process.

DOE used these interviews to tailor each GRIM to reflect unique financial characteristics of each product group. Within each manufacturer group, DOE contacted companies from its database of manufacturers. Small and large companies, subsidiaries and independent firms, and public and private corporations were interviewed to provide a representation of the industry. Interviews were scheduled well in advance to provide every opportunity for key individuals to be available for comment. Although a written response to the questionnaire was acceptable, DOE sought interactive interviews, which help clarify responses and identify additional issues. The resulting information provides valuable inputs to the GRIMs developed for the product classes.

12.2.3.2 Revised Industry Cash-Flow Analysis

In Phase II of the MIA, DOE provided manufacturers with preliminary GRIM input financial figures for review and evaluation. During the interviews, DOE requested comments on the values it selected for the parameters. DOE revised its industry cash-flow models based on this feedback. Section 12.4.3 provides more information on how DOE calculated the parameters.

12.2.3.3 Manufacturer Subgroup Analysis

Using average cost assumptions to develop an industry cash flow estimate is not adequate for assessing differential impacts among manufacturer subgroups. Small manufacturers and other manufacturers with a cost structure significantly different from the industry average could be more negatively affected. DOE uses the results of the industry characterization to group manufacturers exhibiting similar characteristics. During the interviews, DOE discussed the potential subgroups and subgroup members it identified for the analysis. DOE asked manufacturers and other interested parties to suggest what subgroups or characteristics are the most appropriate to analyze. As described in section 12.2.3, DOE presents the industry impacts by the major product groupings covered in this rulemaking. These product groupings represent separate markets served by distinct manufacturers. As discussed below, DOE did not identify any small business manufacturers and therefore did not analyze a separate subgroup of small business manufacturers.

12.2.3.4 Small-Business Manufacturer Subgroup

DOE used the Small Business Administration (SBA) small business size standards published on August 22, 2008, as amended, and the North American Industry Classification System (NAICS) code, presented in Table 12.2.1, to determine whether any small entities would be affected by the rulemaking.[a] For the product classes under review, the SBA bases its small business definition on the total number of employees for a business, its subsidiaries, and its parent companies. An aggregated business entity with fewer employees than the listed limit is considered a small business.

[a] The size standards are available on the SBA's website at www.sba.gov/idc/groups/public/documents/sba_homepage/serv_sstd_tablepdf.pdf.

Table 12.2.1 SBA and NAICS Classification of Small Businesses Potentially Affected by This Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Household Laundry Equipment Manufacturing	N/A	1000	335224
Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing	N/A	750	333415

DOE used the Association of Home Appliance Manufacturers (AHAM)[3] member directory to identify manufacturers of residential clothes dryers and room air conditioners. DOE also reviewed public certification databases including the California Energy Commission (CEC),[4] ENERGY STAR,[5] and other databases. DOE asked interested parties and industry representatives if they were aware of other small business manufacturers. Then, DOE consulted publicly available data, reports from vendors such as D&B, and manufacturers to determine which manufacturers meet SBA's definition of a small business.

During its research, DOE did not identify any residential clothes dryer or room air conditioner companies which manufacture products covered by this rulemaking and qualify as small businesses per the applicable SBA definition. This determination is detailed in section 12.6. Because no manufacturers qualified as a small business, DOE did not analyze a separate subgroup of small business manufacturers for this NOPR.

12.2.3.5 Manufacturing Capacity Impact

One significant outcome of amended energy conservation standards could be the obsolescence of existing manufacturing assets, including tooling and investment. The manufacturer interview guides have a series of questions to help identify impacts of amended standards on manufacturing capacity, specifically capacity utilization and plant location decisions in the United States and North America, with and without amended standards; the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new requirements; the nature and value of any stranded assets; and estimates for any one-time changes to existing plant, property, and equipment (PPE). DOE's estimates of the one-time capital changes and stranded assets affect the cash flow estimates in the GRIMs. These estimates can be found in section 12.4.8; DOE's discussion of the capacity impact can be found in section 12.7.2.

12.2.3.6 Employment Impact

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. To assess how domestic direct employment patterns might be affected, the interviews explored current employment trends in the residential clothes dryer and room air conditioner industries. The interviews also solicited manufacturer views on changes in employment patterns that may result from more stringent standards. The employment impacts section of the interview guide focused on current employment levels associated with manufacturers at each production facility, expected future employment levels with and without amended energy conservation standards, and differences in workforce skills and issues related to the retraining of employees. The employment impacts are reported in section 12.7.1.

12.2.3.7 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects on manufacturers due to amended energy conservation standards and other regulatory actions affecting the same products. DOE analyzed the impact on manufacturers of multiple, product-specific regulatory actions. Based on its own research and discussions with manufacturers, DOE identified regulations relevant to residential clothes dryer and room air conditioner manufacturers, such as State regulations and other Federal regulations that impact other products made by the same manufacturers. Discussion of the cumulative regulatory burden can be found in section 12.7.3.

12.3 MANUFACTURER IMPACT ANALYSIS KEY ISSUES

Each MIA interview starts by asking: "What are the key issues for your company regarding the energy conservation standard rulemaking?" This question prompts manufacturers to identify the issues they feel DOE should explore and discuss further during the interview. The following section describes key issues manufacturers mentioned for all product classes under review.

12.3.1 Residential Clothes Dryers Key Issues

12.3.1.1 Test Procedure

Manufacturers indicated that a key concern for this rulemaking was ensuring that the test procedure accurately measured actual energy use. In particular, manufacturers indicated that proposed changes to the remaining moisture content value and the average number of annual cycles needed to be updated. Manufacturers indicated that without these changes, consumers could be negatively impacted by amended energy conservation standards because clothes dryers have a limited number of improvements that would be cost effective for most consumers.

12.3.1.2 Underwriters Laboratories (UL) Fire Containment Standard

Most manufacturers indicated that they had not fully investigated the exact technical changes that will be required to meet the UL fire containment regulation (UL 2158). However, manufacturers were concerned that this regulation would require changes to all their products around the same time that they would be required to meet amended energy conservation standard. Most manufacturers agreed that even if the exact approach of meeting UL 2158 is different or unknown by individual manufactures, DOE should still treat the regulation as an overall burden.

12.3.1.3 Heat Pump Technology

Manufacturers indicated that the high capital conversion and product conversion costs for clothes dryers at the second gap fill levels or the maximum available units were significant and would represent a substantial burden. Manufacturers also indicated that the pathways to meeting those levels, while potentially costly, were well-defined, proven in the market, and could be made within their existing production facilities. Manufacturers also indicated, however, that heat pump technology at the max-tech levels for electric product classes would represent a significant departure from current products and add significantly to the product and capital conversion costs.

A heat pump standard would require a total renovation of existing facilities. The changes required to manufacture heat pumps would require revamping most existing production equipment and redesigning a new platform. The capital conversion costs would include equipment for new drum lines, assembly line testing equipment, stamping equipment for cabinets, and other production equipment to manufacturer the sealed systems. In addition to the large development costs to develop new platforms, manufacturers would have the additional expense of developing the sealed system. Other increases to the product development costs for head pump clothes dryers that concerned manufacturers were the significant retraining costs for their servicers and the marketing costs to educate consumers and ensure they accept the new technology. With the substantial change that would be required to develop, manufacture, and educate consumers about heat pump clothes dryers, manufacturers were concerned they might not be able to make all the required changes with a three year lead time between the announcement of the final rule and the compliance date of the amended energy conservation.

Manufacturers also indicated that an energy conservation standard at a level that effectively required a heat pump clothes dryer would force them to consider off-shoring any remaining production in the United States. Besides the significant capital and product conversion costs, manufacturers indicated that the much higher labor content of a heat pump clothes dryer would put additional pressure on moving production away from the United States. Finally, manufacturers believed that repair and maintenance costs would increase if an energy conservation standard effectively required heat pump clothes dryers. Repair and maintenance costs would increase due to the more expensive components, potential lint management problems, and some manufacturers' inexperience with the technology.

12.3.1.1 Impacts on Profitability

Manufacturers indicated that the clothes dryer market would make profitability impacts likely under an amended energy conservation standard. Because there is currently no energy label requirement and no ENERGY STAR program for clothes dryers, manufacturers indicated that, unlike clothes washers, efficiency does not command any premium in the market (either in percentage or absolute terms). Because it is difficult to communicate any energy benefit to consumers, it is very unlikely that they could benefit from higher production costs caused by amended energy conservation standards.

In addition, manufacturers indicated that the large incremental cost jumps at some of the higher efficiency levels, including heat pump clothes dryers, were unlikely to be fully passed on to their customers. Beside the inability to show the energy benefit of the products, manufacturers indicated that the concentrated number of players in the retail market would put pressure on all manufacturers to keep costs down in response to amended energy conservation standards. Manufacturers also indicated that many of their sales are from pairs of clothes washers and dryers that have similar price points. If the cost of clothes dryers increased, manufacturers felt that retailers would not accept any price increase to keep the retail prices of the matched pair similar.

12.3.2 Room Air Conditioners Key Issues

12.3.2.1 Impact on Manufacturer Profitability

Several manufacturers stated that they expect amended energy conservation standards to negatively impact the profitability of room air conditioners. Higher component, tooling, and development costs for more efficient products would increase manufacturer production costs, but manufacturers believed these higher costs could not necessarily be passed on to consumers due to the nature of the industry. A few large retailers dominate the industry and exert downward pressure on prices. Retailers demand low prices because consumers have come to expect room air conditioners at particular price points; for example, consumers expect many product offerings of product class 1 for under $100 and retailers have successfully maintained that price point through competitive bidding. This has resulted in price pressure on the most popular units as manufacturers accept lower absolute profit on those units in the hopes of making a larger per unit profit on other more costly products. Many room air conditioner purchases are weather-dependent, so consumers could easily forgo the purchase of a room air conditioner unit altogether if prices increased. Consequently, manufacturers believed that cost increases would be at least partly absorbed by manufacturers to keep retail prices from rising sharply.

If amended energy conservation standards led to a significant reduction in profitability, some manufacturers could exit the market (as a number of large players have in recent years). Many manufacturers source room air conditioner lines from overseas and do not own the production equipment. This arrangement would allow manufacturers to exit the industry without stranded assets.

12.3.2.2 Impact on Product Utility

Manufacturers believed a negative profitability impact could also indirectly affect product utility. Several manufacturers indicated that other features that do not affect efficiency could be removed or component quality could be sacrificed to meet amended standard levels and maintain product prices at levels that would be acceptable to consumers.

Manufacturers also expressed concern that the energy savings from more stringent energy conservation standards would not be great enough to justify passing through the added costs to consumers. Currently, manufacturers bundle higher efficiency with other desirable features to justify higher prices for ENERGY STAR models. According to manufacturers, if amended standards caused prices to increase, the lower operating costs would not justify higher prices because the energy savings would be low compared to the initial price of the unit. Therefore, the increased cost of meeting the amended efficiency requirements may cause manufacturers to reduce the number of features to retain a reasonable price point.

The value of future ENERGY STAR levels is also a concern for manufacturers. Many retailers and other distribution channels require ENERGY STAR products. Because the features bundled with ENERGY STAR products are the selling point to consumers, manufacturers were concerned that a higher ENERGY STAR level after amended standards would result in products with fewer features.

Manufacturers also stated that the financial burden of developing products to meet amended energy conservation standards has an opportunity cost due to limited capital and R&D dollars. Investments incurred to meet amended energy conservation standards reflect foregone investments in innovation and the development of new features that consumers value and on which manufacturers earn higher absolute profit.

12.3.2.3 Component Availability

Several manufacturers stated they were concerned about component availability. Compressor availability since the conversion to R-410A was the main problem cited by manufacturers. Some manufacturers stated that component suppliers do not give priority to room air conditioning because the market is exclusive to North America and smaller than some of the other markets they supply. Since the conversion R-410A, manufacturers noted the total production capacity of compressor suppliers has not fully rebounded. In addition, compressor suppliers have yet to offer the same range of compressor capacities and efficiency tiers.

12.3.2.4 Size Constraints

A number of manufacturers expressed concerns about physical limitations of how large room air conditioners could grow. Most residential buildings have standardized window openings. Because a large portion of air conditioners are installed in these standardized openings, products must still fit in these typical windows after they have been redesigned. Manufacturers were largely concerned that the limited opportunity for growth also limited opportunities for efficiency improvements. Increasing the size of units also presents a problem for smaller air conditioners, typically under 10,000 Btu/hr, since much of their appeal is that these units can be lifted and installed by one person. Increasing the size of these units would greatly alter the market and may move consumers to less efficient portable air-conditioning units.

Manufacturers mentioned refrigerant charge as another reason why room air conditioners are constrained by size. If manufacturers used increased coil size and a smaller compressor capacity to improve efficiency, the larger heat exchangers combined with the reduced nominal compressor capacity could lead to a system refrigerant charge amount that exceeds the recommended level. Exceeding recommended charge levels could damage the compressor, thereby limiting the extent of efficiency improvements associated with coil size growth. To counteract the increase in charge, some manufacturers have used smaller tubing in their heat exchangers, but North American suppliers are not currently equipped properly to support smaller tube sizes and might not be willing to make the investment required to do so.

Several manufacturers stated that size is also a concern because moving from a smaller chassis to larger chassis would cause material costs to increase dramatically due to more costly components and the potential capital costs required for development. If the adopted standards required significant rather than incremental increases in efficiency, the largest units in each capacity range would likely have to move to the next largest or a new chassis in order to meet the required efficiency levels. This is a notable concern for capacities above 28,000 Btu/hr because manufacturers could choose to no longer offer these product lines due to the conversion cost.

Numerous manufacturers stated that size constraints pose a problem for non-louvered units in particular. Non-louvered units inherently have less room for efficiency improvement because they need to fit into the existing sleeves in buildings. They are also constrained by air flow, increasing the depth does not result in significant efficiency gains because air on the condenser side must still flow through the rear face. Additionally, increasing depth creates a product that is less aesthetically pleasing and could decrease the available space in the room.

12.3.2.5 Product Switching

Some manufacturers noted that higher consumer prices after an amended energy conservation standard could result in product switching along the upper capacity boundaries of a product class if efficiency requirements are not implemented proportionally across product classes. For example, if the first cost of units in product class 1 after amended energy conservation standards is not proportionally lower than units in product class 3, this lack of price disparity would drive consumers who would have purchased product class 1 units to purchase less efficient, slightly higher capacity units in product class 3. Without a significant price differential between product classes, consumers would be more likely to buy units with higher capacity, potentially lowering the calculated energy savings.

12.4 GRIM INPUTS AND ASSUMPTIONS

The GRIM serves as the main tool for assessing the impacts on industry due to amended energy conservation standards. DOE relies on several sources to obtain inputs for the GRIM. Data and assumptions from these sources are then fed into an accounting model that calculates the industry cash flow both with and without amended energy conservation standards.

12.4.1 Overview of the GRIM

The basic structure of the GRIM, illustrated in Figure 12.4.1, is an annual cash flow analysis that uses manufacturer prices, manufacturing costs, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM spreadsheet uses a number of inputs to arrive at a series of annual cash flows, beginning with the base year of the analysis, 2011, and continuing to 2043. The model calculates the INPV by summing the stream of annual discounted cash flows during this period.[6]

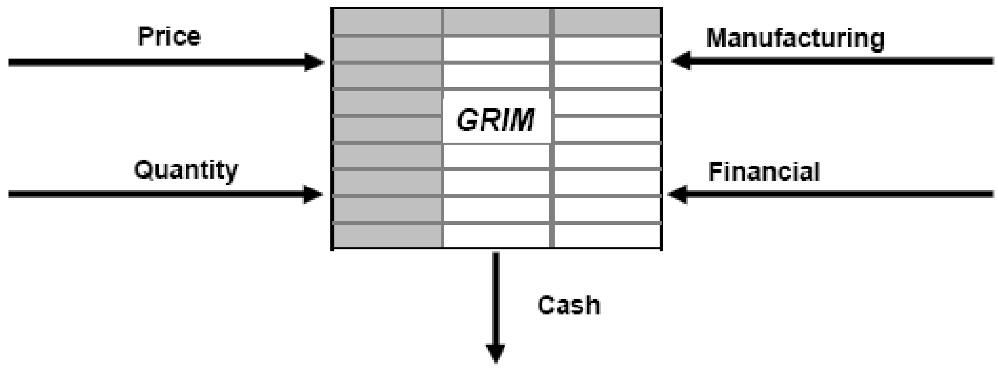

Figure 12.4.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the base-case and the standard-case scenario induced by amended energy conservation standards. The difference in INPV between the base case and the standard case(s) represents the estimated financial impact of the amended energy conservation standard on manufacturers. Appendix 12-B provides more technical details and user information for the GRIM.

12.4.2 Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, Census data, credit ratings, the shipments model, the engineering analysis, and the manufacturer interviews.

12.4.2.1 Corporate Annual Reports

Corporate annual reports to the SEC (SEC 10-Ks) provided many of the financial inputs to the GRIM. These reports exist for publicly held companies and are freely available to the general public. DOE developed initial financial inputs to the GRIM by examining the annual SEC 10-K reports filed by publicly-traded manufacturers primarily engaged in home appliances and whose combined product range includes residential clothes dryers and room air conditioners. Because these companies produce a range of different products, DOE initially assumed that the industry average figures calculated for these companies were representative of manufacturing for both residential clothes dryers and room air conditioners. Since these companies do not provide detailed information about their individual product lines, DOE used the financial information for the entire companies as its initial estimates of the financial parameters in both GRIM analyses. These figures were later revised using feedback from interviews to be representative of manufacturing for each product. DOE used corporate annual reports to derive the following initial inputs to the GRIM:

- Tax rate
- Working capital
- SG&A
- R&D

• Depreciation
• Capital expenditures
• Net PPE

12.4.2.2 Standard and Poor Credit Ratings

S&P provides independent credit ratings, research, and financial information. DOE relied on S&P reports to determine the industry's average cost of debt when calculating the cost of capital.

12.4.2.3 Shipment Model

The GRIM used shipment projections derived from DOE's shipments model in the national impact analysis (NIA). The model relied on historical shipments data for residential clothes dryers and room air conditioners. Chapter 10 of the TSD describes the methodology and analytical model DOE used to forecast shipments.

12.4.2.4 Engineering Analysis

During the engineering analysis, DOE used a manufacturing cost model to develop manufacturer production cost (MPC) estimates for residential clothes dryers and room air conditioners. The analysis provided the labor, materials, overhead, and total production costs for products at each efficiency level. The engineering analysis also estimated a manufacturer markup to provide the manufacturer selling price (MSP) for each product at every efficiency level.

12.4.2.5 Manufacturer Interviews

During the course of the MIA, DOE conducted interviews with a representative cross-section of manufacturers. DOE also interviewed manufacturers representing a significant portion of sales in every product class. During these discussions, DOE obtained information to determine and verify GRIM input assumptions in each industry. Key topics discussed during the interviews and reflected in the GRIM include:

- capital conversion costs (one-time investments in PPE);
- product conversion costs (one-time investments in research, product development, testing, and marketing);
- product cost structure, or the portion of the MPCs related to materials, labor, overhead, and depreciation costs;
- projected total shipment and shipment distribution mix; and
- MPCs estimated in the engineering analysis.

12.4.3 Financial Parameters

In the manufacturer interviews, DOE used the financial parameters from the April 2009 cooking products final rule and the January 2010 commercial clothes washers final rule[b] as a

[b] The final rule for commercial clothes washers was published in the *Federal Register* on January 8, 2010 (75 FR1122). The final rule for cooking products was published in the *Federal Register* on April 8, 2009 (74 FR 16040).

starting point for determining the residential clothes dryer and room air conditioner industry financial parameters. These initial estimates were used because many of the same white goods manufacturers produce clothes washers, cooking products, clothes dryers, and room air conditioners, and no other publicly available SEC 10-K reports for clothes dryer or room air conditioner manufacturers were available. These financial parameters were determined by averaging the values in the annual reports of three publicly traded companies engaged in manufacturing and selling clothes washers over an 8-year period (1999-2006). Table 12.4.1 below shows the data used to determine the initial financial parameter estimates.

Table 12.4.1 GRIM Financial Parameters Based on 1999–2006 Weighted Company Financial Data

Parameter	Industry-Weighted Average	Manufacturer		
		A	B	C
Tax Rate ***(% of Taxable Income)***	33.9	6.6	34.1	34.5
Working Capital ***(% of Revenue)***	2.9	9.6	5.6	2.0
SG&A ***(% of Revenue)***	12.5	12.7	12.3	13.2
R&D ***(% of Revenues)***	2.2	2.3	2.0	2.4
Depreciation ***(% of Revenues)***	3.4	3.9	3.4	3.3
Capital Expenditures ***(% of Revenues)***	3.5	1.9	3.4	3.6
Net Property, Plant, and Equipment ***(% of Revenues)***	19.9	17.3	21.6	19.4

During interviews, manufacturers were asked to provide their own figures for the parameters listed in Table 12.4.1. DOE did not receive feedback from either clothes dryer or room air conditioner manufacturers that indicated that the financial parameters in either GRIM should be adjusted. Therefore, DOE used the same financial parameters for both the residential clothes dryer and room air conditioner industries consistent with those shown in Table 12.4.1

12.4.4 Corporate Discount Rate

DOE used the weighted-average cost of capital (WACC) as the discount rate to calculate the INPV. A company's assets are financed by a combination of debt and equity. The WACC is the total cost of debt and equity weighted by their respective proportions in the capital structure of the industry. DOE estimated the WACC for the clothes dryer and room air conditioner industries based on several representative companies, using the following formula:

WACC = After-Tax Cost of Debt x (Debt Ratio) + Cost of Equity x (Equity Ratio) Eq. 1

The cost of equity is the rate of return that equity investors (including, potentially, the company) expect to earn on a company's stock. These expectations are reflected in the market price of the company's stock. The capital asset pricing model (CAPM) provides one widely used means to estimate the cost of equity. According to the CAPM, the cost of equity (expected return) is:

More information on these rulemakings can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers.html and http://www1.eere.energy.gov/buildings/appliance_standards/residential/cooking_products.html.

Cost of Equity = Riskless Rate of Return + β x Risk Premium Eq. 2

where:

Riskless rate of return is the rate of return on a "safe" benchmark investment, typically considered the short-term Treasury Bill (T-Bill) yield.

Risk premium is the difference between the expected return on stocks and the riskless rate.

Beta (β) is the correlation between the movement in the price of the stock and that of the broader market. In this case, Beta equals one if the stock is perfectly correlated with the S&P 500 market index. A Beta lower than one means the stock is less volatile than the market index.

DOE determined that the industry average cost of equity for the clothes dryer and room air conditioner industries is 17.9 percent (Table 12.4.2). The representative data was taken from the commercial clothes washers final rule since several of the representative manufacturers are the same as in the residential clothes dryer and room air conditioner industries.

Table 12.4.2 Cost of Equity Calculation

Parameter	**Industry-Weighted Average %**	**Manufacturer**		
		A	B	C
(1) Average Beta (2002-2006 year)	1.31	1.0*	1.77	1.17
(2) Yield on 10-Year T-Bill (1990-2006)	5.9	-	-	-
(3) Market Risk Premium (1926-1999)	9.2	-	-	-
Cost of Equity (2)+[(1)*(3)]	17.9	-	-	-
Equity/Total Capital	37.2	23.7	-49.8	64.6

* Estimated Beta

Bond ratings are a tool to measure default risk and arrive at a cost of debt. Each bond rating is associated with a particular spread. One way of estimating a company's cost of debt is to treat it as a spread (usually expressed in basis points) over the risk-free rate. DOE used this method to calculate the cost of debt for all three manufacturers by using S&P ratings and adding the relevant spread to the risk-free rate.

In practice, investors use a variety of different maturity Treasury bonds to estimate the risk-free rate. DOE used the 10-year Treasury bond return because it captures long-term inflation expectations and is less volatile than short-term rates. The risk free rate is estimated to be approximately 6 percent, which is the average 10-year Treasury bond return between 1990 and 2006 (the analysis period used in the initial estimate for commercial clothes washers).

For the cost of debt, S&P's Credit Services provided the average spread of corporate bonds for the three public manufacturers between 2002 and 2006. As stated above, the representative data was taken from the commercial clothes washers final rule since several of the representative manufacturers are the same as in the clothes dryer and room air conditioner industries. DOE added the industry-weighted average spread to the average T-Bill yield over the same period. Since proceeds from debt issuance are tax deductible, DOE adjusted the gross cost of debt by the industry average tax rate to determine the net cost of debt for the industry. Table 12.4.3 presents the derivation of the cost of debt and the capital structure of the industry (*i.e.* the debt ratio (debt/total capital)).

Table 12.4.3 Cost of Debt Calculation

Parameter	Industry-Weighted Average %	Manufacturer		
		A	B	C
S&P Bond Rating	--	B-	BBB	BBB
(1) Yield on 10-Year T-Bill (1990-2006)	5.9	-	-	-
(2) Gross Cost of Debt	8.2	13.9	8.1	8.1
(3) Tax Rate	34	6.6	34.1	34.5
Net Cost of Debt (2) x ((1)-(3))	5.4	-	-	-
Debt/Total Capital	62.8	76.3	149.8	35.4

Using public information for these three companies from the commercial clothes washers final rule, the initial estimate for the clothes dryer and room air conditioner industries' WACC was approximately 10.1 percent. Subtracting an inflation rate of 2.9 percent over the analysis period used in the initial estimate, the inflation-adjusted WACC and the initial estimate of the discount rate used in the straw-man GRIM is 7.2 percent. DOE also asked for feedback on the 7.2 percent discount during manufacturer interviews and used this feedback to determine that 7.2 percent was an appropriate discount rate for use in the GRIM for both residential clothes dryers and room air conditioners.

12.4.5 Trial Standard Levels

DOE developed TSLs for residential clothes dryers and room air conditioners. For residential clothes dryers, DOE analyzed all six product classes. For room air conditioners, consistent with the engineering analysis, DOE analyzed six representative product classes that represent over 75 percent of shipments. These representative product classes are product class 1 (without reverse cycle and with louvered sides - less than 6,000 Btu/h), product class 3 (without reverse cycle and with louvered sides - 8,000 to 13,999 Btu/h), product class 5A (without reverse cycle and with louvered sides - 20,000 to 24,999 Btu/h), product class 5B (without reverse cycle and with louvered sides - 25,000 Btu/h and more), product class 8A (without reverse cycle and without louvered sides - 8,000 to 10,999 Btu/h), and product class 8B (without reverse cycle and without louvered sides - 11,000 to 13,999 Btu/h). DOE extrapolates the amended energy standards to the remaining product classes[c] as described chapter 2 of the TSD. Table 12.4.4 through Table 12.4.5 present the efficiency levels at each TSL used in each GRIM.

[c] The remaining product classes are product class 2 (without reverse cycle and with louvered sides - 6,000 to 7,999 Btu/h), product class 4 (without reverse cycle and with louvered sides - 14,000 to 19,999 Btu/h), product class 6

Table 12.4.4 presents the TSLs and the corresponding product class efficiency levels for clothes dryers. For all clothes dryer TSLs, DOE analyzed efficiency improvements using combined energy factor (CEF). The CEF measurements use the test procedure final rule published in 2010, which incorporated several changes for measuring standby power, changes that affect the active mode efficiency (such as cycles per year, load size, remaining moisture content, etc.), and added additional product classes included in this direct final rule. DOE's test procedure for clothes dryers appears at 10 CFR part 430, subpart B, appendix D. TSL 1 consists of the efficiency levels with the largest market share with a positive NPV (at a 3-percent discount rate). TSL 2 consists of the efficiency levels with the highest NPV (at a 3-percent discount rate). TSL 3 consists of the efficiency levels with the highest energy savings and a positive NPV (at a 3-percent discount rate). TSL 4 consists of the efficiency levels that reflect 5-percent efficiency increase above the baseline. TSL 4 also corresponds to the standards recommended by the Joint Petitioners. TSL 5 consists of non heat pump design efficiency levels with the highest energy savings. TSL 6 consists of the max-tech efficiency levels. DOE shows the design options (for both standby power and active mode efficiency) in section 12.4.8 where it describes the design options analyzed to reach each CEF analyzed.

Table 12.4.4 Trial Standard Levels for Clothes Dryers

Product Class	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**	**TSL 6**
	CEF					
Product Class 1 - Vented Electric Standard	3.56	3.61	3.73	3.73	4.08	5.42
Product Class 2 - Vented Electric Compact 120V	3.43	3.61	3.61	3.61	4.08	5.41
Product Class 3 - Vented Electric Compact 240V	3.12	3.27	3.27	3.27	3.60	4.89
Product Class 4 - Vented Gas	3.16	3.20	3.20	3.30	3.61	3.61
Product Class 5 - Vent-less Electric Compact 240V	2.55	2.69	2.69	2.55	2.80	4.03
Product Class 6 - Vent-less Electric Combination Washer/Dryer	2.08	2.56	2.56	2.08	2.56	3.69

Table 12.4.5 presents the TSLs and the corresponding product class efficiency levels for room air conditioners. For all room air conditioner TSLs, DOE analyzed efficiency improvements using combined energy efficiency ratio (CEER). The CEER measurements use the test procedure final rule published in 2010, which incorporated several changes for measuring standby power. DOE's test procedure for room air conditioners appears at 10 CFR part 430, subpart B, appendix F. TSL 1 consists of the efficiency levels with the largest market share with a positive NPV (at a 3-percent discount rate). TSL 2 consists of the ENERGY STAR levels for each product class. TSL 3 consists of the efficiency levels with the highest NPV (at a 3-percent discount rate). TSL 4 consists of the efficiency levels set forth in the Joint Petition presented to

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(without reverse cycle and without louvered sides - less than 6,000 Btu/h), product class 7 (without reverse cycle and without louvered sides - 6,000 to 7,999 Btu/h), product class 9 (without reverse cycle and without louvered sides - 14,000 to 19,999 Btu/h), product class 10 (without reverse cycle and without louvered sides - 20,000 Btu/h and more), product class 11 (with reverse cycle and with louvered sides - less than 20,000 Btu/h), product class 12 (with reverse cycle and with louvered sides - 20,000 Btu/h and more), prduct class 13 (with reverse cycle and without louvered sides - less than 14,000 Btu/h), product class 14 (with reverse cycle and without louvered sides - 14,000 Btu/h and more), product class 15 (casement only), and product class 16 (casement slider), DOE. TSL 5 consists of the efficiency levels with the highest energy savings and a positive NPV (at a 7-percent discount rate). TSL 6 consists of the max-tech efficiency levels. DOE shows the design options (for both standby power and active mode efficiency) in section 12.4.8 where it describes the design options analyzed to reach each CEER analyzed.

Table 12.4.5 Trial Standard Levels for Room Air Conditioners

Product Class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
	CEER					
Group 1 – includes PC 1	10.10	10.60	10.10	11.10	11.10	11.67
Group 2 – includes PC 2, 3, 4, 11	10.70	10.70	10.90	10.90	11.50	11.96
Group 3 – includes PC 5A, 9, 13	9.40	9.40	8.47	9.40	8.47	10.15
Group 4 – includes PC 5B, 10	9.40	9.40	8.48	9.00	8.48	9.80
Group 5 – includes PC 6, 7, 8A, 12	9.30	9.30	9.60	9.60	10.00	10.35
Group 6 – includes PC 8B, 14, 15, 16	9.30	9.30	9.50	9.50	9.50	10.02

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 the NIA shipments forecasts from 2009 to 2043 for residential clothes dryers and room air conditioners. However, only the shipments in 2011 and after have an impact on INPV because 2011 is the base year to which future cash flows are summed. Chapter 10 of the TSD explains DOE's calculations of total shipments in detail. Table 12.4.6 shows total shipments forecasted in the shipment analysis for residential clothes dryers in 2014; Table 12.4.7 shows forecasted shipments for room air conditioners in 2014.

Table 12.4.6 Total NIA Shipments Forecast in 2014 in the Main NIA Shipment Scenario[d] (Residential Clothes Dryers)

Product Class	Total Industry Shipments
Product Class 1 - Electric Standard Vented Dryers	6,085,810
Product Class 2 - Electric Compact Vented Dryers (120V)	13,155
Product Class 3 - Electric Compact Vented Dryers (240V)	59,196
Product Class 4 - Gas Vented Dryers	1,688,617
Product Class 5- Electric Compact (240V) Ventless Dryers	34,212
Product Class 6 - Electric Combination Ventless Dryers	34,212

[d] The estimated compliance date for the residential clothes dryer energy conservation standard is estimated to be January 2014.

Table 12.4.7 Total NIA Shipments Forecast in 2014[e] (Room Air Conditioners)

Product Class	Total Industry Shipments
Group 1 – includes PC 1	2,797,588
Group 2 – includes PC 2, 3, 4, 11	5,195,683
Group 3 – includes PC 5A, 9, 13	186,784
Group 4 – includes PC 5B, 10	122,237
Group 5 – includes PC 6, 7, 8A, 12	431,954
Group 6 – includes PC 8B, 14, 15, 16	383,763

12.4.6.1 Base Case Shipments Forecast

As part of the shipment analysis, DOE estimated the shipment distribution by efficiency level for residential clothes dryers and room air conditioners. For clothes dryers, DOE held the base-case energy efficiency distribution constant throughout the forecast period. Table 12.4.8 shows the base case distributions of shipments by efficiency level estimated in the NIA for the clothes dryer product classes.

Table 12.4.8 Base-Case Distribution of Efficiencies for Residential Clothes Dryers in 2014

Product Class		Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
Product Class 1 - Electric Standard Vented Dryers	CEF	3.55	3.56	3.61	3.73	3.81	4.08	5.42
	% of the Market at EL	2.6%	18.9%	53.5%	17.9%	6.1%	1.0%	0.0%
Product Class 2 - Electric Compact Vented Dryers (120V)	CEF	3.43	3.48	3.61	3.72	3.80	4.08	5.41
	% of the Market at EL	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Product Class 3 - Electric Compact Vented Dryers (240V)	CEF	3.12	3.16	3.27	3.36	3.48	3.60	4.89
	% of the Market at EL	59.4%	0.0%	15.6%	16.7%	4.2%	4.2%	0.0%
Product Class 4 - Gas Vented Dryers	CEF	3.14	3.16	3.20	3.30	3.42	3.61	
	% of the Market at EL	7.9%	8.2%	42.9%	30.9%	9.3%	0.9%	
Product Class 5 - Electric Compact (240V) Ventless Dryers	CEF	2.55	2.59	2.69	2.71	2.80	4.03	
	% of the Market at EL	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
Product Class 6 - Electric Combination Ventless Dryers	CEF	2.08	2.35	2.38	2.46	2,56	3.69	
	% of the Market at EL	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	

For the room air conditioner industry, DOE assumed a migration of the market toward higher efficiency over time. As such, the base case efficiency distribution is not held constant throughout the forecast period. However, Table 12.4.9 below provides a snapshot of the base case distributions of shipments by efficiency level estimated in the NIA for the representative room air conditioner product classes in 2014, the year the amended energy conservation standards take effect.

[e] The estimated compliance date for the room air conditioners energy conservation standard is estimated to be January 2014.

Table 12.4.9 Base-Case Distribution of Efficiencies for Room Air Conditioners in 2014

Product Class		Baseline	EL 1	EL 2	EL 3	EL 4	EL 5
Group 1 – includes PC 1	CEER	9.52	10.10	10.60	11.10	11.38	11.67
	% of the Market at EL	69.3%	0.0%	29.5%	1.2%	0.0%	0.0%
Group 2 – includes PC 2, 3, 4, 11	CEER	9.69	10.20	10.70	10.90	11.50	11.96
	% of the Market at EL	37.1%	2.5%	58.3%	1.4%	0.3%	0.5%
Group 3 – includes PC 5A, 9, 13	CEER	8.47	9.00	9.40	9.80	10.15	
	% of the Market at EL	13.2%	1.5%	81.3%	1.9%	2.1%	
Group 4 – includes PC 5B, 10	CEER	8.48	9.00	9.40	9.80		
	% of the Market at EL	12.5%	2.3%	85.3%	0.0%		
Group 5 – includes PC 6, 7, 8A, 12	CEER	8.41	9.30	9.60	10.00	10.35	
	% of the Market at EL	10.1%	64.8%	19.5%	3.7%	1.9%	
Group 6 – includes PC 8B, 14, 15, 16	CEER	8.44	9.30	9.50	9.80	10.02	
	% of the Market at EL	10.1%	59.3%	13.3%	17.3%	0.0%	

12.4.6.2 Standards Case Shipments Forecast

To examine the effects of amended energy conservation standards on shipments, which affect the INPV, DOE used the base case shipments described in the previous section. For the standards case, DOE used the shipments developed in the NIA for clothes dryers and room air conditioners. For clothes dryers, DOE used a roll-up scenario to determine efficiency distributions for the standards case. In this scenario, products that fall below the amended energy conservation standard are assumed to “roll-up” to the new standard in 2014. DOE also assumed there was a relative price elasticity in the clothes dryers market, meaning amended energy conservation standards that increase the first cost of clothes dryers would result in lower total shipments.

For room air conditioners, the base case shipments assume that there is a migration over time to more efficient products based on historical trends of penetration of ENERGY STAR products. In the standards case, DOE used a “roll-up + shift” scenario. In this scenario, DOE assumed that amended standards for room air conditioners would likely result in changes to ENERGY STAR levels that would increase the share of products with energy efficiency above the standard. DOE also assumed there was a relative price elasticity in the room air conditioner market, meaning that amended energy conservation standards that increase the first cost of room air conditioners would result in lower total shipments.

12.4.7 Production Costs

Manufacturing a higher-efficiency product is typically more costly than manufacturing a baseline product due to the use of more complex components and higher-cost raw materials. The changes in the MPCs of the analyzed products can affect revenues, gross margins, and cash flow of the industry, making these data a key GRIM input for DOE’s analysis.

For the MIA, DOE used the cost-efficiency curves derived in the engineering analysis (detailed in chapter 5 and appendix 5-A of the TSD) for the year 2009 using appropriate production volume estimates. For instance, more efficient products sold under existing energy conservation standards are manufactured at lower production volumes than baseline efficiency products. Enacting more stringent energy conservation standards will increase production volumes of more efficient units. For clothes dryers, one cost-efficiency curve was developed for each product class. The same is true for each of the six representative room air conditioner product classes, with the exception of product class 3, for which two cost-efficiency curves were developed and averaged.

To develop the cost-efficiency curves for clothes dryers, DOE performed detailed product teardowns and cost modeling on several clothes dryer models spanning a range of efficiencies. These cost-efficiency relationships were compared to AHAM data and manufacturer feedback for validation. DOE also conducted standby power testing, as well as detailed energy performance testing at an independent laboratory to gain insights into energy performance in active, standby, and off modes, and disaggregated energy use of components and subsystems.

To develop the cost-efficiency curves for room air conditioners, in the absence of industry-supplied data, DOE conducted energy modeling analysis of the products obtained for reverse engineering analysis, product designs for R-410A refrigerant based on the reverse engineering products, and product designs using R-410A that incorporate energy-saving design options. The manufacturing cost model developed in conjunction with the reverse-engineering work was used to determine the incremental costs associated with the high-efficiency product designs evaluated in the energy modeling in order to allow development of cost-efficiency relationships for products using R-410A refrigerant. DOE supplemented these analyses with product testing at an independent laboratory and manufacturer interviews.

The GRIM also included the proportion of costs devoted to labor, materials, overhead, and depreciation that make up the full cost of production or MPCs for 2009. DOE estimated the proportion of costs associated with each cost category by using information from the engineering analysis. DOE used the same percentages for material, labor, and total overhead (depreciation and factory overhead) from the engineering analysis. For the MPC breakdown in the MIA, DOE used a depreciation value that is consistent with historical information in SEC 10-Ks. The remainder of total overhead was allocated to factory overhead. To calculate the incremental MPCs for products above the baseline, DOE added the incremental material, labor, and overhead costs from the engineering cost-efficiency curves to the baseline MPCs.

As discussed in the engineering analysis, the MSP is comprised of production costs (the direct manufacturing costs or MPCs), non-production costs (indirect costs like SG&A), and profit. The 2009 MSPs for residential clothes dryers are calculated by multiplying the 2009 MPCs by the appropriate manufacturer markup for that product. For room air conditioners, the 2009 MSP also includes shipping costs in addition to the 2009 MPC multiplied by the manufacturer markup.

Table 12.4.10 through Table 12.4.21 show the production cost estimates for 2009 used in the GRIM for the representative product classes for residential clothes dryers and room air conditioners.

Clothes Dryers Production Cost Estimates

Table 12.4.10 MPC Breakdown for Product Class 1 in 2009 - Electric Standard Vented Dryers

TSL (Efficiency Level)	CEF	Labor *$*	Material *$*	Overhead *$*	Depreciation *$*	MPC *$*	Mfr. Markup	MSP *$*
Baseline	3.55	23.86	147.86	21.11	8.63	201.46	1.26	253.84
TSL 1 (EL 1)	3.56	23.86	148.54	21.08	8.66	202.14	1.26	254.70
TSL 2 (EL 2)	3.61	23.86	148.68	21.07	8.67	202.27	1.26	254.86
TSL 3, TSL 4 (EL 3)	3.73	28.78	147.39	25.02	9.00	210.20	1.26	264.85
TSL 5 (EL 5)	4.08	36.01	212.33	29.58	12.44	290.35	1.26	365.84
TSL 6 (EL 6)	5.42	61.43	358.74	41.18	20.65	482.00	1.26	607.32

Table 12.4.11 MPC Breakdown for Product Class 2 in 2009 -Electric Compact Vented Dryers (120V)

TSL (Efficiency Level)	CEF	Labor *$*	Material *$*	Overhead *$*	Depreciation *$*	MPC *$*	Mfr. Markup	MSP *$*
Baseline, TSL 1 (Baseline)	3.43	25.62	101.69	74.21	9.02	210.54	1.26	265.28
TSL 2, TSL 3, TSL 4 (EL 2)	3.61	25.62	102.50	74.17	9.05	211.35	1.26	266.31
TSL 5 (EL 5)	4.08	39.49	165.56	101.10	13.70	319.85	1.26	403.01
TSL 6 (EL 6)	5.41	60.84	299.02	97.68	20.48	478.01	1.26	602.30

Table 12.4.12 MPC Breakdown for Product Class 3 in 2009 - Electric Compact Vented Dryers (240V)

TSL (Efficiency Level)	CEF	Labor *$*	Material *$*	Overhead *$*	Depreciation *$*	MPC *$*	Mfr. Markup	MSP *$*
Baseline, TSL 1 (Baseline)	3.12	25.62	101.69	74.21	9.02	210.54	1.26	265.28
TSL 2, TSL 3, TSL 4 (EL 2)	3.27	25.62	102.50	74.17	9.05	211.35	1.26	266.31
TSL 5 (EL 5)	3.60	39.49	165.56	101.10	13.70	319.85	1.26	403.01
TSL 6 (EL 6)	4.89	60.84	299.02	97.68	20.48	478.01	1.26	602.30

Table 12.4.13 MPC Breakdown for Product Class 4 in 2009 - Gas Vented Dryers

TSL (Efficiency Level)	CEF	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline	3.14	27.00	165.78	24.88	9.74	227.40	1.26	286.52
TSL 1 (EL 1)	3.16	27.00	166.46	24.85	9.77	228.08	1.26	287.38
TSL 2, TSL 3 (EL 2)	3.20	27.00	166.59	24.85	9.78	228.22	1.26	287.55
TSL 4 (EL 3)	3.30	30.06	170.25	26.08	10.13	236.52	1.26	298.02
TSL 5, TSL 6 (EL 5)	3.61	37.46	255.16	30.30	14.45	337.38	1.26	425.10

Table 12.4.14 MPC Breakdown for Product Class 5 in 2009 - Electric Compact (240V) Ventless Dryers

TSL (Efficiency Level)	CEF	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline, TSL 1, TSL 4 (Baseline)	2.55	60.57	175.42	299.36	23.96	559.31	1.26	704.73
TSL 2, TSL 3 (EL 2)	2.69	60.57	176.53	299.31	24.01	560.42	1.26	706.12
TSL 5 (EL 4)	2.80	67.23	201.94	321.49	26.44	617.11	1.26	777.55
TSL 6 (EL 5)	4.03	94.98	349.36	322.98	34.34	801.67	1.26	1,010.10

Table 12.4.15 MPC Breakdown for Product Class 6 in 2009 - Electric Combination Ventless Dryers

TSL (Efficiency Level)	CEF	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline, TSL 1, TSL 4 (Baseline)	2.08	87.83	322.21	361.34	34.52	805.90	1.26	1,015.44
TSL 2, TSL 3, TSL 5 (EL 4)	2.56	89.52	348.66	363.53	35.88	837.59	1.26	1,055.36
TSL 6 (EL 5)	3.69	126.09	527.62	402.46	47.27	1,103.44	1.26	1,390.33

Room Air Conditioner Production Cost Estimates

Table 12.4.16 MPC Breakdown for Product Class 1 in 2009 - Room Air Conditioners without Reverse Cycle and with Louvered Sides - Less than 6,000 Btu/h

TSL (Efficiency Level)	CEER	Labor $	Matl. $	Overhead $	Depr. $	MPC $	Shipping $	Mfr. Markup	MSP $
Baseline	9.5	22.43	99.88	21.16	6.42	149.89	3.86	1.26	192.73
TSL 1, TSL 3 (EL 1)	10.1	23.11	104.34	22.07	6.69	156.20	4.68	1.26	201.49
TSL 2 (EL 2)	10.6	23.44	109.62	23.36	7.00	163.42	7.22	1.26	213.13
TSL 4, TSL 5 (EL 3)	11.1	24.42	116.37	24.44	7.39	172.62	8.39	1.26	225.89
TSL 6 (EL 5)	11.7	24.42	169.47	22.16	9.67	225.72	8.39	1.26	292.79

Table 12.4.17 MPC Breakdown for Product Class 3 in 2009 - Room Air Conditioners without Reverse Cycle and with Louvered Sides - 8,000 to 13,999 Btu/h

TSL (Efficiency Level)	CEER	Labor $	Matl. $	Overhead $	Depr. $	MPC $	Shipping $	Mfr. Markup	MSP $
Baseline	9.7	30.54	137.22	20.54	8.43	196.73	8.33	1.26	256.21
TSL 1, TSL 2 (EL 2)	10.7	30.97	146.46	20.31	8.85	206.59	9.72	1.26	270.02
TSL 3, TSL 4 (EL 3)	10.9	31.04	149.13	20.23	8.97	209.37	9.95	1.26	273.76
TSL 5 (EL 4)	11.5	31.23	166.27	19.70	9.72	226.91	10.62	1.26	296.52
TSL 6 (EL 5)	12.0	32.60	208.84	19.46	11.68	272.57	15.36	1.26	358.80

Table 12.4.18 MPC Breakdown for Product Class 5A in 2009 - Room Air Conditioners without Reverse Cycle and with Louvered Sides - 20,000 to 24,999 Btu/h

TSL (Efficiency Level)	CEER	Labor $	Matl. $	Overhead $	Depr. $	MPC $	Shipping $	Mfr. Markup	MSP $
Baseline, TSL 3, TSL 5 (Baseline)	8.5	41.11	261.57	26.24	14.72	343.63	24.79	1.26	457.77
TSL 1, TSL 2, TSL 4 (EL 2)	9.4	43.01	277.27	26.85	15.54	362.67	27.22	1.26	484.19
TSL 6 (EL 4)	10.2	43.01	462.85	18.90	23.49	548.25	27.22	1.26	718.02

Table 12.4.19 MPC Breakdown for Product Class 5B in 2009 - Room Air Conditioners without Reverse Cycle and with Louvered Sides - 25,000 Btu/h and more

TSL (Efficiency Level)	CEER	Labor $	Matl. $	Overhead $	Depr. $	MPC $	Shipping $	Mfr. Markup	MSP $
Baseline, TSL 3, TSL 5 (Baseline)	8.5	42.24	305.08	26.61	16.74	390.66	29.75	1.26	521.98
TSL 4 (EL 1)	9.0	44.20	321.94	30.30	17.74	414.18	36.15	1.26	558.02
TSL 1, TSL 2 (EL 2)	9.4	45.33	347.33	29.39	18.89	440.94	36.46	1.26	592.04
TSL 6 (EL 3)	9.8	46.34	525.05	21.73	26.55	619.67	36.46	1.26	817.24

Table 12.4.20 MPC Breakdown for Product Class 8A in 2009 - Room Air Conditioners without Reverse Cycle and without Louvered Sides - 8,000 to 10,999 Btu/h

TSL (Efficiency Level)	CEER	Labor $	Matl. $	Overhead $	Depr. $	MPC $	Shipping $	Mfr. Markup	MSP $
Baseline	8.4	28.64	144.28	29.11	9.04	211.07	12.26	1.26	278.21
TSL 1, TSL 2 (EL 1)	9.3	29.02	148.50	28.92	9.24	215.68	12.26	1.26	284.02
TSL 3, TSL 4 (EL 2)	9.6	29.04	150.55	28.83	9.33	217.75	12.26	1.26	286.63
TSL 5 (EL 3)	10.0	29.04	160.51	28.41	9.75	227.71	12.26	1.26	299.17
TSL 6 (EL 4)	10.4	29.04	232.32	25.33	12.83	299.52	12.26	1.26	389.66

Table 12.4.21 MPC Breakdown for Product Class 8B in 2009 - Room Air Conditioners without Reverse Cycle and without Louvered Sides - 11,000 to 13,999 Btu/h

TSL (Efficiency Level)	CEER	Labor $	Matl. $	Overhead $	Depr. $	MPC $	Shipping $	Mfr. Markup	MSP $
Baseline	8.4	31.41	166.31	29.41	10.17	237.29	12.26	1.26	311.25
TSL 1, TSL 2 (EL 1)	9.3	32.04	177.28	29.02	10.67	249.01	12.26	1.26	326.02
TSL 3, TSL 4, TSL 5 (EL 2)	9.5	32.51	180.40	28.95	10.82	252.68	12.26	1.26	330.64
TSL 6 (EL 4)	10.0	32.55	258.32	25.62	14.17	330.65	12.26	1.26	428.88

DOE also incorporated learning over time into the analysis, which affects the MPC and MSPs over time. These prices trends impact the MIA results by changing industry revenue and cash flow. For the MIA, DOE used the same learning rates as used in the NIA from the base year of the analysis, 2011, through the end of the analysis period. DOE also assumed that MPCs and MSPs were similarly impacted by the learning rates in both the base case and standards cases. See the LCC and NIA chapters 8 and 10 for a description of how DOE incorporated learning rates into the analysis.

12.4.8 Conversion Costs

Amended energy conservation standards typically cause manufacturers to incur one-time conversion costs to bring their production facilities and product designs into compliance with new regulations. For the MIA, DOE classified these one-time conversion costs into two major groups: capital conversion costs and product conversion costs. Capital conversion costs are one-time investments in PPE to adapt or change existing production facilities so that new product designs can be fabricated and assembled under the new regulation. Product conversion costs are one-time investments in research, development, testing, marketing and other costs to make product designs comply with amended energy conservation standards. The following sections describe the inputs DOE used in the GRIM in greater detail.

12.4.8.1 Clothes Dryer Product and Capital Conversion Costs

For clothes dryers, DOE based its conversion cost estimates that would be required to meet each TSL on information obtained from manufacturer interviews, the design pathways analyzed in the engineering analysis, and market information about the number of products that would require modification at each efficiency level. Because no energy label is currently prescribed for clothes dryers, and because clothes dryers are not part of the ENERGY STAR program, the best source of clothes dryer efficiency information is the CEC product database. DOE segmented each product on the CEC website into its appropriate product class using energy source, drum capacity, voltage, and combination unit information. DOE then searched manufacturer websites and numerous retail websites to determine which clothes dryers were current products. DOE assigned each product currently produced into efficiency levels using the reported energy factor. Finally, DOE assigned each of these products into product lines, classifying each group of products made by same manufacturer with identical drum capacities and energy factors into the same product line.

DOE calculated the product and capital conversion costs at each efficiency level for every product class by multiplying the total number of product lines that fell below the required efficiency by an estimate of the conversion costs to reach that efficiency level. DOE calculated the total product development required at each efficiency level by estimating the necessary engineering resources required to implement the design options in the engineering analysis at the efficiency level across a product line. DOE calculated the total capital conversion costs required at each efficiency level by estimating the additional equipment and changes to existing equipment that would be required to implement the design option in the engineering analysis at that efficiency level across a product line.

Table 12.4.22 through Table 12.4.27 show DOE's estimates of the product and capital conversion costs necessary for each clothes dryer product class at each TSL.

DOE also accounted for the conversion costs necessary for the industry to comply with the UL fire containment standard. See section 12.7.3.3 for a description of how DOE calculated the conversion costs for the UL fire containment regulation.

Table 12.4.22 Product and Capital Conversion Costs for Product Class 1 - Electric Standard Vented Dryers by TSL

TSL (Efficiency Level)	CEF	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 1 (EL 1)	3.56	Standby - Switchmode PS	2.8	-
TSL 2 (EL 2)	3.61	EL 1 Design Options + Standby - Transformerless PS	3.1	-
TSL 3, TSL 4 (EL 3)	3.73	EL 2 Design Options + Back-back airflow, Dedicated heater duct	15.7	46.2
TSL 5 (EL 5)	4.08	EL 3 Design Options + IEL 1 + 2-Stage Modulating Heat IEL 2 + Inlet Air Preheating, ECM Fan Motor	84.5	165.6
TSL 6 (EL 6)	5.42	EL 5 Design Options + Heat Pump	275.5	347.5

Table 12.4.23 Product and Capital Conversion Costs for Product Class 2 - Electric Compact Vented Dryers (120V) by TSL

TSL (Efficiency Level)	CEF	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 2, TSL 3, TSL 4 (EL 2)	3.61	Standby - Switchmode PS Standby - Transformerless PS	0.1	-
TSL 5 (EL 5)	4.08	EL 2 Design Options + Back-back airflow, Dedicated heater duct IEL 1 + 2-Stage Modulating Heat IEL 2 + Inlet Air Preheating, ECM Fan Motor	1.8	3.5
TSL 6 (EL 6)	5.41	EL 5 Design Options + Heat Pump	5.5	7.0

Table 12.4.24 Product and Capital Conversion Costs for Product Class 3 - Electric Compact Vented Dryers (240V) by TSL

TSL (Efficiency Level)	CEF	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 2, TSL 3, TSL 4 (EL 2)	3.27	Standby - Switchmode PS Standby - Transformerless PS	0.2	-
TSL 5 (EL 5)	3.60	EL 2 Design Options + Back-back airflow, Dedicated heater duct IEL 1 + 2-Stage Modulating Heat IEL 2 + Inlet Air Preheating, ECM Fan Motor	5.3	10.4
TSL 6 (EL 6)	4.89	EL 5 Design Options + Heat Pump	16.5	20.9

Table 12.4.25 Product and Capital Conversion Costs for Product Class 4 - Gas Vented Dryers by TSL

TSL (Efficiency Level)	CEF	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 1 (EL 1)	3.16	Standby - Switchmode PS	1.5	-
TSL 2, TSL 3 (EL 2)	3.20	EL 1 Design Options + Standby - Transformerless PS	1.7	-
TSL 4 (EL 3)	3.30	EL 2 Design Options + Back-back airflow, Dedicated heater duct	8.4	24.8
TSL 5, TSL 6 (EL 5)	3.61	EL 3 Design Options + IEL 1 + 2-Stage Modulating Heat IEL 2 + Inlet Air Preheating, ECM Fan Motor	73.9	144.9

Table 12.4.26 Product and Capital Conversion Costs for Product Class 5 - Electric Compact (240V) Ventless Dryers by TSL

TSL (Efficiency Level)	CEF	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 2, TSL 3 (EL 2)	2.69	Standby - Switchmode PS Standby - Transformerless PS	0.1	-
TSL 5 (EL 4)	2.80	EL 2 Design Options + Back-back airflow IEL 3 + 2-Stage Modulating Heat	0.3	1.8
TSL 6 (EL 5)	4.03	EL 4 Design Options + Heat Pump	4.0	5.3

Table 12.4.27 Product and Capital Conversion Costs for Product Class 6 - Electric Combination Ventless Dryers by TSL

TSL (Efficiency Level)	CEF	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 2, TSL 3, TSL 5 (EL 4)	2.56	Baseline ATT Standby - Switchmode PS Standby - Transformerless PS IEL 3 + 2-Stage Modulating Heat	0.3	1.8
TSL 6 (EL 5)	3.69	EL 4 Design Options + Heat Pump	8.0	10.5

12.4.8.2 Room Air Conditioner Product and Capital Conversion Costs

While DOE's calculation of conversion costs for room air conditioners was similar to the calculation of conversion costs for clothes dryers, DOE used a slightly different approach to determine the number of product lines at each efficiency level. DOE used the CEC appliance database to determine what models currently exist on the market for room air conditioners and verified these current products through manufacturer and retail websites. DOE eliminated products in the database that were discontinued due to the recent refrigerant switch to R-410A. DOE segmented each product from the CEC database into its appropriate product class using cooling capacity, the existence of louvers, and type of room air conditioner. DOE assigned each product currently produced into efficiency levels using the reported EER. Finally, DOE determined a representative distribution of the industry by extrapolating the information for manufacturers for which it had complete efficiency information to account for the product lines of all manufacturers.

Like its method for clothes dryers, DOE calculated the industry wide conversion costs by multiplying the number of product lines in each product class that fell below the required efficiency by its estimate of the product and capital conversion costs. DOE's estimate was based on the design options at each efficiency level in the engineering analysis. DOE's per line product conversion costs were calculated by estimating the product development time required to make the design change across a product family. For component switch outs, DOE assumed that design changes for components that interacted with other parts of the room air conditioner would be more costly than one-for-one switch outs because these components would require greater engineering effort to be adapted into new product designs. For capital conversion costs, DOE assumed based on manufacturer feedback that the only design changes that would require changes to existing equipment were larger chassis volumes, evaporator changes, and condenser changes.

Table 12.4.28 through Table 12.4.33 show DOE's estimates of the product and capital conversion costs necessary for each room air conditioner product class at each TSL.

Table 12.4.28 Product and Capital Conversion Costs for Product Class 1 - Room Air Conditioners without Reverse Cycle and with Louvered Sides - Less than 6,000 Btu/h by TSL

TSL (Efficiency Level)	CEER	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 1, TSL 3 (EL 1)	10.1	Standby Reduction Increase evaporator width Increase chassis volume	12.7	18.7
TSL 2 (EL 2)	10.6	EL 1 Design Options + Increase chassis volume further	20.1	41.4
TSL 4, TSL 5 (EL 3)	11.1	EL 2 Design Options + Increase Condenser to 3 Tubes	31.7	56.7
TSL 6 (EL 5)	11.7	EL 3 Design Options + Increase PSC Efficiency Increase Evaporator Fin Thickness DC Brushless Motor	41.6	63.0

Table 12.4.29 Product and Capital Conversion Costs for Product Class 3 - Room Air Conditioners without Reverse Cycle and with Louvered Sides - 8,000 to 13,999 Btu/h by TSL

TSL (Efficiency Level)	CEER	Design Options Considered (8,000 Btu/h unit)	Design Options Considered (12,000 Btu/h unit)	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 1, TSL 2 (EL 2)	10.7	Increase Compressor Efficiency Standby Reduction Increase chassis volume	Add Subcooler Increase Compressor Efficiency	7.3	13.3
TSL 3, TSL 4 (EL 3)	10.9	EL 2 Design Options + Increase chassis volume further	EL 2 Design Options + 10 EER Compressor	20.4	38.6
TSL 5 (EL 4)	11.5	EL 3 Design Options + Increase PSC Efficiency Increase chassis volume further	EL 3 Design Options + Standby Reduction Increase PSC Efficiency	31.3	41.2
TSL 6 (EL 5)	12.0	EL 4 Design Options + Increase chassis volume further DC Brushless Motor	EL 4 Design Options + Increase Evaporator Rows to 4 Rows Increase chassis volume	54.2	91.9

Table 12.4.30 Product and Capital Conversion Costs for Product Class 5A - Room Air Conditioners without Reverse Cycle and with Louvered Sides - 20,000 to 24,999 Btu/h by TSL

TSL (Efficiency Level)	CEER	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 1, TSL 2, TSL 4 (EL 2)	9.4	Increase chassis volume Add a fourth condenser row Standby Reduction	0.7	4.5
TSL 6 (EL 4)	10.2	EL 2 Design Options + Increase Compressor Efficiency Increase PSC Efficiency DC Brushless Motor	3.3	16.6

Table 12.4.31 Product and Capital Conversion Costs for Product Class 5B - Room Air Conditioners without Reverse Cycle and with Louvered Sides - 25,000 Btu/h and more by TSL

TSL (Efficiency Level)	CEER	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 4 (EL 1)	9.0	Increase chassis volume	0.2	6.4
TSL 1, TSL 2 (EL 2)	9.4	EL 1 Design Options + Standby Reduction Increase Compressor Efficiency Add a fourth condenser row	0.7	9.0
TSL 6 (EL 3)	9.8	EL 2 Design Options + Increase PSC Efficiency DC Brushless Motor	1.9	18.1

Table 12.4.32 Product and Capital Conversion Costs for Product Class 8A - Room Air Conditioners without Reverse Cycle and without Louvered Sides - 8,000 to 10,999 Btu/h by TSL

TSL (Efficiency Level)	CEER	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 1, TSL 2 (EL 1)	9.3	Increase evaporator width	0.3	0.1
TSL 3, TSL 4 (EL 2)	9.6	EL 1 Design Options + Add Subcooler Increase Compressor Efficiency	6.7	1.6
TSL 5 (EL 3)	10.0	EL 2 Design Options + Standby Reduction Increase PSC Efficiency	9.8	1.8
TSL 6 (EL 4)	10.4	EL 3 Design Options + DC Brushless Motor	11.9	1.9

Table 12.4.33 Product and Capital Conversion Costs for Product Class 8B - Room Air Conditioners without Reverse Cycle and without Louvered Sides - 11,000 to 13,999 Btu/h by TSL

TSL (Efficiency Level)	CEER	Design Options Considered	Product Conversion Costs *2009$ millions*	Capital Conversion Costs *2009$ millions*
TSL 1, TSL 2 (EL 1)	9.3	Increase Compressor Efficiency	0.3	0.3
TSL 3, TSL 4, TSL 5 (EL 2)	9.5	EL 1 Design Options + Increase evaporator width	1.5	1.6
TSL 6 (EL 4)	10.0	EL 2 Design Options + Standby Reduction Increase PSC Efficiency DC Brushless Motor	4.1	2.0

12.4.9 Markup Scenarios

DOE used several standards case markup scenarios to represent the uncertainty about the impacts of amended energy conservation standards on prices and profitability. In the base case, DOE used the same baseline markups calculated in the engineering analysis for all product classes. In the standards case, DOE modeled 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 flat markup scenario, and (2) a preservation of operation profit scenario. These scenarios lead to different markups values, which, when applied to the inputted MPCs, result in varying revenue and cash flow impacts.

12.4.9.1 Flat Markup Scenario

The flat markup scenario assumes that the cost of goods sold for each product is marked up by a flat percentage to cover standard SG&A expenses, R&D expenses, and profit. The flat markup scenario uses the baseline manufacturer markup (discussed in chapter 6 of the direct final rule TSD) for all products in both the base case and the standards case. To derive this percentage, DOE evaluated publicly available financial information for manufacturers of major household appliances whose product offerings include clothes dryers and room air conditioners. DOE also requested feedback on this value during manufacturer interviews. This scenario represents the upper bound of industry profitability in the standards case because under this scenario, manufacturers are able to fully pass through additional costs due to standards to their customers.

12.4.9.2 Preservation of Operating Profit Scenario

DOE also modeled a lower bound profitability scenario. In this scenario, the manufacturer markups are lowered such that, in the standards case, manufacturers are able to maintain only the base-case total operating profit in absolute dollars, despite higher product costs and investment. DOE implemented this scenario in GRIM by lowering the manufacturer markups at each TSL to yield approximately the same earnings before interest and taxes in the standards case in the year after the compliance date of the amended standards as in the base case. For clothes dryers in the preservation of operating profit scenario, DOE assumed that the industry wide impacts would occur under the new minimum efficiency levels. DOE altered the markups only for the minimally compliant products in this scenario, with margin impacts not occurring for products that already exceed the amended energy conservation standard. For room air conditioners, DOE assumed that the margin impacts would affect the minimally compliant products at the amended energy conservation standards and the next highest efficiency level. The NIA analyzed an efficiency migration in both the base case and the standards case due to the assumption that manufacturers will produce increasingly more efficient room air conditioners as ENERGY STAR levels for these products change over time, Therefore, under amended energy conservation standards the shipment weighted average efficiency increases from the new minimum standard to higher efficiency levels. DOE assumed this market shift caused by standards would impact margins on products that also become the de facto minimally efficient product over time. For both clothes dryers and room air conditioners, the preservation of operating profit represents the lower bound of industry profitability following amended energy conservation standards because under this scenario, higher production costs and the investments required to comply with the amended energy conservation standard do not yield additional operating profit.

While DOE used the same markup scenarios for clothes dryers and room air conditioners, DOE captured different concerns for each industry by modeling the preservation of operating profit scenario. For clothes dryers, manufacturers were particularly concerned about the inability to markup the full cost of production. Because there is currently no energy label requirement or ENERGY STAR program for clothes dryers, the lack of consumer information makes it more difficult for customers to calculate individual payback and energy savings. Consequently, the manufacturing cost for more efficient clothes dryers could not be fully marked up because energy efficiency, unlike price and other features, is not a factor in the purchasing decision of most consumers. Manufacturers also cited the highly competitive market, the concentrated retail market that represents the majority of sales, and price points that are fixed partly by paired washing machines as other reasons that additional production costs would not yield higher profits in the standards case.

For room air conditioners, manufacturers stated that higher production costs could severely harm profitability. Manufacturers already earn very little profit on the small, high-volume window units due to the enormous price pressure retailers exert because of their purchasing power, and due to fierce competition within the room air conditioner industry. Manufacturers accept lower absolute profit on these units with the expectation of making a larger per unit profit on other more costly products. They also do so because maintaining high production volumes of these units allows manufacturers to keep factories utilized and to achieve purchasing economies. In addition, because many purchases are impulse buys during periods of atypically warm weather for products that are used sparingly, any increase in first cost could impact these types of sales. Therefore, manufacturers were skeptical that customers would accept the full additional cost of production.

Table 12.4.34 through Table 12.4.39 lists the products DOE analyzed with the corresponding markups at each TSL for clothes dryers. Table 12.4.40 through Table 12.4.45 lists the products DOE analyzed with the corresponding markups at each TSL for room air conditioners.

Clothes Dryers Preservation of Operating Profit Manufacturer Markups

Table 12.4.34 Preservation of Operating Profit Markups for Product Class 1 - Electric Standard Vented Dryers

EL (CEF)	Markups by TSL						
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**	**TSL 6**
Baseline (3.55)	1.2600	-	-	-	-	-	-
EL 1 (3.56)	1.2600	1.2600	-	-	-	-	-
EL 2 (3.61)	1.2600	1.2600	1.2600	-	-	-	-
EL 3 (3.73)	1.2600	1.2600	1.2600	1.2579	1.2579	-	-
EL 4 (3.81)	1.2600	1.2600	1.2600	1.2600	1.2600	-	-
EL 5 (4.08)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2412	-
EL 6 (5.42)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2269

Table 12.4.35 Preservation of Operating Profit Markups for Product Class 2 - Electric Compact Vented Dryers (120V)

EL (CEF)	Markups by TSL						
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**	**TSL 6**
Baseline (3.43)	1.2600	1.2600	-	-	-	-	-
EL 1 (3.48)	1.2600	1.2600	-	-	-	-	-
EL 2 (3.61)	1.2600	1.2600	1.2597	1.2597	1.2597	-	-
EL 3 (3.72)	1.2600	1.2600	1.2600	1.2600	1.2600	-	-
EL 4 (3.80)	1.2600	1.2600	1.2600	1.2600	1.2600	-	-
EL 5 (4.08)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2376	-
EL 6 (5.41)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2272

Table 12.4.36 Preservation of Operating Profit Markups for Product Class 3 - Electric Compact Vented Dryers (240V)

EL (CEF)	Markups by TSL						
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
Baseline (3.12)	1.2600	1.2600	-	-	-	-	-
EL 1 (3.16)	1.2600	1.2600	-	-	-	-	-
EL 2 (3.27)	1.2600	1.2600	1.2598	1.2598	1.2598	-	-
EL 3 (3.36)	1.2600	1.2600	1.2600	1.2600	1.2600	-	-
EL 4 (3.48)	1.2600	1.2600	1.2600	1.2600	1.2600	-	-
EL 5 (3.60)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2399	-
EL 6 (4.89)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2284

Table 12.4.37 Preservation of Operating Profit Markups for Product Class 4 - Gas Vented Dryers

EL (CEF)	Markups by TSL						
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
Baseline (3.14)	1.2600	-	-	-	-	-	-
EL 1 (3.16)	1.2600	1.2599	-	-	-	-	-
EL 2 (3.20)	1.2600	1.2600	1.2600	1.2600	-	-	-
EL 3 (3.30)	1.2600	1.2600	1.2600	1.2600	1.2584	-	-
EL 4 (3.42)	1.2600	1.2600	1.2600	1.2600	1.2600	-	-
EL 5 (3.61)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2402	1.2402

Table 12.4.38 Preservation of Operating Profit Markups for Product Class 5 - Electric Compact (240V) Ventless Dryers

EL (CEF)	Markups by TSL						
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
Baseline (2.55)	1.2600	1.2600	-	-	1.2600	-	-
EL 1 (2.59)	1.2600	1.2600	-	-	1.2600	-	-
EL 2 (2.69)	1.2600	1.2600	1.2571	1.2571	1.2600	-	-
EL 3 (2.71)	1.2600	1.2600	1.2600	1.2600	1.2600	-	-
EL 4 (2.80)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2513	-
EL 5 (4.03)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2391

Table 12.4.39 Preservation of Operating Profit Markups for Product Class 6 - Electric Combination Ventless Dryers

EL (CEF)	Markups by TSL						
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
Baseline (2.08)	1.2600	1.2600	-	-	1.2600	-	-
EL 1 (2.35)	1.2600	1.2600	-	-	1.2600	-	-
EL 2 (2.38)	1.2600	1.2600	-	-	1.2600	-	-
EL 3 (2.46)	1.2600	1.2600	-	-	1.2600	-	-
EL 4 (2.56)	1.2600	1.2600	1.2548	1.2548	1.2600	1.2548	-
EL 5 (3.69)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2410

Room Air Conditioner Preservation of Operating Profit Manufacturer Markups

Table 12.4.40 Preservation of Operating Profit Markups for Product Class 1 - Room Air Conditioners without Reverse Cycle and with Louvered Sides - Less than 6,000 Btu/h

EL (CEER)	Markups by TSL						
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
Baseline (9.5)	1.2600	-	-	-	-	-	-
EL 1 (10.1)	1.2600	1.2565	-	1.2565	-	-	-
EL 2 (10.6)	1.2600	1.2528	1.2528	1.2528	-	-	-
EL 3 (11.1)	1.2600	1.2600	1.2485	1.2600	1.2485	1.2485	-
EL 4 (11.4)	1.2600	1.2600	1.2600	1.2600	1.2446	1.2446	-
EL 5 (11.7)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2308

Table 12.4.41 Preservation of Operating Profit Markups for Product Class 3 - Room Air Conditioners without Reverse Cycle and with Louvered Sides - 8,000 to 13,999 Btu/h

EL (CEER)	Markups by TSL						
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**	**TSL 6**
Baseline (9.7)	1.2600	-	-	-	-	-	-
EL 1 (10.2)	1.2600	-	-	-	-	-	-
EL 2 (10.7)	1.2600	1.2558	1.2558	-	-	-	-
EL 3 (10.9)	1.2600	1.2547	1.2547	1.2547	1.2547	-	-
EL 4 (11.5)	1.2600	1.2600	1.2600	1.2484	1.2484	1.2484	-
EL 5 (12.0)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2358	1.2358

Table 12.4.42 Preservation of Operating Profit Markups for Product Class 5A - Room Air Conditioners without Reverse Cycle and with Louvered Sides - 20,000 to 24,999 Btu/h

EL (CEER)	Markups by TSL						
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**	**TSL 6**
Baseline (8.5)	1.2600	-	-	1.2600	-	1.2600	-
EL 1 (9.0)	1.2600	-	-	1.2600	-	1.2600	-
EL 2 (9.4)	1.2600	1.2554	1.2554	1.2600	1.2554	1.2600	-
EL 3 (9.8)	1.2600	1.2488	1.2488	1.2600	1.2488	1.2600	-
EL 4 (10.2)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2275

Table 12.4.43 Preservation of Operating Profit Markups for Product Class 5B - Room Air Conditioners without Reverse Cycle and with Louvered Sides - 25,000 Btu/h and more

EL (CEER)	Markups by TSL						
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**	**TSL 6**
Baseline (8.5)	1.2600	-	-	1.2600	-	1.2600	-
EL 1 (9.0)	1.2600	-	-	1.2600	1.2551	1.2600	-
EL 2 (9.4)	1.2600	1.2501	1.2501	1.2600	1.2501	1.2600	-
EL 3 (9.8)	1.2600	1.2278	1.2278	1.2600	1.2600	1.2600	1.2278

Table 12.4.44 Preservation of Operating Profit Markups for Product Class 8A - Room Air Conditioners without Reverse Cycle and without Louvered Sides - 8,000 to 10,999 Btu/h

EL	Markups by TSL						
(CEER)	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
Baseline (8.4)	1.2600	-	-	-	-	-	-
EL 1 (9.3)	1.2600	1.2581	1.2581	-	-	-	-
EL 2 (9.6)	1.2600	1.2573	1.2573	1.2573	1.2573	-	-
EL 3 (10.0)	1.2600	1.2600	1.2600	1.2536	1.2536	1.2536	-
EL 4 (10.4)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2343	1.2343

Table 12.4.45 Preservation of Operating Profit Markups for Product Class 8B - Room Air Conditioners without Reverse Cycle and without Louvered Sides - 11,000 to 13,999 Btu/h

EL	Markups by TSL						
(CEER)	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
Baseline (8.4)	1.2600	-	-	-	-	-	-
EL 1 (9.3)	1.2600	1.2559	1.2559	-	-	-	-
EL 2 (9.5)	1.2600	1.2547	1.2547	1.2547	1.2547	1.2547	-
EL 3 (9.8)	1.2600	1.2600	1.2600	1.2514	1.2514	1.2514	-
EL 4 (10.0)	1.2600	1.2600	1.2600	1.2600	1.2600	1.2600	1.2354

12.5 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, the GRIM estimated indicators of financial impacts on the residential clothes dryer and room air conditioner industries. The main results of the MIA are also reported in this section. The MIA consists of two key financial metrics: INPV and annual cash flows.

12.5.1 Introduction

The INPV measures the industry value and is used in the MIA to compare the economic impacts of different TSLs in the standards case. The INPV is different from DOE's NPV, which is applied to the U.S. economy. The INPV is the sum of all net cash flows discounted at the industry's cost of capital, or discount rate. The clothes dryer and room air conditioner GRIMs estimate cash flows from 2011 to 2043. This timeframe models both the short-term impacts on the industry from the announcement of the standard until the compliance date (2011 until an estimated compliance date of January 2014) and a long-term assessment over the 30 year analysis period used in the NIA (2014 – 2043).

In the MIA, DOE compares the INPV of the base case (no amended energy conservation standards) to that of each TSL in the standards case. The difference between the base case and a standards case INPV is an estimate of the economic impacts that implementing that particular TSL would have on the industry. For the clothes dryer and room air conditioner industries, DOE examined the two markup scenarios described above: the flat markup and the preservation of operating profit. DOE also notes that incorporating learning rates into the analysis impacts INPV in both the base and standards case. Since the trends for MPC and MSP using learning rates decline over the analysis period, the base case industry value is lower for all product groupings. Thus, incorporating learning rates in the MIA increases the relative impacts on INPV due to standards.

While INPV is useful for evaluating the long-term effects of amended energy conservation standards, short-term changes in cash flow are also important indicators of the industry's financial situation. For example, a large investment over one or two years could strain the industry's access to capital. Consequently, the sharp drop in financial performance could cause investors to flee, even though recovery may be possible. Thus, a short-term disturbance can have long-term effects that the INPV cannot capture. To get an idea of the behavior of annual net cash flows, Figure 12.5.1 through Figure 12.5.4 below present the annual net or free cash flows from 2010 through 2025 for the base case and different TSLs in the standards case.

Because the same markup scenarios are used for clothes dryers and room air conditioners, each of the figures below has a similar shape. Annual cash flows are discounted to the base year, 2011. Between 2011 and the 2014 compliance date of the amended energy conservation standard, cash flows are driven by the level of conversion costs and the proportion of these investments spent every year. After the standard announcement date (*i.e.*, the publication date of the final rule), industry cash flows begin to decline as companies use their financial resources to prepare for the amended energy conservation standard. The more stringent the amended energy conservation standard, the greater the impact on industry cash flows in the years leading up to the compliance date, as product conversion costs lower cash inflows from operations and capital conversion costs increase cash outflows for capital expenditures.

Free cash flow in the year the amended energy conservation standards take effect is driven by two competing factors. In addition to capital and product conversion costs, amended energy conservation standards could create stranded assets, *i.e.*, tooling and equipment that would have enjoyed longer use if the energy conservation standard had not made them obsolete. In this year, manufacturers write down the remaining book value of existing tooling and equipment whose value is affected by the amended energy conservation standard. This one time write down acts as a tax shield that alleviates decreases in cash flow from operations in the year of the write-down. In this year, there is also an increase in working capital that reduces cash flow from operations. A large increase in working capital is needed due to more costly production components and materials, higher inventory carrying to sell more expensive products, and higher accounts receivable for more expensive products. Depending on these two competing factors, cash flow can either be positively or negatively affected in the year the standard takes effect.

In the years following the compliance date of the standard, the impact on cash flow depends on the operating revenue. More stringent TSLs typically have a positive impact on cash flows relative to the base case under the flat markup scenario because manufacturers are able to earner higher operating profit at each TSL in the standards case, which increases cash flow from operations. There is very little impact on cash flow from operations under the preservation of operating profit scenario because this scenario is calibrated to have the same operating income in the standards case at each TSL as the base case as in the year after the standard takes effect. In this scenario, the industry value is impacted because production costs increase, but operating profit remains approximately equal to the base case which decreases profit margins as a percentage of revenue.

12.5.2 Residential Clothes Dryer Industry Financial Impacts

Table 12.5.1 through Table 12.5.2 provide the INPV estimates for the residential clothes dryer industry. Figure 12.5.1 through Figure 12.5.2 present the annual net cash flows for residential clothes dryers for each of the different markup scenarios.

Table 12.5.1 Changes in Industry Net Present Value for Residential Clothes Dryers (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level					
			1	2	3	4	5	6
INPV	*(2009$ millions)*	1,003.6	1,001.1	1,000.0	962.5	939.2	827.1	699.7
Change in INPV	*(2009$ millions)*	-	(2.6)	(3.6)	(41.13)	(64.46)	(176.5)	(303.9)
	(%)	-	-0.3%	-0.4%	-4.1%	-6.4%	-17.6%	-30.3%

*For tables in section 12.5, values in parenthesis indicate negative numbers

Table 12.5.2 Changes in Industry Net Present Value for Residential Clothes Dryers (Preservation of Operating Profit Markup Scenario)

	Units	Base Case	Trial Standard Level					
			1	2	3	4	5	6
INPV	*(2009$ millions)*	1,003.6	1,001.0	998.7	948.2	923.0	606.2	273.6
Change in INPV	*(2009$ millions)*	-	(2.6)	(4.9)	(55.46)	(80.63)	(397.4)	(730.0)
	(%)	-	-0.3%	-0.5%	-5.5%	-8.0%	-39.6%	-72.7%

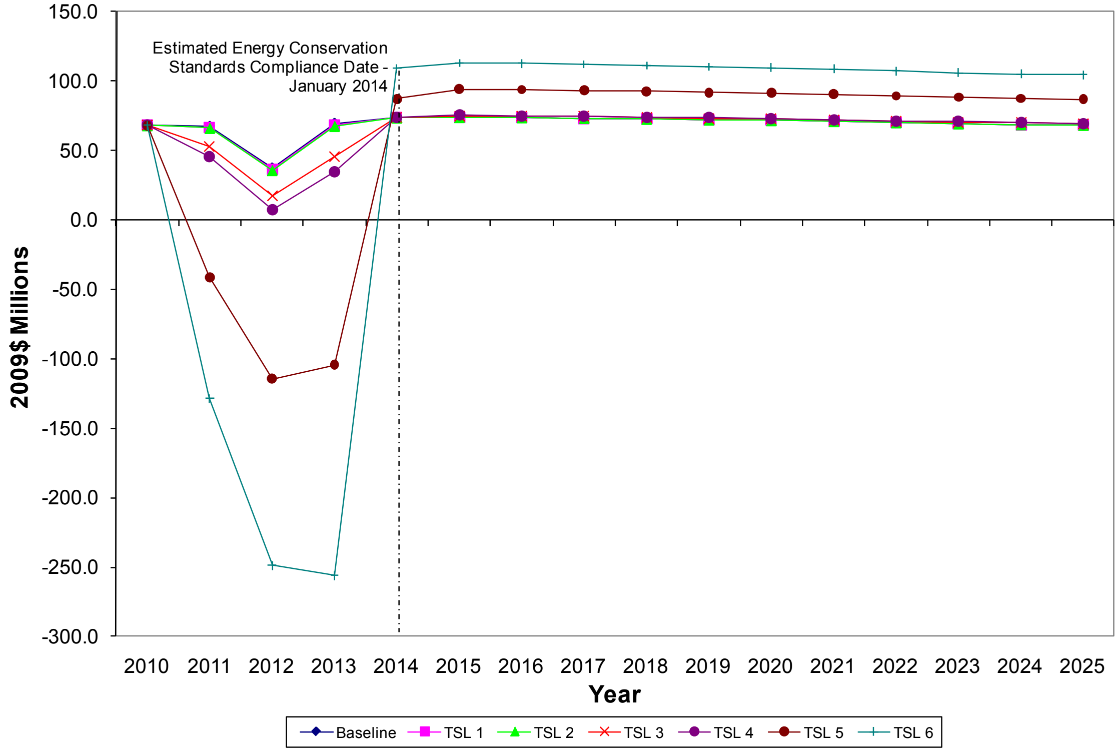

Figure 12.5.1 Annual Industry Net Cash Flows for Residential Clothes Dryers (Flat Markup Scenario)

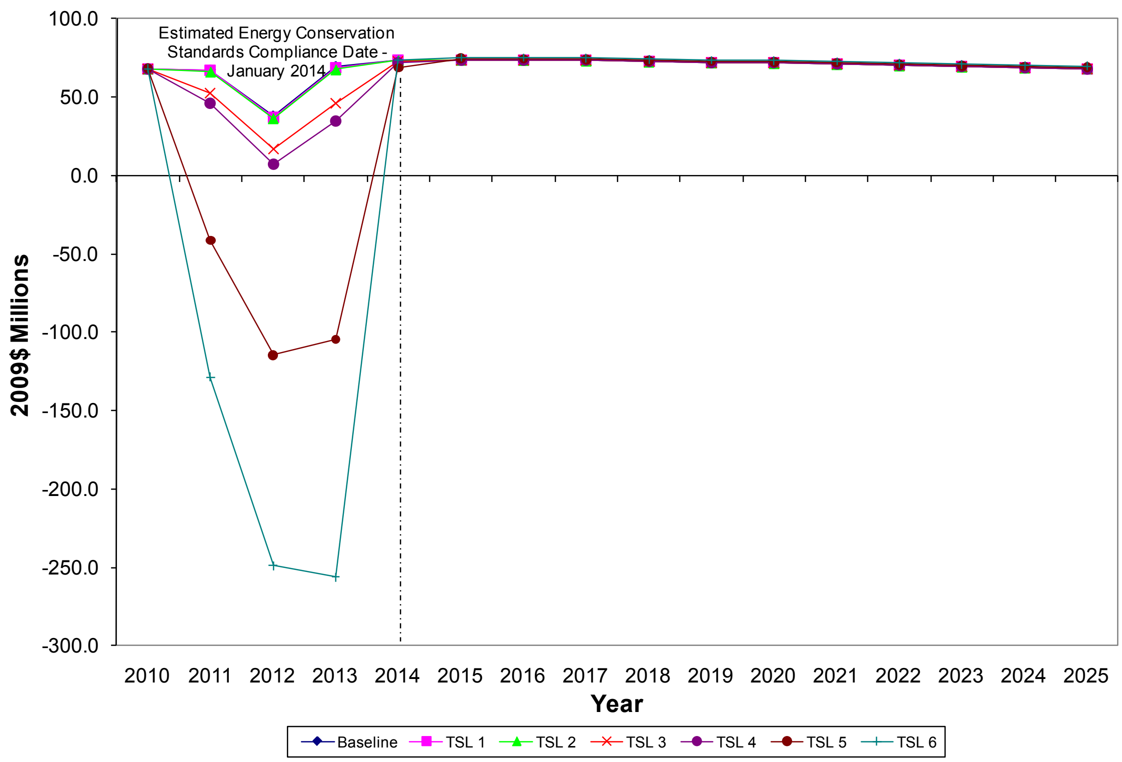

Figure 12.5.2 Annual Industry Net Cash Flows for Residential Clothes Dryers

(Preservation of Operating Profit Markup Scenario)

12.5.3 Room Air Conditioner Industry Financial Impacts

Table 12.5.3 through Table 12.5.4 provide the INPV estimates for the room air conditioner industry. Figure 12.5.3 through Figure 12.5.4 present the annual net cash flows for room air conditioners for each markup scenario.

Table 12.5.3 Changes in Industry Net Present Value for Room Air Conditioners (Flat Markup Scenario)

	Units	Base Case	TSL					
			1	2	3	4	5	6
INPV	*2009$ millions*	956.0	911.8	890.6	890.3	844.7	869.5	875.9
Change in INPV	*2009$ millions**	-	(44.2)	(65.4)	(65.7)	(111.3)	(86.6)	(80.2)
	%	-	-4.6%	-6.8%	-6.9%	-11.6%	-9.1%	-8.4%

*For tables in section 12.5.3, values in parenthesis indicate negative numbers

Table 12.5.4 Changes in Industry Net Present Value for Room Air Conditioners (Preservation of Operating Profit Markup Scenario)

	Units	Base Case	TSL					
			1	2	3	4	5	6
INPV	*2009$ millions*	956.0	871.1	843.3	843.6	778.4	771.6	611.5
Change in INPV	*2009$ millions*	-	(84.9)	(112.7)	(112.4)	(177.6)	(184.4)	(344.5)
	%	-	-8.9%	-11.8%	-11.8%	-18.6%	-19.3%	-36.0%

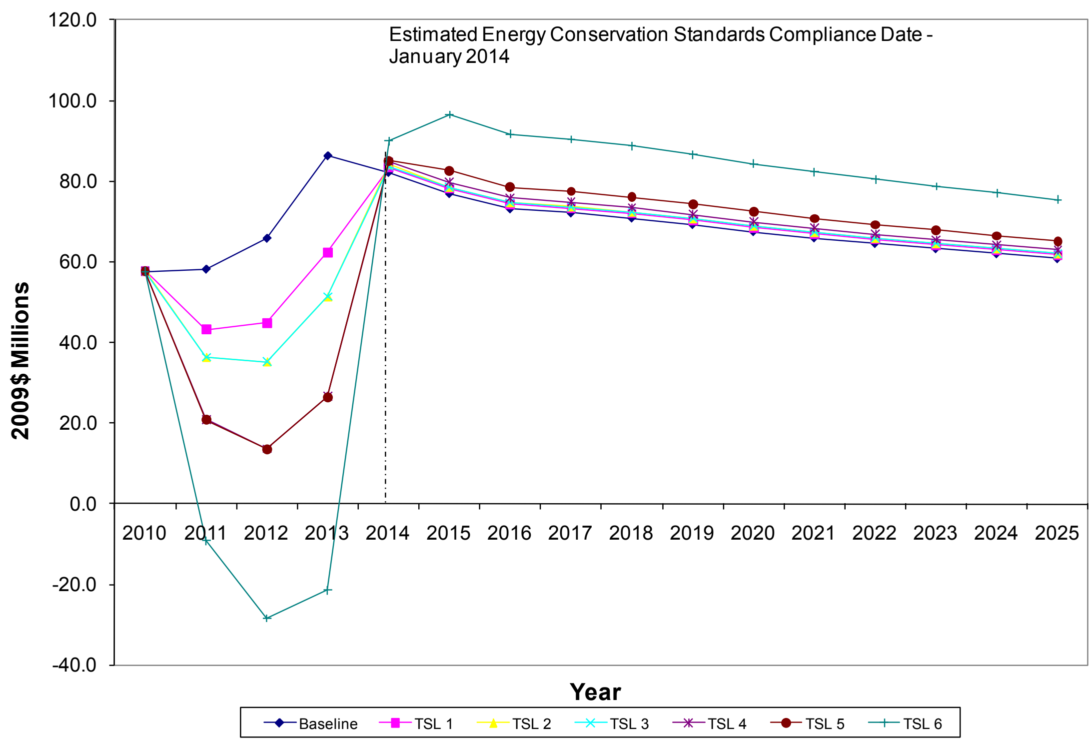

Figure 12.5.3 Annual Industry Net Cash Flows for Room Air Conditioners (Flat Markup

Scenario)

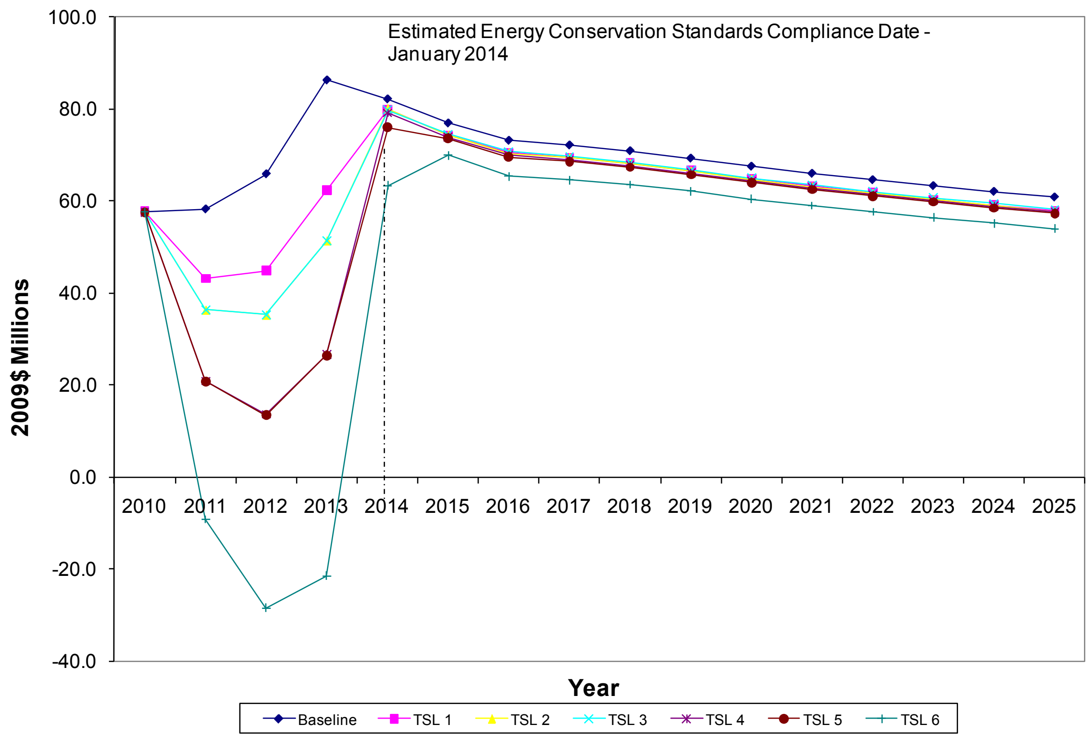

Figure 12.5.4 Annual Industry Net Cash Flows for Room Air Conditioners (Preservation of Operating Profit Markup Scenario)

12.6 IMPACTS ON SMALL RESIDENTIAL CLOTHES DRYER AND ROOM AIR CONDITIONER MANUFACTURERS

DOE conducted a more focused inquiry of the companies that could be small business manufacturers of products covered by this rulemaking. During its market survey, DOE used all available public information to identify potential small manufacturers. DOE's research included the AHAM membership directory, product databases (the AHRI, AHAM, CEC, and ENERGY STAR databases), individual company websites, and the SBA dynamic small business search to find potential small business manufacturers. DOE also asked stakeholders and industry representatives if they were aware of any other small business manufacturers during manufacturer interviews and at previous DOE public meetings. DOE reviewed all publicly-available data and contacted various companies, as necessary, to determine whether they met the SBA's definition of a small business manufacturer of covered residential clothes dryers or room air conditioners. DOE screened out companies that did not offer products covered by this rulemaking, did not meet the definition of a "small business," or are foreign owned and operated.

DOE initially identified at least 14 distinct brands of residential clothes dryers sold in the United States. DOE determined that 13 of these companies exceeded the SBA's maximum number of employees or foreign-owned and operated. Thus, DOE identified only one potential small business manufacturer of residential clothes dryers. DOE notes that while the potential small business manufacturer has developed a highly efficient technology that could be used by other manufacturers to increase the efficiency of clothes dryers, the company does not produce clothes dryers and the technology is not yet commercially available. DOE acknowledges that the technology developed by this small business is a potential design option for clothes dryers, but DOE does not believe this rulemaking would in any way affect the ability of this company to commercialize or sell its technology.

For room air conditioners, DOE initially identified at least 11 distinct brands of room air conditioners sold in the United States. DOE determined that 10 of these were large or foreign-owned and operated. DOE determined that the one room air conditioner manufacturer that was previously designated as a small business manufacturer was acquired by another company and now exceeds SBA's employment threshold for consideration as a small business under the appropriate NAICS code. As such, DOE did not identify any small business manufacturers of room air conditioners.

DOE did not conduct a more in-depth analysis of the potential impacts on small business manufacturers because there is only one potential small business manufacturer in the residential clothes dryer market, this potential small business has developed a technology that will not be impacted by amended energy conservation standards for clothes dryers, and because this business is not a manufacturer of clothes dryers. Additionally, DOE did not identify any small manufacturers of room air conditioners. As such, DOE does not believe small manufacturers would be significantly impacted by amended energy conservation standards.

12.7 OTHER IMPACTS

12.7.1 Employment

12.7.1.1 Residential Clothes Dryer Employment Impacts

For clothes dryers, DOE used the GRIM to estimate the domestic labor expenditures and number of domestic production workers in the base case and at each TSL from 2011 to 2043. DOE used statistical data from the most recent U.S. Census Bureau's 2008 Annual Survey of Manufacturers, the results of the engineering analysis, and interviews with manufacturers to determine the inputs necessary to calculate industry-wide labor expenditures and domestic employment levels. Labor expenditures for the manufacture of a product are a function of the labor intensity of the product, the sales volume, and an assumption that wages in real terms remain constant.

In the GRIM, DOE used the labor content of each product and the manufacturing production costs from the engineering analysis to estimate the annual labor expenditures in the clothes dryers and room air conditioner industries. DOE used Census data and interviews with manufacturers to estimate the portion of the total labor expenditures that is attributable to U.S. (i.e., domestic) labor.

The production worker estimates in this section only cover workers up to the line-supervisor level who are directly involved in fabricating and assembling a product within an Original Equipment Manufacturer (OEM) facility. Workers performing services that are closely associated with production operations, such as material handing with a forklift, are also included as production labor. DOE's estimates only account for production workers who manufacture the specific products covered by this rulemaking.

The employment impacts shown in Table 12.7.1 represent the potential production employment that could result following amended energy conservation standards. The upper end of the results in this table estimates the maximum change in the number of production workers after amended energy conservation standards must be met. The upper end of the results assumes manufacturers would continue to produce the same scope of covered products in the same production facilities. The upper end of the range also assumes that domestic production does not shift to lower-labor-cost countries. Because there is a real risk of manufacturers evaluating sourcing decisions in response to amended energy conservation standards, the lower end of the range of employment results in Table 12.7.1 includes the estimated total number of U.S. production workers in the industry who could lose their jobs if all existing production were moved outside of the United States. While the results present a range of employment impacts following the compliance date of amended energy conservation standards, the discussion below also includes a qualitative discussion of the likelihood of negative employment impacts at the various TSLs. Finally, the employment impacts shown are independent of the employment impacts from the broader U.S. economy, which are documented in chapter 13, Employment Impact Analysis, of the direct final rule TSD.

The GRIM forecasts the residential clothes dryer domestic labor expenditure for production labor in 2014 will be approximately $140 million. Using the $18.77 wage rate and 1,886 production hours per year per employee found in the 2008 ASM, the GRIM estimates there will be approximately 3,962 U.S. production employees involved in manufacturing residential clothes dryers covered by this rulemaking. In addition, DOE estimates that 304 non-production employees in the United States will support residential clothes dryer production.[f] The employment spreadsheet of the clothes dryer GRIM shows the annual domestic employment impacts in further detail. Approximately three-quarters of residential clothes dryers sold in the United States are manufactured domestically.

Table 12.7.1 illustrates the range of potential impacts of amended energy conservation standards on domestic production employment levels at each TSL for the residential clothes dryer market.

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[f] As defined in the 2008 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."

Table 12.7.1 Potential Changes in the Total Number of Domestic Residential Clothes Dryer Production Workers in 2014

	Trial Standard Level						
	Baseline	1	2	3	4	5	6
Total Number of Domestic Production Workers in 2014 (without changes in production locations)	3,962	3,962	3,965	4,370	4,420	5,040	6,218
Potential Changes in Domestic Production Workers in 2014*	-	0 - (3,962)	3 - (3,962)	408 - (3,962)	458 - (3,962)	1,078 - (3,962)	2,256 - (3,962)

*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.

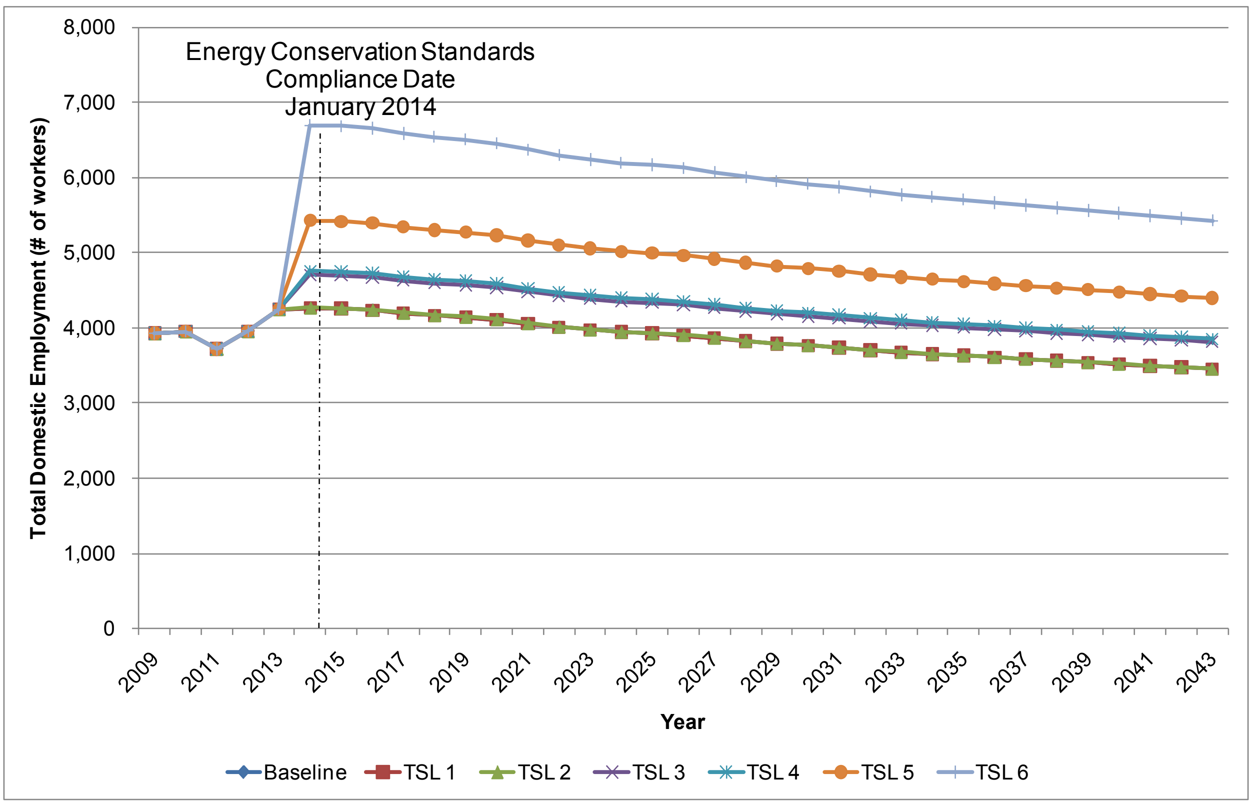

Figure 12.7.1 Total Residential Clothes Dryer Industry Domestic Employment by Year

All examined TSLs show relatively minor impacts on domestic employment levels at the lower end of the range. In particular, the design options used in the engineering analysis for TSL 1 and TSL 2 almost exclusively involve changes to standby power. These TSLs would not measurably impact domestic employment levels.

At TSL 3 through TSL 5, DOE analyzed design options for the most common product classes that would add labor content to the final product. If manufacturers continue to produce these more complex products in house, it is likely that employment would increase in response to the energy conservation standards. At TSL 3 through 5, greater levels of domestic production employment are also likely because, while requiring more labor, the product changes could be made within existing platforms. The ability to make product changes within existing platforms mitigates some of the pressure to find lower labor costs because this decision would add disruptions with suppliers and add capital costs. However, TSL 6 would effectively require heat pump clothes dryers for all electric units. Manufacturers indicated that such a drastic change to existing products could force them to consider moving domestic production to countries with lower labor costs. Besides the large capital conversion costs, the much higher labor content in heat pump clothes dryers would also put pressure on manufacturers to consider a lower-labor-cost country.

12.7.1.2 Room Air Conditioner Employment Impacts

DOE's research suggests that currently no room air conditioners are made domestically. All manufacturers or their domestic distributors do maintain offices in the United States to handle design, technical support, training, certification, and other requirements. As amended energy conservation standards for room air conditioners are implemented, however, DOE does not anticipate any changes in domestic employment levels.

12.7.2 Production Capacity

12.7.2.1 Residential Clothes Dryer Capacity Impacts

At TSL 1 through TSL 5, manufacturers could maintain capacity levels and continue to meet market demand under amended energy conservation standards. While the changes required at these TSLs would require changes that could be made within most existing designs, TSL 6, which would effectively require heat pump technology, could result in short-term capacity constraints. Significant changes to production facilities would be required if amended energy conservation standards effectively mandated heat pump clothes dryers at TSL 6. Several manufacturers stated that they could move all or part of their production if they were required exclusively manufacture heat pump clothes dryers. Because of these drastic changes, a 3-year time period between the announcement of the final rule and the compliance date of the amended energy conservation standard might not be sufficient to design and manufacture products that have yet to be introduced in the United States and which would require new dryer designs from each manufacturer that continued to offer electric clothes dryers for the United States market.

12.7.2.2 Room Air Conditioner Capacity Impacts

DOE anticipates that amended energy conservation standards would not significantly affect the production capacity of room air conditioner manufacturers. Manufacturers mentioned two issues that could potentially constrain capacity. One is the availability of high efficiency compressors, which are currently difficult to obtain. Because amended energy conservation standards would cause the demand for high efficiency compressors to increase, manufacturers worried that they would not be able to obtain the quantities they need to maintain desired production levels. DOE understands that compressor availability is a concern at present. DOE does not believe this shortage will continue when amended standards take effect in 2014 because the number of R-410A compressors available for the room air conditioner industry has already greatly expanded since the ban on R-22 took effect. Because there is a 3-year delay between the announcement of the final rule and the compliance date of the amended energy conservation standard, DOE believes suppliers will have sufficient time to anticipate demand and ramp up production of high efficiency compressors for room air conditioners.

The second potential capacity constraint involves changes to existing chassis sizes, which could be required by amended energy conservation standards. Manufacturers stated that increasing chassis volume requires significant product development and capital investments, which could severely disrupt production at their facilities. DOE understands that increasing chassis volume causes substantial conversion costs, which are quantified in the GRIM. DOE does not believe, however, that the proposed standards would significantly affect production capacity. Even though chassis size increases require large capital and product conversion costs, this design option is not required across all analyzed product classes. In addition, manufacturers were more concerned about the capital and product conversion costs to make these changes than having a three year implementation period to do so, and DOE has accounted for these costs in the establishment of the room air conditioner standards. DOE believes that room air conditioner manufacturers will be able to increase chassis volumes by 2014 while maintaining production capacity levels and continuing to meet market demand for all room air conditioner standard levels.

12.7.3 Cumulative Regulatory Burden

While any one regulation may not impose a significant burden on manufacturers, the combined effects of several impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. For the cumulative regulatory burden analysis, DOE looks at other significant product-specific regulations that could affect clothes dryer and room air conditioner manufacturers that will take effect 3 years before or after the compliance date of amended energy conservation standards for these products.[g] In addition to the amended energy conservation regulations on clothes dryers and room air conditioners, several other Federal regulations apply to these products and other equipment produced by the same manufacturers. While the cumulative regulatory burden focuses on the impacts on manufacturers of other Federal requirements, DOE also has described a number of other regulations in section 12.7.3.3 because it recognizes that these regulations also impact the products covered by this rulemaking.

Companies that produce a wide range of regulated products may be faced with more capital and product development expenditures than competitors with a narrower scope of products. Regulatory burdens can prompt companies to exit the market or reduce their product offerings, potentially reducing competition. Smaller companies in particular can be affected by regulatory costs since these companies have lower sales volumes over which they can amortize the costs of meeting new regulations. A proposed standard is not economically justified if it contributes to an unacceptable level of cumulative regulatory burden.

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[g] The compliance date for clothes dryers and room air conditioners is 3 years from the date of publication of the final rule (approximately January 2014).

12.7.3.1 DOE Regulations for Other Products Produced by Residential Clothes Dryer and Room Air Conditioner Manufacturers

In addition to the amended energy conservation standards on clothes dryers and room air conditioners, several other Federal regulations and pending regulations apply to other products produced by the same manufacturers. DOE recognizes that each regulation can significantly affect a manufacturer's financial operations. Multiple regulations affecting the same manufacturer can quickly strain manufacturers' profits and possibly cause an exit from the market. Table 12.7.2 lists the other DOE energy conservation standards that could also affect manufacturers of clothes dryers and room air conditioners in the 3 years leading up to and after the compliance date of amended energy conservation standards for these products.

Table 12.7.2 Other DOE and Federal Actions Affecting the Residential Clothes Dryer and Room Air Conditioner Industries

Regulation	Approximate Compliance Date*	Number of Impacted Companies from the Market and Technology Assessment (MTA) (See Chapter 3)		Estimated Total Industry Conversion Costs
		Clothes Dryers	Room Air Conditioners	
ASHRAE Products	2012	0	0	N/A
Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps	2012	4	5	\$17.3 million (2007\$)[h]
Cooking Products	2012	10	6	\$22.6 million (2006\$)[i]
Residential Boilers	2012	0	1	N/A†
General Service Fluorescent Lamps and Incandescent Reflector Lamps	2012	2	1	\$363.1 million (2008\$)[j]
Dehumidifiers	2012	5	3	N/A†††
Beverage Vending Machines	2012	1	0	\$14.5 million (2008\$)[k]
Commercial Clothes Washers	2013	6	2	\$20.4 million (2008\$)[l]
Direct Heating Equipment	2013	0	0	\$5.39 million (2009\$)[m]
Residential Pool Heaters	2013	0	0	\$0.3 million (2009\$)[n]
Battery Chargers and External Power Supplies	2013*	3	3	N/A††

[h] Estimated industry conversion expenses were published in the TSD for the October 2008 packaged terminal air conditioners and packaged terminal heat pumps final rule. 73 FR 58772. The TSD for the 2008 packaged terminal air conditioners and packaged terminal heat pumps final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/ptacs_pthps_final_tsd.html.

[i] Estimated industry conversion expenses were published in the TSD for the April 2009 residential cooking products final rule. 74 FR 16040. The TSD for the 2009 residential cooking products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/cooking_products_final_rule_tsd.html.

[j] Estimated industry conversion expenses were published in the TSD for the July 2009 general service fluorescent lamps and incandescent reflector lamps final rule. 74 FR 34080. The TSD for the 2009 lamps final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps_standards_final_rule_tsd.html.

[k] Estimated industry conversion expenses were published in the TSD for the August 2009 beverage vending machines final rule. 74 FR 44914. The TSD for the 2009 beverage vending machines final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/beverage_machines_final_rule_tsd.html.

[l] Estimated industry conversion expenses were published in the TSD for the January 2010 commercial clothes washers final rule. 75 FR 1122. The TSD for the 2010 commercial clothes washers final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_ecs_final_rule_tsd.html

[m] Estimated industry conversion expenses were published in the TSD for the April 2010 heating products final rule. 75 FR 20112. The TSD for the 2010 heating products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_tsd.html.

[n] Estimated industry conversion expenses were published in the TSD for the April 2010 heating products final rule. 75 FR 20112. The TSD for the 2010 heating products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_tsd.html.

Residential Refrigerators and Freezers	2014*	10	5	N/A††
Room Air Conditioners	2014*	5	N/A	N/A††
Residential Clothes Dryers	2014*	N/A	5	N/A††
Fluorescent Lamp Ballasts	2014*	2	1	N/A††
Walk-In Freezers and Coolers	2015*	0	0	N/A††
Metal Halide Lamp Fixtures	2015*	0	0	N/A††
Residential Clothes Washers	2015*	12	5	N/A††
Small Electric Motors	2015	0	0	$51.2 million (2009$)[o]
Residential Water Heaters	2015	2	1	$95.9 million (2009$)[p]
Commercial Electric Motors	2015*	2	1	N/A††
Residential Furnaces	2015*	2	1	N/A††
Commercial Distribution Transformers	2016*	2	1	N/A††
Commercial Refrigeration Equipment	2016*	0	0	N/A††
Residential Central Air Conditioners	2016*	2	2	N/A††

*The dates listed are an approximation. The exact dates are pending final DOE action.
† Energy conservation standards and compliance dates for residential boilers can be found at 10 CFR 430.32(e)(2)(ii)-(iv).
†† For energy conservation standards for rulemakings awaiting DOE final action, DOE does not have a finalized estimated total industry conversion cost.
††† For minimum performance requirements prescribed by the Energy Independence and Security Act of 2007 (EISA 2007), DOE did not estimate total industry conversion costs because an MIA was not completed as part of a rulemaking. Pub. L. 110-140. EISA 2007 made numerous amendments to the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 U.S.C. 6291–6309), which established an energy conservation program for major household appliances and industrial and commercial equipment.

Some Federal DOE regulations have a more significant impact on manufacturers of clothes dryers and room air conditioners than others because manufacturers hold a significant market share in those covered products. Table 12.7.3 below shows the DOE energy conservation standards with compliance dates within three years of clothes dryers and room air conditioners where manufacturers are expected to be most impacted due to their market positions. For these rulemakings, clothes dryer and room air conditioner manufacturers would likely be burdened by a significant portion of the estimated industry conversion costs. In some cases, specific market share data was not available, but manufacturers were identified as major or minor manufacturers in the given market when this information was publicly available.

[o] Estimated industry conversion expenses were published in the TSD for the March 2010 small motors final rule. 75 FR 10874. The TSD for the 2010 small motors final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/sem_finalrule_tsd.html.
[p] Estimated industry conversion expenses were published in the TSD for the April 2010 heating products final rule. 75 FR 20112. The TSD for the 2010 heating products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_tsd.html.

Table 12.7.3 DOE Regulations on Products For Which Clothes Dryer and Room Air Conditioner Manufacturers Hold Significant Market Share

		Manufacturer Market Share in DOE Regulated Product						
Regulation	**Estimated Industry Total Conv. Expenses (millions)**	**GE**	**Whirlpool**	**Electrolux**	**LG**	**Samsung**	**Haier**	**Carrier**
Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps	$17.3 million (2007$)	N/A (major)	N/A (major)		N/A (minor)			N/A (major)
Ranges and Ovens	$22.6 million (2006$)	47% (electric); 37% (gas)	29% (electric); 25% (gas)	8% (electric); 23% (gas)	N/A (major)	N/A (minor)	N/A (minor)	
General Service Fluorescent Lamps and Incandescent Reflector Lamps	$363.1 million (2008$)	N/A (major)						
Dehumidifiers	N/A		35%	6%	35%	3%		
Commercial Clothes Washers	$20.4 million (2008$)	N/A (major)	N/A (major)	N/A (minor)	N/A (minor)			
Room Air Conditioners	N/A			13%	32%	5%	8%	
Residential Clothes Dryers	N/A	16% (electric); 10% (gas)	8% (electric); 5% (gas)	N/A (minor)	N/A (minor)	N/A (minor)		
Fluorescent Lamp Ballasts	N/A	N/A (major)						
Residential Clothes Washers	N/A	16%	64%	6%	6%			
Residential Refrigerators and Freezers	N/A	27% (refrig.)	33% (refrig.)	64% (freezers); 23% (refrig.)			16% (freezers); 6% (refrig.)	
Central Air Conditioners	N/A							27%
Furnaces	N/A							32%

12.7.3.2 Other Federal Regulations

EPA HCFC Ban

In 1992, the Montreal Protocol was amended to establish a schedule for the phaseout of HCFCs (hydrochlorofluorocarbons) to curb ozone depletion. This included HCFC-22, also known as R-22, which was the refrigerant most commonly found in room air conditioners and other residential heating and air-conditioning systems. Manufacturers were required to cease using virgin R-22 in new equipment as of January 1, 2010. As such, this ban required manufacturers of room air conditioners to convert all of their products to an alternate refrigerant (most commonly R-410A). DOE acknowledges that the transition to R-410A required significant investment and engineering effort, but because the compliance date of the R-22 ban does not fall within three years of the estimated compliance date for room air conditioners, DOE did not account for the conversion costs required for manufacturers to comply with the regulation as part of the cumulative regulatory burden. The engineering analysis, however, does account for the ban on R-22. See chapter 5 for information on how the cost-efficiency curves were modified to account for the use of R-410A.

Potential Climate Change and Greenhouse Gas Legislation

Many manufacturers expressed concern about potential climate change legislation. One proposed regulation that would exacerbate the manufacturer burden caused by more stringent energy conservation standards on refrigeration products is H.R. 2454, the American Clean Energy and Security Act of 2009. This legislation would initiate a phase-down of hydrofluorocarbons (HFCs) and would make the amended energy conservation standard levels considered in this rulemaking more difficult to achieve. Manufacturer were particularly concerned that these regulations could impact U.S. heat pump dryer designs in the future.

12.7.3.3 Other Regulations That Could Impact Clothes Dryer and Room Air Conditioner Manufacturers

While the cumulative regulatory burden focuses on the impacts on manufacturers of other Federal requirements, in this section DOE has described a number of other regulations below that could also impact the clothes dryers and room air conditioners covered by this rulemaking

UL Fire Containment Standard

The UL fire containment standard (UL 2158) was a major regulatory burden manufacturers mentioned during interviews and in written comments. Because the compliance date of the UL standard falls within three years of the estimated compliance date for clothes dryers, DOE accounted for the conversion costs required for manufacturers to comply with the UL regulation as part of the cumulative regulatory burden.

For the UL conversion costs, DOE used the same per product line market data used to calculate the conversion costs to comply the amended energy conservation standards. However, since the UL regulation only applies to electric dryers, DOE calculated the capital and product conversion costs for product classes 1, 2, 3, 5 and 6 only. Manufacturers mentioned a range of estimated engineering time and capital changes that would be required for the UL regulation. These estimates varied due to the different approaches manufacturers would take to comply with UL 2158, the resources already devoted to examining the regulation's impact, and the design of products that would be impacted. Because of the range of responses and circumstances, DOE took a representative number for both product and capital conversion costs and multiplied by the number of total platforms in each electric product class. DOE assumed that these estimates of the product and capital conversion costs would occur in 2012, the year before the compliance date of the regulation. Finally, because the UL regulation is not due to amended energy conservation standards, DOE applied these costs in both the base case and the standards case, which lowers the industry value in both.

State Energy Conservation Standards

Manufacturers indicated that California has several programs that are either already in place or are currently in development that affect manufacturers of residential clothes dryers and room air conditioners. Various building, electrical, mechanical, and plumbing codes in California affect clothes dryers and room air conditioners, and products are also subject to California's laws on the Restriction on the use of certain Hazardous Substances (RoHS). California's RoHS law took effect January 1, 2007 and was modeled after the EU's directive (described below), which bans certain hazardous substances from electrical and electronic equipment.

International Energy Conservation Standards

Residential clothes dryer and room air conditioner manufacturers that sell products outside of the United States are subject to several international energy conservation standards. In the EU, products are also subject to RoHS. This regulation bans the sale of new equipment in the EU that contains more than agreed levels of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and PBDE flame retardants. Waste Electrical and Electronic Equipment (WEEE) and the Registration, Evaluation, Authorization, and restriction of Chemicals (REACH) are additional regulations that create compliance costs for manufacturers that compete in Europe. REACH deals with chemicals and their safe use and has provisions that will be phased-in over eleven years, beginning June 1, 2007. The EU also sets limits for the amount of energy consumed by equipment when it is in standby mode and off mode. Additionally, HFCs are banned in refrigerants in several countries, such as Austria, Denmark, and Switzerland. Canada and several other foreign countries have regulations or have initiated regulations affecting clothes dryer and room air conditioner manufacturers.

12.8 CONCLUSION

The following sections summarize the different impacts for the scenarios DOE believes are most likely to capture the range of impacts on residential clothes dryer and room air conditioner manufacturers at each TSL in the standards case. While these scenarios bound the range of the most plausible impacts on manufacturers, some circumstances could cause manufacturers to experience impacts outside this range.

12.8.1 Residential Clothes Dryers

TSL 1 represents the baseline CEF for 120V electric compact clothes dryers (product class 2), 240V electric compact clothes dryers (product class 3), 240V compact ventless clothes dryers (product class 5), and electric combination ventless clothes dryers (product class 6). TSL 1 represents a CEF of 3.56 for standard-size vented electric clothes dryers (product class 1) and a CEF of 3.16 for gas vented clothes dryers (product class 4). At TSL 1, DOE estimates impacts on INPV to range -$2.55 million to -$2.62 million, or a change in INPV of -0.3 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 1.6 percent to $68.6 million, compared to the base-case value of $69.7 million in the year leading up to the proposed energy conservation standards.

The design options DOE analyzed for product class 1 and 4 include lowering standby power consumption only. Standby power changes would result in only minor changes to baseline products and would take a minimal effort by manufacturers to comply with the amended energy conservation standards. The standby power changes at TSL 1 would require relatively small product development efforts to reach the CEF levels and would not change the assembly of currently products, greatly limiting the necessary capital conversion costs. In addition, the design options for standby power do not add significant costs to existing products. Therefore, the impact on manufacturers is very small at TSL 1.

TSL 2 represents a CEF of 3.61 for product class 1, a CEF of 3.61 for product class 2, a CEF of 3.27 for product class 3, a CEF of 3.20 for product class 4, a CEF of 2.69 for product class 5, and a CEF of 2.56 for product class 6. At TSL 2, DOE estimates impacts on INPV to range -\$3.6 million to -\$4.9 million, or a change in INPV of -0.4 percent to -0.5 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 3.0 percent to \$67.6 million, compared to the base-case value of \$69.7 million in the year leading up to the proposed energy conservation standards.

The design options analyzed at TSL 2 for product classes 1 through 5 represent improvements to standby power consumption only. The changes required at TSL 2 would not greatly alter baseline products for these product classes because these analyzed design options are small component changes for standby power for product classes 1 through 5.The design options analyzed for product class 6 include changes to active mode power consumption. However, these active mode changes for product class 6 are also relatively minor and would take a minimal effort by manufacturers to comply with the amended energy conservation standards. For product class 6, the analyzed design option for active mode is automatic cycle termination technology which adds very little cost to the product and takes minimal capital and product conversion costs to implement. Because the changes for product class 1 through 5 only include standby power changes and the active mode changes for product class 6 are minor, the impact on manufacturers is very small at TSL 2.

The efficiency requirements for product classes 2 to 6 are the same at TSL 3 as at TSL 2. TSL 3, however, represents a further improvement to a CEF of 3.73 for product class 1. At TSL 3, DOE estimates impacts on INPV to range from -\$41.1 million to -\$55.5 million, or a change in INPV of -4.1 percent to -5.5 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 34.2 percent to \$45.9 million, compared to the base-case value of \$69.7 million in the year leading up to the proposed energy conservation standards.

The design options DOE analyzed for product class 1 include improvements to standby and active power consumption (airflow improvements, a dedicated heater duct, and an open cylinder drum). While the actual design path taken by manufacturers could vary at TSL 3, these technologies represent incremental improvements and are well known in the industry. The changes for design options analyzed for product class 1 would require both changes to production equipment and product development costs. These design options would not greatly alter the production process for product class 1 and could be made within most existing products. The conversion costs to implement these changes are also relatively low compared to the total value of the industry. The industry impacts would increase at TSL 3, however, because for product class 1, manufacturers would have to make changes for a large volume of the common standard-size electric models.

TSL 4 represents the baseline efficiency for product classes 5 and 6. TSL 4 also represents the same efficiency requirements for product classes 2 and 3 as TSL 2 and TSL 3.

TSL 4 also has the same efficiency requirements for product class 1 as TSL 3, but represents a 3.30 CEF for product class 4. At TSL 4, DOE estimates impacts on INPV to range -$64.5 million to -$80.6 million, or a change in INPV of -6.4 percent to -8.0 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 49.8 percent to $35.0 million, compared to the base-case value of $69.7 million in the year leading up to the proposed energy conservation standards.

The impacts at TSL 4 are due primarily to the efficiency requirements for product classes 1 and 4 because all other product classes are at baseline efficiency or could be met with changes to standby power consumption. For both product classes 1 and 4, DOE analyzed changes to standby power consumption and the same improvements to active mode power consumption for both gas and electric units (airflow improvements, a dedicated heater duct, and an open cylinder drum). As with TSL 3, while the actual design path taken by manufacturers could vary at TSL 4, these technologies represent incremental improvements to most products and are well known in the industry. Industry impacts would increase at TSL 4, however, because for both product classes 1 and 4, the changes would require improvements in the most common standard-size gas and electric products on the market today. The changes for design options analyzed for product class 1 and 4 would require both changes to production equipment and product development costs. These design options would not greatly alter the production processes for either product class and could be made within most existing products. The conversion costs to implement these changes for both product class 1 and 4 are still relatively low compared to the total value of the industry.

TSL 5 represents a CEF of 4.08 for product class 1, a CEF of 4.08 for product class 2, a CEF of 3.60 for product class 3, a CEF of 3.61 for product class 4, a CEF of 2.80 for product class 5, and a CEF of 2.56 for product class 6. At TSL 5, DOE estimates impacts on INPV to range -$176.5 million to -$397.4 million, or a change in INPV of -17.6 percent to -39.6 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 249.7 percent to -$104.4 million, compared to the base-case value of $69.7 million in the year leading up to the proposed energy conservation standards.

Most of the impacts on INPV at TSL 5 are due to the efficiency requirements for product classes 1 through 4. Very few products on the market today meet the efficiency requirements at TSL 5, and for product classes 1 through 4, TSL 5 represents the most efficient units currently on the market. The design options DOE analyzed for these product classes included similar design options for all product classes as for product classes 1 and 4 at TSL 4 (airflow improvements, a dedicated heater duct, and an open cylinder drum) plus additional changes. In addition to airflow improvements, a dedicated heater duct, and an open cylinder drum, the design options analyzed by DOE also include modulating heat, inlet air preheating, and a more efficient fan motor. Out of all these design options used the reach the required efficiencies at TSL 5, inlet air preheating would require the most substantial changes to existing products because it would change the ducting system. This change would impact drum stamping equipment and, possibly, the fabrication of the cabinets for some product lines. The impacts also increase dramatically at TSL 5 due to the large increase in production costs for the additional design options beyond those needed to reach the required efficiencies at TSL 4. The large incremental costs result in lower shipments due to the price elasticity. These additional costs also cause a greater impact on INPV if manufactures are unable to earn additional profit on these added costs (under the preservation of operating profit markup scenario).

TSL 6 represents the max-tech level for all product classes. The max-tech level corresponds to a CEF of 5.42 for product class 1, a CEF of 5.41 for product class 2, a CEF of 4.89 for product class 3, a CEF of 3.61 for product class 4, a CEF of 4.03 for product class 5, and a CEF of 3.69 for product class 6. At TSL 6, DOE estimates impacts on INPV to range -$303.9 million to -$730.0 million, or a change in INPV of -30.3 percent to -72.7 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 467.5 percent to -$256.2 million, compared to the base-case value of $69.7 million in the year leading up to the proposed energy conservation standards.

At TSL 6, the efficiency requirements for all electric clothes dryers would effectively require a heat pump clothes dryer. Currently, there are no heat pump clothes dryers on the market in the United States. Manufacturing exclusively heat pump clothes dryers would be extremely disruptive to existing manufacturing facilities. A heat pump standard would require a total renovation of existing facilities and would force the industry to design completely new clothes dryer platforms. The capital conversion costs for these changes are extremely large—more than double the capital conversion costs calculated for these products to meet TSL 5. The product development costs to manufacturer heat pump clothes dryers also increase substantially because manufacturers must not only redesign clothes washer platforms, but also design the heat pump system. Manufacturers also indicated that training their service and installation network to use a completely different technology would be extremely costly, as would the cost to educate consumers. Finally, the impacts on INPV are also great at TSL 6 because the cost of a heat pump clothes dryer is more than double a minimally compliant clothes dryer in the market today. If manufactures are unable to earn additional profit on these production costs, profitability is severely impacted.

12.8.2 Room Air Conditioners

TSL 1 represents a CEER of 9.30 for product class 8A (without reverse cycle and without louvered sides—8,000 to 10,999 Btu/h) and product class 8B (without reverse cycle and without louvered sides—11,000 to 13,999 Btu/h), 9.40 for product class 5A (without reverse cycle and with louvered sides—20,000 to 24,999 Btu/h) and product class 5B (without reverse cycle and with louvered sides—25,000 Btu/h and more), 10.10 for product class 1 (without reverse cycle and with louvered sides—less than 6,000 Btu/h), and 10.70 for product class 3 (without reverse cycle and with louvered sides—8,000 to 13,999 Btu/h). At TSL 1, DOE estimates impacts on INPV to range from -$44.2 million to -$84.9 million, or a change in INPV of -4.6 percent to -8.9 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 27.7 percent to $62.4 million, compared to the base-case value of $86.3 million in the year leading up to the proposed energy conservation standards.

The INPV impacts at TSL 1 are relatively minor, in part because the vast majority of manufacturers produce units that exceed this level (i.e., ENERGY STAR and other high efficiency units) in significant volumes. Approximately 60 percent of product class 3 shipments, 85 percent of product class 5A and 5B shipments, and 90 percent of product class 8A and 8B shipments currently meet this TSL. By contrast, the vast majority of product class 1 shipments are baseline units. Although most of the design options DOE analyzed at this proposed level are one-for-one component swaps, some more complex design options that would be required at TSL 1 necessitate more substantial changes. These design options that have a significant impact on conversion costs at TSL 1 are heat exchanger changes and increased chassis volumes. Changes to the condenser or evaporator require machinery for new dies for every product line and require greater design effort than component swaps. Increased chassis volumes require a complete redesign of the product and substantial tooling to make the unit larger. Although some room air conditioners, particularly those in product class 1, will require these changes at TSL 1, these changes would not be required across the entire industry because the majority of units in most product classes already meet TSL 1. As such, DOE estimated total product conversion costs of $22 million and capital conversion costs of $46 million, which is relatively low compared to the industry value of $956 million.

The efficiency requirements for product class 3, product class 5A, product class 5B, product class 8A, and product class 8B are the same at TSL 2 as TSL 1. Thus, the only change from TSL 1 occurs for product class 1, which requires a CEER of 10.60 at TSL 2. DOE estimates the INPV impacts at TSL 2 range from -$65.4 million to -$112.7 million, or a change in INPV of -6.8 percent to -11.8 percent. At this proposed level, the industry cash flow is estimated to decrease by approximately 40.5 percent to $51.4 million, compared to the base-case value of $86.3 million in the year leading up to the proposed energy conservation standard.

The additional impacts at TSL 2 relative to TSL 1 result from the further improvements manufacturers must make to meet a CEER of 10.6 for product class 1. Most units in product class 1 would need to increase their chassis size even further than at TSL 1 in order to meet TSL 2, resulting in estimated product and capital conversion costs of $29 million and $69 million, respectively.

TSL 3 represents different efficiency levels for every product class compared to TSL 2. TSL 3 represents the baseline CEERs of 8.47 and 8.48 for product classes 5A and 5B, respectively, meaning that no amended standards would be set and no impacts on INPV would occur. TSL 3 represents a CEER of 9.50 for product class 8B, 9.60 for product class 8A, 10.10 for product class 1, and 10.90 for product class 3. DOE estimates the INPV impacts at TSL 3 to range from -$65.7 million to -$112.4 million, or a change in INPV of -6.9 percent to -11.8 percent. At this proposed level, the industry cash flow is estimated to decrease by approximately 40.5 percent to $51.4 million, compared to the base-case value of $86.3 million in the year leading up to the standards.

At TSL 3, several product classes require design options that increase conversion costs. For product class 1, some units would require increased chassis volumes, though not as substantially as at TSL 2. For product class 3, all smaller units would require chassis changes, driving the majority of the conversion costs at TSL 3. For product classes 8A and 8B, some changes to the heat exchangers would be required. However, no conversion costs would be applied to product classes 5A and 5B, resulting in total product and capital conversion costs at TSL 3 of $41 million and $61 million, respectively.

TSL 4 represents the same efficiency requirements as TSL 3 for product classes 3, 8A, and 8B. For product class 5B, TSL 4 represents a CEER of 9.00. For product class 5A, TSL 4 represents a CEER of 9.40, and for product class 1, TSL 4 represents a CEER of 11.10. DOE estimates the INPV impacts at TSL 4 to range from -$111.3 million to -$177.6 million, or a change in INPV of -11.6 percent to -18.6 percent. At this proposed level, the industry cash flow is estimated to decrease by approximately 69.1 percent to $26.7 million, compared to the base-case value of $86.3 million in the year leading up to the proposed energy conservation standards.

At TSL 4, significant changes to the manufacturing process would be required. Product classes 1, 5A, and 5B would all require increased chassis volumes, and product classes 1 and 5A would also require heat exchanger changes. These design options drive increases of $20 million in product conversion costs and $48 million in capital conversion costs compared to TSL 3.

TSL 5 represents the same efficiency requirements as TSL 4 for product classes 1 and 8B. For product classes 5A and 5B, TSL 5 represents the baseline CEERs of 8.47 and 8.48, respectively, so all impacts of TSL 4 on these product classes, such as chassis changes, would not be required. For product class 8A, TSL 5 represents a CEER of 10.00, and for product class 3, TSL 5 represents a CEER of 11.50. DOE estimates the INPV impacts at TSL 5 to range from -$86.6 million to -$184.4 million, or a change in INPV of -9.1 percent to -19.3 percent. At this proposed level, the industry cash flow is estimated to decrease by approximately 69.3 percent to $26.5 million, compared to the base-case value of $86.3 million in the year leading up to the proposed energy conservation standards.

At TSL 5, impacts are negative under both scenarios due to the high conversion costs that exist at TSL 5. Although capital conversion costs would be $8 million lower at TSL 5 than at TSL 4 due to the removal of any capital costs associated with product classes 5A and 5B (despite higher capital costs for product class 3), product conversion costs are $13 million higher at TSL 5 compared to TSL 4 because a greater number of product lines would need to be redesigned at this level.

TSL 6 represents max-tech for all room air conditioners. The max-tech level corresponds to CEERs of 9.80, 10.02, 10.15, 10.35, 11.67, and 11.96 for product classes 5B, 8B, 5A, 8A, 1, and 3, respectively. DOE estimates the INPV impacts at TSL 6 to range from -$80.2 million to -$344.5 million, or a change in INPV of -8.4 percent to -36.0 percent. At this proposed level, the industry cash flow is estimated to decrease by 124.8 percent to -$21.4 million, compared to the base-case value of $86.3 million in the year leading up to the proposed energy conservation standards.

At TSL 6, all products would need to be fully redesigned, resulting in large product and capital conversion costs of $117 million and $193 million, respectively. These conversion costs are mostly driven by the high-volume product classes 1 and 3 and their associated chassis and heat exchanger changes.

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CHAPTER 13. EMPLOYMENT IMPACT ANALYSIS

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CHAPTER 13. EMPLOYMENT IMPACT ANALYSIS

13.1 INTRODUCTION

DOE conducted an employment impact analysis for the NOPR and Final Rule. 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 residential clothes dryers and room air conditioners.

13.2 ASSUMPTIONS

DOE expects energy conservation standards to decrease energy consumption, and therefore to reduce energy expenditures. The savings in energy expenditures may be spent on new investment or not at all (i.e., they may remain "saved"). The standards may increase the purchase price of appliances, including the retail price plus sales tax, and increase installation costs.

Using an input/output econometric model of the U.S. economy, this analysis estimated the year-to-year effect of these expenditure impacts on net economic output and employment. DOE intends this analysis to quantify the indirect employment impacts of these expenditure changes. It evaluated direct employment impacts at manufacturers' facilities in the manufacturer impact analysis (see chapter 12).

13.3 METHODOLOGY

The Department based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 3.1.1[1] (Impact of Sector Energy Technologies) as a successor to ImBuild[2], a special-purpose version of the IMPLAN[3] national input/output model. ImSET estimates the employment and income effects of building energy technologies. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy-efficiency investments in buildings.

In an input/output model, the level of employment in an economy is determined by the relationship of different sectors of the economy and the spending flows among them. Different sectors have different levels of labor intensity and so changes in the level of spending (e.g., due to the effects of an efficiency standard) in one sector of the economy will affect flows in other sectors, which affects the overall level of employment.

ImSET uses a 187-sector model of the national economy to predict the economic effects of residential and commercial buildings technologies. ImSET collects estimates of initial investments, energy savings, and economic activity associated with spending the savings resulting from standards (e.g., changes in final demand in personal consumption, business investment and spending, and government spending). It provides overall estimates of the change in national output for each input-output sector. The model applies estimates of employment and wage income per dollar of economic output for each sector and calculates impacts on national employment and wage income.

Energy-efficiency technology primarily affects the U.S. economy along three spending pathways. First, general investment funds are diverted to sectors that manufacture, install, and maintain energy-efficient appliances. The increased cost of appliances leads to higher employment in the appliance manufacturing sectors and lower employment in other economic sectors. Second, commercial firm and residential spending are redirected from utilities toward firms that supply production inputs. Third, electric utility sector investment funds are released for use in other sectors of the economy. When consumers use less energy, electric utilities experience relative reductions in demand which leads to reductions in utility sector investment and employment.

13.4 RESULTS

The results in this section refer to impacts of residential clothes dryer and room air conditioner standards relative to the base case for each appliance. 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. These component effects and a summary impact are presented for residential clothes dryers and room air conditioners. No significant change in non-energy operations and maintenance cost is anticipated for room air conditioners or residential clothes dryers.

Figures 13.4.1-13.4.2 summarize the employment impacts of the increased investment and spending on higher-efficiency equipment. Clothes dryer manufacturing is relatively more capital intensive compared to other sectors of the economy, on average, so the net result is a loss of employment. The air conditioning, refrigeration and forced air heating manufacturing sector, which includes room air conditioners, is somewhat less capital intensive than other sectors of the economy, so the net result is a small increase in employment.

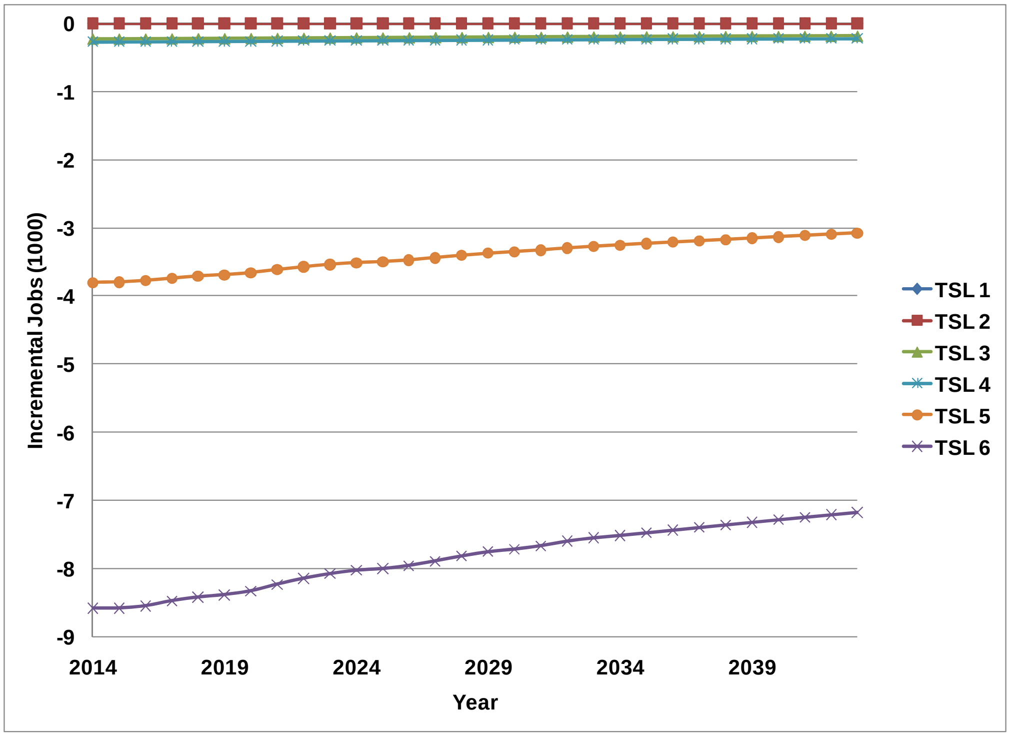

Figure 13.4.1 Clothes Dryer Employment Impact of Increased Equipment Cost

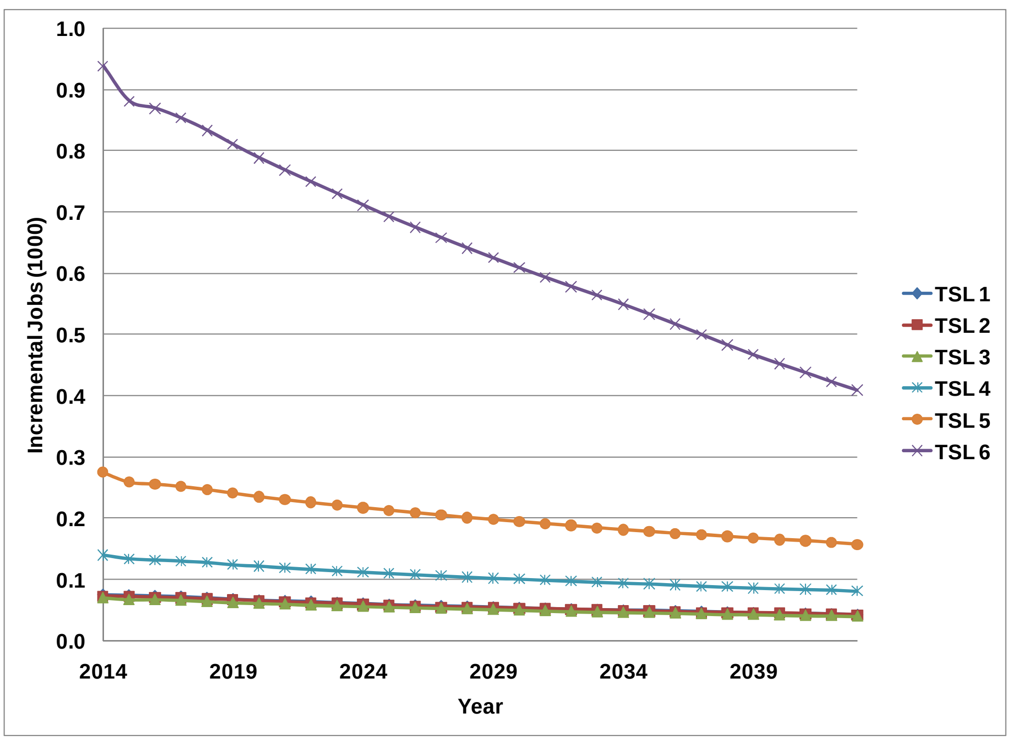

Figure 13.4.2 Room Air Conditioner Employment Impact of Increased Equipment Cost

Figures 13.4.3-13.4.4 show the employment impact of redirected spending made possible by appliance operating cost savings. In this case, the employment impact is strongly positive.

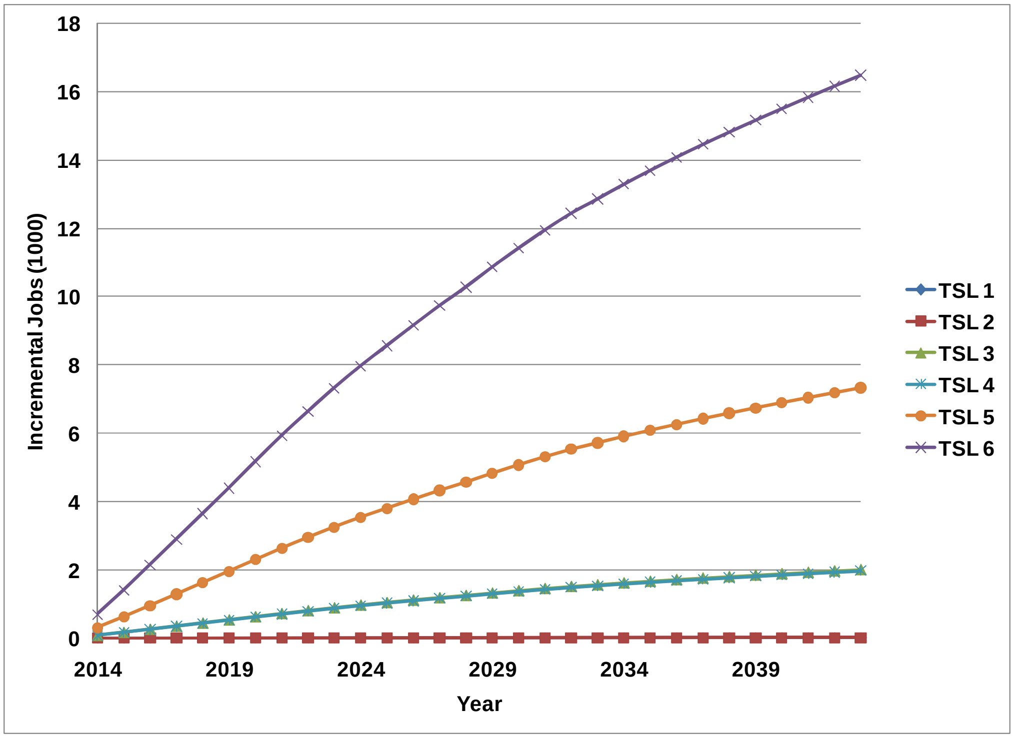

Figure 13.4.3 Clothes Dryer Employment Impact of Operating Cost Savings

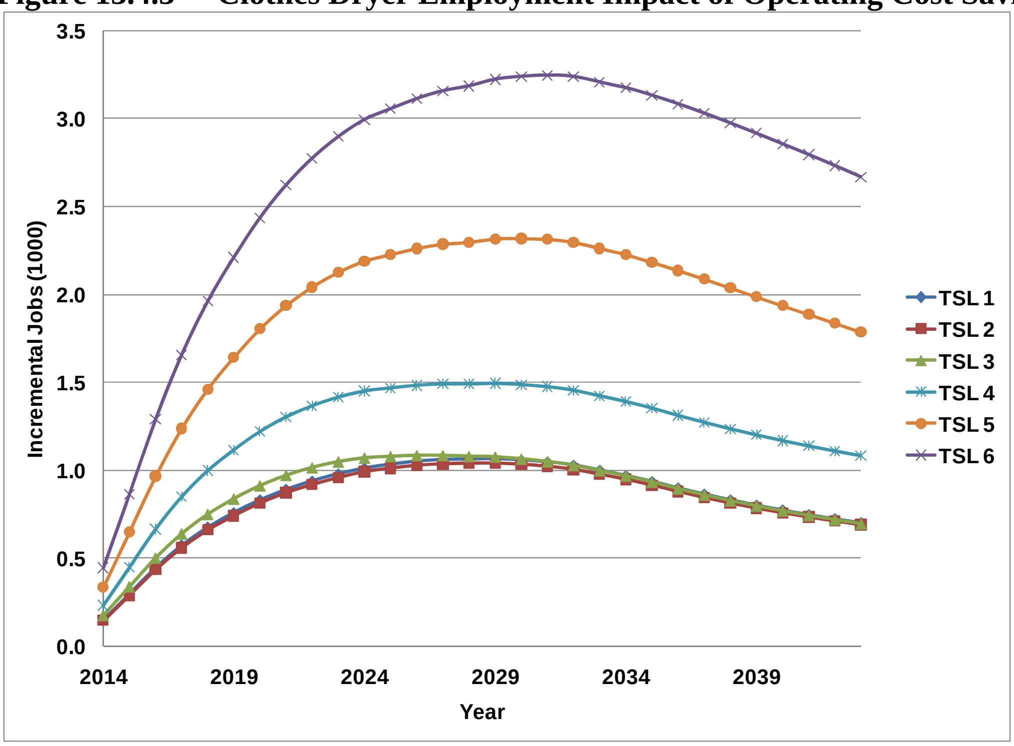

Figure 13.4.4 Room Air Conditioner Employment Impact of Operating Cost Savings

Figures 13.4.5-13.4.6 show the estimated net national employment impacts of the clothes dryer and room air conditioner product trial standard levels. For any given year, these figures show the net change in the number of jobs in the economy relative to if there were no change in standards (and thus no resulting change in spending and cash flow patterns throughout the economy). These figures show the combined effects of equipment cost, operations and maintenance cost, and energy use changes due to standards.

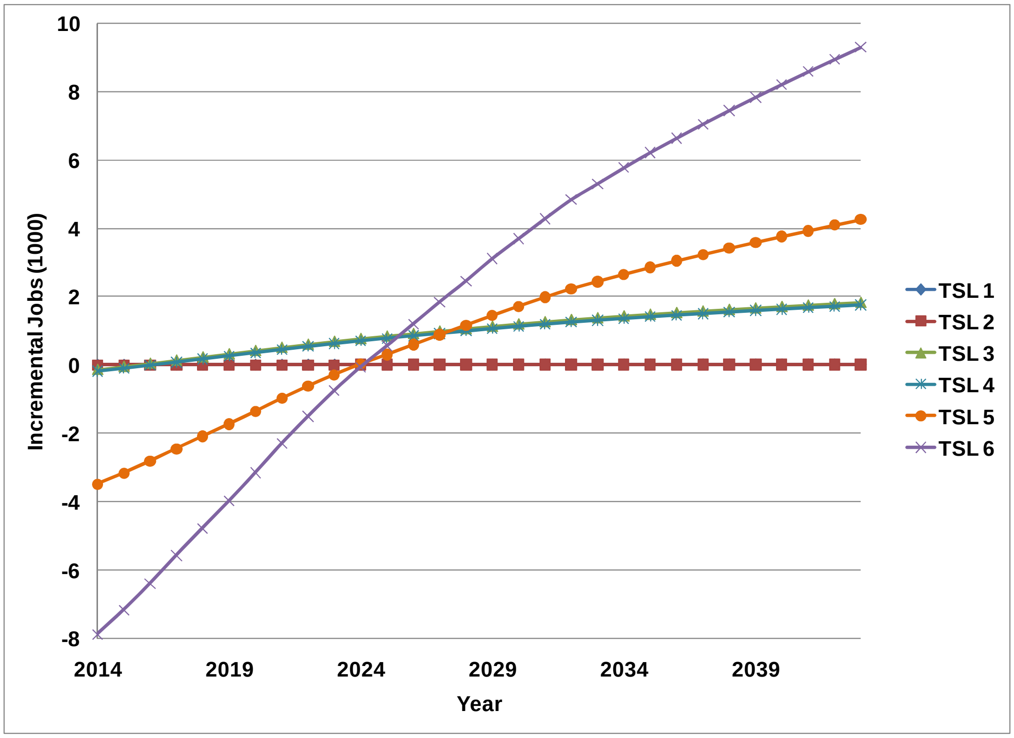

Figure 13.4.5 Clothes Dryer Net National Change in Employment

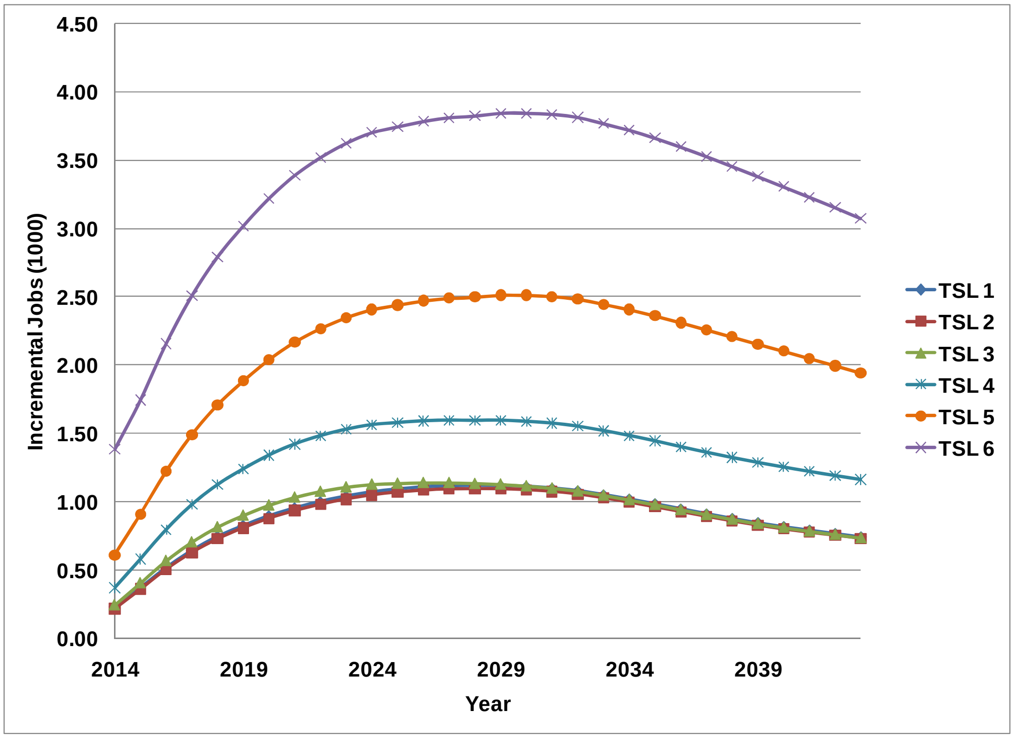

Figure 13.4.6 Room Air Conditioner Net National Change in Employment

Tables 13.4.1-13.4.2 show the net national employment impact in specific years for each product, as well as the average annual employment impact over the 2014-2043 time period. For clothes dryers, the initial decrease in net employment is caused by the dominance of capital costs in early years, while the impacts of operating cost savings from reduced energy use build up slowly over time, resulting in a net positive impact on employment in later years.

Table 13.4.1 Clothes Dryer Net National Change in Employment (Thousand jobs)

Trial Standard Level	2014	2020	2030	2043	Average 2014-2043
1	0.00	0.00	0.01	0.01	0.01
2	0.00	0.00	0.01	0.01	0.01
3	-0.14	0.41	1.18	1.82	0.99
4	-0.19	0.36	1.13	1.75	0.93
5	-3.50	-1.37	1.71	4.25	0.95
6	-7.89	-3.16	3.69	9.30	1.99

Table 13.4.2 Room Air Conditioner Net National Change in Employment (Thousand jobs)

Trial Standard Level	2014	2020	2030	2043	Average 2014-2043
1	0.23	0.90	1.11	0.74	0.90
2	0.22	0.88	1.09	0.73	0.88
3	0.25	0.97	1.11	0.74	0.92
4	0.37	1.34	1.59	1.16	1.32
5	0.61	2.04	2.51	1.94	2.11
6	1.38	3.22	3.84	3.07	3.31

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CHAPTER 14. UTILITY IMPACT ANALYSIS

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CHAPTER 14. UTILITY IMPACT ANALYSIS

14.1 INTRODUCTION

DOE analyzed the effects of its amended standard levels on the electric and natural gas utility industry using a variant of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS).[a] NEMS is a public domain, multi-sectored, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce an energy forecast for the United States, the *Annual Energy Outlook (AEO)*. The *AEO* for 2010 *(AEO2010)* forecasts energy supply and demand through 2035. [1] DOE used a variant of this model, referred to as NEMS-BT,[b] to account for the impacts of clothes dryer and room air conditioner energy conservation standards. DOE's utility impact analysis consists of a comparison between model results for the *AEO2010* Reference Case and for cases in which standards are in place, and applies the same basic set of assumptions as the *AEO2010*. The *AEO2010* reference case corresponds to medium economic growth.

The utility impact analysis reports the changes in electric installed capacity and generation that result for each trial standard level (TSL) by plant type, as well as changes in residential electricity and natural gas consumption.

NEMS-BT has several advantages that have led to its adoption as the forecasting tool in the analysis of energy conservation standards. NEMS-BT uses a set of assumptions that are well known and fairly transparent, due to the exposure and scrutiny each *AEO* receives. In addition, the comprehensiveness of NEMS-BT permits the modeling of interactions among the various energy supply and demand sectors, producing a complete picture of the effects of energy conservation standards. Perhaps most importantly, NEMS-BT can be used to estimate marginal effects, which yield a better estimate of the actual impact of energy conservation standards than considering only average effects.

14.2 METHODOLOGY

NEMS provides reference case load shapes for several end uses. The model uses predicted growth in demand for each end use to build up a projection of the total electric system load growth for each region, which it uses in turn to predict the necessary additions to capacity. DOE uses NEMS-BT to account for the implementation of energy conservation standards by

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[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003), March, 2003.

[b] DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on DOE/EIA assumptions, DOE refers to it by the name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed). NEMS-BT was previously called NEMS-BRS.

decrementing the appropriate reference case load shape. For clothes dryers the drying end use was decremented and for room air conditioners the cooling end use. These decrements are also divided amongst the nine U.S. Census divisions based upon the share of energy end use consumption in each division, as given in NEMS. Clothes dryers and room air conditioners will have different allocations among the census divisions.

DOE used the site energy savings developed in the national impact analysis (chapter 10) for each TSL as input to NEMS-BT. The magnitude of the energy decrement that would be required for NEMS-BT to produce stable results out of the range of numerical noise is larger than the highest efficiency standard under consideration. Therefore, DOE estimated results corresponding to each TSL using interpolation. DOE ran higher energy use reduction levels in NEMS-BT, representing multipliers of each TSL, and used these outputs to linearly interpolate the results to estimate actual changes in generation and capacity due to the standard.

Although the current time horizon of NEMS-BT is 2035, other parts of the energy conservation standards analysis extend through the year 2043. It is not feasible to extend the forecast period of NEMS-BT for the purposes of this analysis, nor does DOE/EIA have an approved method for extrapolation of many outputs beyond 2035. While it might seem reasonable to make simple linear extrapolations of results, in practice this is not advisable because outputs could be contradictory. An analysis of various trends sufficiently detailed to guarantee consistency is beyond the scope of this work, and, in any case, would involve a great deal of uncertainty. Therefore, all extrapolations beyond 2035 are simple replications of year 2035 results. To emphasize the extrapolated results wherever they appear, they are shaded in gray to distinguish them from actual NEMS-BT results.

14.3 RESULTS

This utility impact analysis reports NEMS-BT forecasts for residential sector electricity consumption, natural gas consumption, total electricity generation by fuel type, and installed electricity generation capacity by fuel type. Results are presented in five-year increments through 2035. Beyond 2035, an extrapolation through 2043 for each TSL represents a simple replication of the 2035 results.

The results from the *AEO2010* Reference Case are shown in Table 14.3.1.

A separate set of TSLs was modeled for room air conditioners and clothes washers. The results for the clothes dryer TSLs are presented in Tables 14.3.2 through 14.3.7, and the results for room air conditioner TSLs are presented in Tables 14.3.7 through 14.3.12. Each table shows forecasts using interpolated results, as described in section 14.2, for total U.S. electricity generation and installed capacity.

The considered clothes dryer TSLs reduce electricity as well as natural gas consumption compared to the *AEO2010* Reference Case. The electricity savings predicted by the NIA Model for all clothes dryer products range from 0.001 to 1.02 percent of total residential electricity consumption in the year 2035. The natural gas savings range from 0.000 percent to 0.122 percent of total residential natural gas savings in the year 2035.

The considered room air conditioner TSLs reduce only electricity consumption compared to the *AEO2010* Reference Case. The electricity savings predicted by the NIA Model for all room air conditioner products range from 0.049 to 0.206 percent of total residential electricity consumption in the year 2035.

Table 14.3.1 AEO 2010 Reference Case Forecast

NEMS-BT Results: AEO2010 Reference							
	2005	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Residential Sector Energy Consumption [1]							
Electricity Sales (TWh)[2]	1,359	1,388	1,400	1,472	1,553	1,637	1,707
Total U.S. Electric Generation [3]							
Coal (TWh)	2,013	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	759	857	690	769	886	1,018	1,095
Petroleum (TWh)	122	45	46	47	48	48	49
Nuclear (TWh)	782	813	834	883	886	886	895
Renewables (TWh)	358	462	649	714	797	850	890
Total (TWh)[4]	4,034	4,005	4,257	4,503	4,746	5,012	5,234
Installed Generating Capacity [5]							
Coal (GW)	314	321	325	326	326	330	337
Other Fossil (GW)[6]	439	468	445	446	467	501	534
Nuclear (GW)	100	102	105	111	111	111	113
Renewables (GW)	99	133	171	177	186	196	209
Total (GW)[7]	952	1,024	1,046	1,059	1,091	1,138	1,192

[1] Comparable to Table A2 of AEO2010: Energy Consumption, Residential

[2] Comparable to Table A8 of AEO2010: Electricity Sales by Sector

[3] Comparable to Table A8 of AEO2010: Electric Generators and Cogenerators

[4] Excludes "Other Gaseous Fuels" cogenerators and "Other" cogenerators

[5] Comparable to Table A9 of AEO2010: Electric Generators and Cogenerators Capability

[6] Includes "Other Gaseous Fuels" cogenerators

[7] Excludes Pumped Storage and Fuel Cells

Table 14.3.2 Clothes Dryers Trial Standard Level 1 Forecast

NEMS-BT Results:	2010	2015	2020	2025	2030	2035	Difference from AEO2010 Reference Case	2010	2015	2020	2025	2030	2035	Extrapolation 2040	Extrapolation 2043
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*								
Electricity Sales (TWh)	1,388	1,400	1,472	1,553	1,637	1,707	Electricity Sales (TWh)	0.000	-0.001	-0.005	-0.009	-0.011	-0.013	-0.014	-0.015
Natural Gas (EJ)	5.22	5.11	5.24	5.31	5.31	5.29	Natural Gas (EJ)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35	Other (EJ)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Natural Gas (Quads)	4.95	4.85	4.97	5.04	5.03	5.01	Natural Gas (Quads)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other (Quads)	1.59	1.45	1.40	1.35	1.31	1.28	Other (Quads)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total U.S. Electric Generation							*Total U.S. Electric Generation*								
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305	Coal (TWh)	0.000	0.000	-0.001	0.000	-0.002	-0.002	-0.002	-0.002
Gas (TWh)	857	690	769	886	1,018	1,095	Gas (TWh)	0.000	0.001	-0.001	-0.005	-0.005	-0.004	-0.004	-0.004
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nuclear (TWh)	813	834	883	886	886	895	Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001
Renewables (TWh)	462	649	714	797	850	890	Renewables (TWh)	0.000	-0.003	-0.003	-0.003	-0.004	-0.005	-0.005	-0.005
Total (TWh)	4,005	4,257	4,503	4,746	5,012	5,234	Total (TWh)	0.000	-0.002	-0.005	-0.008	-0.010	-0.012	-0.012	-0.012
Installed Generating Capacity							*Installed Generating Capacity*								
Coal (GW)	321	325	326	326	330	337	Coal (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other Fossil (GW)	468	445	446	467	501	534	Other Fossil (GW)	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001
Nuclear (GW)	102	105	111	111	111	113	Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	133	171	177	186	196	209	Renewables (GW)	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192	Total (GW)	0.000	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002

Table 14.3.3 Clothes Dryers Trial Standard Level 2 Forecast

NEMS-BT Results:	2010	2015	2020	2025	2030	2035	Difference from AEO2010 Reference Case	2010	2015	2020	2025	2030	2035	Extrapolation 2040	Extrapolation 2043
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*								
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,637	1,707	Electricity Sales (TWh)	0.000	-0.041	-0.148	-0.242	-0.312	-0.361	-0.397	-0.415
Natural Gas (EJ)	5.22	5.11	5.24	5.31	5.31	5.29	Natural Gas (EJ)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35	Other (EJ)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Natural Gas (Quads)	4.95	4.85	4.97	5.04	5.03	5.01	Natural Gas (Quads)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other (Quads)	1.59	1.45	1.40	1.35	1.31	1.28	Other (Quads)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total U.S. Electric Generation							*Total U.S. Electric Generation*								
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305	Coal (TWh)	0.004	0.010	-0.033	0.000	-0.053	-0.052	-0.052	-0.052
Gas (TWh)	857	690	769	885	1,018	1,095	Gas (TWh)	0.006	0.037	-0.038	-0.132	-0.136	-0.123	-0.123	-0.123
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.000	0.000	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002
Nuclear (TWh)	813	834	883	886	886	895	Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	-0.023	-0.023	-0.023
Renewables (TWh)	462	648	714	797	850	890	Renewables (TWh)	-0.010	-0.091	-0.081	-0.099	-0.106	-0.129	-0.129	-0.129
Total (TWh)	4,005	4,257	4,502	4,746	5,011	5,233	Total (TWh)	0.000	-0.044	-0.153	-0.232	-0.296	-0.329	-0.329	-0.329
Installed Generating Capacity							*Installed Generating Capacity*								
Coal (GW)	321	325	326	326	330	337	Coal (GW)	0.000	-0.002	-0.001	-0.001	-0.004	-0.003	-0.003	-0.003
Other Fossil (GW)	468	445	446	467	501	534	Other Fossil (GW)	0.000	-0.008	-0.010	-0.022	-0.021	-0.023	-0.023	-0.023
Nuclear (GW)	102	105	111	111	111	113	Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	-0.003	-0.003	-0.003
Renewables (GW)	133	171	177	186	196	209	Renewables (GW)	-0.003	-0.025	-0.025	-0.022	-0.024	-0.031	-0.031	-0.031
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192	Total (GW)	-0.003	-0.034	-0.036	-0.046	-0.049	-0.060	-0.060	-0.060

Table 14.3.4 Clothes Dryers Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,552	1,635	1,705
Natural Gas (EJ)	5.22	5.11	5.24	5.31	5.31	5.29
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35
Natural Gas (Quads)	4.95	4.85	4.97	5.04	5.03	5.01
Other (Quads)	1.59	1.45	1.40	1.35	1.31	1.28
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304
Gas (TWh)	857	691	769	885	1,017	1,094
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	796	849	890
Total (TWh)	4,005	4,257	4,502	4,745	5,010	5,232
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	112
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation	
	2010	2015	2020	2025	2030	2035	2040	2043
Residential Sector Energy Consumption								
Electricity Sales (TWh)	0.00	-0.24	-0.88	-1.45	-1.86	-2.15	-2.36	-2.47
Natural Gas (EJ)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other (EJ)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Natural Gas (Quads)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other (Quads)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total U.S. Electric Generation								
Coal (TWh)	0.02	0.06	-0.20	0.00	-0.31	-0.31	-0.31	-0.31
Gas (TWh)	0.04	0.22	-0.23	-0.79	-0.81	-0.73	-0.73	-0.73
Petroleum (TWh)	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.14	-0.14	-0.14
Renewables (TWh)	-0.06	-0.55	-0.49	-0.59	-0.63	-0.77	-0.77	-0.77
Total (TWh)	0.00	-0.26	-0.91	-1.38	-1.76	-1.96	-1.96	-1.96
Installed Generating Capacity								
Coal (GW)	0.000	-0.009	-0.008	-0.008	-0.026	-0.016	-0.016	-0.016
Other Fossil (GW)	0.000	-0.048	-0.062	-0.134	-0.124	-0.136	-0.136	-0.136
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	-0.018	-0.018	-0.018
Renewables (GW)	-0.017	-0.149	-0.148	-0.131	-0.141	-0.187	-0.187	-0.187
Total (GW)	-0.017	-0.206	-0.217	-0.273	-0.291	-0.358	-0.358	-0.358

Table 14.3.5 Clothes Dryers Trial Standard Level 4 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,552	1,635	1,705
Natural Gas (EJ)	5.22	5.11	5.24	5.31	5.31	5.29
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35
Natural Gas (Quads)	4.95	4.85	4.96	5.04	5.03	5.01
Other (Quads)	1.59	1.45	1.40	1.35	1.31	1.28
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304
Gas (TWh)	857	691	769	885	1,017	1,094
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	796	850	890
Total (TWh)	4,005	4,257	4,502	4,745	5,010	5,232
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	112
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation	
	2010	2015	2020	2025	2030	2035	2040	2043
Residential Sector Energy Consumption								
Electricity Sales (TWh)	0.00	-0.24	-0.85	-1.40	-1.79	-2.07	-2.28	-2.38
Natural Gas (EJ)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.002	-0.002
Other (EJ)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Natural Gas (Quads)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.002
Other (Quads)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total U.S. Electric Generation								
Coal (TWh)	0.02	0.06	-0.19	0.00	-0.30	-0.30	-0.30	-0.30
Gas (TWh)	0.04	0.22	-0.22	-0.76	-0.78	-0.71	-0.71	-0.71
Petroleum (TWh)	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.13	-0.13	-0.13
Renewables (TWh)	-0.06	-0.53	-0.47	-0.57	-0.61	-0.74	-0.74	-0.74
Total (TWh)	0.00	-0.25	-0.88	-1.33	-1.70	-1.89	-1.89	-1.89
Installed Generating Capacity								
Coal (GW)	0.000	-0.009	-0.007	-0.007	-0.025	-0.015	-0.015	-0.015
Other Fossil (GW)	0.000	-0.046	-0.059	-0.129	-0.120	-0.131	-0.131	-0.131
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	-0.018	-0.018	-0.018
Renewables (GW)	-0.016	-0.144	-0.143	-0.127	-0.136	-0.181	-0.181	-0.181
Total (GW)	-0.017	-0.199	-0.210	-0.263	-0.280	-0.345	-0.345	-0.345

Table 14.3.6 Clothes Dryers Trial Standard Level 5 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,399	1,468	1,548	1,630	1,700
Natural Gas (EJ)	5.22	5.11	5.24	5.31	5.31	5.28
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35
Natural Gas (Quads)	4.95	4.85	4.96	5.03	5.03	5.01
Other (Quads)	1.59	1.44	1.40	1.35	1.31	1.28
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,208	2,304
Gas (TWh)	857	691	768	883	1,015	1,092
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	894
Renewables (TWh)	462	647	712	795	848	888
Total (TWh)	4,005	4,256	4,499	4,741	5,005	5,227
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	445	467	501	533
Nuclear (GW)	102	105	111	111	111	112
Renewables (GW)	133	171	176	186	195	209
Total (GW)	1,024	1,045	1,058	1,090	1,137	1,191

Difference from AEO2010 Reference Case

							Extrapolation	
	2010	2015	2020	2025	2030	2035	2040	2043
Residential Sector Energy Consumption								
Electricity Sales (TWh)	0.00	-0.87	-3.15	-5.15	-6.62	-7.65	-8.42	-8.79
Natural Gas (EJ)	0.000	-0.001	-0.003	-0.004	-0.006	-0.006	-0.007	-0.007
Other (EJ)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Natural Gas (Quads)	0.000	-0.001	-0.003	-0.004	-0.005	-0.006	-0.007	-0.007
Other (Quads)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total U.S. Electric Generation								
Coal (TWh)	0.08	0.22	-0.70	0.01	-1.12	-1.11	-1.11	-1.11
Gas (TWh)	0.14	0.80	-0.82	-2.81	-2.90	-2.61	-2.61	-2.61
Petroleum (TWh)	0.00	0.00	-0.02	-0.02	-0.03	-0.04	-0.04	-0.04
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.49	-0.49	-0.49
Renewables (TWh)	-0.21	-1.95	-1.73	-2.11	-2.24	-2.73	-2.73	-2.73
Total (TWh)	0.00	-0.93	-3.26	-4.93	-6.28	-6.98	-6.98	-6.98
Installed Generating Capacity								
Coal (GW)	0.00	-0.03	-0.03	-0.03	-0.09	-0.06	-0.06	-0.06
Other Fossil (GW)	0.00	-0.17	-0.22	-0.48	-0.44	-0.49	-0.49	-0.49
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.06	-0.06	-0.06
Renewables (GW)	-0.06	-0.53	-0.53	-0.47	-0.50	-0.67	-0.67	-0.67
Total (GW)	-0.06	-0.73	-0.78	-0.97	-1.04	-1.27	-1.27	-1.27

Table 14.3.7 Clothes Dryers Trial Standard Level 6 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,398	1,464	1,542	1,622	1,690
Natural Gas (EJ)	5.22	5.11	5.24	5.31	5.31	5.28
Other (EJ)	1.68	1.52	1.47	1.42	1.38	1.35
Natural Gas (Quads)	4.95	4.85	4.96	5.03	5.03	5.01
Other (Quads)	1.59	1.44	1.40	1.35	1.31	1.28
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,089	2,128	2,206	2,302
Gas (TWh)	858	691	767	878	1,010	1,088
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	894
Renewables (TWh)	462	645	711	793	846	885
Total (TWh)	4,005	4,255	4,496	4,733	4,997	5,217
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	445	466	500	533
Nuclear (GW)	102	105	111	111	111	112
Renewables (GW)	133	171	176	185	195	208
Total (GW)	1,024	1,045	1,058	1,089	1,136	1,190

Difference from AEO2010 Reference Case

							Extrapolation	
	2010	2015	2020	2025	2030	2035	2040	2043
Residential Sector Energy Consumption								
Electricity Sales (TWh)	0.00	-1.98	-7.20	-11.76	-15.11	-17.47	-19.21	-20.07
Natural Gas (EJ)	0.000	-0.001	-0.003	-0.004	-0.006	-0.006	-0.007	-0.007
Other (EJ)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Natural Gas (Quads)	0.000	-0.001	-0.003	-0.004	-0.005	-0.006	-0.007	-0.007
Other (Quads)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total U.S. Electric Generation								
Coal (TWh)	0.04	-0.04	-1.52	-1.39	-2.77	-3.05	-3.05	-3.05
Gas (TWh)	0.48	1.05	-2.52	-7.27	-7.77	-7.30	-7.30	-7.30
Petroleum (TWh)	0.00	-0.01	-0.03	-0.05	-0.07	-0.08	-0.08	-0.08
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.75	-0.75	-0.75
Renewables (TWh)	-0.50	-3.09	-3.00	-3.87	-4.09	-5.10	-5.10	-5.10
Total (TWh)	0.01	-2.09	-7.07	-12.57	-14.69	-16.29	-16.29	-16.29
Installed Generating Capacity								
Coal (GW)	0.00	-0.12	-0.07	-0.07	-0.19	-0.16	-0.16	-0.16
Other Fossil (GW)	0.00	-0.25	-0.38	-0.82	-0.96	-0.88	-0.88	-0.88
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.10	-0.10	-0.10
Renewables (GW)	-0.15	-0.86	-0.87	-0.78	-0.83	-1.12	-1.12	-1.12
Total (GW)	-0.15	-1.22	-1.32	-1.67	-1.98	-2.27	-2.27	-2.27

Table 14.3.8 Room Air Conditioners Trial Standard Level 1 Forecast

NEMS-BT Results:							Difference from AEO2010 Reference Case							Extrapolation	
	2010	2015	2020	2025	2030	2035		2010	2015	2020	2025	2030	2035	2040	2043
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*								
Electricity Sales (TWh)	1,388	1,400	1,471	1,552	1,636	1,707	Electricity Sales (TWh)	0.000	-0.300	-0.837	-1.030	-1.009	-0.840	-0.644	-0.560
Total U.S. Electric Generation							*Total U.S. Electric Generation*								
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304	Coal (TWh)	-0.001	-0.021	-0.141	-0.086	-0.158	-0.195	-0.195	-0.195
Gas (TWh)	857	690	769	885	1,018	1,095	Gas (TWh)	0.063	0.060	-0.272	-0.515	-0.364	-0.237	-0.237	-0.237
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.000	-0.002	-0.006	-0.006	-0.004	-0.004	-0.004	-0.004
Nuclear (TWh)	813	834	883	886	886	895	Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001
Renewables (TWh)	462	648	714	797	850	890	Renewables (TWh)	-0.060	-0.328	-0.297	-0.324	-0.284	-0.220	-0.220	-0.220
Total (TWh)	4,005	4,257	4,502	4,745	5,011	5,233	Total (TWh)	0.002	-0.292	-0.716	-0.931	-0.811	-0.658	-0.658	-0.658
Installed Generating Capacity							*Installed Generating Capacity*								
Coal (GW)	321	325	326	326	330	336	Coal (GW)	0.000	-0.007	-0.011	-0.010	-0.018	-0.023	-0.023	-0.023
Other Fossil (GW)	468	445	446	467	501	534	Other Fossil (GW)	0.000	-0.094	-0.129	-0.192	-0.262	-0.271	-0.271	-0.271
Nuclear (GW)	102	105	111	111	111	113	Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	133	171	177	186	196	209	Renewables (GW)	-0.018	-0.091	-0.086	-0.076	-0.067	-0.055	-0.055	-0.055
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192	Total (GW)	-0.018	-0.192	-0.226	-0.278	-0.347	-0.348	-0.348	-0.348

Table 14.3.9 Room Air Conditioners Trial Standard Level 2 Forecast

NEMS-BT Results:							Difference from AEO2010 Reference Case							Extrapolation	
	2010	2015	2020	2025	2030	2035		2010	2015	2020	2025	2030	2035	2040	2043
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*								
Electricity Sales (TWh)	1,388	1,400	1,471	1,552	1,636	1,706	Electricity Sales (TWh)	0.00	-0.36	-1.00	-1.23	-1.21	-1.03	-0.83	-0.74
Total U.S. Electric Generation							*Total U.S. Electric Generation*								
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304	Coal (TWh)	-0.001	-0.026	-0.168	-0.103	-0.191	-0.239	-0.239	-0.239
Gas (TWh)	857	690	769	885	1,018	1,095	Gas (TWh)	0.075	0.072	-0.325	-0.615	-0.438	-0.292	-0.292	-0.292
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.000	-0.002	-0.007	-0.007	-0.005	-0.005	-0.005	-0.005
Nuclear (TWh)	813	834	883	886	886	895	Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	-0.002	-0.002	-0.002
Renewables (TWh)	462	648	713	797	850	890	Renewables (TWh)	-0.072	-0.392	-0.354	-0.386	-0.342	-0.271	-0.271	-0.271
Total (TWh)	4,005	4,257	4,502	4,745	5,011	5,233	Total (TWh)	0.002	-0.348	-0.854	-1.112	-0.976	-0.809	-0.809	-0.809
Installed Generating Capacity							*Installed Generating Capacity*								
Coal (GW)	321	325	326	326	330	336	Coal (GW)	0.000	-0.009	-0.013	-0.012	-0.022	-0.028	-0.028	-0.028
Other Fossil (GW)	468	445	446	467	501	533	Other Fossil (GW)	0.000	-0.112	-0.154	-0.229	-0.315	-0.334	-0.334	-0.334
Nuclear (GW)	102	105	111	111	111	113	Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	133	171	176	186	196	209	Renewables (GW)	-0.021	-0.109	-0.103	-0.091	-0.081	-0.067	-0.067	-0.067
Total (GW)	1,024	1,046	1,059	1,090	1,138	1,192	Total (GW)	-0.021	-0.230	-0.269	-0.332	-0.418	-0.429	-0.429	-0.429

Table 14.3.10 Room Air Conditioners Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,470	1,552	1,636	1,706
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	797	850	890
Total (TWh)	4,005	4,257	4,502	4,745	5,011	5,233
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	533
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,090	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation	
	2010	2015	2020	2025	2030	2035	2040	2043
Residential Sector Energy Consumption								
Electricity Sales (TWh)	0.00	-0.42	-1.13	-1.32	-1.25	-1.05	-0.84	-0.74
Total U.S. Electric Generation								
Coal (TWh)	-0.001	-0.030	-0.190	-0.110	-0.196	-0.244	-0.244	-0.244
Gas (TWh)	0.091	0.085	-0.366	-0.658	-0.452	-0.297	-0.297	-0.297
Petroleum (TWh)	0.000	-0.003	-0.008	-0.008	-0.005	-0.005	-0.005	-0.005
Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	-0.002	-0.002	-0.002
Renewables (TWh)	-0.087	-0.462	-0.400	-0.413	-0.352	-0.276	-0.276	-0.276
Total (TWh)	0.00	-0.41	-0.96	-1.19	-1.01	-0.82	-0.82	-0.82
Installed Generating Capacity								
Coal (GW)	0.000	-0.010	-0.014	-0.013	-0.023	-0.029	-0.029	-0.029
Other Fossil (GW)	0.000	-0.132	-0.174	-0.245	-0.324	-0.340	-0.340	-0.340
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	-0.026	-0.128	-0.116	-0.097	-0.084	-0.068	-0.068	-0.068
Total (GW)	-0.026	-0.271	-0.304	-0.356	-0.431	-0.436	-0.436	-0.436

Table 14.3.11 Room Air Conditioners Trial Standard Level 4 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,470	1,552	1,635	1,706
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	796	850	890
Total (TWh)	4,005	4,257	4,501	4,744	5,010	5,233
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	445	467	501	533
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,090	1,137	1,192

Difference from AEO2010 Reference Case

							Extrapolation	
	2010	2015	2020	2025	2030	2035	2040	2043
Residential Sector Energy Consumption								
Electricity Sales (TWh)	0.00	-0.56	-1.50	-1.79	-1.74	-1.52	-1.27	-1.15
Total U.S. Electric Generation								
Coal (TWh)	-0.001	-0.040	-0.254	-0.149	-0.274	-0.353	-0.353	-0.353
Gas (TWh)	0.121	0.112	-0.489	-0.894	-0.629	-0.430	-0.430	-0.430
Petroleum (TWh)	0.000	-0.004	-0.011	-0.010	-0.008	-0.008	-0.008	-0.008
Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	-0.002	-0.002	-0.002
Renewables (TWh)	-0.115	-0.611	-0.534	-0.561	-0.491	-0.399	-0.399	-0.399
Total (TWh)	0.00	-0.54	-1.29	-1.61	-1.40	-1.19	-1.19	-1.19
Installed Generating Capacity								
Coal (GW)	0.000	-0.014	-0.019	-0.018	-0.032	-0.041	-0.041	-0.041
Other Fossil (GW)	0.000	-0.175	-0.232	-0.333	-0.452	-0.492	-0.492	-0.492
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	-0.034	-0.169	-0.155	-0.132	-0.116	-0.099	-0.099	-0.099
Total (GW)	-0.034	-0.358	-0.406	-0.483	-0.600	-0.632	-0.632	-0.632

Table 14.3.12 Room Air Conditioners Trial Standard Level 5 Forecast

NEMS-BT Results:							**Difference from AEO2010 Reference Case**								
														Extrapolation	
	2010	**2015**	**2020**	**2025**	**2030**	**2035**		**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2043**
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*								
Electricity Sales (TWh)	1,388	1,399	1,469	1,551	1,634	1,705	Electricity Sales (TWh)	0.00	-0.81	-2.21	-2.69	-2.70	-2.44	-2.10	-1.90
Total U.S. Electric Generation							*Total U.S. Electric Generation*								
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304	Coal (TWh)	0.00	-0.06	-0.37	-0.22	-0.42	-0.57	-0.57	-0.57
Gas (TWh)	857	690	768	884	1,017	1,094	Gas (TWh)	0.17	0.16	-0.72	-1.35	-0.97	-0.69	-0.69	-0.69
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.00	-0.01	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01
Nuclear (TWh)	813	834	883	886	886	895	Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (TWh)	462	648	713	796	849	890	Renewables (TWh)	-0.17	-0.88	-0.78	-0.85	-0.76	-0.64	-0.64	-0.64
Total (TWh)	4,005	4,256	4,501	4,743	5,010	5,232	Total (TWh)	0.01	-0.78	-1.89	-2.43	-2.17	-1.91	-1.91	-1.91
Installed Generating Capacity							*Installed Generating Capacity*								
Coal (GW)	321	325	326	326	330	336	Coal (GW)	0.00	-0.02	-0.03	-0.03	-0.05	-0.07	-0.07	-0.07
Other Fossil (GW)	468	445	445	467	501	533	Other Fossil (GW)	0.00	-0.25	-0.34	-0.50	-0.70	-0.79	-0.79	-0.79
Nuclear (GW)	102	105	111	111	111	113	Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (GW)	133	171	176	186	196	209	Renewables (GW)	-0.05	-0.24	-0.23	-0.20	-0.18	-0.16	-0.16	-0.16
Total (GW)	1,024	1,045	1,058	1,090	1,137	1,191	Total (GW)	-0.05	-0.52	-0.60	-0.73	-0.93	-1.01	-1.01	-1.01

Table 14.3.13 Room Air Conditioners Trial Standard Level 6 Forecast

NEMS-BT Results:							**Difference from AEO2010 Reference Case**								
														Extrapolation	
	2010	**2015**	**2020**	**2025**	**2030**	**2035**		**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2043**
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*								
Electricity Sales (TWh)	1,388	1,399	1,469	1,550	1,633	1,704	Electricity Sales (TWh)	0.00	-1.08	-2.99	-3.70	-3.78	-3.52	-3.11	-2.85
Total U.S. Electric Generation							*Total U.S. Electric Generation*								
Coal (TWh)	1,828	2,038	2,090	2,129	2,209	2,304	Coal (TWh)	0.00	-0.08	-0.51	-0.31	-0.59	-0.81	-0.81	-0.81
Gas (TWh)	857	691	768	884	1,017	1,094	Gas (TWh)	0.23	0.22	-0.97	-1.85	-1.37	-0.99	-0.99	-0.99
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.00	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Nuclear (TWh)	813	834	883	886	886	895	Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01
Renewables (TWh)	462	647	713	796	849	889	Renewables (TWh)	-0.22	-1.18	-1.06	-1.16	-1.06	-0.92	-0.92	-0.92
Total (TWh)	4,005	4,256	4,500	4,743	5,009	5,231	Total (TWh)	0.01	-1.05	-2.56	-3.35	-3.04	-2.75	-2.75	-2.75
Installed Generating Capacity							*Installed Generating Capacity*								
Coal (GW)	321	325	326	326	330	336	Coal (GW)	0.00	-0.03	-0.04	-0.04	-0.07	-0.10	-0.10	-0.10
Other Fossil (GW)	468	445	445	467	500	533	Other Fossil (GW)	0.00	-0.34	-0.46	-0.69	-0.98	-1.14	-1.14	-1.14
Nuclear (GW)	102	105	111	111	111	113	Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (GW)	133	171	176	186	196	209	Renewables (GW)	-0.07	-0.33	-0.31	-0.27	-0.25	-0.23	-0.23	-0.23
Total (GW)	1,024	1,045	1,058	1,090	1,137	1,191	Total (GW)	-0.07	-0.69	-0.81	-1.00	-1.30	-1.46	-1.46	-1.46

Table 14.3.14 presents the estimated reduction in electricity generating capacity in 2043 for the TSLs that DOE considered in this rulemaking.

Table 14.3.14 Reduction in Electric Generating Capacity in 2043 Under Clothes Dryer and Room Air Conditioner Trial Standard Levels

	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
	Gigawatts					
Clothes Dryers	0.002	0.060	0.358	0.345	1.27	2.27
Room Air Conditioners	0.348	0.429	0.436	0.632	1.01	1.46

14.4 IMPACT OF STANDARDS ON ELECTRICITY PRICES AND ASSOCIATED BENEFITS FOR CONSUMERS

Using the framework of the utility impact analysis, DOE analyzed the potential impact on electricity prices resulting from the standards on clothes dryer and room air conditioner products. Associated benefits for all electricity users in all sectors of the economy are then derived from these price impacts.

DOE's analysis of energy price impacts used NEMS-BT in a similar manner as described in section 14.2. Like other widely-used energy-economic models, NEMS uses elasticities to estimate the energy price change that would result from a change (increase or decrease) in energy demand. The elasticity of price to a decrease in demand is the "inverse price elasticity." The calculated inverse price elasticity based on NEMS-BT simulations differs throughout the forecast period in response to the dynamics of supply and demand for electricity.

14.4.1 Impact on Electricity Prices

DOE analyzed the electricity price effect of clothes dryers and room air conditioners separately. A separate regression was completed for both products to determine their effect on electricity prices independent of one another. After generating results using higher decrements to energy consumption, a regressed interpolation toward the origin derived the price effects associated with the energy savings of the TSLs. Results were then scaled to the appropriate TSL; the amended standard for both of these products is TSL 4. The electricity price impacts for clothes dryers and room air conditioners are presented separately below.

Figure 14.4.1 and 14.4.2 show the annual change in U.S. electricity sales for the amended standards, relative to the base case which involves no new standards.

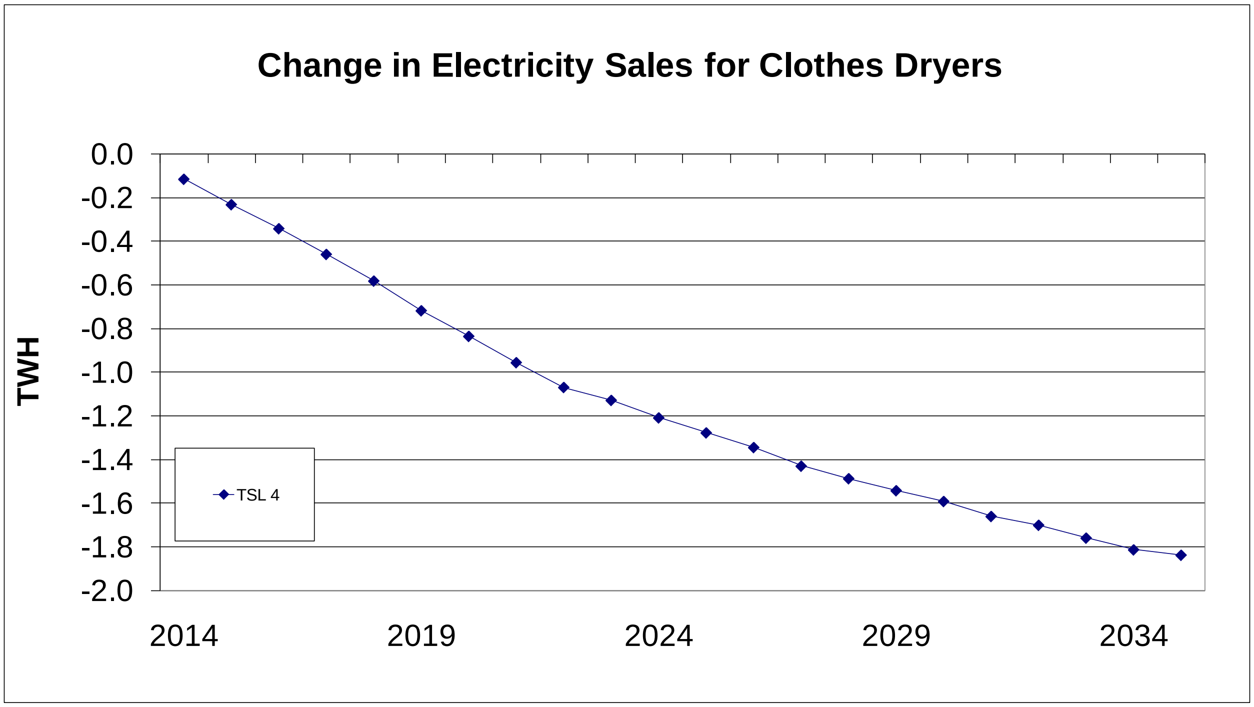

Figure 14.4.1 Change in U.S. Electricity Sales Associated with Amended Clothes Dryer Energy Conservation Standard

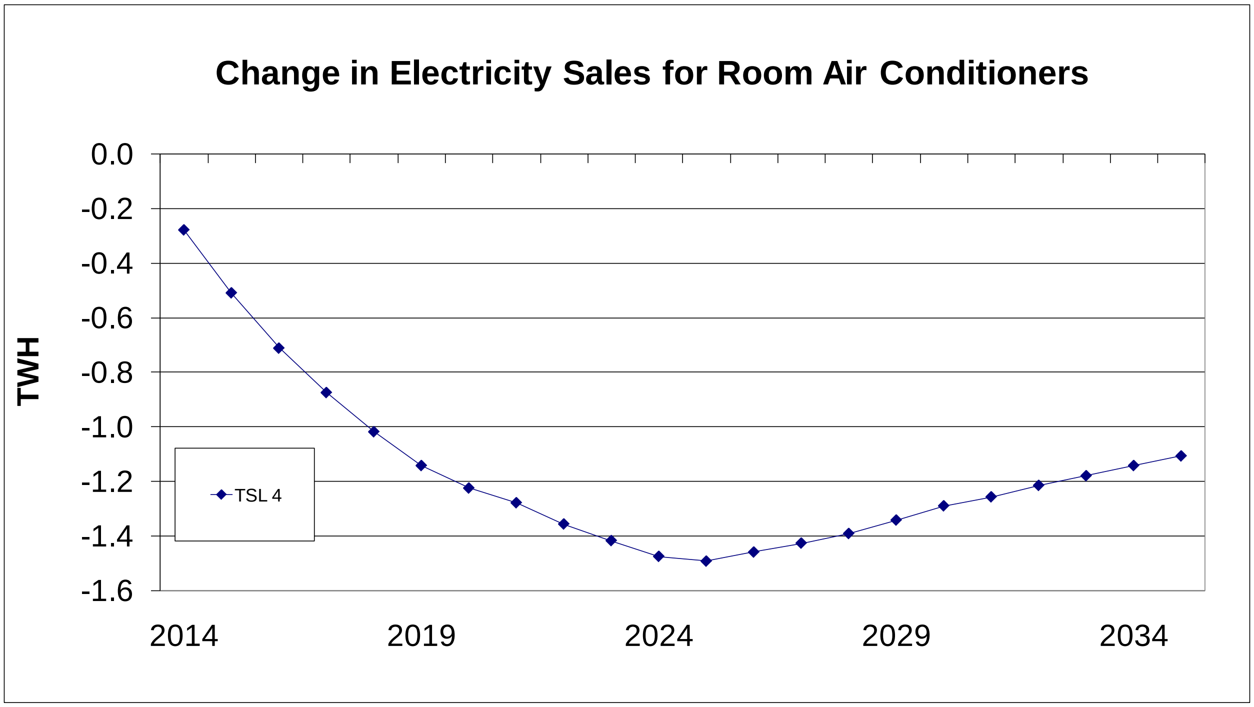

Figure 14.4.2 Change in U.S. Electricity Sales Associated with Amended Room Air Conditioner Energy Conservation Standard

Figures 14.4.3 and 14.4.4 show the annual change in average U.S. price for electricity, relative to the Reference case, projected to result from the amended standards. For clothes dryers the price reduction averages 0.001 cents per kWh (in 2009$), or a price reduction of 0.01 percent, over the period from 2014 through 2035. For room air conditioners the price reduction averages 0.003 cents per kWh (in 2009$), or a price reduction of 0.03 percent over the same period.

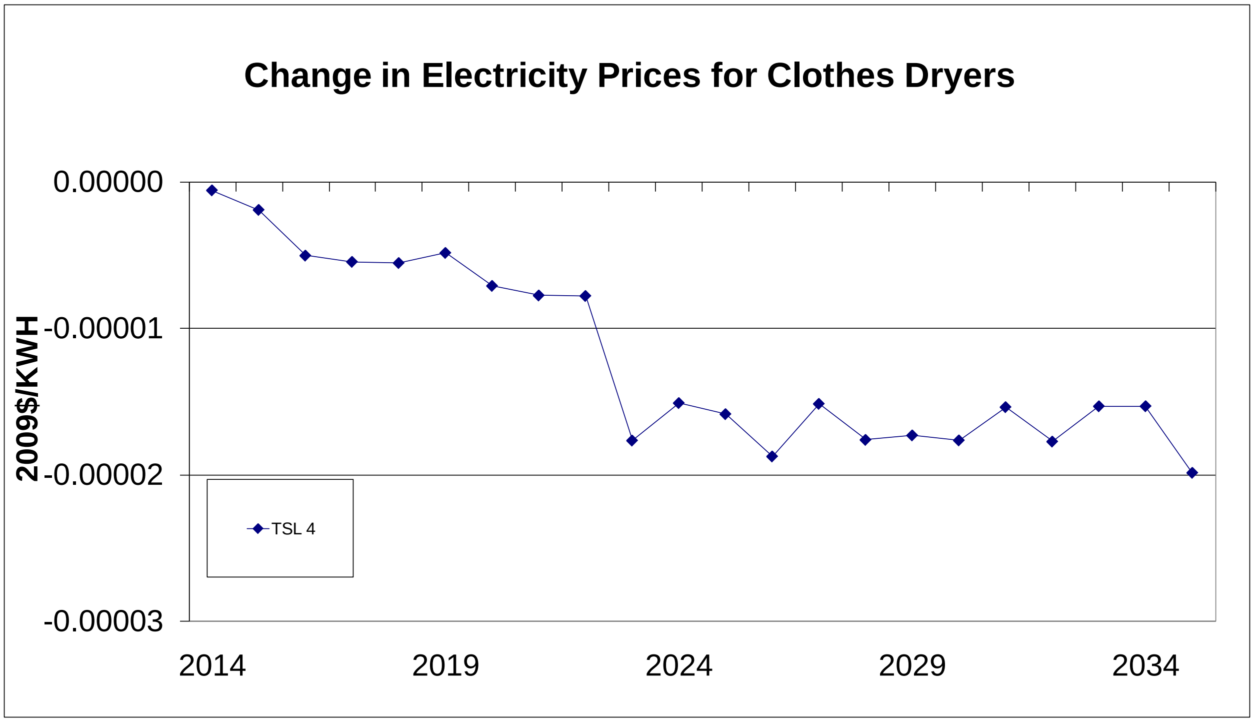

Figure 14.4.3 Effect of Proposed Clothes Dryer Energy Conservation Standard on Average U.S. Electricity Price (All Users)

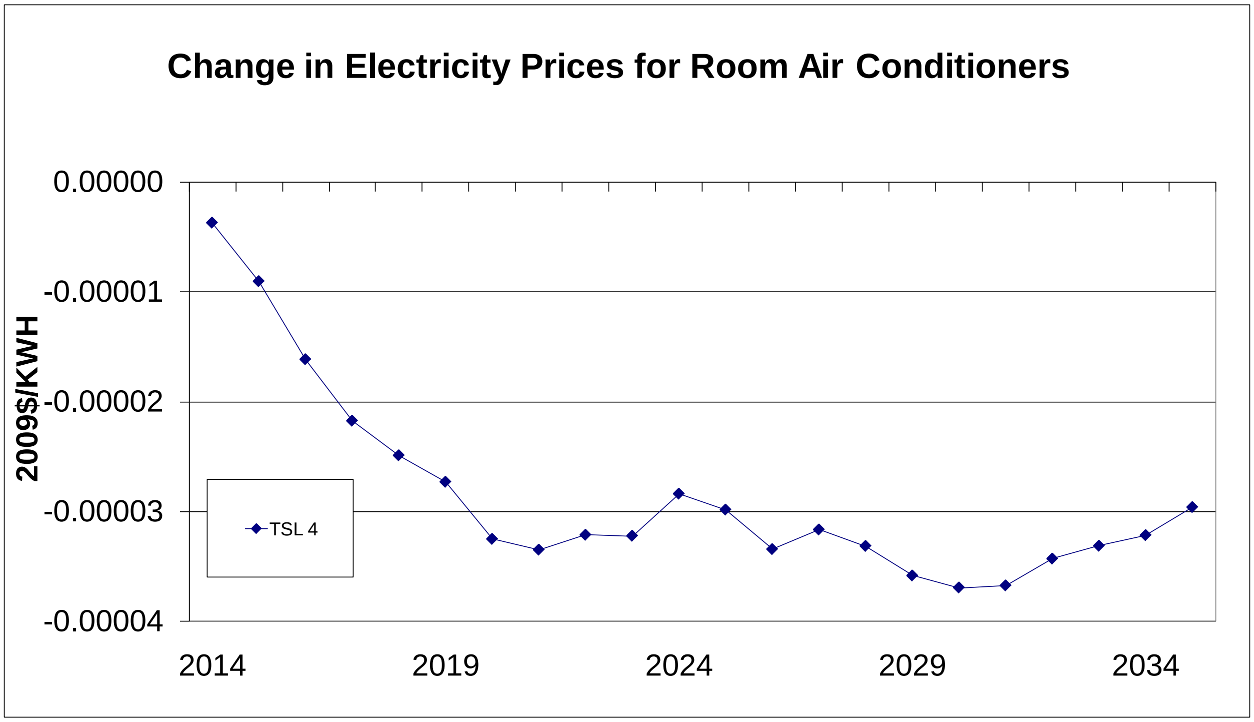

Figure 14.4.4 Effect of Proposed Room Air Conditioner Energy Conservation Standard on Average U.S. Electricity Price (All Users)

14.4.2 Impact of Changes in Electricity Price on Electricity Users

Using the estimated electricity price impacts, DOE calculated the nominal savings in total electricity expenditures in each year by multiplying the annual change in the average-user price for electricity by the total annual U.S. electricity sales forecast by NEMS, adjusted for the impact of the standards. The amended standards would continue to reduce demand for electricity after 2035 (which is the last year in the NEMS forecast). DOE's estimate for 2036–2043 (the period used to estimate the NPV of the national consumer benefits from amended standards) multiplied the average electricity price reduction in 2015–2035 by estimated total annual electricity sales in 2036–2043.[c] DOE then discounted the stream of reduced expenditures to calculate a NPV.

Table 14.4.1 shows the calculated NPV of the economy-wide savings in electricity expenditures for each considered TSL at 3-percent and 7-percent discount rates. The need to extrapolate price effects and electricity sales beyond 2035 suggests that one should interpret the post-2035 results as a rough indication of the benefits to electricity users in the post-2035 period.

[c] The estimation of electricity sales after 2035 uses the average annual growth rate in 2031-2035 of total U.S. electricity sales forecasted by NEMS. This forecast includes the impact of the standards.

Table 14.4.1 Cumulative NPV of the Economy-Wide Savings in Electricity Expenditures Due to the Projected Decline in Electricity Prices Resulting from the Proposed Standards for Clothes Dryers and Room Air Conditioners*

Discount Rate	Clothes Dryers *(billion $2009)*	Room Air Conditioners *(billion $2009)*
3 percent	0.862	2.098
7 percent	0.409	1.051

* Impacts for units sold from 2014 to 2043

14.4.3 Discussion of Savings in Electricity Expenditures

Although the aggregate benefits for all electricity users are potentially large, there may be negative effects on the actors involved in electricity supply. The electric power industry is a complex mix of power plant providers, fuel suppliers, electricity generators, and electricity distributors. While the distribution of electricity is regulated everywhere, the institutional structure of the power sector varies, and has changed over time. For these reasons, an assessment of impacts on the actors involved in electricity supply from reduction in electricity demand associated with energy conservation standards is beyond the scope of this rulemaking.

In considering the potential benefits to electricity users, DOE takes under advisement the provided by the Office of Management and Budget (OMB) to Federal agencies on the development of regulatory analysis (OMB Circular A-4 (Sept. 17, 2003), section E, “Identifying and Measuring Benefits and Costs”). Specifically, at page 38, Circular A-4 instructs that transfers should be excluded from the estimates of the benefits and costs of a regulation. DOE is continuing to investigate the extent to which change in electricity prices projected to result from standards represents a net gain to society.

REFERENCES

1. Energy Information Administration, *Updated Annual Energy Outlook 2010 Reference Case Service Report*, 2010. Washington, DC. Report No. DOE/EIA-0383(2010). <http://www.eia.doe.gov/oiaf/aeo/>

CHAPTER 15. ENVIRONMENTAL IMPACTS ANALYSIS

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CHAPTER 15. ENVIRONMENTAL IMPACTS ANALYSIS

15.1 INTRODUCTION

This chapter describes potential environmental effects that may result from amended energy conservation standards for residential clothes dryers and room air conditioners. The U.S. Department of Energy (DOE)'s energy conservation standards are not site-specific, and would apply to all 50 States and U.S. territories. Therefore, none of the standards would impact land uses, cause any direct disturbance to the land, or directly affect biological resources in any one area.

All of the trial standard levels (TSLs) are expected to reduce energy consumption in comparison to the base case. These changes in energy consumption are the primary drivers in analyzing environmental effects. The estimates of energy savings that serve as inputs to the environmental impacts analysis can be found in the utility impact analysis in chapter 14 of this technical support document (TSD).

The primary impact of the TSLs is on air emissions resulting from power plant operations. Therefore, much of this chapter describes the air emissions analysis, and the latter part of the chapter describes potential impacts to other environmental resources. For clothes dryers there are some household emissions resulting from natural gas usage.

15.2 AIR EMISSIONS ANALYSIS

A primary focus of the environmental analysis is the impact on air emissions of amended energy conservation standards for residential clothes dryers and room air conditioner products. The outcomes of the environmental analysis are largely driven by changes in power plant types and quantities of electricity generated under each of the alternatives. Changes in electricity generation are described in the utility impact analysis in chapter 14.

15.2.1 Air Emissions Descriptions

For each of the TSLs, DOE calculated total power-sector emissions based on output from the NEMS-BT model (see chapter 14 for description of the model). This analysis considers three pollutants: sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury (Hg). An air pollutant is any substance in the air that can cause harm to humans or the environment. Pollutants may be natural or man-made (i.e., anthropogenic) and may take the form of solid particles (i.e., particulates or particulate matter), liquid droplets, or gases.[a] This analysis also considers carbon dioxide (CO_2).

[a] More information on air pollution characteristics and regulations is available on the U.S. Environment Protection Agent (EPA)'s website at www.epa.gov.

Sulfur Dioxide. Sulfur dioxide, or SO_2, belongs to the family of sulfur oxide gases (SOx). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron. SOx gases are formed when fuel containing sulfur, such as coal and oil, is burned, and when gasoline is extracted from oil, or metals are extracted from ore. SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment.[1]

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

Nitrogen Oxides. Nitrogen oxides**,** or NO_X, is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2), along with particles in the air can often be seen as a reddish-brown layer over many urban areas. NO_2 is the specific form of NO_X reported in this document. NO_X is one of the main ingredients involved in the formation of ground-level ozone, which can trigger serious respiratory problems. It can contribute to the formation of acid rain, and can impair visibility in areas such as national parks. NO_X also contributes to the formation of fine particles that can impair human health.[1]

Nitrogen oxides form when fossil fuel is burned at high temperatures, as in a combustion process. The primary manmade sources of NO_X are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fossil fuels. NO_X can also be formed naturally. Electric utilities account for about 22 percent of NO_X emissions in the United States.[2]

There is a cap on NO_x emissions in 28 eastern states and the District of Columbia. All these States and D.C. have elected to reduce their NOx emissions by participating in cap-and-trade programs for EGUs. Therefore, energy conservation standards for clothes dryers and room air conditioners may have little or no physical effect on these emissions in the 28 eastern states and the D.C. for the same reasons that they may have little or no physical effect on NO_X emissions.

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

Mercury. Coal-fired power plants emit mercury (Hg) found in coal during the burning process. While coal-fired power plants are the largest remaining source of human-generated Hg emissions in the United States, they contribute very little to the global Hg pool or to contamination of U.S. waters.[1] U.S. coal-fired power plants emit Hg in three different forms: oxidized Hg (likely to deposit within the United States); elemental Hg, which can travel thousands of miles before depositing to land and water; and Hg that is in particulate form. Atmospheric Hg is then deposited on land, lakes, rivers, and estuaries through rain, snow, and dry deposition. Once there, it can transform into methylmercury and accumulate in fish tissue through bioaccumulation.

Americans are exposed to methylmercury primarily by eating contaminated fish. Because the developing fetus is the most sensitive to the toxic effects of methylmercury, women of childbearing age are regarded as the population of greatest concern. Children exposed to methylmercury before birth may be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities, and verbal memory.[3]

Carbon Dioxide. Carbon dioxide (CO_2) is not a criteria pollutant (see below), but it is of interest because of its classification as a greenhouse gas (GHG). GHGs trap the sun's radiation inside the Earth's atmosphere and either occur naturally in the atmosphere or result from human activities. Naturally occurring GHGs include water vapor, CO_2, methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Human activities, however, add to the levels of most of these naturally occurring gases. For example, CO_2 is emitted to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), wood, and wood products are burned. In 2007, over 90 percent of anthropogenic (i.e., human-made) CO_2 emissions resulted from burning fossil fuels.[4]

Concentrations of CO_2 in the atmosphere are naturally regulated by numerous processes, collectively known as the "carbon cycle." The movement of carbon between the atmosphere and the land and oceans is dominated by natural processes, such as plant photosynthesis. While these natural processes can absorb some of the anthropogenic CO_2 emissions produced each year, billions of metric tons are added to the atmosphere annually. In the United States, in 2007, CO_2 emissions from electricity generation accounted for 39 percent of total U.S. GHG emissions.[4]

Particulate Matter. Particulate matter (PM) also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

PM impacts are of concern due to human exposures that can impact health. Particle pollution - especially fine particles - contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including:

increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, for example; decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease.

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

Air Quality Regulation. The Clean Air Act Amendments of 1990 list 188 toxic air pollutants that EPA is required to control.[6] EPA has set national air quality standards for six common pollutants (also referred to as "criteria" pollutants), two of which are SO_2 and NO_X. Also, the Clean Air Act Amendments of 1990 gave EPA the authority to control acidification and to require operators of electric power plants to reduce emissions of SO_2 and NO_X. Title IV of the 1990 amendments established a cap-and-trade program for SO_2, in all 50 states and the District of Columbia (D.C.), intended to help control acid rain.[6] This cap-and-trade program serves as a model for more recent programs with similar features.

In 2005, EPA issued the Clean Air Interstate Rule (CAIR) under sections 110 and 111 of the Clean Air Act (40 CFR Parts 51, 96, and 97).[7] [b] CAIR will permanently cap emissions of SO_2 and NO_X in eastern States of the United States. CAIR achieves large reductions of SO_2 and/or NO_X emissions across 28 eastern States and the District of Columbia. CAIR will gradually replace the Title IV program in the 28 states and D.C. States must achieve the required emission reductions using one of two compliance options: 1) meet an emission budget for each regulated state by requiring power plants to participate in an EPA-administered interstate cap-and-trade system that caps emissions in two stages, or 2) meet an individual state emissions budget through measures of the state's choosing. Phase 1 caps for NO_X have been in place since

[b] See http://www.epa.gov/cleanairinterstaterule/.

2009. Phase 1 caps for SO_2 are to be in place beginning in 2010. The Phase 2 caps for both NO_X and SO_2 are due in 2015.

On July 11, 2008, the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) issued its decision in North Carolina v. Environmental Protection Agency, which vacated the CAIR issued by the U.S. Environmental Protection Agency on March 10, 2005.[c] CAIR was the vehicle for capping NO_X emissions.[d] On December 23, 2008, the D.C. Circuit decided to allow CAIR to remain in effect until it is replaced by a rule consistent with the court's earlier opinion. North Carolina v. EPA, 550 F.3d 1176 (D.C. Cir. 2008) (remand of vacatur).[e] Thus, CAIR is currently in force. However, on July 6, 2010, EPA proposed the Transport Rule, a replacement for CAIR, which would limit emissions from EGUs in 32 states, potentially through the interstate trading of allowances, among other options. 75 FR 45210 (Aug. 2, 2010).

With respect to Hg emissions, in 2005, EPA issued the final rule entitled "Standards of Performance for New and Existing Stationary Sources: Electric Steam Generating Units," under sections 110 and 111 of the Clean Air Act (40 CFR Parts 60, 63, 72, and 75)[8]. This rule, called the Clean Air Mercury Rule (CAMR), was closely related to the CAIR and established standards of performance for Hg emissions from new and existing coal-fired electric utility steam generating units. The CAMR regulated Hg emissions from coal-fired power plants.

On February 8, 2008, the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) issued its decision in State of New Jersey, *et al.* v. Environmental Protection Agency,[f] in which the Court, among other actions, vacated the CAMR referenced above.

15.2.2 Global Climate Change

Climate change has evolved into a matter of global concern because it is expected to have widespread, adverse effects on natural resources and systems. A growing body of evidence points to anthropogenic sources of greenhouse gases, such as carbon dioxide (CO_2), as major contributors to climate change. Because this Rule, if finalized, will likely decrease CO_2 emission rates from the fossil fuel sector in the United States, the Department here examines the impacts and causes of climate change and then the potential impact of the Rule on CO_2 emissions and global warming.

Impacts of Climate Change on the Environment. Climate is usually defined as the average weather, over a period ranging from months to many years. Climate change refers to a change in the state of the climate, which is identifiable through changes in the mean and/or the variability of its properties (e.g., temperature or precipitation) over an extended period, typically decades or longer.[9]

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[c] See http://www.epa.gov/cleanairinterstaterule/.

[d] *See id.* at 903.

[e] State of North Carolina, et al. v. Environmental Protection Agency, 550 F.3d 1176 (D.C. Cir. 2008).

[f] 517 F.3d 574, 583 (D.C. Cir. 2008).

The World Meteorological Organization and United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) to provide an objective source of information about climate change. According to the IPCC Fourth Assessment Report (IPCC Report), published in 2007, climate change is consistent with observed changes to the world's natural systems; the IPCC expects these changes to continue.[9]

Changes that are consistent with warming include warming of the world's oceans to a depth of 3000 meters; global average sea level rise at an average rate of 1.8 mm per year from 1961 to 2003; loss of annual average Arctic sea ice at a rate of 2.7 percent per decade, changes in wind patterns that affect extra-tropical storm tracks and temperature patterns, increases in intense precipitation in some parts of the world, as well as increased drought and more frequent heat waves in many locations worldwide, and numerous ecological changes.[9]

Looking forward, the IPCC describes continued global warming of about 0.2 °C per decade for the next two decades under a wide range of emission scenarios for carbon dioxide (CO_2), other greenhouse gases (GHGs), and aerosols. After that period, the rate of increase is less certain. The IPCC Report describes increases in average global temperatures of about 1.1 °C to 6.4 °C at the end of the century relative to today. These increases vary depending on the model and emissions scenarios.[9]

The IPCC Report describes incremental impacts associated with the rise in temperature. At ranges of incremental increases to the global average temperature, IPCC reports, with either high or very high confidence, that there is likely to be an increasing degree of impacts such as coral reef bleaching, loss of wildlife habitat, loss to specific ecosystems, and negative yield impacts for major cereal crops in the tropics, but also projects that there likely will be some beneficial impacts on crop yields in temperate regions.

Causes of Climate Change. The IPCC Report states that the world has warmed by about 0.74 °C in the last 100 years. The IPCC Report finds that most of the temperature increase since the mid-20th century is very likely due to the increase in anthropogenic concentrations of CO_2 and other long-lived greenhouse gases such as methane and nitrous oxide in the atmosphere, rather than from natural causes.

Increasing the CO_2 concentration partially blocks the earth's re-radiation of captured solar energy in the infrared band, inhibits the radiant cooling of the earth, and thereby alters the energy balance of the planet, which gradually increases its average temperature. The IPCC Report estimates that currently, CO_2 makes up about 77 percent of the total CO_2-equivalent[g] global warming potential in GHGs emitted from human activities, with the vast majority (74 percent) of the CO_2 attributable to fossil fuel use.[10] For the future, the IPCC Report describes a

[g] GHGs differ in their warming influence (radiative forcing) on a global climate system due to their different radiative properties and lifetimes in the atmosphere. These warming influences may be expressed through a common metric based on the radiative forcing of CO_2, i.e., CO_2-equivalent. CO_2 equivalent emission is the amount of CO_2 emission that would cause the same- time integrated radiative forcing, over a given time horizon, as an emitted amount of other long- lived GHG or mixture of GHGs.

wide range of GHG emissions scenarios, but under each scenario CO_2 would continue to comprise above 70 percent of the total global warming potential.[10]

Stabilization of CO_2 Concentrations. Unlike many traditional air pollutants, CO_2 mixes thoroughly in the entire atmosphere and is long-lived. The residence time of CO_2 in the atmosphere is long compared to the emission processes. Therefore, the global cumulative emissions of CO_2 over long periods determine CO_2 concentrations because it takes hundreds of years for natural processes to remove the CO_2. Globally, 49 billion metric tons of CO_2 – equivalent of anthropogenic (man-made) greenhouse gases are emitted every year. Of this annual total, fossil fuels contribute about 29 billion metric tons of CO_2.[11] [h]

Researchers have focused on considering atmospheric CO_2 concentrations that likely will result in some level of global climate stabilization, and the emission rates associated with achieving the "stabilizing" concentrations by particular dates. They associate these stabilized CO_2 concentrations with temperature increases that plateau in a defined range. For example, at the low end, the IPCC Report scenarios target CO_2 stabilized concentrations range between 350 ppm and 400 ppm (essentially today's value)—because of climate inertia, concentrations in this low-end range would still result in temperatures projected to increase 2.0 °C to 2.4 °C above pre-industrial levels[i] (about 1.3 °C to 1.7 °C above today's levels). To achieve concentrations between 350 ppm to 400 ppm, the IPCC scenarios present that there would have to be a rapid downward trend in total annual global emissions of greenhouse gases to levels that are 50 to 85 percent below today's annual emission rates by no later than 2050. Since it is assumed that there would continue to be growth in global population and substantial increases in economic production, the scenarios identify required reductions in greenhouse gas emissions intensity (emissions per unit of output) of more than 90 percent. However, even at these rates, the scenarios describe some warming and some climate change is projected due to already accumulated CO_2 and GHGs in the atmosphere.[12]

The Beneficial Impact of the Rule on CO_2 Emissions. It is anticipated that the Rule will reduce energy-related CO_2 emissions, particularly those associated with energy consumption in buildings. The U.S. Energy Information Administration (EIA) reports in its 2010 *Annual Energy Outlook* (*AEO2010*)[13] that U.S. annual energy-related emissions of CO_2 in 2007 were about 6.0 billion metric tons, of which 1.2 billion tons were attributed to the residential buildings sector (including related energy–using products such as clothes dryer and room air conditioner products). Most of the greenhouse gas emissions attributed to residential buildings are emitted from fossil fuel-fired power plants that generate electricity used in this sector. In the *AEO2010* Reference Case, EIA projected that annual energy-related CO_2 emissions would grow from 5.7 billion metric tons in 2015 to 6.3 billion metric tons in 2035, an increase of 10 percent (see *AEO2010*), while residential emissions would grow to from 1.2 billion metric tons to 1.3 billion metric tons, an increase of 12 percent.

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[h] Other non-fossil fuel contributors include CO_2 emissions from deforestation and decay from agriculture biomass; agricultural and industrial emissions of methane; and emissions of nitrous oxide and fluorocarbons.

[i] IPCC Working Group 3 Table TS 2

The estimated cumulative CO_2 emission reductions from residential clothes dryers and room air conditioner efficiency standards (shown as a range of alternative TSLs) during the 30-year analysis period are indicated in Table 15.2.1. Estimated CO_2 emission reductions in Table 15.2.1 come from electricity generation (i.e., power plants) and household emissions. The estimated CO_2 emission reductions from electricity generation are calculated using the NEMS-BT model.

Table 15.2.1 Reduction in Cumulative Energy-Related Emissions of CO_2 from 2014 through 2043 from Residential Clothes Dryer and Room Air Conditioner Energy Conservation Standards

	Trial Standard Levels					
	TSL 1	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**	**TSL 6**
	Million Metric Tons					
Clothes Dryers	0.119	2.99	17.7	18.7	70.5	187
Room Air Conditioners	9.83	11.9	12.5	17.4	26.9	37.7
Total	9.95	14.9	30.2	36.1	97.4	224
Percent of Total Cumulative Emissions Reduction compared with the *AEO2010* Reference Case in 2014-2043	0.013	0.020	0.041	0.048	0.131	0.301

The Incremental Impact of the Rule on Climate Change. It is difficult to correlate specific emission rates with atmospheric concentrations of CO_2 and specific atmospheric concentrations with future temperatures because the IPCC Report describes a clear lag in the climate system between any given concentration of CO_2 (even if maintained for long periods) and the subsequent average worldwide and regional temperature, precipitation, and extreme weather regimes. For example, a major determinant of climate response is "equilibrium climate sensitivity", a measure of the climate system response to sustained radiative forcing. It is defined as the global average surface warming following a doubling of carbon dioxide concentrations. The IPCC Report describes its estimated, numeric value as about 3 °C, but the likely range of that value is 2 °C to 4.5 °C, with cloud feedbacks the largest source of uncertainty. Further, as illustrated above, the IPCC Report scenarios for stabilization rates are presented in terms of a range of concentrations, which then correlates to a range of temperature changes. Thus, climate sensitivity is a key uncertainty for CO_2 mitigation scenarios that aim to meet specific temperature levels.

Because of how complex global climate systems are, it is difficult to know to what extent and when particular CO_2 emissions reductions will impact global warming. However, as Table 15.2.1 indicates, the rule is expected to reduce CO_2 emissions associated with energy consumption in buildings.

15.2.3 Analytical Methods for Air Emissions

Coal-fired electric generation is the single largest source of electricity in the United States. Because the mix of coals used significantly affects the emissions produced, the model includes a detailed representation of coal supply. The model considers the rank of the coal as well as the sulfur contents of the fuel used when determining optimal dispatch.[14]

Within the NEMS-BT model, planning options for achieving emissions restrictions in the Clean Air Act Amendments include installing pollution control equipment on existing power plants and building new power plants with low emission rates. These methods for reducing emission are compared to dispatching options such as fuel switching and allowance trading. Environmental regulations also affect capacity expansion decisions. For instance, new plants are not allocated SO_2 emissions allowances according to the Clean Air Act Amendments. Consequently, the decision to build a particular capacity type must consider the cost (if any) of obtaining sufficient allowances. This could involve purchasing allowances or over complying at an existing unit.

DOE's analysis assumes the presence of nationwide emission caps on SO_2 and caps on NO_X emissions in the 28 States covered by the CAIR. The NEMS-BT modeling system that DOE plans to use to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2. However, in contrast to the modeling forecasts of NEMS-BT that SO_2 emissions reductions will remain at the cap, during the years 2007 and 2008, SO_2 emissions have been below the trading cap. The difference between the emissions levels that NEMS-BT forecasts and those that EPA forecasts is an indicator of the uncertainties associated with long-range energy sector forecasts. Because of such uncertainties, DOE is unable to estimate the economic and physical benefit from SO_2 emissions reductions at this time.

With respect to Hg, in the absence of CAMR or other trading program, a DOE standard would likely reduce Hg emissions and DOE uses NEMS-BT to estimate these emission reductions. However, DOE continues to review the impact of rules that reduce energy consumption on Hg emissions, and may revise its assessment of Hg emission reductions in future rulemakings.

As noted in chapter 14, NEMS-BT model forecasts end in year 2035. Emissions impacts beyond 2035 are assumed to be equal to the impacts in 2035.

15.2.4 Effects on Power Plant Emissions

Table 15.2.2 shows *AEO2010* reference case power plant emissions in selected years. The Reference Case emissions are the emissions shown by the NEMS-BT model to result if none of the TSLs are promulgated (the base case).

Table 15.2.2 Power Sector Emissions Forecast from *AEO2010* Reference Case

NEMS-BT Results	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
CO_2 (million metric tons)	2,218	2,278	2,341	2,421	2,534	2,636
NO_X (million tons)	2.24	2.06	2.02	2.03	2.06	2.07
Hg (tons)	40.6	30.6	30.1	30.0	30.2	30.3

Tables 15.2.3 and 15.2.4 show the estimated changes in power plant emissions by TSL for residential clothes dryers and room air conditioners. The tables display changes in CO_2, NO_x, and Hg emissions in selected years for each of the TSLs. "Mt" refers to "million metric tons."

Similarly Table 15.2.5 shows household emissions impacts for residential clothes dryers by TSL in selected years. This table displays changes in CO_2, NO_X, and SO_2 emissions. There are no household emissions impacts for room air conditioners.

Table 15.2.3 Power Sector Emissions Impacts Forecasts for Clothes Dryer TSLs

NEMS-BT Results*	Difference from AEO2010 Reference Case								
							Extrapolation		Total
	2010	2015	2020	2025	2030	2035	2040	2043	2014-2043
Standard Level 1									
CO2 (Mt/yr)	0.000	0.001	-0.002	-0.004	-0.005	-0.005	-0.005	-0.005	**-0.104**
NOx (1,000 tons/yr)	0.000	0.001	-0.002	-0.003	-0.004	-0.004	-0.004	-0.004	**-0.084**
Hg (ton/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Standard Level 2									
CO2 (Mt/yr)	0.008	0.039	-0.058	-0.105	-0.147	-0.136	-0.136	-0.136	**-2.97**
NOx (1,000 tons/yr)	0.008	0.035	-0.050	-0.088	-0.119	-0.106	-0.106	-0.106	**-2.39**
Hg (ton/yr)	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	**-0.009**
Standard Level 3									
CO2 (Mt/yr)	0.048	0.235	-0.345	-0.625	-0.877	-0.808	-0.808	-0.808	**-17.7**
NOx (1,000 tons/yr)	0.049	0.212	-0.298	-0.525	-0.712	-0.633	-0.633	-0.633	**-14.2**
Hg (ton/yr)	0.000	0.000	-0.003	-0.001	-0.003	-0.002	-0.002	-0.002	**-0.053**
Standard Level 4									
CO2 (Mt/yr)	0.047	0.227	-0.333	-0.603	-0.846	-0.779	-0.779	-0.779	**-17.1**
NOx (1,000 tons/yr)	0.047	0.205	-0.287	-0.507	-0.687	-0.611	-0.611	-0.611	**-13.7**
Hg (ton/yr)	0.000	0.000	-0.003	-0.001	-0.003	-0.002	-0.002	-0.002	**-0.051**
Standard Level 5									
CO2 (Mt/yr)	0.173	0.837	-1.231	-2.227	-3.125	-2.878	-2.878	-2.878	**-63.2**
NOx (1,000 tons/yr)	0.174	0.757	-1.061	-1.871	-2.537	-2.256	-2.256	-2.256	**-50.8**
Hg (ton/yr)	0.001	-0.001	-0.012	-0.005	-0.009	-0.007	-0.007	-0.007	**-0.188**
Standard Level 6									
CO2 (Mt/yr)	0.421	0.826	-3.279	-6.880	-8.205	-7.971	-7.971	-7.971	**-179**
NOx (1,000 tons/yr)	0.425	0.747	-2.825	-5.781	-6.662	-6.248	-6.248	-6.248	**-145**
Hg (ton/yr)	0.006	-0.009	-0.018	-0.015	-0.012	-0.022	-0.022	-0.022	**-0.569**

*CO_2 results are in metric tons, NO_X and Hg results are in short tons.

Table 15.2.4 Power Sector Emissions Impact Forecasts for Room Air Conditioner TSLs

NEMS-BT Results*	Difference from AEO2010 Reference Case								
							Extrapolation		Total
	2010	2015	2020	2025	2030	2035	2040	2043	2014-2043
Standard Level 1									
CO2 (Mt/yr)	0.050	0.030	-0.338	-0.480	-0.408	-0.333	-0.333	-0.333	**-9.83**
NOx (1,000 tons/yr)	0.051	0.027	-0.291	-0.403	-0.331	-0.261	-0.261	-0.261	**-8.02**
Hg (ton/yr)	0.000	0.001	-0.001	-0.001	0.000	0.000	0.000	0.000	**-0.012**
Standard Level 2									
CO2 (Mt/yr)	0.060	0.036	-0.403	-0.573	-0.491	-0.410	-0.410	-0.410	**-11.9**
NOx (1,000 tons/yr)	0.061	0.033	-0.347	-0.482	-0.398	-0.321	-0.321	-0.321	**-9.69**
Hg (ton/yr)	0.000	0.001	-0.001	-0.001	0.000	0.000	0.000	0.000	**-0.015**
Sandard Level 3									
CO2 (Mt/yr)	0.073	0.042	-0.455	-0.613	-0.506	-0.418	-0.418	-0.418	**-12.5**
NOx (1,000 tons/yr)	0.074	0.038	-0.392	-0.515	-0.410	-0.327	-0.327	-0.327	**-10.2**
Hg (ton/yr)	0.000	0.001	-0.002	-0.001	0.000	0.000	0.000	0.000	**-0.017**
Standard Level 4									
CO2 (Mt/yr)	0.097	0.056	-0.607	-0.833	-0.705	-0.604	-0.604	-0.604	**-17.4**
NOx (1,000 tons/yr)	0.097	0.051	-0.523	-0.700	-0.572	-0.474	-0.474	-0.474	**-14.2**
Hg (ton/yr)	0.001	0.001	-0.002	-0.002	-0.001	0.000	0.000	0.000	**-0.022**
Standard Level 5									
CO2 (Mt/yr)	0.139	0.081	-0.892	-1.255	-1.091	-0.970	-0.970	-0.970	**-26.9**
NOx (1,000 tons/yr)	0.141	0.073	-0.769	-1.054	-0.885	-0.760	-0.760	-0.760	**-21.9**
Hg (ton/yr)	0.001	0.002	-0.003	-0.002	-0.001	0.000	0.000	0.000	**-0.032**
Standard Level 6									
CO2 (Mt/yr)	0.186	0.108	-1.208	-1.726	-1.528	-1.396	-1.396	-1.396	**-37.7**
NOx (1,000 tons/yr)	0.187	0.098	-1.041	-1.450	-1.241	-1.094	-1.094	-1.094	**-30.7**
Hg (ton/yr)	0.001	0.002	-0.004	-0.003	-0.001	0.000	0.000	0.000	**-0.044**

*CO_2 results are in metric tons, NO_X and Hg results are in short tons.

Table 15.2.5 Household Emissions Impact Forecasts for Clothes Dryer TSLs

NEMS-BT Results*	Difference from AEO2010 Reference Case							
							Extrapolation		Total
	2010	2015	2020	2025	2030	2035	2040	2043	2014-2043
Standard Level 1									
CO2 (Mt/yr)	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	**-0.015**
NOx (1,000 tons/yr)	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	**-0.012**
SO2 (1,000 tons/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Standard Level 2									
CO2 (Mt/yr)	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	**-0.021**
NOx (1,000 tons/yr)	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	**-0.017**
SO2 (1,000 tons/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Standard Level 3									
CO2 (Mt/yr)	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	**-0.021**
NOx (1,000 tons/yr)	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	**-0.017**
SO2 (1,000 tons/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Standard Level 4									
CO2 (Mt/yr)	0.000	-0.008	-0.031	-0.050	-0.064	-0.074	-0.074	-0.074	**-1.57**
NOx (1,000 tons/yr)	0.000	-0.007	-0.025	-0.040	-0.052	-0.060	-0.060	-0.060	**-1.27**
SO2 (1,000 tons/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**-0.010**
Standard Level 5									
CO2 (Mt/yr)	0.000	-0.039	-0.143	-0.232	-0.298	-0.344	-0.344	-0.344	**-7.31**
NOx (1,000 tons/yr)	0.000	-0.032	-0.115	-0.188	-0.241	-0.278	-0.278	-0.278	**-5.90**
SO2 (1,000 tons/yr)	0.000	0.000	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	**-0.046**
Standard Level 6									
CO2 (Mt/yr)	0.000	-0.039	-0.143	-0.232	-0.298	-0.344	-0.344	-0.344	**-7.31**
NOx (1,000 tons/yr)	0.000	-0.032	-0.115	-0.188	-0.241	-0.278	-0.278	-0.278	**-5.90**
SO2 (1,000 tons/yr)	0.000	0.000	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	**-0.046**

*All results in metric tons (t), equivalent to 1.1 short tons

15.2.5 Effects on Upstream Fuel-Cycle Emissions

Upstream fuel-cycle emissions refer to the emissions associated with the amount of energy used in the upstream production and downstream consumption of electricity, including energy used at the power plant.[17] Upstream processes include the mining of coal or extraction of natural gas, physical preparatory and cleaning processes, and transportation to the power plant. The NEMS-BT does a thorough accounting of emissions at the power plant due to downstream energy consumption, but does not account for upstream emissions (i.e., emissions from energy losses during coal and natural gas production). Thus, this analysis reports only power plant emissions.

However, previous DOE environmental assessment documents have developed approximate estimates of effects on upstream fuel-cycle emissions. These emissions factors provide the reader with a sense of the possible magnitude of upstream effects. These upstream emissions would be in addition to emissions from direct combustion.

Relative to the entire fuel cycle, estimates based on the work of Dr. Mark DeLuchi, and reported in earlier DOE environmental assessment documents, find that an amount approximately equal to eight percent, by mass, of emissions (including SO_2) from coal production are due to mining, preparation that includes cleaning the coal, and transportation from the mine to the power plant.[18] Transportation emissions include emissions from the fuel used by the mode of transportation that moves the coal from the mine to the power plant. In addition, based on Dr. DeLuchi's work, DOE estimated that an amount equal to approximately 14 percent of emissions from natural gas production result from upstream processes.

Emission factor estimates and corresponding percentages of contributions of upstream emissions from coal and natural gas production, relative to power plant emissions, are shown in Table 15.2.6 for CO_2 and NO_X. The percentages provide a means to estimate upstream emission savings based on changes in emissions from power plants. This approach does not address Hg emissions.

Table 15.2.6 Estimated Upstream Emissions of Air Pollutants as a Percentage of Direct Power Plant Combustion Emissions

Pollutant	Percent of Coal Combustion Emissions	Percent of Natural Gas Combustion Emissions
CO_2	2.7	11.9
NO_X	5.8	40

15.3 WETLAND, ENDANGERED AND THREATENED SPECIES, AND CULTURAL RESOURCES

Because residential clothes dryers and room air conditioners are not water-consuming products, more energy efficient operation would not reduce the amount of water discharged into the waste stream. As a result, the energy conservation standards do not have the effect of improving the quality of wetlands, nor threatened or endangered species that reside in these wetlands. This action is also not expected to impact cultural resources such as historical or archaeological sites.

15.4 SOCIOECONOMIC IMPACTS

DOE's analysis has shown that the increase in the first cost of purchasing more efficient clothes dryers and room air conditioners at the proposed standard levels is, in most cases, completely offset by a reduction in the life-cycle cost (LCC) of owning a more efficient product for the average consumer. In other words, the consumer will pay less operating costs over the life of the product even through the first cost increases. The complete LCC analysis and its conclusions are presented in chapter 8 of the TSD.

For subgroups of low-income and senior consumers that purchase clothes dryer and room air conditioner products, DOE determined that the average LCC impact of the standards is similar to that for the full sample of consumers. Therefore, DOE concludes that the proposed standards would have no significant adverse socioeconomic impact. For a complete discussion on the LCC impacts on consumer subgroups, see chapter 11 of the TSD.

15.5 ENVIRONMENTAL JUSTICE IMPACTS

In view of Executive Order 12898 of February 11, 1994, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,” DOE examined the effect of the energy conservation standards on low-income households. As described in the LCC subgroup analysis in chapter 11 of the TSD, DOE found that there were no disproportionately high and adverse human health or environmental effects on low-income populations that would result from the proposed energy conservation standards.

15.6 NOISE AND AESTHETICS

Improvements in efficiency of residential clothes dryers and room air conditioners are expected to result from changes in the choice of components and other design features. These changes are described in chapter 5 of this TSD. These design changes are not expected to change noise levels in comparison to products in today’s market. Products that are currently manufactured in the existing market that would meet the standards are no louder than less efficient products. Changes to the design to improve the efficiency levels are not anticipated to affect the product aesthetics.

15.7 SUMMARY OF ENVIRONMENTAL IMPACTS

Table 15.7.1 summarizes the estimated emissions impacts for each of the TSLs for clothes dryers and room air conditioners. It shows cumulative changes in emissions for CO_2, NO_X, and Hg for 2014 through 2043 for each of the TSLs. Cumulative CO_2, NO_X, and Hg emissions are reduced compared to the Reference case for all TSLs. For comparison, the cumulative power sector emissions in the *AEO2010* Reference case, over the period 2014 through 2043, are 74,571 Mt for CO_2, 61,625 kt for NOx, and 917 tons for Hg.

Upstream fuel cycle emission of CO_2 and NO_X are described but not quantified in section 15.2.6. The text describes potential reductions in fuel cycle emissions as percentage of decreases in power plant emissions. This approach suggests that upstream fuel cycle emissions would decrease and provides a sense for the magnitude of effects; however DOE does not report actual estimates of the effects.

For subgroups of low-income and senior consumers that purchase room air conditioning and clothes dryer products, DOE determined that the average LCC impact of the standards is similar to that for the full sample of consumers. Therefore, DOE concludes that the proposed standards would have no significant adverse socioeconomic impact.

No impacts are anticipated in the areas of environmental justice, wetlands, endangered and threatened species, and cultural resources; or noise and aesthetics.

Table 15.7.1 Cumulative Emissions Reductions Under Clothes Dryer and Room Air Conditioner TSLs*

	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
Clothes Dryers						
CO_2 (Mt)	0.119	2.99	17.7	18.7	70.5	187
NO_X (1,000 tons)	0.097	2.41	14.3	15.1	57.3	151
Hg (ton)	0.000	0.009	0.053	0.051	0.188	0.569
Room Air Conditioners						
CO_2 (Mt)	9.83	11.9	12.5	17.4	26.9	37.7
NO_X (1,000 tons)	8.02	9.69	10.2	14.2	21.9	30.7
Hg (ton)	0.012	0.015	0.017	0.022	0.032	0.044

*CO_2 results are in metric tons; NO_X and Hg results are in short tons.

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CHAPTER 16. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

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CHAPTER 16. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

16.1 INTRODUCTION

As part of its assessment of energy conservation standards, DOE considered the estimated monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_X) that are expected to result from each of the TSLs considered. In order to make this calculation similar to the calculation of the NPV of consumer benefit, DOE considered the reduced emissions expected to result over the lifetime of products shipped in the forecast period for each TSL. This chapter summarizes the basis for the monetary values used for each of these emissions and presents the benefits estimates considered.

16.2 MONETIZING CARBON DIOXIDE EMISSIONS

16.2.1 Social Cost of Carbon

Under section 1(b) of Executive Order 12866, "Regulatory Planning and Review," 58 FR 51735 (Oct. 4, 1993), 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 social cost of carbon (SCC) estimates presented here is to allow Federal agencies to incorporate the monetized social benefits of reducing CO_2 emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

As part of the interagency process that developed these SCC estimates, technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The social cost of carbon is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. Estimates of the SCC are provided in dollars per metric ton of carbon dioxide.

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Research Council[a] points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Consistent with the directive quoted above, the purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. Most Federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the agency can estimate the benefits from reduced (or costs from increased) emissions in any future year by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions. DOE does not attempt to answer that question here.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, the interagency group has set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, the interagency group will continue to explore the issues raised by this analysis and consider public comments as part of the ongoing interagency process.

16.2.2 Social Cost of Carbon Values Used in Past Regulatory Analyses

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing carbon dioxide emissions. In the final model year 2011 CAFE rule, the Department of Transportation (DOT) used both a "domestic" SCC value of

[a] National Research Council. Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use. National Academies Press: Washington, DC. 2009.

$2 per ton of CO_2 and a “global” SCC value of $33 per ton of CO2 for 2007 emission reductions (in 2007 dollars), increasing both values at 2.4 percent per year. It also included a sensitivity analysis at $80 per ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in carbon dioxide emissions, while a global SCC value is meant to reflect the value of damages worldwide.

A 2008 regulation proposed by DOT assumed a domestic SCC value of $7 per ton of CO_2 (in 2006 dollars) for 2011 emission reductions (with a range of $0-$14 for sensitivity analysis), also increasing at 2.4 percent per year. A regulation finalized by DOE in October of 2008 used a domestic SCC range of $0 to $20 per ton CO_2 for 2007 emission reductions (in 2007 dollars). In addition, EPA’s 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as “very preliminary” SCC estimates subject to revision. EPA’s global mean values were $68 and $40 per ton CO_2 for discount rates of approximately 2 percent and 3 percent, respectively (in 2006 dollars for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted. The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006 dollars) of $55, $33, $19, $10, and $5 per ton of CO_2.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and CO_2 tailpipe emission proposed rules.

16.2.3 Current Approach and Key Assumptions

Since the release of the interim values, the interagency group reconvened on a regular basis to generate improved SCC estimates, which were considered for this proposed rule. Specifically, the group considered public comments and further explored the technical literature in relevant fields. The interagency group relied on three integrated assessment models (IAMs) commonly used to estimate the SCC: the FUND, DICE, and PAGE models.[b] These models are frequently cited in the peer-reviewed literature and were used in the last assessment of the Intergovernmental Panel on Climate Change. Each model was given equal weight in the SCC values that were developed.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches to

[b] The models are described in appendix 16-A of the TSD.

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: (1) climate sensitivity; (2) socio-economic and emissions trajectories; and (3) 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 socio-economic 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 three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For emissions (or emission reductions) that occur in later years, these values grow in real terms over time, as depicted in Table 16-1. 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,[c] although preference is given to consideration of the global benefits of reducing CO_2 emissions.

Table 16-1 Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per metric ton)

	Discount Rate			
	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Research Council report mentioned above points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model

[c] It is recognized that this calculation for domestic values is 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.

these effects. There are a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC.

The U.S. Government intends to periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance. The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them and with a sincere promise to continue work to improve them.

In summary, in considering the potential global benefits resulting from reduced CO_2 emissions, DOE used the most recent SCC values identified by the interagency process, adjusted to 2009$ using the GDP price deflator values for 2008 and 2009. For each of the four cases specified, the values used for emissions in 2010 were $4.9, $22.1, $36.3, and $67.1 per metric ton avoided (values expressed in 2009$). To monetize the CO_2 emissions reductions expected to result from amended standards for clothes dryers and room air conditioners, DOE used the values identified in Table A1 of the "Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866," which is reprinted in appendix 16-A of this TSD, appropriately escalated to 2009$.[d] To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the specific discount rate that had been used to obtain the SCC values in each case.

16.3 VALUATION OF OTHER EMISSIONS REDUCTIONS

DOE considered the potential monetary benefit of reduced NO_X emissions from the TSLs it considered. As noted in chapter 15, new or amended energy conservation standards would reduce NO_X emissions in those 22 States that are not affected by the CAIR, in addition to the reduction in site NO_X emissions nationwide. DOE estimated the monetized value of NO_X emissions reductions resulting from each of the TSLs considered based on environmental damage estimates from the literature. Available estimates suggest a very wide range of monetary values, ranging from $370 per ton to $3,800 per ton of NO_X from stationary sources, measured in 2001$ (equivalent to a range of $447 to $4,591 per ton in 2009$).[e] In accordance with OMB guidance, DOE conducted two calculations of the monetary benefits using each of the above values used for NO_X, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.[f]

DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to

[d] Table A1 presents SCC values through 2050. For DOE's calculation, it derived values after 2050 using the 3-percent per year escalation rate used by the interagency group.
[e] For additional information, refer to U.S. Office of Management and Budget, Office of Information and Regulatory Affairs, ''2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities,'' Washington, DC.
[f] OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003).

await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg in its rulemakings.

16.4 RESULTS

Table 16-2 and Table 16-3 present the global values of CO_2 emissions reductions for each TSL. DOE calculated domestic values as a range from 7 percent to 23 percent of the global values, and these results are presented in Table 16-4 and Table 16-5.

Table 16-2 Clothes Dryers: Estimates of Global Present Value of CO_2 Emissions Reduction in 2014–2043 Under Trial Standard Levels

TSL	Million 2009$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	1	3	5	10
2	15	79	134	239
3	88	465	793	1,417
4	93	489	834	1,490
5	351	1,848	3,148	5,626
6	929	4,894	8,339	14,902

***** Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table incorporate the escalation of the SCC over time.

Table 16-3 Room Air Conditioners: Estimates of Global Present Value of CO_2 Emissions Reduction in 2014–2043 Under Trial Standard Levels

TSL	Million 2009$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	43	212	357	648
2	52	259	436	790
3	55	271	455	826
4	77	382	642	1,164
5	118	591	996	1,803
6	166	833	1,404	2,541

***** Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table incorporate the escalation of the SCC over time.

Table 16-4 Clothes Dryers: Estimates of Domestic Present Value of CO_2 Emissions Reduction in 2014–2043 Under Trial Standard Levels

TSL	Million 2009$*			
	5% discount rate, average**	**3% discount rate, average****	**2.5% discount rate, average****	**3% discount rate, 95th percentile****
1	0.042 to 0.14	0.22 to 0.72	0.37 to 1.22	0.67 to 2.19
2	1.04 to 3.43	5.50 to 18.1	9.37 to 30.8	16.7 to 55.0
3	6.19 to 20.3	32.6 to 107	55.5 to 182	99.2 to 326
4	6.51 to 21.4	34.3 to 113	58.4 to 192	104 to 343
5	24.6 to 80.7	129 to 425	220 to 724	394 to 1294
6	65.1 to 214	343 to 1126	584 to 1,918	1,043 to 3,428

* Domestic values are presented as a range between 7 percent and 23 percent of the global values.
** Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table incorporate the escalation of the SCC over time.

Table 16-5 Room Air Conditioners: Estimates of Domestic Present Value of CO_2 Emissions Reduction in 2014–2043 Under Trial Standard Levels

TSL	Million 2009$*			
	5% discount rate, average**	**3% discount rate, average****	**2.5% discount rate, average****	**3% discount rate, 95th percentile****
1	3.00 to 9.85	14.9 to 48.8	25.0 to 82.1	45.4 to 149
2	3.64 to 12.0	18.1 to 59.6	30.5 to 100	55.3 to 182
3	3.83 to 12.6	18.9 to 62.3	31.9 to 105	57.8 to 190
4	5.36 to 17.6	26.7 to 87.8	45.0 to 148	81.5 to 268
5	8.29 to 27.2	41.4 to 136	69.7 to 229	126 to 415
6	11.6 to 38.3	58.3 to 192	98.3 to 323	178 to 584

* Domestic values are presented as a range between 7 percent and 23 percent of the global values.
** Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table incorporate the escalation of the SCC over time.

Table 16-6 and Table 16-7 present the cumulative monetary value of the economic benefits associated with NO_X emissions reductions for each TSL, calculated using seven-percent and three-percent discount rates.

Table 16-6 Clothes Dryers: Estimates of Present Value of NO_X Emissions Reduction in 2014-2043 Under Trial Standard Levels

TSL	3% discount rate Million 2009$	7% discount rate Million 2009$
1	0.031 to 0.314	0.013 to 0.136
2	0.759 to 7.8	0.328 to 3.37
3	4.49 to 46.2	1.94 to 19.98
4	4.77 to 49.02	2.06 to 21.2
5	18.0 to 185	7.8 to 80.2
6	47.6 to 490	20.6 to 212

Table 16-7 Room Air Conditioners: Estimates of Present Value of NO_X Emissions Reduction in 2014-2043 Under Trial Standard Levels

TSL	3% discount rate Million 2009$	7% discount rate Million 2009$
1	2.34 to 24.0	1.25 to 12.9
2	2.83 to 29.1	1.50 to 15.4
3	2.99 to 30.7	1.61 to 16.6
4	4.16 to 42.7	2.2 to 22.6
5	6.40 to 65.8	3.35 to 34.4
6	8.96 to 92.1	4.64 to 47.7

CHAPTER 17. REGULATORY IMPACT ANALYSIS

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CHAPTER 17. REGULATORY IMPACT ANALYSIS

17.1 INTRODUCTION

The U.S. Department of Energy (DOE) has determined that energy conservation standards for clothes dryers and room air conditioners constitute an "economically significant regulatory action" under Executive Order (E.O.) 12866, Regulatory Planning and Review. 58 FR 51735, Volume 58, No. 190, page 51735. (October 4, 1993). Under 10 CFR part 430, subpart C, appendix A, section III.12, DOE committed to evaluating non-regulatory alternatives to proposed standards by performing a regulatory impact analysis (RIA). 61 FR 36981, Volume 61, No. 136, page 36978. (November 15, 1996). This RIA, which DOE has prepared pursuant to E.O. 12866, evaluates potential non-regulatory alternatives, comparing the costs and benefits of each to those of the proposed standards. 58 FR 51735, page 51741. As noted in E.O. 12866, this RIA is subject to review by the Office of Management and Budget's Office of Information and Regulatory Affairs. 58 FR 51735, page 51740.

For this Regulatory Impact Analysis, DOE used integrated NIA-RIA integrated models built on the NIA models discussed in chapter 10 for its analysis. DOE studied the impacts of the non-regulatory policies on the representative product classes analyzed for the direct final rule. It then applied the assumptions of the impacts of each policy on these representative product classes to the shipments of the remaining product classes associated with each representative class. Thus, the savings reported in this chapter represent the savings for all the considered product classes for clothes dryers. For room air conditioners DOE studied the impacts of the policies on only the residential product classes.

DOE identified six non-regulatory policy alternatives that feasibly could provide incentives for the same energy efficiency levels as the proposed standards for the products that are the subject of this rulemaking. The non-regulatory policy alternatives are listed in Table 17.1.1. DOE evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each to the effectiveness of the proposed standard.

Table 17.1.1 Non-Regulatory Alternatives to National Standards

No New Regulatory Action
Consumer Rebates
Consumer Tax Credits
Manufacturer Tax Credits
Voluntary Energy Efficiency Targets
Early Replacement
Bulk Government Purchases

In addition to the above six non-regulatory policy alternatives, for this rulemaking DOE evaluated a super-efficient voluntary targets (SEVT) program. Sections 17.2 and 17.3 discuss the analysis of the six policies listed above, and section 17.3.8 describes the SEVT policy. Sections 17.4 and 17.5 present the results of the six policy alternatives, and section 17.6 describes the analysis of the SEVT policy and presents the results.

17.2 NON-REGULATORY POLICIES

This section describes the method DOE used to analyze the energy savings and cost effectiveness of the six non-regulatory policy alternatives (excluding the alternative of no new regulatory action) for the identified clothes dryers and room air conditioners. This section also describes the assumptions underlying the analysis.

17.2.1 Methodology

DOE used its integrated national impact analysis–regulatory impact analysis (NIA-RIA) spreadsheet models to calculate the national energy savings (NES) and net present value (NPV) associated with each non-regulatory policy alternative. Chapter 10 of the technical support document (TSD) describes the NIA spreadsheet models. Appendix 17-A, section 17-A.2, discusses the new NIA-RIA integrated model approach.

DOE quantified the effect of each alternative on the purchase of products that meet *target levels*, which are defined as the efficiency levels in the proposed standards. After establishing the quantitative assumptions underlying each alternative, DOE appropriately revised inputs to the NIA-RIA spreadsheet models. The primary model inputs revised were market shares of products meeting target efficiency levels and equipment replacement rates. The shipments of products for any given year reflect a distribution of efficiency levels. DOE assumed that the proposed standards would affect 100 percent of the shipments of products that did not meet target levels in the base case,[a] whereas the non-regulatory policies would affect a smaller percentage of those shipments. DOE made certain assumptions about the percentage of shipments affected by each alternative policy. DOE used those percentages to calculate the shipment-weighted average energy consumption and costs of clothes dryers and room air conditioners attributable to each policy alternative.

Increasing the efficiency of a product often increases its average installed cost. On the other hand, 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 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.

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[a] The base case for the NIA is a market-weighted average of units at several efficiency levels.

The following are key measures for evaluating the impact of each alternative.

- National energy savings, given in quadrillion Btus (quads), describes the cumulative national primary energy savings for products bought during the period from the effective date of the policy (2014) through the end of the analysis period (2043).

- Net present value represents the value in 2009$ (discounted to 2010) of net monetary savings from products bought during the period from the effective date of the policy (2014) through the end of the analysis period (2043).

- DOE calculated the NPV as the difference between the present value of installed equipment cost and operating expenditures in the base case and the present value of those costs in each policy case. DOE calculated operating expenses (including energy costs) for the life of the product.

17.2.2 Assumptions Regarding Non-Regulatory Policies

The effects of non-regulatory policies are by nature uncertain, because they depend on program implementation and marketing efforts and on consumers' responses to a program. Because the projected effects depend on assumptions regarding the rate of consumer participation, they are subject to more uncertainty than are the impacts of mandatory standards, which DOE assumes will meet with full compliance. To increase the robustness of the analysis, DOE conducted a literature review regarding each non-regulatory policy and consulted with recognized experts to gather information on similar incentive programs that have been implemented in the United States. By studying experiences with the various types of programs, DOE sought to make credible assumptions regarding potential market impacts. Section 17.3 presents the sources DOE relied on in developing assumptions about each alternative policy and reports DOE's conclusions as they affected the assumptions that underlie the modeling of each policy.

Each non-regulatory policy that DOE considered would improve the average efficiency of new clothes dryers and room air conditioners relative to their base case efficiency scenarios (which involve no new regulatory action). The analysis considered that each alternative policy would induce consumers to purchase units having the same efficiency levels as required by the proposed standards (the target levels). As opposed to the standards case, however, the policy cases may not lead to 100 percent market penetration of units that meet target levels.

Tables 17.2.1 and 17.2.2 show the efficiency levels stipulated in the proposed standards for clothes dryers and room air conditioners.

Table 17.2.1 Efficiency Levels in Proposed Standard Levels for Clothes Dryers

Product Class	TSL 4 CEF
Vented Electric Standard	3.73
Vented Electric Compact 120V	3.61
Vented Electric Compact 240V	3.27
Vented Gas	3.30
Vent-less Electric Compact 240V	2.55
Vent-less Electric Combination Washer/Dryer	2.08

Table 17.2.2 Efficiency Levels in Proposed Standard Levels for Room Air Conditioners

Product Class	TSL 4 CEER
Group 1 – includes PC 1	11.10
Group 2 – includes PC 2, 3, 4, 11	10.90
Group 3 – includes PC 5a, 9, 13	9.40
Group 4 – includes PC 5b, 10	9.00
Group 5 – includes PC 6, 7, 8a, 12	9.60
Group 6 – includes PC 8b, 14, 15, 16	9.50

Besides the above policy alternatives, DOE evaluated a Super-Efficient Voluntary Targets policy where a new voluntary efficiency target program would be implemented *in addition to* the proposed standards. The voluntary efficiency targets would feature "super-efficient" products at one efficiency level above the current max-tech levels. The program would target consumers in the highest electricity price regions of the country, to make the products maximally cost-effective.

DOE assumed that the effects of non-regulatory policies would last from the effective date of standards—2014—through the end of the analysis period, which is 2043.

17.2.3 Policy Interactions

DOE calculated the effects of each non-regulatory policy separately from those of the other policies. In practice, some policies are most effective when implemented in combination, such as early replacement implemented with consumer rebates, or early replacement implemented with bulk government purchases. However, DOE attempted to make conservative assumptions to avoid double-counting policy impacts. The resulting policy impacts are not additive: the combined effect of several or all policies cannot be inferred from summing their results.

Section 17.3 presents graphs that show the market penetration estimated under each non-regulatory policy for clothes dryers and room air conditioners.

17.3 NON-REGULATORY POLICY ASSUMPTIONS

The following subsections describe DOE's analysis of the impacts of the six non-regulatory policy alternatives to proposed standards for clothes dryers and room air conditioners. (Because the alternative of No New Regulatory Action has no energy or NPV impacts, essentially representing the NIA base case, DOE did not perform additional analysis for that alternative.) DOE developed estimates of the market penetration of high-efficiency products both with and without each of the non-regulatory policy alternatives.

17.3.1 No New Regulatory Action

The case in which no new regulatory action is taken with regard to the energy efficiency of clothes dryers and room air conditioners constitutes the base case, as described in chapter 10, National Impact Analysis. The base case provides the basis of comparison for all other policies. By definition, no new regulatory action yields zero energy savings and an NPV of zero dollars.

17.3.2 Consumer Rebates

DOE considered this scenario in which the Federal government would provide financial incentives in the form of rebates to consumers for purchasing energy efficient appliances. This policy provides a consumer rebate for purchasing clothes dryers or room air conditioners that operate at (or above) the same efficiencies as stipulated in proposed standards (target levels).

To inform its estimate of the market impacts of consumer rebates, DOE performed a thorough search for existing rebate programs nationwide. It gathered data on utility or agency rebates for clothes dryers or room air conditioners throughout the country. DOE also reviewed the current State Energy Efficient Appliance Rebate Program (SEEARP) funded by the American Recovery and Reinvestment Act (ARRA).[1], [b] This program may be considered a combination of a consumer rebate and an early replacement program, with intention to induce appliance sales during the economic recession. DOE analyzed summary material from DOE on SEEARP rebates for room air conditioners.[2]

DOE based its evaluation methodology for consumer rebates on a comprehensive study of California's potential for achieving energy efficiency. This study, performed by XENERGY, Inc.,[c] summarized experiences with various utility rebate programs.[3] 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

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[b] DOE provided funding for State-run rebate programs for consumer purchases of new ENERGY STAR® qualified home appliances. The resulting SEEARP was implemented beginning in late 2009 by the 50 States and six U.S. territories, each selecting its own appliances, rebate levels, efficiency levels, appliance recycling requirements, and eligible populations.

[c] XENERGY is now owned by KEMA, Inc. (www.kema.com)

efficient technologies. The other methods, developed after the referenced XENERGY report was published,[4, 5, 6, 7, 8, 9] 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.[7] DOE decided that the most appropriate available method for this RIA analysis was the XENERGY approach of penetration curves based on B/C ratio, which incorporates lifetime operating cost savings.

XENERGY's model estimates market impacts induced by financial incentives based on the premise that two types of information diffusion drive the adoption of new technologies. *Internal sources* of information encourage consumers to purchase new products primarily through word-of-mouth from early adopters. *External sources* affect consumer purchase decisions through marketing efforts and information from outside the consumer group. Appendix 17-A, section 17-A.3.1, 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 measure. XENERGY then calibrated the curves based on participation data from utility rebate programs. The curves illustrate the increased penetration (i.e., increased market share) of efficient products driven by consumer response to changes in B/C ratio induced by rebate programs. The penetration curves depict various diffusion patterns based on perceived barriers (from no barriers to extremely high barriers) to consumer purchase of high-efficiency products.

DOE adjusted the XENERGY penetration curves based on expert advice founded on more recent utility program experience.[7, 10] DOE also devised an interpolation method to create penetration curves based on relationships between the actual base case market penetrations and actual B/C ratios for each representative product class. Appendix 17-A, sections 17-A.3.2 and 17-A.3.3, contain discussion on DOE's methodology for adjusting and interpolating the curves.

DOE modeled the effects of a consumer rebate policy for clothes dryers and room air conditioners by determining the increases in market penetration of products meeting the target level relative to their market penetrations in the base case. It did this using the interpolated penetration curves created for each representative product class based on the XENERGY methodology to best reflect the market barrier levels faced by each product class.

Section 17.3.2.1 shows examples of these interpolated curves for two clothes washer product classes: vented electric standard and vented gas. Section 17.3.2.2 shows examples of these interpolated curves for two room air conditioner product classes: PC 1 (Group 1) and PC 3 (Group 2).

17.3.2.1 Clothes Dryers

For clothes dryers, DOE estimated the effect of increasing the B/C ratio via a rebate that would pay part or all of the increased installed cost of a unit that met the target efficiency level compared to one meeting the baseline efficiency level.[d] DOE based the rebate amounts on a large sample of utility and agency rebate programs for clothes dryers.

For gas clothes dryers, DOE gathered data on 16 rebate programs initiated by 16 utilities or agencies in several States. For electric clothes dryers, DOE gathered data on four rebate programs initiated by three utilities or agencies in States throughout the country, and for electric combination washer/dryer units it found one program. (Appendix 17-A, section 17-A.5, identifies the rebate programs.) To represent the rebate level for gas, electric, and combination clothes dryers, DOE used the simple average of the rebate amounts in these respective sets of programs. DOE assumed that these averages would apply to models at all efficiency levels at or above the target level for each representative product class. None of the rebates specified an efficiency level, but rather specified a moisture sensor or a conversion from electric to gas. DOE assumed that the impact of these rebates would be equivalent to those of rebates at the target levels.

DOE assumed that rebates would remain in effect at the same levels throughout the forecast period (2014–2043).

For clothes dryers, DOE first calculated B/C ratios without a rebate using the difference in total installed costs and lifetime operating cost savings between the unit meeting the target level and the baseline unit. It then calculated B/C ratios given a rebate for the unit meeting the target efficiency level. Because the rebate reduced the incremental cost, the unit receiving the rebate had a larger B/C ratio. Table 17.3.1 shows the effects of consumer rebates on B/C ratios for the two largest product classes, vented standard electric and vented gas clothes dryers. Each B/C ratio value for units with rebates represents a weighted average[e] of the values for the efficiency levels at or above the target level to which the rebate would apply.

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[d] The baseline technology for each product class is defined in the engineering analysis, chapter 5, as the technology that represents the basic characteristics of products in that class. A baseline unit typically is one that just meets current Federal energy conservation standards and provides basic consumer utility.

[e] The weighting factor is the 2014 base case market share of each of the corresponding efficiency levels.

Table 17.3.1 Benefit/Cost Ratios Without and With Rebates for Clothes Dryers (2009$)

	Vented Standard Electric	Vented Gas
B/C Ratio Without Rebate	1.8	1.2
Rebate Amount	$31	$91
B/C Ratio With Rebate	Inf.	Inf.
Calculated Market Barrier Curve	Low - Moderate	No - Low

Inf. = infinite B/C ratio, which occurs when the rebate pays the full incremental cost.

DOE used the B/C ratios along with the penetration curves such as those shown in Figures 17.3.1 and 17.3.2 to estimate the percentage of consumers who would purchase clothes dryers that meet the target levels both with and without a rebate incentive.

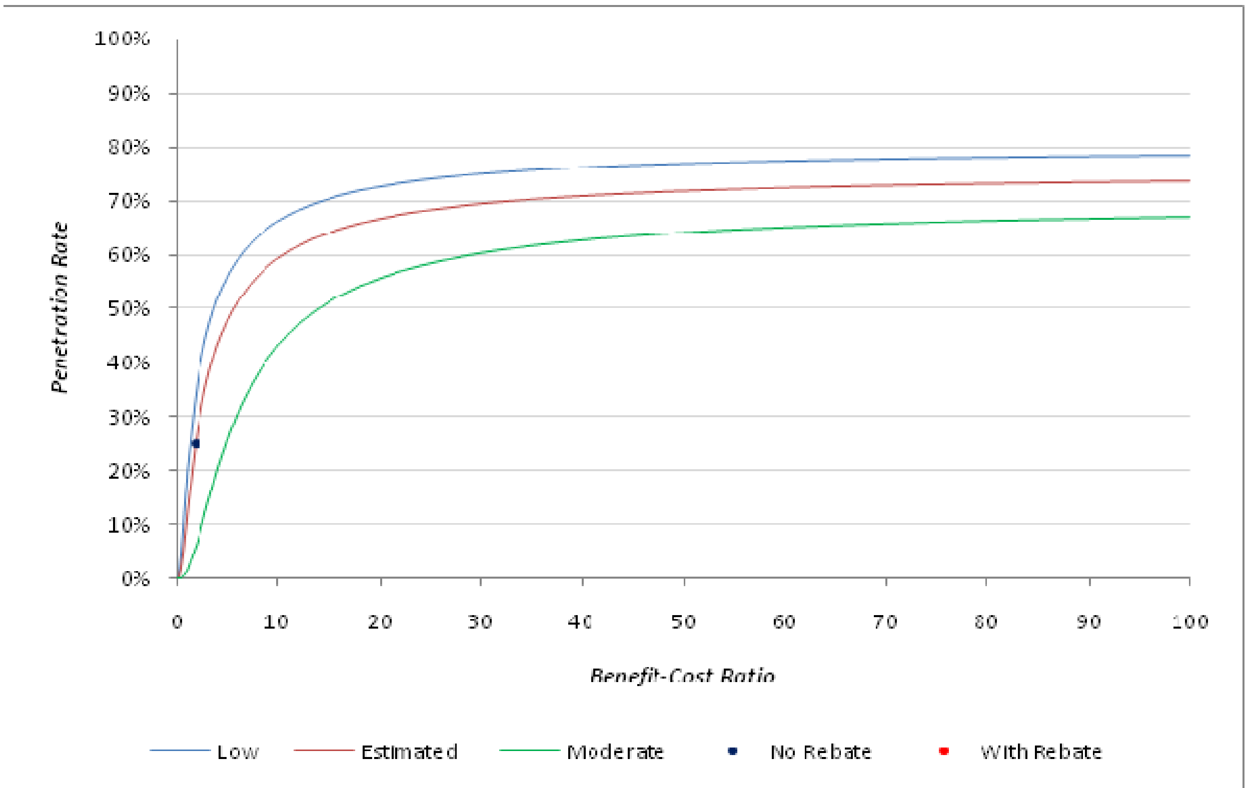

Figure 17.3.1 Market Penetration Curve for Vented Standard Electric Dryers

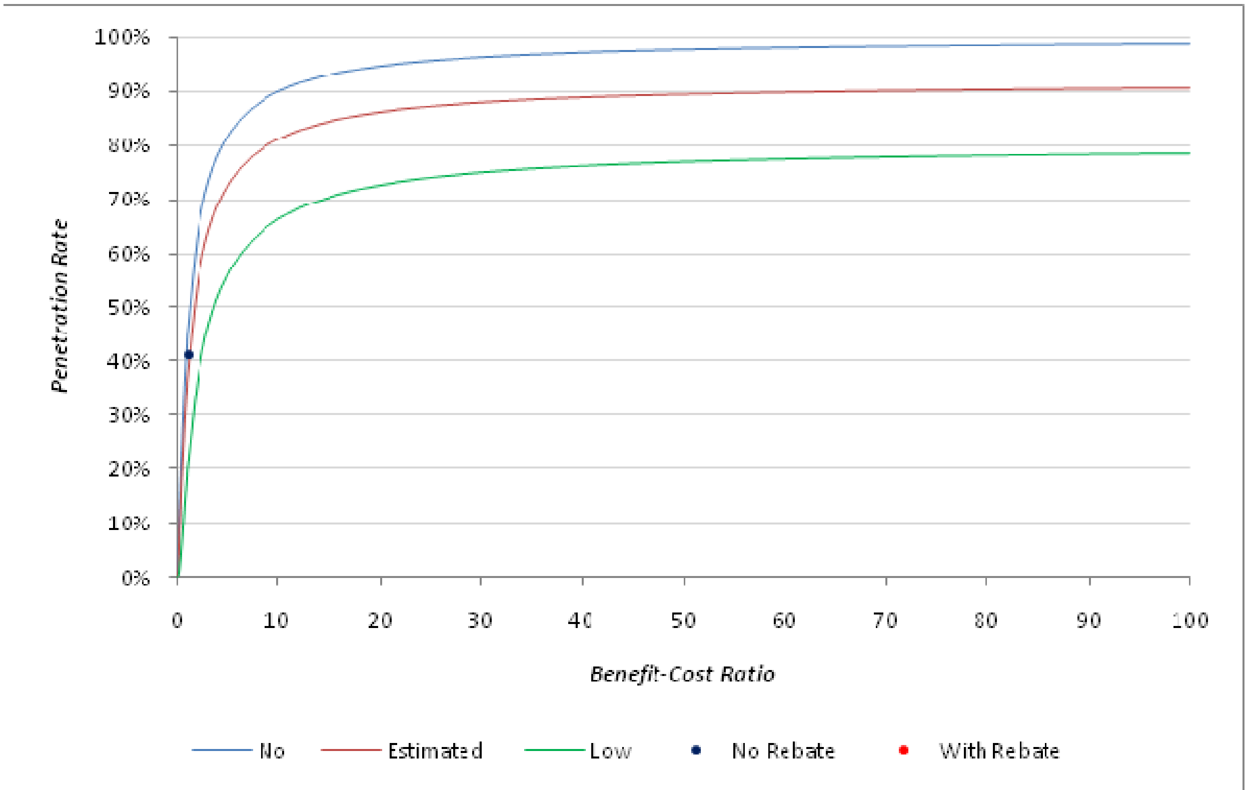

Figure 17.3.2 Market Penetration Curve for Vented Gas Dryers

The curve calculated by DOE to represent the market behavior for vented standard electric clothes dryers was between the *low* and *moderate barriers* penetration curves. For vented gas clothes dryers the curve was between the *no barriers* and *low barriers* penetration curve.

For each product class, DOE next estimated the percent increase represented by the change in penetration rate shown on the penetration curve. It then added that percent increase to the market share of units that meet the target level in the base case to obtain the market share of units that meet the target level in the rebate case. Table 17.3.2 summarizes the market shares of clothes dryers in 2014. DOE used the resulting increases in market shares as inputs to represent the policy case scenarios in its NIA-RIA model. Appendix 17-A, section 17-A.4, shows the annual market share increases due to this policy. Section 17.4 presents the resulting efficiency trends for the policy case of consumer rebates for clothes dryers

Table 17.3.2 Market Penetrations in 2014 Without and With Rebates for Clothes Dryers

	Vented Electric Standard %	**Vented Gas %**
Base-Case Market Share of Units that Meet Target Levels	25	41
Market Share of Units that Meet Target Levels With Rebates	76	92
Increased Market Share of Units that Meet Target Level With Rebates	51	51

17.3.2.2 Room Air Conditioners

For room air conditioners, DOE estimated the effect of increasing the B/C ratio via a rebate that would pay part or all of the increased installed cost of a unit that met the target efficiency level compared to the cost of a unit meeting the baseline level. DOE based the rebate amounts on a large sample of utility and agency rebate programs for room air conditioners.

DOE gathered data on 62 rebate programs provided by 61 utilities or agencies in various States. (Appendix 17-A, section 17-A.5, identifies the rebate programs.) To represent the rebate level for room air conditioners, DOE used the simple average of the rebate amounts in these 62 programs. DOE assumed that this average amount would apply to models at all efficiency levels at or above the target level for each representative product class. For each of these efficiency levels, the rebate amount represented a certain percent of the increase in total installed cost. Since nearly all of the utility/agency rebates were for room air conditioners at the ENERGY STAR level, while the proposed standard levels for room air conditioners were set at a higher efficiency level, DOE sought data on rebates requiring levels higher than ENERGY STAR to determine whether to adjust this average rebate level amount. Most of the SEEARP room air conditioner rebates were also for the ENERGY STAR efficiency level, but one rebate was for the CEE Tier 1 level. DOE adjusted the rebate amount by the ratio of the rebate amount for the higher efficiency level to the average of the rebate amounts for the ENERGY STAR level.

DOE assumed that rebates would remain in effect until the market had been transformed; that is, the shift in market share of efficient units seen in the first year of the rebate program would be maintained throughout the forecast period (2014–2043).

For room air conditioners, DOE first calculated B/C ratios without a rebate using the difference in lifetime operating costs and total installed costs between the unit meeting the target level and the baseline unit. It then calculated B/C ratios given a rebate for the unit meeting the target efficiency. Because the rebate reduced the incremental cost, the unit receiving the rebate had a larger B/C ratio. Table 17.3.3 shows the effects of consumer rebates on B/C ratios for the two largest product classes of room air conditioners. Each B/C ratio value for units with rebates represents a weighted average[f] of the values for the efficiency levels at or above the target level to which the rebate would apply.

Table 17.3.3 Benefit/Cost Ratios Without and With Rebates for Room Air Conditioners

	Group 1 (PC1)	Group 2 (PC3)
B/C Ratio Without Rebate	26.3	41.0
Rebate Amount	$65	$65
B/C Ratio With Rebate	Inf.	Inf.
Calculated Market Barrier Curve	Extremely High	Extremely High

Inf. = infinite B/C ratio, which occurs when the rebate pays the full incremental cost.

DOE used these B/C ratios, along with the penetration curves such as those shown in Figures 17.3.3 and 17.3.4 to estimate the percentage of consumers who would purchase room air conditioners that meet the target efficiency level both with and without a rebate incentive. The curve calculated by DOE to represent the market behavior for product class 1 (Group 1) product and class 3 (Group 2) was closest to the *extremely high barriers* curve.

[f] The weighting factor is the 2014 base case market share of each of the corresponding efficiency levels.

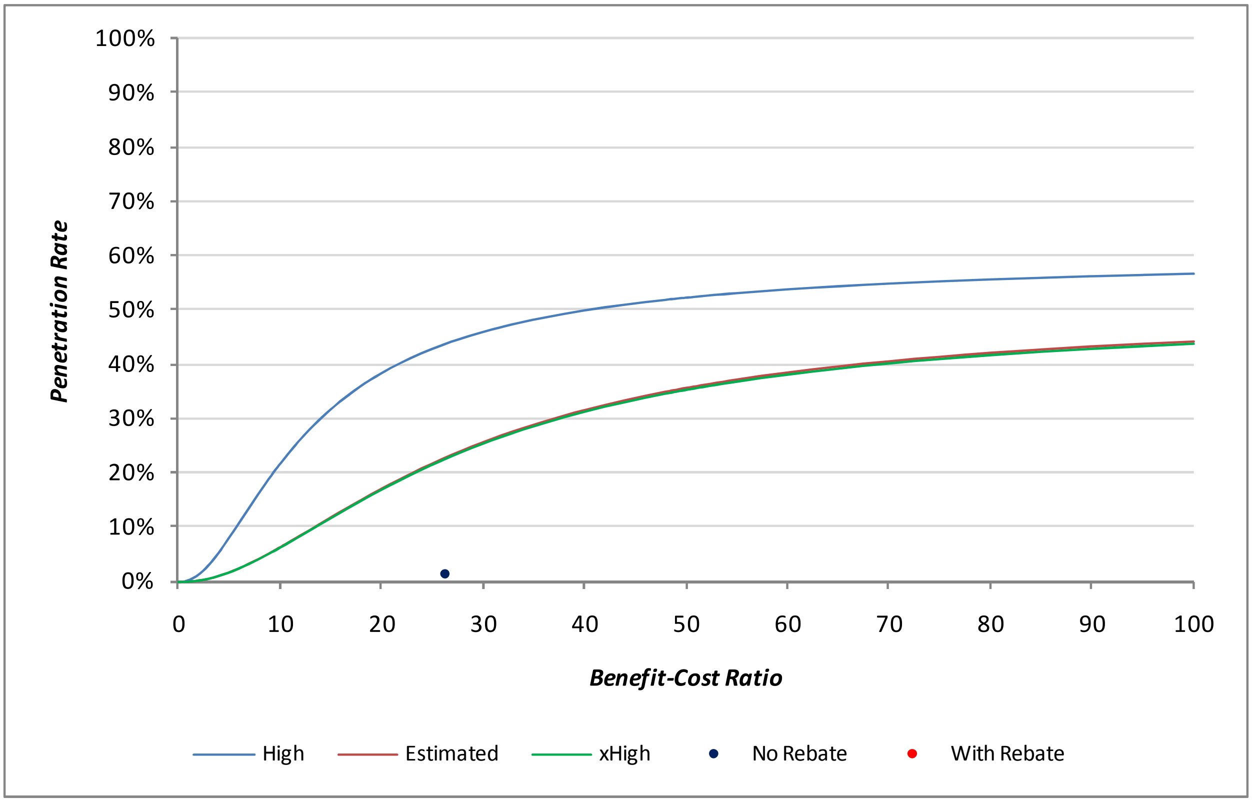

Figure 17.3.3 Market Penetration Curve for Room Air Conditioners, Less than 6,000 Btu/h, with Louvers

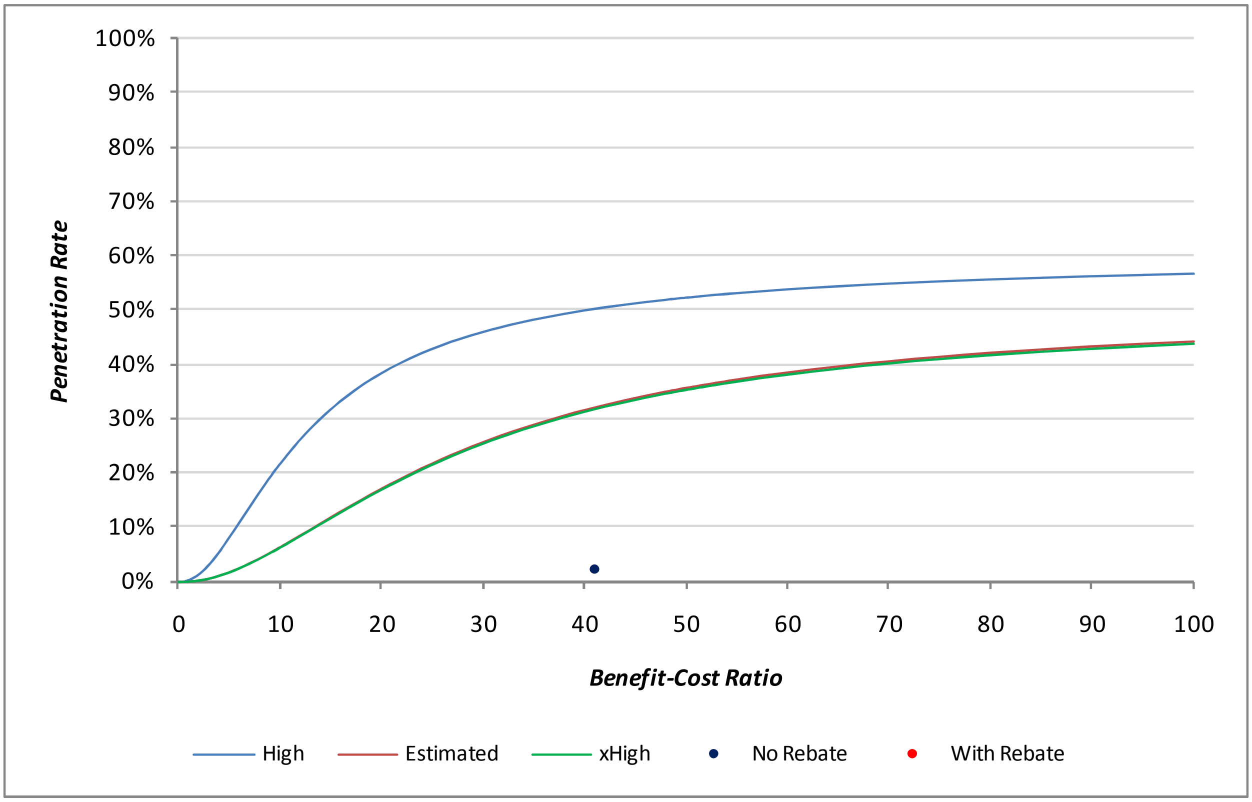

Figure 17.3.4 Market Penetration Curve for Room Air Conditioners, 28,000-13,999 Btu/h, with Louvers

For each product class, DOE next estimated the percent increase represented by the change in penetration rate shown on the penetration curve. It then added that percent increase to the market share of units that meet the target level in the base case to obtain the market share of units that meet the target level in the rebate case. Table 17.3.4 summarizes market shares of target-level room air conditioners estimated for 2014. DOE used the resulting increased market shares attributable to the rebate policy as inputs to the NIA-RIA model. Appendix 17-A, section 17-A.4, shows the annual market share increases due to this policy. Section 17.4 presents the resulting efficiency trends for the policy case of consumer rebates for room air conditioners.

Table 17.3.4 Market Penetration in 2014 Without and With Rebates for Room Air Conditioners

	PC 1 (Group 1) %	PC 3 (Group 2) %
Base-Case Market Share of Units that Meet Target Levels	1.2	2.2
Market Share of Units that Meet Target Levels With Rebates	2.6	3.4
Increased Market Share of Units that Meet Target Level With Rebates	1.4	1.2

17.3.3 Consumer Tax Credits

DOE estimated the effects of tax credits on consumer purchases based on its previous analysis of consumer participation in tax credits. DOE supported its approach using data from Oregon State's tax credit program for energy efficient appliances. DOE also incorporated previous research that disaggregated the effect of rebates and tax credits into a *direct price effect*, which derives from the savings in purchase price, and an *announcement effect*, which is independent of the amount of the incentive.[11, 12] The announcement effect derives from the credibility that a technology receives from being included in an incentive program, as well as changes in product marketing and modifications in markup and pricing. DOE assumed that the rebate and consumer tax credit policies would encompass both direct price effects and announcement effects, and that half the increase in market penetration associated with either policy would be due to the direct price effect and half to the announcement effect.

In estimating the effects of a tax credit on purchases of consumer products that meet new efficiency standards, DOE assumed the amount of the tax credits for each product class would be the same as the corresponding rebate amounts discussed above.

DOE estimated that fewer consumers would participate in a tax credit program than would take advantage of a rebate. Research has shown that the delay required for a consumer to receive a tax credit, plus the added time and cost in preparing the tax return, make a tax credit incentive less effective than a rebate received at the time of purchase. Based on previous analyses, DOE assumed that only 60 percent of the consumers who would take advantage of a rebate would take advantage of a tax credit.[13]

In preparing its assumptions, 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 equipment, including water heaters, furnaces, and furnace fans for new or existing homes.[14] Those tax credits were in effect in 2006 and 2007, expired in 2008, and were reinstated for 2009–2010 by ARRA.[1, 15] DOE reviewed Internal

Revenue Service data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. However, DOE did not find data specific enough to refrigerators to warrant adjusting its analysis method for the Consumer Tax Credits policy case. Appendix 17-A, section 17-A.6.1, contains more information on Federal consumer tax credits.

DOE also reviewed its previous analysis on Oregon's tax credits for clothes washers to provide support for its assumptions.[16] In the previous analysis, DOE compared the market shares of ultra-high efficiency (UHE) residential clothes washers in Oregon, which offered both State tax credits and utility rebates, with those in Washington State, which offered only utility rebates during the same period. Based on this analysis, DOE estimated that in Oregon the impact of tax credits was 62 percent of the impact of rebates for UHE clothes washers having equivalent 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 17-A, section 17-A.6.3.

DOE applied the assumed 60 percent participation described above to the penetration rates estimated for the rebate policy to estimate penetration rates attributable to consumer tax credits. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the penetration curves selected for each product class.

Tables 17.3.5 and 17.3.6 summarize DOE's assumptions for clothes dryers and room air conditioners regarding the market penetration of units in 2014 that meet target efficiency levels given a consumer tax credit.

Table 17.3.5 Market Penetrations in 2014 Attributable to Consumer Tax Credits for Clothes Dryers

	Vented Electric Standard **%**	**Vented Gas** **%**
Base-Case Market Share of Units that Meet Target Levels	25	41
Market Share of Units that Meet Target Levels With Consumer Tax Credits	56	72
Increased Market Share of Units that Meet Target Level With Consumer Tax Credits	30	31

Table 17.3.6 Market Penetrations in 2014 Attributable to Consumer Tax Credits for Room Air Conditioners

	PC 1 (Group 1) %	PC 3 (Group 2) %
Base-Case Market Share of Units that Meet Target Levels	1.2	2.2
Market Share of Units that Meet Target Levels With Consumer Tax Credits	2.0	2.9
Increased Market Share of Units that Meet Target Level With Consumer Tax Credits	0.8	0.7

DOE assumed that this policy would transform the market permanently, so that the increase in market share seen in the first year of the program for room air conditioners would be maintained throughout the forecast period. The increased market shares attributable to consumer tax credits shown in Tables 17.3.5 and 17.3.6 were used as inputs to the NIA-RIA model. Appendix 17-A, section 17-A.4, shows the annual market share increases due to this policy. Section 17.4 presents the resulting efficiency trends for the policy case of consumer tax credits for clothes dryers and room air conditioners that meet target efficiency levels.

17.3.4 Manufacturer Tax Credits

To analyze the potential effects of a policy that offers tax credits to manufacturers that produce refrigeration products that meet target efficiency levels, DOE assumed that a manufacturer tax credit would lower the consumer's purchase cost by an amount equivalent to that provided by the consumer rebates or tax credits described above. DOE further assumed that manufacturers would pass on some of their reduced costs to consumers, causing a direct price effect. DOE assumed that no announcement effect would occur, because the program would not be visible to consumers.[g] Because the direct price effect is approximately equivalent to the announcement effect,[11] DOE estimated that a manufacturer tax credit would induce half the number of consumers assumed to take advantage of a consumer tax credit to purchase more efficient products. This 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.[17] Those manufacturer tax credits were in effect for models produced in 2006 and 2007 and reinstated for 2009 and 2010. DOE was unable to locate data from the Internal Revenue Service or other sources on manufacturer response to the Federal credits. Appendix 17-A, section 17-A.6.2, presents details on Federal manufacturer tax credits.

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[g] Note that this is a conservative assumption, since it is possible that manufacturers or utility/agency efficiency programs might promote the models for which manufacturers increase production due to the tax credits, which in turn might induce some announcement effect. However, DOE found no data on such programs on which to base an estimate of the magnitude of this possible announcement effect on consumer behavior.

DOE applied the assumption of 30 percent participation to the penetration rates predicted for the rebate policy to estimate the effects of a manufacturer tax credit policy. In doing so, the Department incorporated the assumptions for consumer response to financial incentives from the penetration curves selected for each product class.

Tables 17.3.7 and 17.3.8 summarize DOE's assumptions for clothes dryers and room air conditioners regarding the market penetration of units in 2014 meeting target efficiency levels given a manufacturer tax credit.

Table 17.3.7 Market Penetrations in 2014 Attributable to Manufacturer Tax Credits for Clothes Dryers

	Vented Electric Standard %	**Vented Gas %**
Base-Case Market Share of Units that Meet Target Levels	25	41
Market Share of Units that Meet Target Levels With Manufacturer Tax Credits	40	56
Increased Market Share of Units that Meet Target Level With Manufacturer Tax Credits	15	15

Table 17.3.8 Market Penetrations in 2014 Attributable to Manufacturer Tax Credits for Room Air Conditioners

	PC 1 (Group 1) %	**PC 3 (Group 2) %**
Base-Case Market Share of Units that Meet Target Levels	1.2	2.2
Market Share of Units that Meet Target Levels With Manufacturer Tax Credits	1.6	2.6
Increased Market Share of Units that Meet Target Level With Manufacturer Tax Credits	0.4	0.4

DOE assumed that this policy would transform the market permanently, so that the increase in market share seen in the first year of the program for clothes dryers or room air conditioners would be maintained throughout the forecast period. The increased market shares attributable to a manufacturer tax credit shown in Tables 17.3.7 and 17.3.8 were used as inputs to the NIA-RIA model. Appendix 17-A, section 17-A.4, shows the annual market share increases due to this policy. Section 17.4 presents the resulting efficiency trends for the policy case of manufacturer tax credits for clothes dryers and room air conditioners.

17.3.5 Voluntary Energy Efficiency Targets

For each product, DOE assumed that voluntary energy efficiency targets would be achieved as manufacturers gradually stopped producing units that operated below the target efficiency levels. DOE assumed that the impetus for phasing out production of low-efficiency units would be a program similar to the ENERGY STAR labeling program conducted by the Environmental Protection Agency (EPA) and DOE. The ENERGY STAR program specifies the minimum energy efficiencies that various products, including room air conditioners, 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.[18, 19, 20]

17.3.5.1 Clothes Dryers

Since there is no ENERGY STAR program for clothes dryers, DOE instead based its estimates of market penetration for clothes dryers on the ENERGY STAR projections for residential clothes washers as an analogous product. DOE estimated the percentage of market shares attributable to the existing ENERGY STAR program for clothes washers for 1996 – 2025.[21] DOE then assumed that an ENERGY STAR program for clothes dryers would produce the same patterns of annual increases in market penetration beginning in 2014. From this forecast DOE calculated the annual percent increases in market share for units represented by the shipments attributed to ENERGY STAR. DOE added those percent increases to the market shares of clothes dryers that met the target levels in the RIA base case, starting in 2014, to obtain the annual market shares of units meeting the target efficiency level in the voluntary efficiency targets case.

DOE estimated that the programs developed in support of the voluntary efficiency targets policy would increase market shares of efficient units. Appendix 17-A, section 17-A.4, shows the annual market share increases due to this policy. Section 17.4 presents the resulting efficiency trends for the policy case of voluntary energy efficiency targets for clothes dryers that meet target efficiency levels.

17.3.5.2 Room Air Conditioners

To model the effects of a voluntary energy efficiency policy for room air conditioners, DOE assumed that such a program would be an expansion of existing ENERGY STAR efforts for this product. The ENERGY STAR program developed projections for 1996–2025 of increased market penetration attributable to its program for room air conditioners.[21] DOE estimated that an expanded ENERGY STAR program would increase the annual market share of efficient units by 50 percent more than the increase that was attributable to the existing ENERGY STAR program for room air conditioners, which began in 1996. Using ENERGY STAR's forecast for 1996 – 2025, DOE first performed interpolation to smooth out fluctuations due to periodic program specification updates. From this adjusted forecast, DOE calculated the annual percent increases in market share for room air conditioners represented by an additional 50 percent market share that would result from an enhanced program. DOE added those percent increases to the market shares of room air conditioners that meet the target level in the RIA base case,[h] starting in 2014, to obtain the annual market shares of units meeting the target efficiency level in the voluntary efficiency targets policy case. DOE assumed that the programs resulting from the expanded voluntary efficiency targets policy would produce projected increases in market share. Appendix 17-A, section 17-A.4, shows the annual market share increases due to this policy. Section 17.4 presents the resulting efficiency trends for the policy case of voluntary energy efficiency targets for room air conditioners.

17.3.6 Early Replacement

The non-regulatory policy of early replacement refers to a program to replace residential appliances before the ends of their useful lives. The purpose of such a policy is to replace old, inefficient units with higher efficiency units. The economic feasibility of early replacement depends on the vintage of the unit being replaced, the installed cost of the new unit, and the energy cost savings.

DOE reviewed analysis of the Connecticut Retirement Program (ARP), which was conducted June through December 2004 by Nexus Market Research, Inc., and RLW Analytics, Inc., for Northeast Utilities–Connecticut Light and Power and the United Illuminating Company's State programs.[25] The purpose of the ARP was to help Connecticut utility customers overcome barriers to recycling room air conditioners (RACs), secondary refrigerators, and freezers. The program picked up used appliances at customers' homes or at turn-in events, paid participants to retire their units, and educated customers about the costs of operating older appliances. In addition, the program provided consumers with financial incentives to replace inefficient RACs with ENERGY STAR-qualified units. DOE considered the RAC program to most closely resemble the early replacement policy scenario for clothes dryers considered herein. Nexus/RLW used program data and surveys to estimate the number of RACs retired by ARP participants, the percentage of retired units that were replaced with an ENERGY STAR model,

[h] The base case projections for refrigeration products incorporate assumptions on the percentage of qualifying shipments under the current ENERGY STAR program.

and the number of RACs replaced by non-participants during the program. According to the Nexus/RLW analysis, about 7 percent of all RACs retired during the program were retired through the ARP, and 63 percent of those were replaced with ENERGY STAR models. Thus the program resulted directly in about 4 percent of total eligible RAC consumers deciding on early replacement of inefficient units.

In 2006, GDS Associates, Inc performed a study of the potentials for electric energy efficiency for the State of Vermont.[26] The report estimated the potentials for reducing electricity use and peak demand through energy efficiency and fuel conversion measures. The study took an aggressive, multi-program approach, one aspect of which was early replacement of appliances. GDS considered that under the program residential appliances, including RACs, would be replaced during four years (2006–2009). GDS estimated achievable market penetrations assuming that consumers would receive a financial incentive equal to 50 percent of the incremental cost of each measure. GDS assumed an 80 percent penetration limit. For early replacement of RACs, GDS estimated a maximum achievable participation of 5 percent of eligible single-family or multi-family homes in the year before the program began (2005).

DOE also reviewed an earlier study it conducted in the 1990s, under Energy Policy Act of 1992 (EPACT 1992), which analyzed the feasibility of a Federal program to promote early replacement of appliances.[27] The study identified policy options for early replacement that included a direct national program; replacement of Federally-owned appliances; and promotion through equipment manufacturers, consumer incentives, incentives to utilities, and building regulations.[i]

While the SEEARP rebate program has been an early replacement program, the program was still in process during the preparation of this TSD. The amount of money available for rebates for each State, apportioned between several appliances per State, may not have been adequate to demonstrate the full market potential of an early replacement program targeted at one appliance.

For this RIA analysis, DOE analyzed a program that would target installed units having efficiency levels that are lower than target levels and encourage their early replacement with products that perform at target levels. For each product, DOE modeled the effects of the early replacement policy by increasing by a certain percentage per year the retirement rate of units that were in the stock in the first year of the analysis period (2014). For clothes dryers and room air conditioners DOE used the 4 percent rate from the Connecticut ARP program report, because it dealt with room air conditioners.

[i] The analysis concluded that, although cost-effective opportunities for early replacement exist, a widespread Federal program was not justified economically. Because early retirement means that a unit may be replaced by an appliance less efficient than the eventual replacement would have been, energy savings would be less than anticipated. Early replacement programs also could increase long-term sales volatility by encouraging a temporary increase in production, followed by a lull in demand. Early replacement could be economical in localities subject to high energy costs or environmental constraints; when replacement appliances are much more efficient than existing stock; or when a major technology breakthrough has occurred, creating the need for a ready market.

DOE assumed that the early replacement program would continue until it had facilitated the replacement of all eligible clothes dryers and room air conditioners in the stock in the year the program began (2014). Shipments of new units in 2014 and beyond were not affected by the program, but remained at base-case efficiency levels. After the stock of inefficient units was completely replaced, the policy would produce no additional impacts.

An early replacement policy would create a fairly immediate jump in shipments of products that meet target efficiency levels relative to the base case, as shown in Figures 17.3.5 and 17.3.6. High-efficiency units would be brought quickly into the stock, leading to an immediate gain in the market share of efficient units compared to the base case. As opposed to the policy cases discussed previously, however, an early replacement policy results in market shares of efficient units returning to base-case percentages as the eligible market is depleted. In addition, as the figures illustrate, because units removed early from the stock would have been replaced later (at the ends of their useful lives) without the program, the number of shipments in later years drops slightly below the base-case shipments forecast for a period of years. The shipments shown in Figures 17.3.5 and 17.3.6 represent units that replace existing units (replacement shipments). Appendix 17-A, section 17-A.4, shows the annual market share increases due to this policy. Section 17.4 presents the resulting efficiency trends for the policy case of early replacement for clothes dryers and room air conditioners.

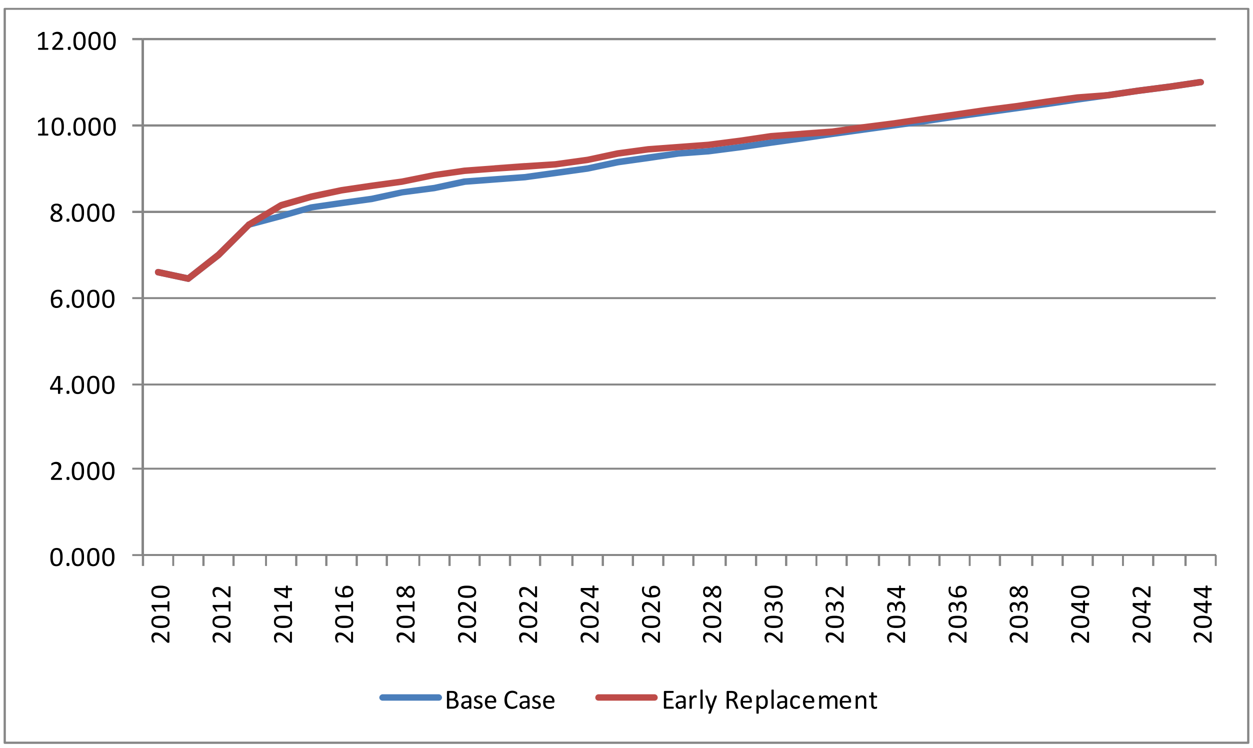

Figure 17.3.5 Estimated Replacement Shipments of Clothes Dryers With and Without an Early Replacement Program

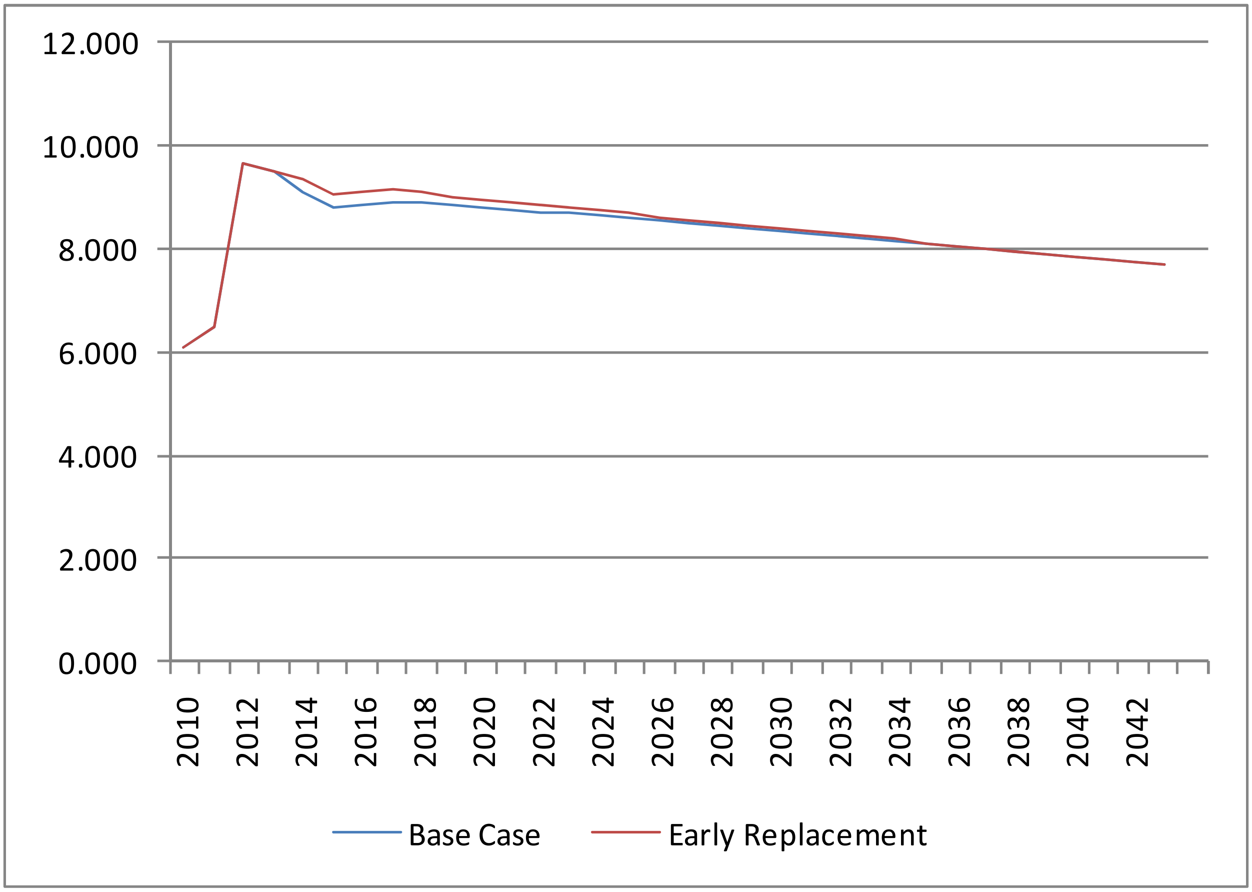

Figure 17.3.6 Estimated Replacement Shipments of Room Air Conditioners With and Without an Early Replacement Program

17.3.7 Bulk Government Purchases

DOE assumed that a policy requiring bulk government purchases would lead to Federal, State, and local governments purchasing products that meet target efficiency levels. Combining the market demands of multiple public sectors also would provide a market signal to manufacturers and vendors that some of their largest customers seek products that meet an efficiency target at favorable prices. Such a program also could induce "market pull," whereby manufacturers and vendors would achieve economies of scale for high-efficiency products.

Most of the previous bulk government purchase (procurement) initiatives at the Federal, State, and municipal levels have not tracked data on number 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 a policy calling for bulk government purchases on studies the Federal Energy Management Program (FEMP) performed regarding the savings potential of its procurement specifications for appliances and other equipment. FEMP, however, does not track purchasing data, because of the range of complex the purchasing systems, number of vendors, etc. 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.[28, 29]

DOE assumed that government agencies, such as the Department of Housing and Urban Development, would administer a bulk purchasing program for refrigeration products. The bulk purchasing policy also could be incorporated at the Federal level into the FEMP program, which has established procurement guidelines. Federal construction requirements include the FEMP guidelines for installing or replacing equipment. The FEMP program currently has procurement guidelines in place for room air conditioners.[30]

DOE also 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 the year 2000 already incorporated energy efficiency requirements based on FEMP guidelines. One scenario in the DOE report showed energy efficient Federal purchasing ramping up during 10 years from 20 percent to 80 percent of all Federal purchases.[31]

17.3.7.1 Clothes Dryers

Based on its study described above, DOE estimated that a bulk government purchase program instituted within a 10-year period would result in at least 80 percent of government-purchased clothes dryers meeting target efficiency levels.

DOE assumed that bulk government purchases would affect a subset of housing units for which government agencies purchased or influenced the purchase of clothes dryers. This subset would consist primarily of public housing and housing on military bases. DOE defined this subset based on publicly owned housing identified in the American Housing Survey (AHS) for 2009, which was 1.8 million households, or about 1.4 percent of all U.S. households.[32] (The AHS reports 130.0 million U.S. households.[33]) According to the 2005 Residential Energy Consumption Survey (RECS 2005), 20.8 percent of publicly owned households had electric clothes dryers and 23.4 percent had gas dryers.[34] DOE therefore estimated that 0.3 percent of U.S. housing units represent publicly owned households using electric clothes dryers and 0.3 percent using gas clothes dryers; these constitute the populations to which this policy would apply.

DOE estimated that each year of a bulk government purchase policy (2014) an increasing percent of shipments of government-purchased clothes dryers beyond the base case would meet target efficiency levels. DOE estimated that by 2024 bulk government purchasing programs would result in 80 percent of the clothes dryer market for publicly owned housing meeting target levels.[j] DOE modeled the bulk government purchase program assuming that the market share for each product achieved in 2024 would be maintained throughout the rest of the forecast period. Section 17.4 presents the resulting efficiency trends for the policy case of bulk government purchase of clothes dryers.

17.3.7.2 Room Air Conditioners

DOE analyzed the market for room air conditioners and determined that compact refrigerators are sold to the residential and commercial sectors. However, DOE did not analyze the potential impacts of bulk government purchases on commercial sector room air conditioners because it assumed that the penetration of this product in publicly owned buildings was very small. DOE lacked data to estimate their percentages in publicly owned commercial buildings.

Based on its study described above, DOE estimated that a bulk government purchase program instituted within a 10-year period eventually would result in at least 80 percent of government-purchased room air conditioners meeting target efficiency levels.

For the residential sector, DOE assumed that bulk government purchases would affect a subset of housing units for which government agencies purchased or influenced the purchase of compact refrigerators. DOE defined this subset based on publicly owned housing identified in the American Housing Survey (AHS) for 2009, which was 1.8 million households, or about 1.4 percent of all U.S. households.[32] (The AHS reports 130.0 million U.S. households.[33]) According to the 2005 Residential Energy Consumption Survey (RECS 2005), 38.4 percent of publicly owned households used room air conditioners.[34] DOE therefore estimated that 0.5 percent of U.S. housing units represent publicly owned households using room air conditioners, to which this policy would apply.

DOE estimated that by 2024 bulk government purchasing programs would result in 80 - 100 percent of the room air conditioner market for publicly owned buildings meeting target levels. DOE modeled the bulk government purchase program assuming that the market share for each product achieved in 2024 would be maintained throughout the rest of the forecast period. Section 17.4 presents the resulting efficiency trends for the policy case of bulk government purchase of room air conditioners.

17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

This section presents graphs of the projected annual market shares of units meeting the target levels that result from the non-regulatory policies for each product class of for clothes dryers and room air conditioners analyzed in the RIA-NIA integrated model. It also presents the tables of the national energy savings and net present value (NPV) for each of the six non-regulatory policies analyzed.

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[j] For some product classes where the market share in the base case was already above 80%, the estimated 10-year market penetration was set at 90% or 100%.

17.4.1 Clothes Dryers

Figures 17.4.1 through 17.4.6 show the effects of each non-regulatory policy on market penetration for clothes dryers. Note that the market share of products that meet the target level is forecasted to remain constant in the base case (i.e., the case with neither standards nor non-regulatory policies). Note that for product classes whose base case market shares are 100 percent, the non-regulatory policies have no impact and therefore their projections are identical to the base case. For the other product classes whose base case market shares are less than 100 percent, relative to the base case, the policy cases increase the market share of room air conditioners that meet the target level. Consumer rebates are most effective in increasing the market share of clothes dryers that meet the target level, while bulk government purchases is least effective in increasing market share. Recall that the standards (not shown in the figures) would result in a 100 percent market penetration of products that meet target efficiency levels.

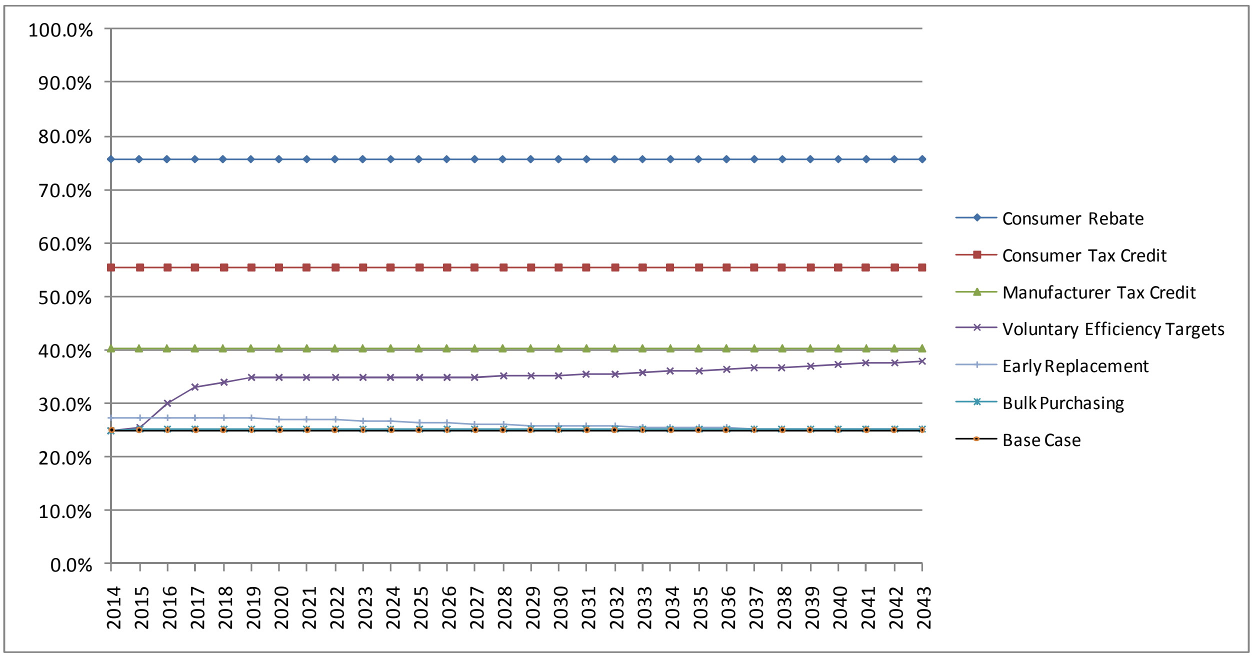

Figure 17.4.1 Market Penetration of Vented Electric Standard Clothes Dryers Meeting Target Level in Policy Cases

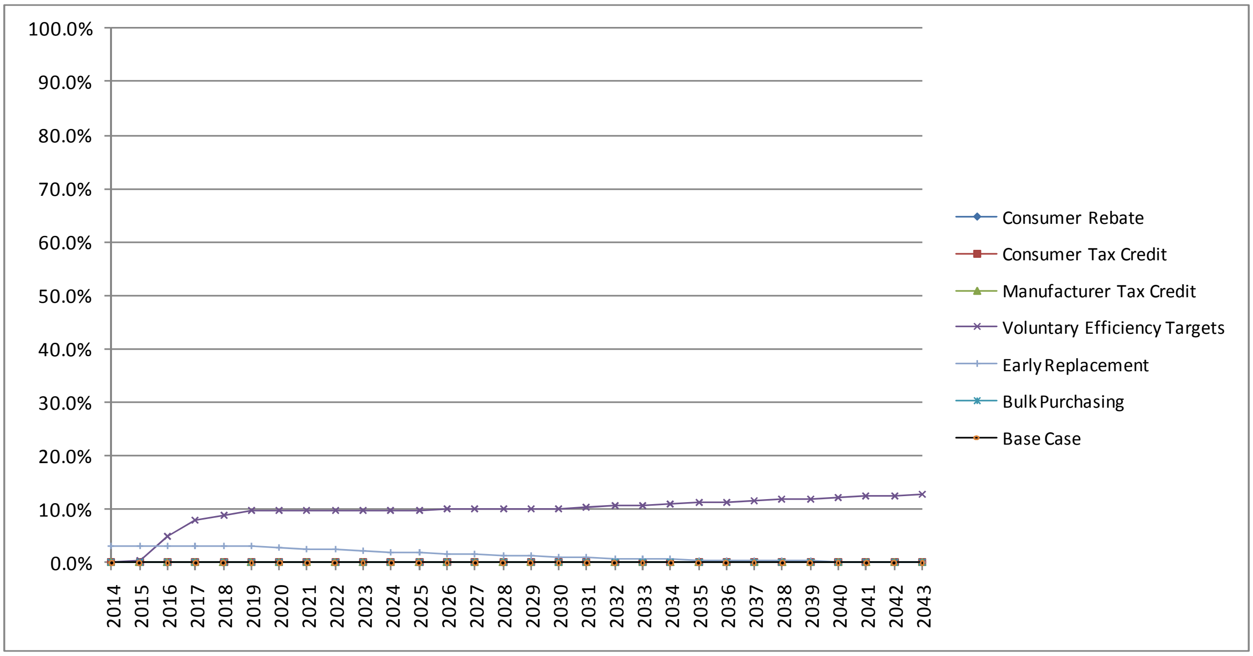

Figure 17.4.2 Market Penetration of Vented Electric Compact 120V Clothes Dryers Meeting Target Level in Policy Cases

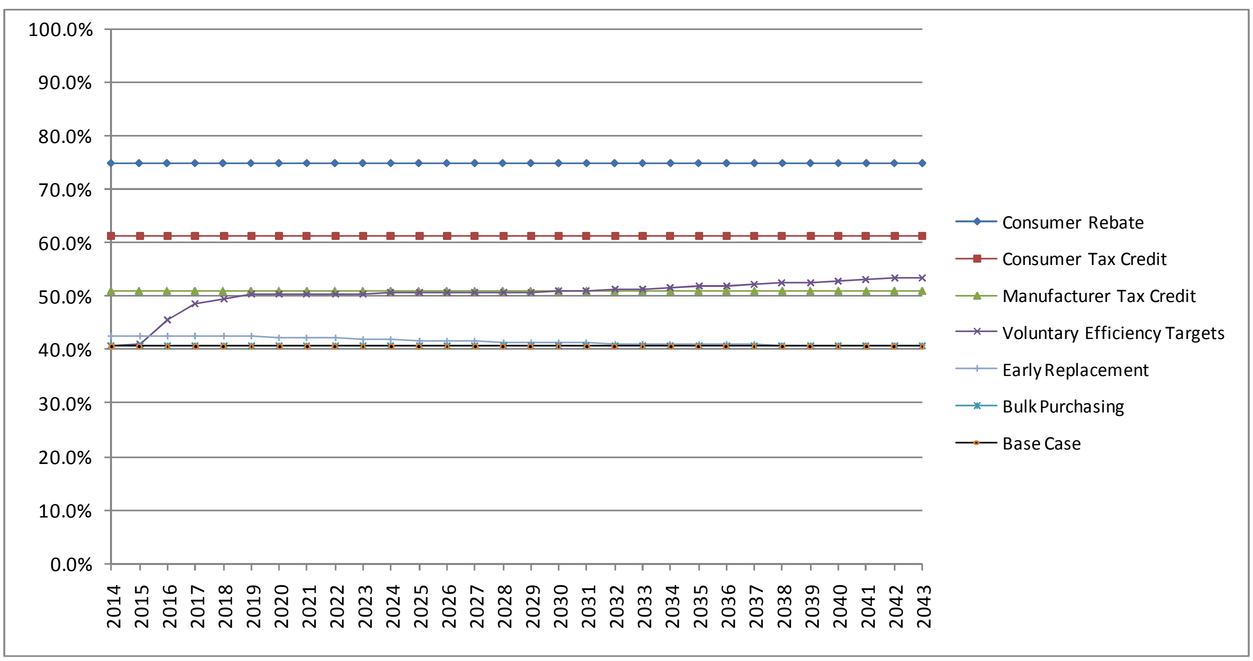

Figure 17.4.3 Market Penetration of Vented Electric Compact 240V Clothes Dryers Meeting Target Level in Policy Cases

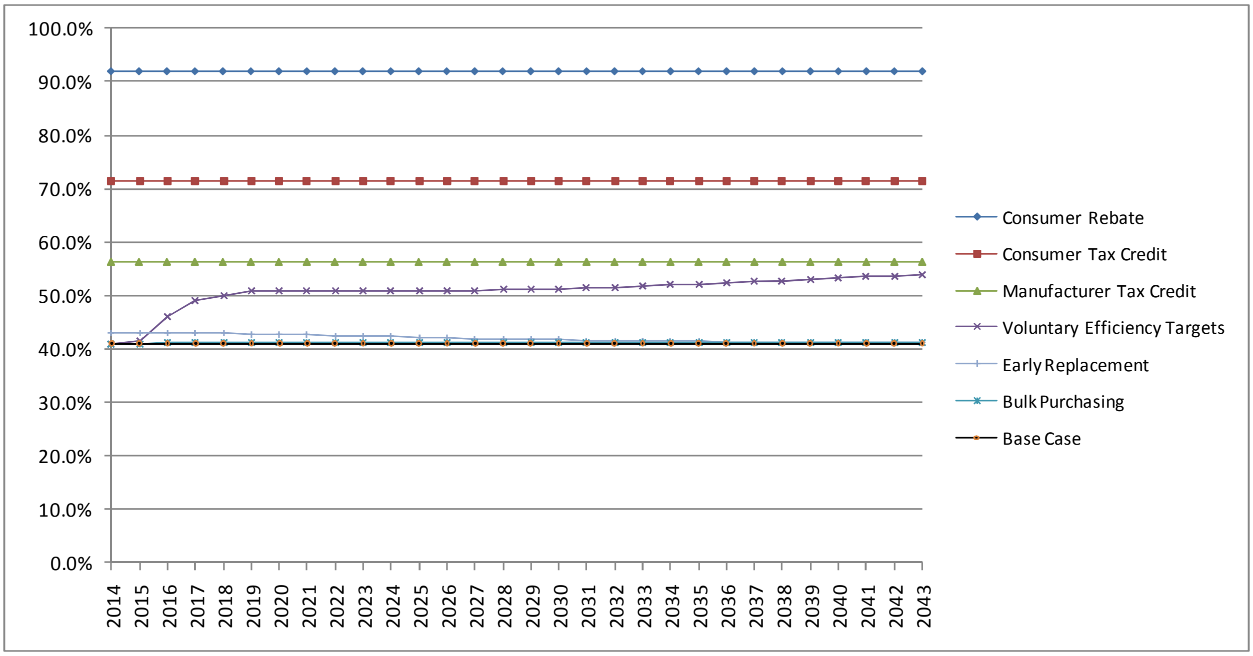

Figure 17.4.4 Market Penetration of Vented Gas Clothes Dryers Meeting Target Level in Policy Cases

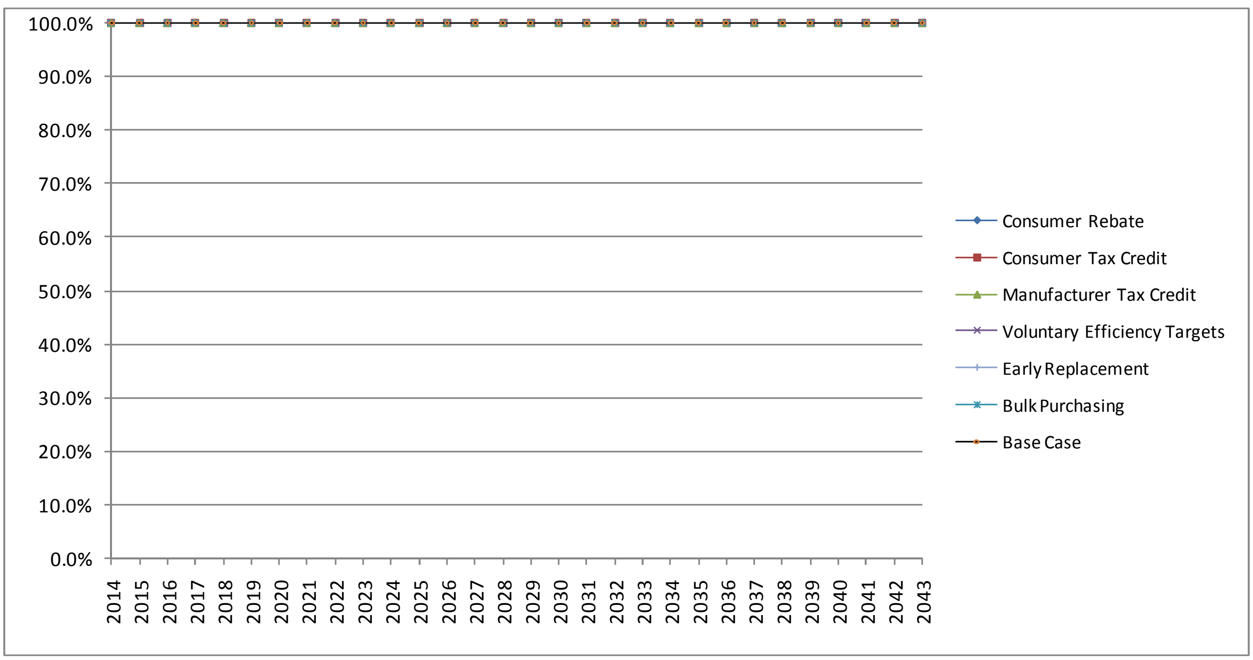

Figure 17.4.5 Market Penetration of Vent-less Electric Compact 240V Clothes Dryers Meeting Target Level in Policy Cases

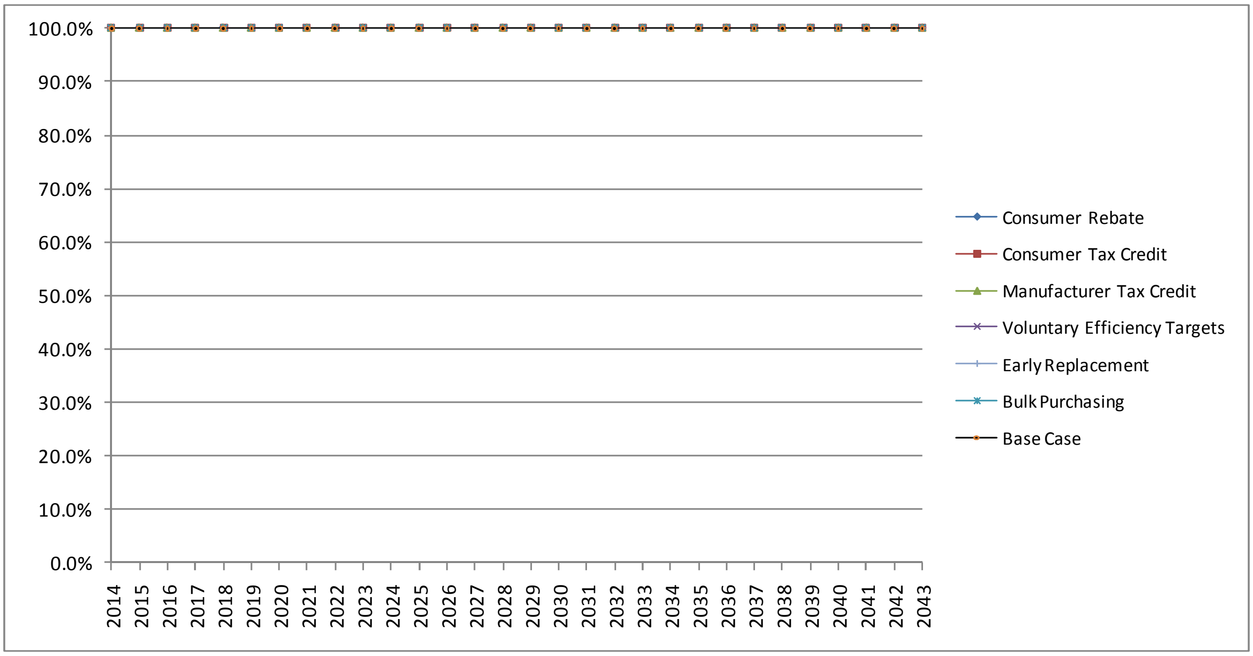

Figure 17.4.6 Market Penetration of Vent-less Electric Combination Washer/Dryer Meeting Target Level in Policy Cases

Tables 17.4.1 through 17.4.6 show the national energy savings and net present value (NPV) for each of the six non-regulatory policies analyzed in detail for clothes dryers, where the target level for each policy equals the efficiency level in the corresponding proposed standard.

The cases in which no regulatory action is taken with regard to clothes dryers and room air conditioners constitute the base cases (or "No New Regulatory Action" scenarios), in which energy savings and NPV zero by definition. For comparison, the tables include the impacts of the proposed standards. Energy savings are given in quadrillion British thermal units (quads). The NPVs shown in Tables 17.4.1 through 17.4.12 are based on two discount rates, 7 percent and 3 percent. Negative NPVs are shown in parentheses.

Table 17.4.1 Impacts of Non-Regulatory Alternatives for Vented Electric Standard Dryers that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.287	0.320	1.426
Consumer Tax Credits	0.173	0.193	0.859
Manufacturer Tax Credits	0.087	0.097	0.431
Voluntary Energy Efficiency Targets	0.050	0.161	0.442
Early Replacement	0.004	0.014	0.026
Bulk Government Purchases	0.001	0.002	0.006
Proposed Standards	0.347	1.017	2.779

* For products shipped in 2014─ 2043

Table 17.4.2 Impacts of Non-Regulatory Alternatives for Vented Electric Compact 120V Dryers that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.000	0.000	0.000
Consumer Tax Credits	0.000	0.000	0.000
Manufacturer Tax Credits	0.000	0.000	0.000
Voluntary Energy Efficiency Targets	0.000	0.000	0.001
Early Replacement	0.000	0.000	0.000
Bulk Government Purchases	0.000	0.000	0.000
Proposed Standards	0.000	0.002	0.005

* For products shipped in 2014─ 2043

Table 17.4.3 Impacts of Non-Regulatory Alternatives for Vented Electric Compact 240V Dryers that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings Quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.001	(0.002)	0.001
Consumer Tax Credits	0.001	(0.001)	0.001
Manufacturer Tax Credits	0.000	(0.001)	0.000
Voluntary Energy Efficiency Targets	0.000	0.001	0.003
Early Replacement	0.000	0.000	0.000
Bulk Government Purchases	0.000	0.000	0.000
Proposed Standards	0.001	0.006	0.014

* For products shipped in 2014– 2043

Table 17.4.4 Impacts of Non-Regulatory Alternatives for Vented Gas Dryers that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.040	(0.126)	(0.074)
Consumer Tax Credits	0.024	(0.076)	(0.045)
Manufacturer Tax Credits	0.012	(0.038)	(0.022)
Voluntary Energy Efficiency Targets	0.007	0.014	0.049
Early Replacement	0.000	0.003	0.005
Bulk Government Purchases	0.000	0.000	0.001
Proposed Standards	0.038	0.051	0.215

* For products shipped in 2014– 2043

Table 17.4.5 Impacts of Non-Regulatory Alternatives for Vent-less Electric Compact 240V Dryers that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.000	0.000	0.000
Consumer Tax Credits	0.000	0.000	0.000
Manufacturer Tax Credits	0.000	0.000	0.000
Voluntary Energy Efficiency Targets	0.000	0.000	0.000
Early Replacement	0.000	0.000	0.000
Bulk Government Purchases	0.000	0.000	0.000
Proposed Standards	0.000	0.000	0.000

* For products shipped in 2014─ 2043

Table 17.4.6 Impacts of Non-Regulatory Alternatives for Vent-less Electric Combination Washer/Dryer Dryers that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.000	0.000	0.000
Consumer Tax Credits	0.000	0.000	0.000
Manufacturer Tax Credits	0.000	0.000	0.000
Voluntary Energy Efficiency Targets	0.000	0.000	0.000
Early Replacement	0.000	0.000	0.000
Bulk Government Purchases	0.000	0.000	0.000
Proposed Standards	0.000	0.000	0.000

* For products shipped in 2014─ 2043

17.4.2 Room Air Conditioners

Figures 17.4.7 through 17.4.12 show the effects of each non-regulatory policy on market penetration for residential sector room air conditioners; these results do not include room air conditioners used in the commercial sector. The market share of products that meet the target level in the base case is forecasted to be constant for some product classes and to increase over time for some product classes. Note that for product classes whose base case market shares are

100 percent, the non-regulatory policies have no impact and their projections are identical to the base case. For the other product classes whose base case market shares are less than 100 percent, relative to the base case, the policy cases increase the market share of room air conditioners that meet the target level. Consumer rebates produce the greatest market share increases and bulk government purchases the least market share increases of those policy cases. Recall that the proposed standards (not shown in the figures) would result in a 100 percent market penetration of products that meet the target efficiency level.

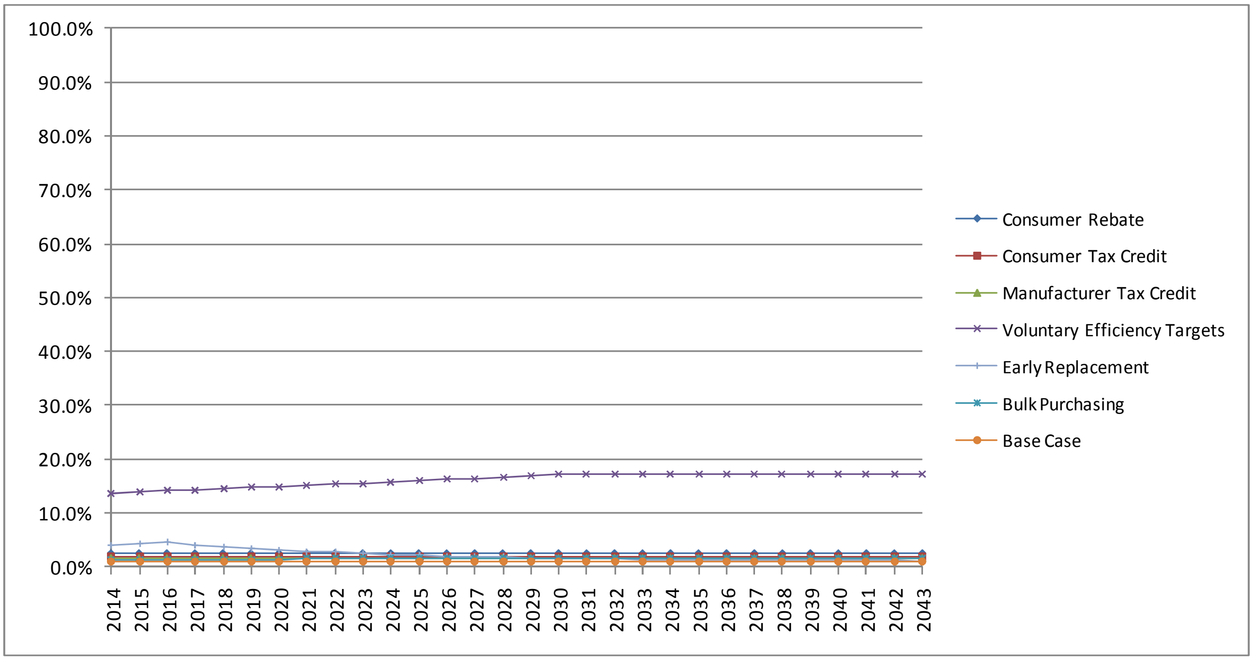

Figure 17.4.7 Market Penetration of Room Air Conditioners Less than 6,000 Btu/h, with Louvers, Meeting Target Level in Policy Cases

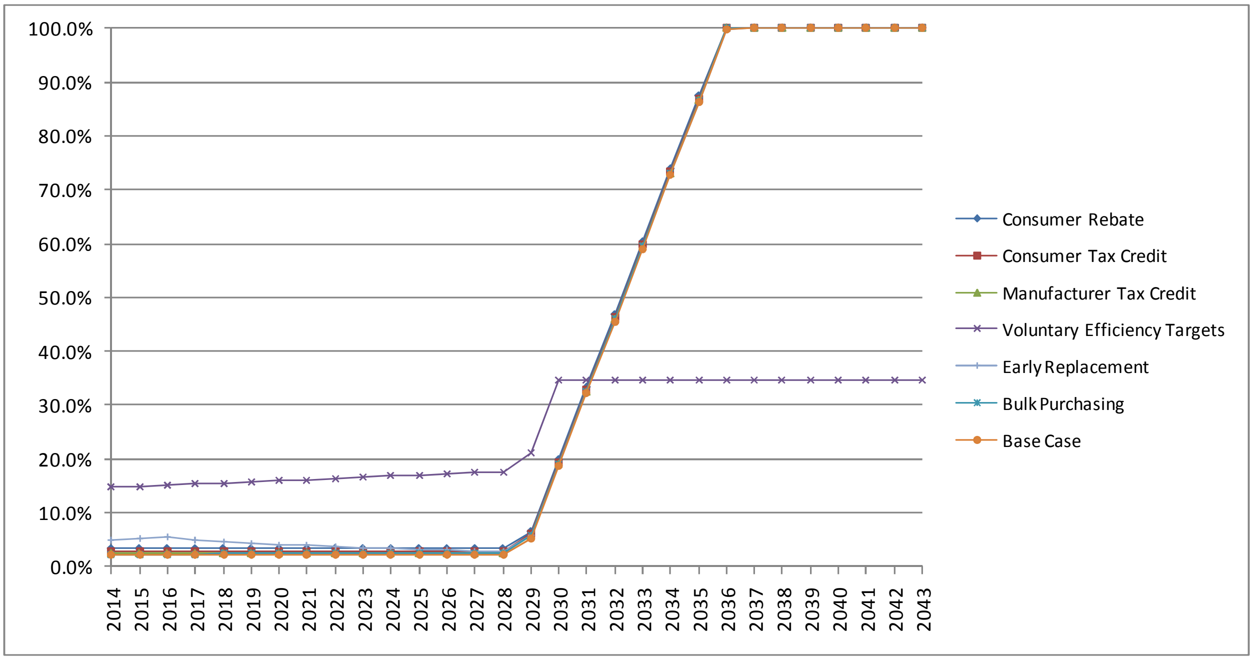

Figure 17.4.8 Market Penetration of Room Air Conditioners 8,000-13,999 Btu/h, with Louvers, Meeting Target Level in Policy Cases

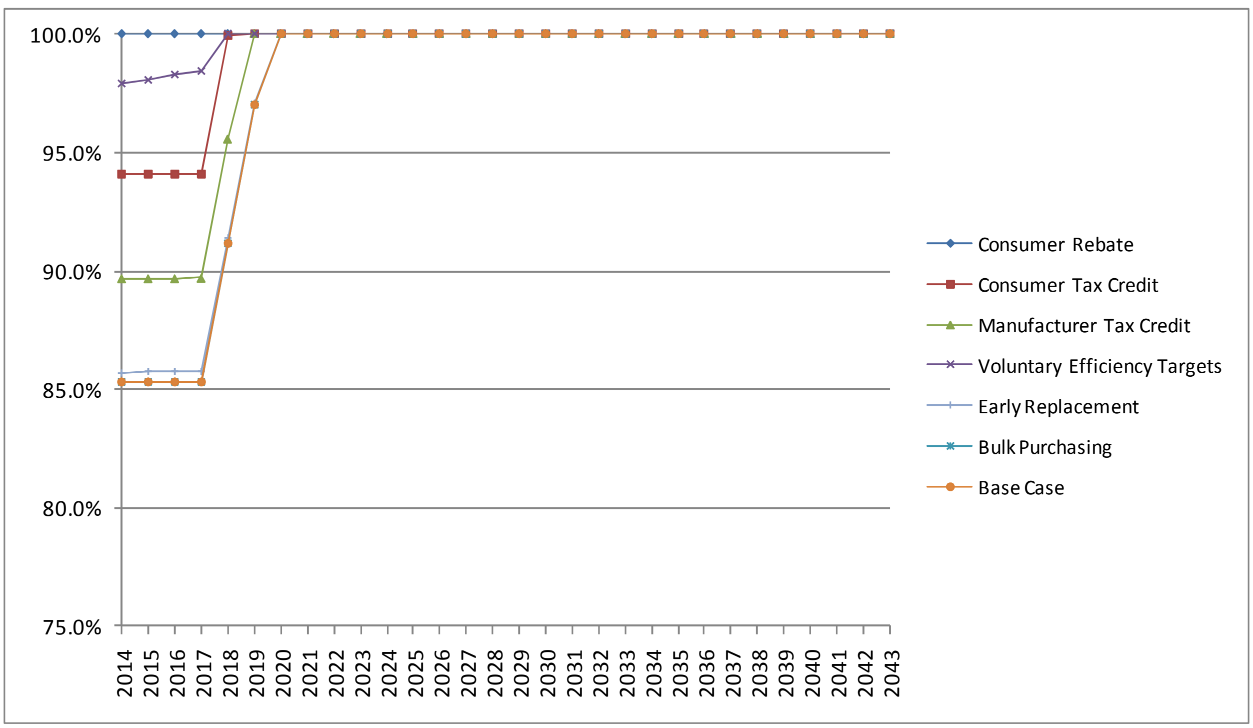

Figure 17.4.9 Market Penetration of Room Air Conditioners 20,000-24,999 Btu/h, with Louvers, Meeting Target Level in Policy Cases

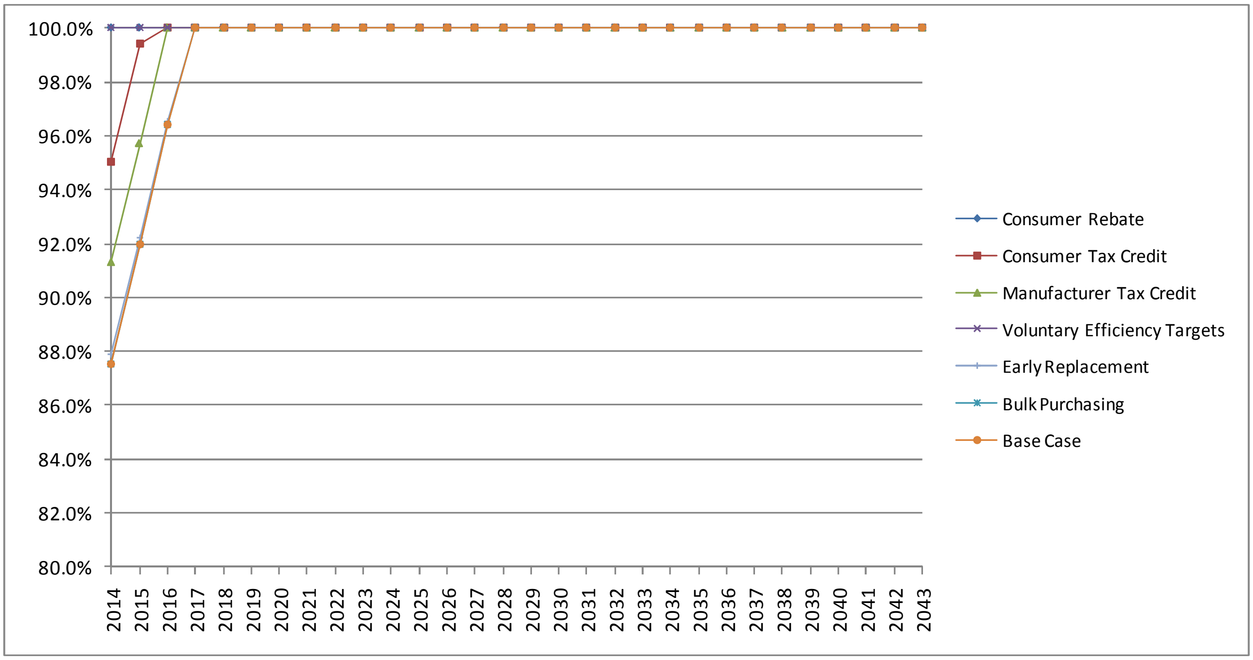

Figure 17.4.10 Market Penetration of Room Air Conditioners 25,000 Btu/h or more, with Louvers, Meeting Target Level in Policy Cases

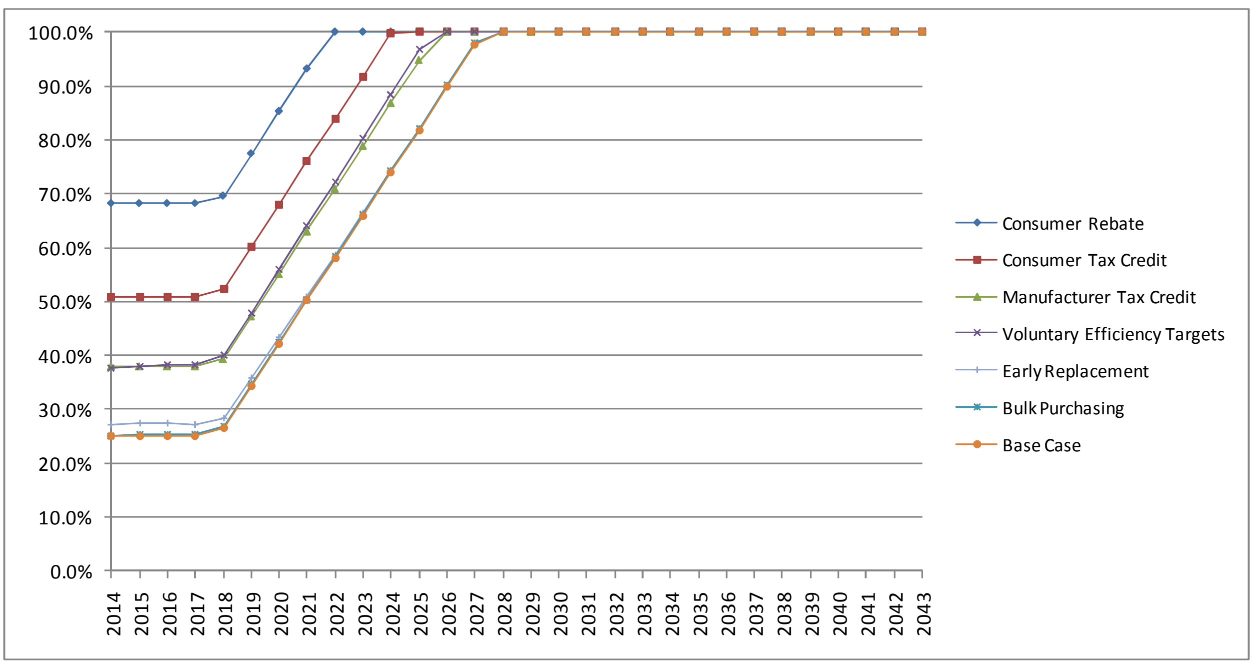

Figure 17.4.11 Market Penetration of Room Air Conditioners 8,000-10,999 Btu/h, without Louvers Meeting Target Level in Policy Cases

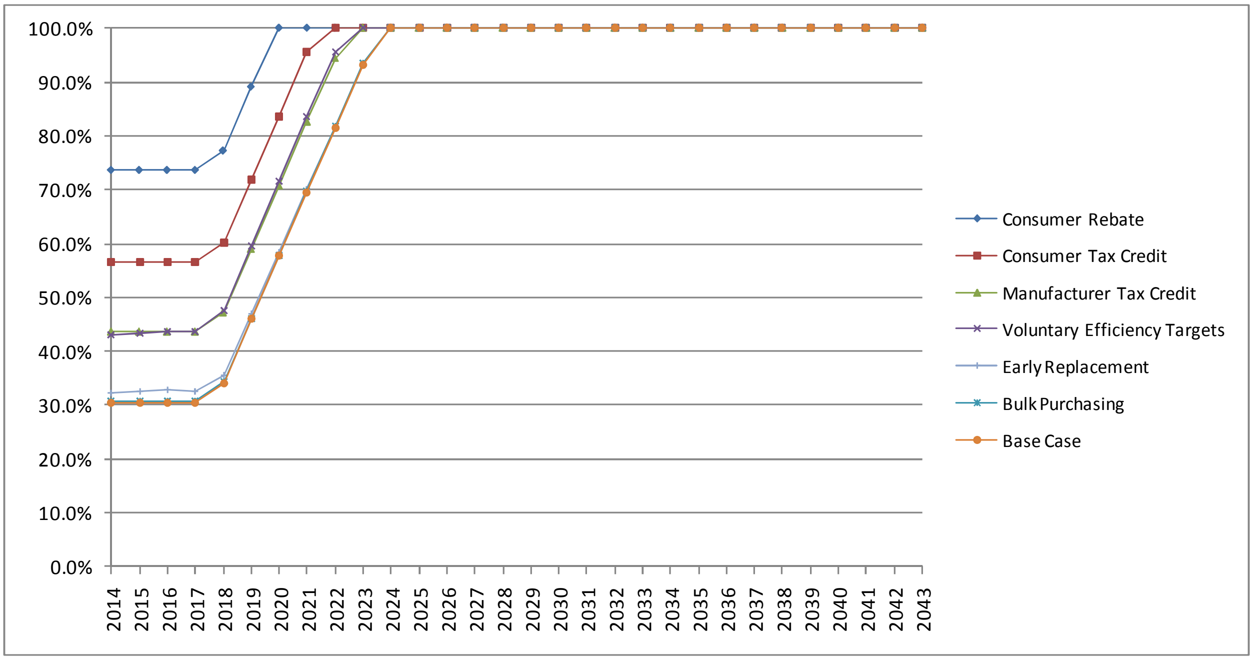

Figure 17.4.12 Market Penetration of Room Air Conditioners 11,000-13,999 Btu/h, without Louvers Meeting Target Level in Policy Cases

Tables 17.4.7 through 17.4.12 show the national energy savings and net present value (NPV) for each of the six non-regulatory policies analyzed in detail for room air conditioners, where the target level for each policy equals the efficiency level in the corresponding proposed standard. The results shown in Tables 17.4.7 through 17.4.12 represent savings and NPV for room air conditioners used in the residential sector only.

The cases in which no regulatory action is taken with regard to room air conditioners constitute the base cases (or "No New Regulatory Action" scenarios), in which energy savings and NPV zero by definition. For comparison, the tables include the impacts of the proposed standards. Energy savings are given in quadrillion British thermal units (quads). The NPVs shown in Tables 17.4.7 through 17.4.12 are based on two discount rates, 7 percent and 3 percent. Negative NPVs are shown in parentheses.

Table 17.4.7 Impacts of Non-Regulatory Alternatives for Room Air Conditioners Group 1 - Less than 6,000 Btu/h, with Louvers, that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.002	0.000	0.004
Consumer Tax Credits	0.001	0.000	0.002
Manufacturer Tax Credits	0.000	0.000	0.001
Voluntary Energy Efficiency Targets	0.016	0.001	0.037
Early Replacement	0.002	(0.001)	0.003
Bulk Government Purchases	0.000	0.000	0.001
Proposed Standards	0.133	(0.020)	0.245

* For products shipped in 2014─ 2043

Table 17.4.8 Impacts of Non-Regulatory Alternatives for Room Air Conditioners in Group 2 - based on 8,000-13,999 Btu/h, with Louvers, that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings Quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.002	(0.001)	0.004
Consumer Tax Credits	0.001	0.000	0.002
Manufacturer Tax Credits	0.001	0.000	0.001
Voluntary Energy Efficiency Targets	0.014	0.052	0.100
Early Replacement	0.002	0.008	0.013
Bulk Government Purchases	0.000	0.001	0.002
Proposed Standards	0.161	0.558	1.162

* For products shipped in 2014─ 2043

Table 17.4.9 Impacts of Non-Regulatory Alternatives for Room Air Conditioners in Group 3 - based on 20,000-24,999 Btu/h, with Louvers, that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.000	0.000	0.001
Consumer Tax Credits	0.000	0.000	0.000
Manufacturer Tax Credits	0.000	0.000	0.000
Voluntary Energy Efficiency Targets	0.000	0.000	0.001
Early Replacement	0.000	0.000	0.000
Bulk Government Purchases	0.000	0.000	0.000
Proposed Standards	0.001	(0.003)	(0.003)

* For products shipped in 2014─ 2043

Table 17.4.10 Impacts of Non-Regulatory Alternatives for Room Air Conditioners in Group 4 - based on 25,000 Btu/h or more Btu/h, with Louvers, that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.000	(0.001)	(0.001)
Consumer Tax Credits	0.000	0.000	0.000
Manufacturer Tax Credits	0.000	0.000	0.000
Voluntary Energy Efficiency Targets	0.000	0.000	0.000
Early Replacement	0.000	0.000	0.001
Bulk Government Purchases	0.000	0.000	0.000
Proposed Standards	0.000	(0.002)	(0.002)

* For products shipped in 2014─ 2043

Table 17.4.11 Impacts of Non-Regulatory Alternatives for Room Air Conditioners in Group 5 - based on 8,000-10,999 Btu/h, without Louvers, that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.002	0.005	0.011
Consumer Tax Credits	0.002	0.003	0.007
Manufacturer Tax Credits	0.001	0.002	0.004
Voluntary Energy Efficiency Targets	0.001	0.003	0.006
Early Replacement	0.000	0.000	0.001
Bulk Government Purchases	0.000	0.000	0.000
Proposed Standards	0.006	0.025	0.049

* For products shipped in 2014─ 2043

Table 17.4.12 Impacts of Non-Regulatory Alternatives for Room Air Conditioners in Group 6 - based on 11,000-13,999 Btu/h, without Louvers, that Meet the Proposed Standard (TSL 4)

Policy Alternative	Primary Energy Savings quads	Net Present Value* billion 2009$	
		7% discount rate	3% discount rate
Consumer Rebates	0.002	0.007	0.013
Consumer Tax Credits	0.001	0.004	0.009
Manufacturer Tax Credits	0.001	0.002	0.004
Voluntary Energy Efficiency Targets	0.000	0.002	0.003
Early Replacement	0.000	0.000	0.000
Bulk Government Purchases	0.000	0.000	0.000
Proposed Standards	0.004	0.013	0.024

* For products shipped in 2014─ 2043

17.5 SUPER-EFFICIENT VOLUNTARY TARGETS

Besides the above policy alternatives, DOE evaluated a policy where a new voluntary efficiency target program was implemented *in addition to* the proposed standards. The voluntary efficiency targets would feature “super-efficient” products at one efficiency level (designated Super-Maxtech) above the current max-tech levels. The policy would target consumers willing to purchase highly efficient equipment, typically located in the highest electricity price regions of the country. For the purpose of evaluating the policy, all product classes were considered. In the case of clothes dryers, the electric Super-Maxtech models would employ a CO_2 heat pump and the gas based models would use full modulating heat. For room air-conditioners, all Super-Maxtech models would use a compressor with 10.4 EER, and models from Groups 2 and 3 would have their unit size increased. Tables 17.5.1 and 17.5.2 show the targeted efficiency levels and parameters from the life-cycle cost analysis, respectively, for the clothes dryers and room air-conditioners Super-Maxtech models. Additionally, Tables 17.5.3 to 17.5.5 present, for each of the nine Census Divisions, the consumer benefit/cost ratio (in 2014) from purchasing and using such models.[k]

Table 17.5.1 Super-efficient Voluntary Targets Program Parameters for Clothes Dryers

	Product Class					
	Elec Stand	Elec Comp 120v	Elec Comp 240v	Gas	Elec Comp Ventless	Elec Wash/Dryer
Efficiency level (lb/kWh)	5.60	5.58	5.05	3.83	4.16	3.81
LCC Parameters						
Annual electricity consumption (kWh)	461.6	190.6	214.6	24.9	200.6	215.0
Annual gas consumption (MMBtu)	-	-	-	2.12	-	-
Total installed cost (2009$)	$1,129	$1,174	$1,174	$793	$1,966	$2,536
Annual maintenance cost (2009$)	$0.36	$0.37	$0.37	$0.36	$0.55	$0.69

[k] Benefits and costs are estimated for equipment purchased in 2014 and used during their corresponding unit average lifetime (8 years for clothes dryers, and 4 years for room air-conditioners).

Table 17.5.2 Super-efficient Voluntary Targets Program Parameters for Room Air-Conditioners

	Product Class					
	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**
Efficiency level (CEER)	11.10	10.90	9.40	9.00	9.60	9.50
LCC Parameters						
Annual electricity consumption (kWh)						
• Residential use	312.3	493.5	400.0	479.1	405.7	622.5
• Commercial use	468.6	846.3	2505.9	2580.0	975.2	1200.5
Total installed cost (2009$)						
• Residential use	$515.86	$658.36	$1278.85	$1358.37	$660.72	$747.50
• Commercial use	$515.59	$657.22	$1277.70	$1357.17	$659.49	$746.16
Annual maintenance cost (2009$)	$0.11	$0.28	$1.26	$1.18	$0.28	$0.28

Table 17.5.3 Super-efficient Voluntary Targets Program Benefit/Cost Ratio per Census Division for Clothes Dryers

	Product Class					
	Elec Stand	Elec Comp 120v	Elec Comp 240v	Gas	Elec Comp Ventless	Elec Wash/Dryer
New England	0.49	0.23	0.25	0.31	0.25	0.32
Middle Atlantic	0.43	0.20	0.22	0.27	0.22	0.28
East North Central	0.30	0.14	0.15	0.21	0.15	0.19
West North Central	0.27	0.13	0.14	0.21	0.14	0.18
South Atlantic	0.32	0.15	0.16	0.27	0.16	0.21
East South Central	0.28	0.13	0.14	0.23	0.14	0.18
West South Central	0.33	0.16	0.17	0.23	0.17	0.22
Mountain	0.30	0.14	0.16	0.22	0.16	0.20
Pacific	0.34	0.16	0.18	0.24	0.18	0.23

Table 17.5.4 Super-efficient Voluntary Targets Program Benefit/Cost Ratio per Census Division for Room Air-Conditioners (residential sector)

	Product Class					
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
New England	0.35	0.51	0.16	0.19	0.45	0.59
Middle Atlantic	0.30	0.44	0.14	0.17	0.39	0.51
East North Central	0.21	0.31	0.10	0.12	0.27	0.36
West North Central	0.20	0.29	0.09	0.11	0.25	0.33
South Atlantic	0.23	0.33	0.11	0.12	0.29	0.38
East South Central	0.20	0.29	0.09	0.11	0.25	0.33
West South Central	0.23	0.35	0.11	0.13	0.30	0.40
Mountain	0.21	0.32	0.10	0.12	0.28	0.36
Pacific	0.25	0.36	0.12	0.14	0.32	0.42

Table 17.5.5 Super-efficient Voluntary Targets Program Benefit/Cost Ratio per Census Division for Room Air-Conditioners (commercial sector)

	Product Class					
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
New England	0.37	0.63	0.68	0.66	0.76	0.80
Middle Atlantic	0.35	0.60	0.65	0.63	0.72	0.76
East North Central	0.26	0.44	0.48	0.47	0.53	0.56
West North Central	0.24	0.40	0.43	0.42	0.48	0.51
South Atlantic	0.28	0.47	0.51	0.50	0.57	0.60
East South Central	0.25	0.41	0.45	0.44	0.50	0.53
West South Central	0.25	0.42	0.46	0.45	0.51	0.54
Mountain	0.25	0.42	0.46	0.45	0.51	0.54
Pacific	0.34	0.57	0.62	0.60	0.69	0.72

The benefit/cost analysis indicates that for all Super-Maxtech models evaluated, despite the energy savings they can provide, costs outweigh benefits for consumers in all Census Divisions. Nevertheless, DOE assumed that consumers willing to buy highly efficient equipment would move toward such models, and therefore Super-Maxtech equipment would have some market penetration. Further, DOE considered that the market penetration of those models would increase with time as their price decrease.

Because the products modeled under this super-efficient voluntary targets program rely on advanced technology, DOE adopted a learning model approach to estimate their market penetration. In such an approach, while the cost of mature technology ("low-tech") components remains constant over time, the cost of the advanced technology ("high-tech") components decreases as a function of cumulative production of those products. DOE calculated the dynamic cost of Super-Maxtech models from the following expressions:

$$C_{\text{total}}(\text{t}) = C_{\text{high-tech}}(\text{t}) + C_{\text{low-tech}}$$

$$C_{\text{high-tech}}(\text{t}) = C_{\text{high-tech}}(0) \times (Q/Q_0)^b$$

$$b = \ln(PR) / \ln(2)$$

where:

$C_{\text{total}}(\text{t})$ =	(dynamic) total cost
$C_{\text{high-tech}}(\text{t})$ =	(dynamic) cost of high-tech components
$C_{\text{low-tech}}$ =	(constant) cost of low-tech components
$C_{\text{high-tech}}(0)$ =	cost of high-tech components in 2014
Q =	cumulative production of the Super-Maxtech model since 2014
Q_0 =	production of the Super-Maxtech model in 2014
b =	learning rate coefficient
PR =	progress ratio (=0.85).

DOE estimated the costs of the high-tech (in 2014) and low-tech components of Super-Maxtech models after breaking down their costs into two parts: (a) the incremental cost in relation to the projected max-tech model (high-tech components cost); and (b) the cost of the projected max-tech model (low-tech components cost). Tables 17.5.6 through 17.5.8 show the total installed cost of Super-Maxtech products in selected model years.

Table 17.5.6 Super-efficient Voluntary Targets Program Total Installed Cost of Clothes Dryers (2009$)

	Product Class					
	Elec Stand	Elec Comp 120v	Elec Comp 240v	Gas	Elec Comp Ventless	Elec Wash/Dryer
2014	$674.54	$704.55	$704.55	$238.98	$873.46	$1,002.86

2020	$579.47	$589.01	$592.05	$208.57	$669.46	$780.46
2025	$553.24	$556.74	$561.36	$200.14	$610.96	$717.11
2030	$538.35	$538.50	$544.09	$195.21	$578.59	$681.96
2035	$528.09	$525.99	$532.28	$191.78	$556.81	$658.23
2040	$520.39	$516.65	$523.45	$189.18	$540.79	$640.74
2043	$516.57	$512.02	$519.08	$187.88	$532.94	$632.15

Table 17.5.7 Super-efficient Voluntary Targets Program Total Installed Cost of Room Air-Conditioners (residential sector) (2009$)

	Product Class					
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
2014	$164.21	$180.37	$418.26	$375.51	$171.66	$173.22
2020	$148.79	$161.09	$376.91	$361.22	$155.42	$159.06
2025	$144.66	$155.91	$365.95	$357.53	$151.11	$155.32
2030	$142.40	$153.06	$359.94	$355.50	$148.73	$153.27
2035	$140.85	$151.09	$355.84	$354.12	$147.10	$151.85
2040	$139.70	$149.64	$352.82	$353.10	$145.91	$150.81
2043	$139.14	$148.94	$351.35	$352.60	$145.32	$150.31

Table 17.5.8 Super-efficient Voluntary Targets Program Total Installed Cost of Room Air-Conditioners (commercial sector) (2009$)

	Product Class					
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
2014	$168.04	$184.34	$448.85	$410.72	$175.03	$178.05
2020	$150.86	$163.22	$394.98	$384.17	$157.36	$161.95
2025	$146.17	$157.44	$380.31	$377.30	$152.59	$157.63
2030	$143.56	$154.26	$372.26	$373.53	$149.97	$155.25
2035	$141.72	$152.03	$366.65	$370.98	$148.14	$153.60
2040	$140.35	$150.37	$362.50	$369.11	$146.78	$152.38
2043	$139.67	$149.56	$360.46	$368.19	$146.11	$151.78

DOE used the Super-Maxtech models time-varying costs to estimate their dynamic benefit/cost ratios and market penetrations. For the estimation of the dynamic benefit/cost ratios, DOE used forecasted energy prices at the level of Census Divisions to calculate the energy cost savings for consumers in each region. To estimate the dynamic market penetration, DOE followed the same approach as described in Section 17.3.2, where an implementation rate is calculated from the benefit/cost ratio and the market barrier level of the targeted market. In this case, since there is no market information for the Super-Maxtech models, DOE assumed that the market barrier level for those models is the same as the market barrier level of the highest efficiency level with non-zero shipments projected to 2014. Tables 17.5.9 through 17.5.11 present the estimated market penetration for all Super-Maxtech models.

Table 17.5.9 Super-efficient Voluntary Targets Program Market Penetration of Clothes Dryers

	Product Class					
	Elec Stand	Elec Comp 120v	Elec Comp 240v	Gas	Elec Comp Ventless	Elec Wash/Dryer
2014	0.2%	0.03%	2.3%	0.8%	0.0%	0.1%
2020	0.4%	0.06%	3.4%	1.2%	0.1%	0.2%
2025	0.4%	0.07%	3.9%	1.5%	0.1%	0.2%
2030	0.5%	0.08%	4.4%	1.9%	0.2%	0.3%
2035	0.6%	0.10%	4.8%	2.2%	0.2%	0.3%
2040	0.6%	0.11%	5.2%	2.5%	0.2%	0.4%
2043	0.7%	0.12%	5.4%	2.7%	0.2%	0.4%

Table 17.5.10 Super-efficient Voluntary Targets Program Market Penetration of Room Air-Conditioners (residential sector)

	Product Class					
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
2014	0.04%	0.3%	1.7%	8.1%	2.1%	3.4%
2020	0.06%	0.5%	2.2%	8.7%	2.7%	4.2%
2025	0.06%	0.5%	2.4%	9.0%	3.0%	4.5%
2030	0.07%	0.6%	2.7%	9.5%	3.4%	5.1%
2035	0.08%	0.7%	2.9%	9.9%	3.7%	5.5%
2040	0.09%	0.7%	3.1%	10.2%	3.9%	5.8%
2043	0.09%	0.8%	3.2%	10.4%	4.1%	6.0%

Table 17.5.11 Super-efficient Voluntary Targets Program Market Penetration of Room Air-Conditioners (commercial sector)

	Product Class					
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
2014	0.04%	0.5%	1.4%	28.9%	2.0%	3.1%
2020	0.06%	0.8%	2.1%	31.3%	2.7%	4.0%
2025	0.07%	0.9%	2.4%	32.3%	3.0%	4.4%
2030	0.09%	1.1%	2.8%	33.9%	3.5%	5.1%
2035	0.11%	1.3%	3.2%	35.2%	4.0%	5.6%
2040	0.12%	1.4%	3.6%	36.3%	4.4%	6.1%
2043	0.13%	1.5%	3.8%	36.9%	4.6%	6.5%

The market penetration of Super-Maxtech models provides higher energy savings then the proposed standards (TSL 4). Concerning net-present values, only the room air-conditioner Super-Maxtech models offer higher energy savings to consumers when compared to the proposed standards (TSL 4). Tables 17.5.12 and 17.5.13 summarize the NES and NPV additional values from the super-efficient voluntary targets program (at three levels of progress-ratio) in relation to the ones from the proposed standards (TSL 4).

Table 17.5.12 Super-efficient Voluntary Targets Program Additional Outputs for Clothes Dryers

	Policy Outputs		
	PR = 0.80	*PR* = 0.85	*PR* = 0.90
NES (quads)			
Elec Standard	0.018	0.016	0.013
Elec Comp 120v	0.000	0.000	0.000
Elec Comp 240v	0.001	0.001	0.001
Gas	0.003	0.003	0.002
Elec Comp Ventless	0.000	0.000	0.000
Elec Wash/Dryer	0.000	0.000	0.000
Total	0.022	0.019	0.016
NPV (7% dr) (2009$ bil)			
Elec Standard	(0.230)	(0.217)	(0.205)
Elec Comp 120v	0.000	0.000	0.000
Elec Comp 240v	(0.013)	(0.012	(0.010)
Gas	(0.048)	(0.046)	(0.043)

Elec Comp Ventless	0.000	0.000	0.000
Elec Wash/Dryer	0.000	0.000	0.000
Total	(0.290)	(0.274)	(0.259)
NPV (3% dr) (2009$ bil)			
Elec Standard	(0.416)	(0.397)	(0.379)
Elec Comp 120v	0.000	0.000	0.000
Elec Comp 240v	(0.022)	(0.020)	(0.018)
Gas	(0.089)	(0.085)	(0.082)
Elec Comp Ventless	0.000	0.000	0.000
Elec Wash/Dryer	0.000	0.000	0.000
Total	(0.528)	(0.502)	(0.478)

Table 17.5.13 Super-efficient Voluntary Targets Program Additional Outputs for Room Air-Conditioners

	Policy Outputs		
	PR = 0.80	*PR* = 0.85	*PR* = 0.90
NES (quads)			
Group 1	0.001	0.001	0.001
Group 2	0.029	0.027	0.024
Group 3	0.005	0.004	0.004
Group 4	0.025	0.024	0.024
Group 5	0.011	0.010	0.009
Group 6	0.021	0.020	0.019
Total	0.092	0.086	0.081
NPV (7% dr) (2009$ bil)			
Group 1	0.012	0.011	0.010
Group 2	0.295	0.271	0.247
Group 3	0.069	0.065	0.061
Group 4	0.297	0.293	0.289
Group 5	0.119	0.112	0.105
Group 6	0.200	0.191	0.181
Total	0.991	0.943	0.892
NPV (3% dr) (2009$ bi)			
Group 1	0.023	0.021	0.019
Group 2	0.592	0.540	0.487
Group 3	0.132	0.123	0.114
Group 4	0.567	0.559	0.549
Group 5	0.231	0.217	0.202
Group 6	0.396	0.376	0.354
Total	1.942	1.836	1.725

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APPENDIX 5-A. DRAFT ENGINEERING ANALYSIS DATA REQUEST SHEETS

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DOE seeks average **<u>incremental production cost</u>** to take basic models in the categories shown from the current DOE minimum efficiency level (or proposed baseline level) to the specified efficiency level. For those product classes where more than one basic model may exist, please indicate the minimum and maximum incremental costs that would be incurred across the array of basic models.

The data sheets are divided by product and contain tables requesting shipment and manufacturer cost data.

Shipments

For residential clothes dryers and room air conditioners, the AHAM *<u>2005 Fact Book</u>* offers historical shipments data (for both products) and efficiency data (for room air conditioners only), but the information is not disaggregated by product class. As shown in the "shipment request" tables below, DOE hopes to collect both shipments data and shipment-weighted average efficiency data dating back to 1993. In addition, DOE hopes to collect market share efficiency (*i.e.*, data on the distribution of product shipments by efficiency) for each of the product classes.

Manufacturer Costs

Incremental cost data (in U.S. dollars) include the materials, labor, and overhead needed to take basic models from the current minimum DOE baseline efficiency standard to each higher efficiency level. The depreciation of the conversion capital expenditures is an important component of the overhead for DOE to understand. Therefore, DOE is requesting information about conversion capital expenditures by efficiency level.

5-A.1 ENGINEERING ANALYSIS DATA REQUEST SHEETS FOR RESIDENTIAL CLOTHES DRYERS

Table A1-1 Residential Clothes Dryer Shipment and Shipment-Weighted Average Efficiency Data

Year	Shipments, Domestic + Imports (Thousands of Units)						Shipment-Weighted Average Efficiency (EF)			
	Vented				Vent-less		Vented			
	Electric			Gas	Electric		Electric			Gas
	Standard	Compact 120v	Compact 240v		Compact 240v	Combo	Standard	Compact 120v	Compact 240v	
1993										
1994										
1995										
1996										
1997										
1998										
1999										
2000										
2001										
2002										
2003										
2004										
2006										

Table A1-2 Residential Clothes Dryer Market Share Efficiency Data: Vented Electric Standard and Compact 120v

Vented Electric Standard		Vented Electric Compact 120v	
Efficiency Bins (EF)	Market Share for 2005 or 2006* (Percent)	Efficiency Bins (EF)	Market Share for 2005 or 2006* (Percent)
3.01-3.09		**3.13-3.19**	
3.10-3.19		**3.20-3.29**	
3.20-3.29		**3.30-3.39**	
> 3.29		**> 3.39**	

* Total market share percentages should equal 100%.

Table A1-3 Residential Clothes Dryer Market Share Efficiency Data: Vented Electric Compact 240v and Gas

Vented Electric Compact 240v		Vented Gas	
Efficiency Bins (EF)	Market Share for 2005 or 2006* (Percent)	Efficiency Bins (EF)	Market Share for 2005 or 2006* (Percent)
2.90-2.96		**2.67-2.74**	
2.97-3.06		**2.75-2.84**	
3.07-3.17		**2.85-2.94**	
> 3.17		**> 2.94**	

* Total market share percentages should equal 100%.

Table A1-4 Residential Clothes Dryer Manufacturer Cost Data: Vented Electric Standard and Electric Compact 120V

Product Class ➔	Vented Electric Standard			Vented Electric Compact 120V		
Efficiency Level	1	2	3	1	2	3
EF (lb/KWh)	3.10	3.16	3.39	++	++	3.79
Design Options+						
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						

+Manufacturer respondents should suggest the design option or design option combinations that they believe should be associated with each efficiency level.
++ DOE was unable to obtain data for any clothes dryers with efficiencies between the standard level of EF = 3.13 and the max available level of EF = 3.79. Therefore, manufacturer respondents should suggest representative intermediate efficiency levels.
# 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 current Federal standard for residential clothes dryers.

Table A1-5 Residential Clothes Dryer Manufacturer Cost Data: Vented Electric Compact 240V and Gas

Product Class →	Vented Electric Compact 240 V			Vented Gas		
Efficiency Level	1	2	3	1	2	3
EF (lb/KWh)	2.98	3.07	3.23	2.75	2.77	3.02
Design Options+						
	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						

+Manufacturer respondents should suggest the design option or design option combinations that they believe should be associated with each efficiency level.
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 current federal standard for residential clothes dryers.

Other Information:
1. What depreciation method would your company use to depreciate the conversion capital expenditures? ____.

Direct material – Costs of raw materials including scrap that can be traced to final or end products. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process but are not assigned to final products (*e.g.*, lubricating oil for production machinery).
Direct labor – The earnings of workers who assemble parts into a finished good for operate machines in the production process. Direct labor includes the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor does not include indirect labor which is defined as the earnings of employees who do not work directly in assembling a product, such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.
Overhead – Factory overhead excluding depreciation. Factory overhead includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A); research and development (R&D); interest; or profit (accounted for by DOE separately).

Full Production Cost = Direct Material + Direct Labor + Overhead (factory) + Depreciation
Full Cost of Product = Full Production Cost + Non-production Costs (SG&A, R&D, interest, and profit)

5-A.2 ENGINEERING ANALYSIS DATA REQUEST SHEETS FOR ROOM AIR CONDITIONERS

Table A2-1 Room Air Conditioner Market Share Product Class Data (percent)*

Year	Without Reverse Cycle (RC) and With Louvered Sides (LS)					Without Reverse Cycle (RC) and Without Louvered Sides (LS)					With RC and With LS		With RC and Without LS		Casement	
	<6k	6-8k	8-14k	14-20k	>20k	<6k	6-8k	8-14k	14-20k	>20k	<20k	>20k	<14k	>14k	Only	Slider
2000																
2001																
2002																
2003																
2004																
2005																
2006																

* Total market share percentages for each year should equal 100%.

Table A2-2 Room Air Conditioner Shipment-Weighted Efficiency Data (EER)

Year	Without Reverse Cycle (RC) and With Louvered Sides (LS)					Without Reverse Cycle (RC) and Without Louvered Sides (LS)					With RC and With LS		With RC and Without LS		Casement	
	<6k	6-8k	8-14k	14-20k	>20k	<6k	6-8k	8-14k	14-20k	>20k	<20k	>20k	<14k	>14k	Only	Slider
2000																
2001																
2002																
2003																
2004																
2005																
2006																

Table A2-3 Room Air Conditioner Market Share Efficiency Data: Without Reverse Cycle and With Louvered Sides

Less than 6,000 Btu/h		6,000 to 7,999 Btu/h		8,000 to 13,999 Btu/h		14,000 to 19,999 Btu/h		20,000 Btu/h and more	
Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)
9.7-10.0		**9.7-10.0**		**9.8-10.0**		**9.7-10.0**		**8.5-8.9**	
10.1-10.5		**10.1-10.5**		**10.1-10.5**		**10.1-10.5**		**9.0-9.4**	
10.6-11.0		**10.6-11.0**		**10.6-11.0**		**10.6-11.0**		**9.5-9.9**	
> 11.0		**> 11.0**		**> 11.0**		**> 11.0**		**> 9.9**	

* Total market share percentage should equal 100%.

Table A2-4 Room Air Conditioner Market Share Efficiency Data: Without Reverse Cycle and Without Louvered Sides

Less than 6,000 Btu/h		6,000 to 7,999 Btu/h		8,000 to 13,999 Btu/h		14,000 to 19,999 Btu/h		20,000 Btu/h and more	
Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)
9.0-9.4		9.0-9.4		8.5-8.9		8.5-8.9		8.5-8.9	
9.5-9.9		9.5-9.9		9.0-9.4		9.0-9.4		9.0-9.4	
10.0-10.4		10.0-10.4		9.5-9.9		9.5-9.9		9.5-9.9	
> 10.4		> 10.4		10.0-10.4		> 9.9		10.0-10.4	
				>10.4				>10.4	

* Total market share percentage should equal 100%.

Table A2-5 Room Air Conditioner Market Share Efficiency Data: With Reverse Cycle

With Louvered Sides, Less than 20,000 Btu/h		With Louvered Sides, 20,000 Btu/h and more		Without Louvered Sides, Less than 14,000 Btu/h		Without Louvered Sides, 14,000 Btu/h and more	
Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)
9.0-9.4		8.5-8.9		8.5-8.9		8.0-8.4	
9.5-9.9		9.0-9.4		9.0-9.4		8.5-8.9	
10.0-10.4		9.5-9.9		9.5-9.9		9.0-9.4	
10.5-10.9		> 9.9		> 9.9		9.5-9.9	
> 10.9						>9.9	

* Total market share percentage should equal 100%.

Table A2-6 Room Air Conditioner Market Share Efficiency Data: Casement Units

Casement-Only		Casement-Slider	
Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)	Efficiency Bins (EER)	Market Share for 2006 or 2007* (percent)
8.7-9.0		9.5-9.9	
9.1-9.5		10.0-10.4	
9.6-10.0		10.5-10.9	
> 10.0		> 10.9	

* Total market share percentage should equal 100%.

Table A2-7 Room Air Conditioner Manufacturer Cost Data

Product Class ➔	**Without Reverse Cycle and with Louvered Sides, less than 6,000 Btu/h**				**Without Reverse Cycle and With Louvered Sides, 8000 - 13,999 Btu/h**				
Efficiency Level	1	2	3	4	1	2	3	4	
EER	10.2	10.7	11.2	11.6	10.3	10.8	11.3	11.8	
Average Incremental Costs ($ Per Unit)*									
Material									
Labor									
Overhead#									
Minimum Incremental Costs ($ Per Unit)*									
Material									
Labor									
Overhead#									
Maximum Incremental Costs ($ Per Unit)*									
Material									
Labor									
Overhead#									
Conversion Capital Expenditures ($, Millions)									
Building CAPX									
Tooling/ Equipment CAPX									
One-Time Product Conversion Expenses ($, Millions)									
R&D									
Marketing									

Depreciation on the conversion capital expenditure should NOT be included in the incremental overhead.
* Incremental costs per unit should be reported relative to the baseline unit's cost. The baseline unit complies with the federal standard for room air conditioners and is equal to an EER of 9.7 Btu/h/W for a unit without reverse cycle and with louvered sides and with a capacity of less than 6,000 Btu/h, an EER of 9.8 Btu/h/W for a unit without reverse cycle and with louvered sides and with a capacity of 8,000 to 13,999 Btu/h, and an EER of 8.5 Btu/h/W for a unit without reverse cycle and with louvered sides and with a capacity of 20,000 Btu/h and more.

Table A2-8 Room Air Conditioner Manufacturer Cost Data, continued

Product Class ➔	Without Reverse Cycle and with Louvered Sides, 20,000 Btu/h and more				Without Reverse Cycle and Without Louvered Sides, 8000 - 13,999 Btu/h				
Efficiency Level	1	2	3		1	2	3	4	
EER	9.0	9.5	10.0		9.0	9.5	10.0	10.5	
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									

Other Information:

1. What depreciation method would your company use to depreciate the conversion capital expenditures? ____.

Direct material – Costs of raw materials including scrap that can be traced to final or end products. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process but are not assigned to final products (*e.g*., lubricating oil for production machinery).
Direct labor – The earnings of workers who assemble parts into a finished good for operate machines in the production process. Direct labor includes the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor does not include indirect labor which is defined as the earnings of employees who do not work directly in assembling a product, such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.
Overhead – Factory overhead excluding depreciation. Factory overhead includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A); research and development (R&D); interest; or profit (accounted for by DOE separately).
Full Production Cost = Direct Material + Direct Labor + Overhead (factory) + Depreciation
Full Cost of Product = Full Production Cost + Non-production Costs (SG&A, R&D, interest, and profit)

Table A2-9: Portable Air-Conditioner Shipment Data

Year	Total Sales	Percent of Sales by Different Condenser Air Duct Configurations			Percent of Sales with Condensate Re-evaporation Capability
		Single Duct	Two-Duct	Other	
2000					
2001					
2002					
2003					
2004					
2005					
2006					
2007					

Table A2-10: Portable Air-Conditioner Capacity Data

Capacity Range (Btu/hr)	Percent of Sales for a Recent Year (2006 or 2007)
Less than 6,000	
6,000 to 7,999	
8,000 to 13,999	
14,000 to 19,999	
20,000 or more	

5-A.3 DATA REQUESTS FOR STANDARDS RULEMAKING FOR RESIDENTIAL CLOTHES DRYERS AND ROOM AIR-CONDITIONERS

Data Requests for Standards Rulemaking for Residential Clothes Dryers and Room Air-Conditioners – 01/09/2009

Clothes Dryers

1. Shipment-weighted average remaining moisture content (RMC) over time for residential clothes washers for top-loading units, front-loading units, and combined.

2. Data regarding consumer usage patterns for residential clothes dryers- the # of annual use cycles. Preferably the number of dryer use cycles independent of wash cycles. If not, then the % of loads washed that are machine dried.

3. Has AHAM made any progress on the development of a clothes dryer test procedure which tests dryer operation using automatic termination?

4. Is AHAM developing test methodology for condensing dryers?

Room Air Conditioners

1. Data regarding consumer usage patterns – room air-conditioner annual hours of operation.

APPENDIX 5-B. DATA SUBMITTAL

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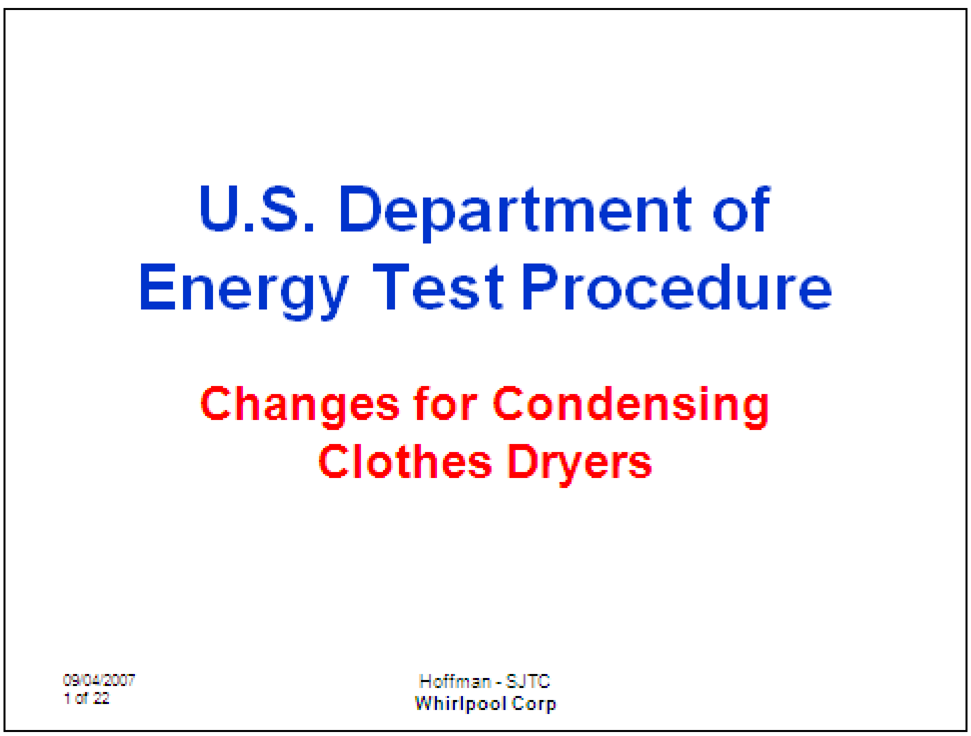
APPENDIX 5-B. DATA SUBMISSIONS

5-B.1 INTRODUCTION

This appendix presents the shipments and incremental cost data submitted to the U.S. Department of Energy (DOE) by the interested parties in support of the engineering analysis for this rulemaking. This appendix presents the Whirlpool Corporation (Whirlpool) proposed amendments to the DOE test procedure for clothes dryers to include methods for the testing of condensing dryers. Information was provided for residential clothes dryers in response to data request sheets generated by DOE and provided to the Association of Home Appliance Manufacturers (AHAM). See chapter 5 of the preliminary technical support document (preliminary TSD) for details of the engineering analysis for which these data were used.

5-B.2 WHIRLPOOL PROPOSED AMENDMENTS TO DOE CLOTHES DRYER TEST PROCEDURE

Whirlpool submitted the following proposed amendments to the DOE clothes dryer test procedure to include methods for the testing of condensing dryers to DOE on Sept. 4, 2007.



Background

- Code of Federal Regulations Title 10 – Energy, Part 430 “Energy Conservation Program for Consumer Products”
- Subpart A section 430.2 states “Electric clothes Dryer means a cabinet like appliance designed to dry fabrics in a tumble-type Drum with forced air circulation. The heat source is electricity and the Drum and Blower(s) are driven by an electric Motor(s)”
- Appendix D to Subpart B of Part 430 – Uniform Test Method For Measuring The Energy Consumption of Clothes Dryers

Background – cont’d

- Appendix D procedure steps which conflict for a condensing Dryer:
  - Paragraph 2.1 of section 2, “Installation” states: Install the clothes Dryer in accordance with the manufacturer’s instructions. The Dryer exhaust shall be restricted by adding the AHAM exhaust simulator described in 3.3.5 of HDL-1……………
  - Paragraph 2.8 of section 2, “Clothes Dryer preconditioning” states: Before any test cycle, operate the Dryer without a test load in the non-heat mode for (15) minutes or until the discharge air temperature is varying less than (1) degree F for (10) minutes, whichever is longer, in the test installation location with the ambient conditions within the specified test condition tolerances of 2.2

Assessment

- The condensing Dryer falls within the DOE definition for a clothes Dryer and therefore is required to meet this energy standard
- Define non-exhausted and exhausted Dryers in the DOE standard.
- Paragraph 2.1 of section 2 should state non-exhausted Dryers are exempt from the exhaust requirement.
- Paragraph 2.8 of section 2, "Clothes Dryer preconditioning" needs to be revised to account for dryer preconditioning cycle differences between exhausted and non-exhausted Dryers

Condensing Dryer Energy Results

Eurotech model EDC158

- Class "C" European energy rating
- (3.7) FT^3
- (240) VAC @ (60) Hz
- Unit has NO Air Cycle
- (1) unit tested
- Average energy factor = (2.86) lbs/Kwh for (3) **cold** runs
- Average energy factor = (3.16) lbs/Kwh for (3) **hot** runs
- There is a (10.5) percent difference between "**cold** runs and **hot** runs

Whirlpool model AWZ9995

- Class "B" European energy rating
- (3.7) FT^3
- (230) VAC @ (50) Hz
- Unit has an Air Cycle
- (4) units tested
- Average energy factor = (3.04) lbs/Kwh for (4) **cold** runs
- Average energy factor = (3.22) lbs/Kwh for (8) **hot** runs
- There is a (5.9) percent difference between "**cold** runs and **hot** runs

Condensing Dryer Energy Results (continued)

Whirlpool model AWZ9995 with additional runs, see previous slide for model detail

Previous Data

- (4) unit tested
- Average energy factor = (3.04) lbs/Kwh for (4) **cold** runs
- Average energy factor = (3.22) lbs/Kwh for (8) **hot** runs
- A (5.9) percent difference between **cold** & **hot** runs

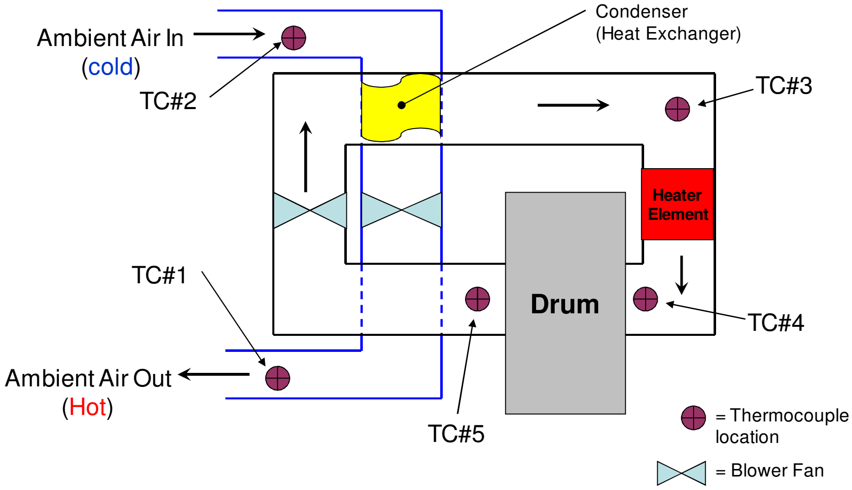
New Data

- (1) unit tested
- Average energy factor = (3.15) lbs/Kwh for (3) **cold** runs
- Average energy factor = (3.32) lbs/Kwh for (3) **hot** runs
- A (5.4) percent difference between **cold** & **hot** runs
- Average energy factor = (3.24) lbs/Kwh for (3) **pre-conditioned** runs with "Air" cycle
- A (2.9) percent difference between **cold** & **Pre-conditioned** runs

Temperature Results

- The Eurotech Condensing Dryer, model # EDC158, was thermocoupled in (5) locations
  - TC#1 - Ambient air OUT of the Condenser system
  - TC#2 - Ambient air INTO the Condenser system
  - TC #3 - Drum inlet air after the Condenser but before the Heater Element
  - TC #4 - Drum inlet air coming from the Heater Element
  - TC #5 - Drum outlet air leaving the Drum
- See next slide for graphical view of the Condensing system

Thermocouple Locations



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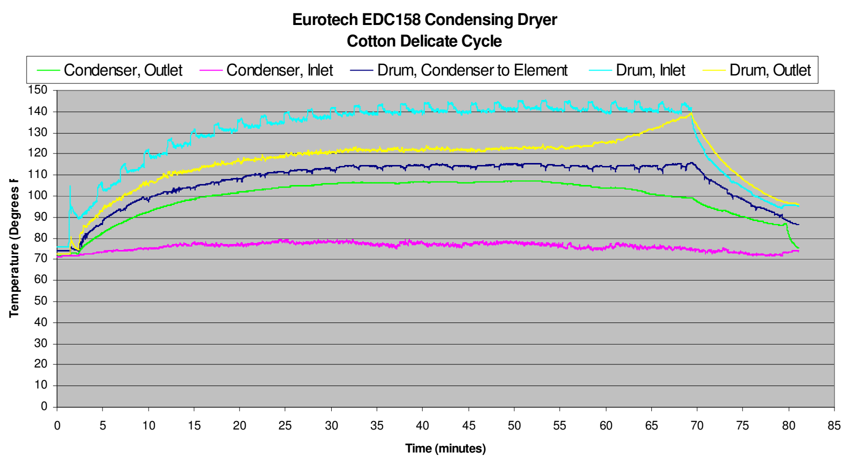
Temperature Data
Eurotech - Cotton Delicate Cycle



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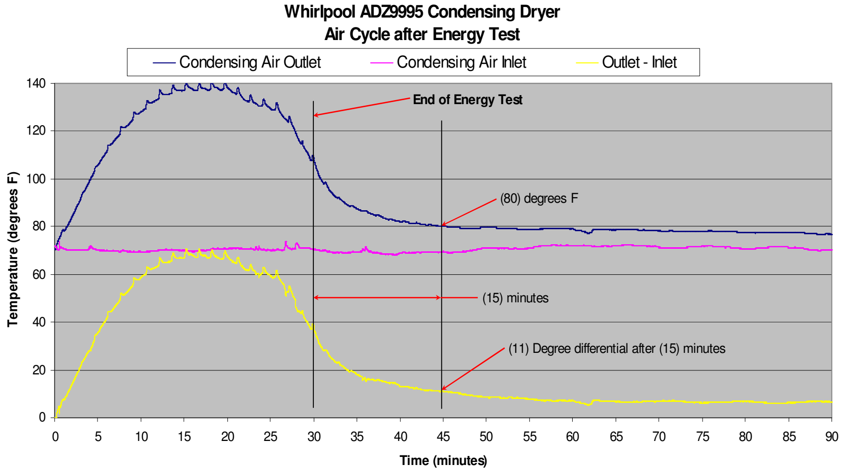
Temperature Data
Whirlpool - Air Cycle



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Preliminary Summary

- Condensing Dryer models are sold both with and without "Air" Cycles
- For a condensing Dryer model with an "Air" cycle, the current procedure is potentially valid if the condensing air system is considered the exhaust
- What should be done with condensing Dryers with NO "Air" cycle?
- European Energy Standards may address this condensing Dryer pre-conditioning issue and address other condensing Dryer test procedure differences between exhausted Dryers

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Whirlpool Corp

Other Potential Resources to Consider?

- European Energy Standards may address the condensing Dryer pre-conditioning issue and other condensing Dryer test procedure differences between exhausted Dryers
- EN 61121:2005 is the latest standard for Dryer Energy in Europe

EN 61121:2005 Related to Condensing Dryers

- Section 6.1 “General” states:
  - “ The measurements shall be carried out on a tumble Dryer installed and used in accordance with the manufacturer’s instructions, except as required by this standard”
  - “ Where the tumble Dryer is intended for use without a duct (i.e. the tumble Dryer is intended to be vented into the room) the tumble Dryer shall be tested as supplied without a duct”

EN 61121:2005 Related to Condensing Dryers (continued)

- Section 6.2.3 “Resources and Ambient Conditions - Ambient Temperature” states:
  - “The ambient temperature of the room in the vicinity of the Dryer shall be maintained t (23 2) C throughout the test. The measured ambient temperature shall be recorded. Note: this can be done by leaving the machine at ambient conditions for at least (12) hours”
  - (23) C = (73.4) F (3.6) F

EN 61121:2005 Related to Condensing Dryers (continued)

- Section 9.1 “Performance Tests - General” states:
  - “Tumble Dryers shall be configured with or without a duct as specified in section 6.1.”
  - “ All tests shall be started with the tumble Dryer at ambient temperature according to 6.2.3.”

EN 61121:2005 Related to Condensing Dryers (continued)

- Section 9.2.1 "Procedure for drying performance – Drying Tests General" states:
  - "For automatic tumble Dryers, those programmes are selected which aim to achieve the final moisture values given in table 3."
  - "Table 3: Dry cotton has a nominal final moisture content (0) percent with an allowable range for final moisture content of (-3) to (+3) percent."
  - "The minimum number of valid cycles shall be five. The reported results of the valid cycles are used for further evaluation according to clause 10. If the Dryer is automatically stopped during a cycle and the reason is that the condensation box is full of water, the fact is reported and the test is stopped."
  - "Note: If the manufacturer gives the option to use a condensing tumble Dryer both with or without condensation box, the Dryer should be tested with the condensation box."

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EN 61121:2005 Related to Condensing Dryers (continued)

- Section 9.2.2 "Procedure for drying performance – Condensation Efficiency" states:
  - "The condensation efficiency for a condenser tumble Dryer, shall be measured using the Dry Cotton programme and setting selected to achieve the "dry cotton" result (this means the equivalent timer setting for a timer Dryer) in the drying test."
  - "The mass of the test load is measured immediately before and after the cycle. The mass of the moisture condensed during the cycle and collected in the container is determined. The first cycle after a period of non-operation longer than (36) hours shall not be used for evaluation."
  - "During the time between two cycles, the door of the tumble Dryer shall be closed except for loading"

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EN 61121:2005 Related to Condensing Dryers (continued)

- Section 10.5 "Evaluation and Calculation – Condensation Efficiency" states:
  - "Efficiency of condensation, C, is determined according to 9.2.2 as the ratio between the water produced during the cycle Ww, relative to the total mass of water evaporated from the load"
  - " C = Ww /(Wi – Wf) is calculated for each cycle and expressed as percentage"
  - "Efficiency of condensation is the mean value of a minimum of four valid cycles. Note: Due to this requirement the first run of a condensation efficiency test has normally to be discarded "

Whirlpool's Condensing Dryer Test Procedure Proposal to DOE

Changes to
Appendix D to Subpart B of Part 430, Title 10
Clothes Dryer Energy Standard

Whirlpool's Condensing Dryer Proposal to DOE

- Section 1 must incorporate definitions of an exhausted Dryer, non-exhausted Dryer, and a condensing Dryer
  - An exhausted Dryer has a blower system which is intended to deliver the heated, moist air from the Drum cavity into a duct system external to the Dryer and this duct system is exhausted into the outdoors.
  - A non-exhausted Dryer is intended to be used without an external duct system and has no provision to connect to such a duct system.
  - A condensing Dryer is a non-exhausted tumble Dryer in which the air used for the drying process is dehumidified by using room ambient air for cooling. The blower system used for circulating room ambient air is independent of the heated moist air from the Drum cavity.
- Paragraph 2.1 of Section 2 must be updated to include non-exhausted Dryers
  - Where the tumble Dryer is defined as a non-exhausted Dryer and is intended for use without a duct. The tumble Dryer shall be tested as supplied without a duct.
  - Where the tumble Dryer is defined as an exhausted Dryer and is intended for use with a duct The Dryer exhaust shall be restricted by adding the AHAM exhaust simulator described in 3.3.5 of HDL-1…………….

Whirlpool's Condensing Dryer Proposal for DOE (continued)

- To align with the European energy procedure, Paragraph 2.8 of section 2 should incorporate the following condensing Dryer pre-conditioning cycle
  - For condensing Dryers, the Dryer steady state temperature must be equal to ambient room temperature according to 2.2 before the start of all test runs. Note: this can be done by leaving the machine at ambient room conditions for at least (12) hours between tests but not more than (36) hours between tests

Whirlpool's Condensing Dryer Proposal to DOE (continued)

- To align with the European energy procedure and for consistency in results (per Luise Christmann of Whirlpool Schorndorf), the U.S. energy procedure should incorporate the following condensing Dryer test procedure steps
  - If the manufacturer gives the option to use a condensing tumble Dryer both with or without condensation box, the Dryer shall be tested with the condensation box
  - If the Dryer is automatically stopped during a cycle and the reason is that the condensation box is full of water, the test is stopped, and the run is invalid
  - During the time between two cycles, the door of the tumble Dryer shall be closed except for loading
  - The first cycle after a period of non-operation longer than (36) hours shall not be used for evaluation
  - Results from the first test run on an unused (dry) condensing Dryer are invalid and cannot be used for the energy efficiency calculations
  - The Condenser unit of the Dryer must remain in place and not be taken out of the Dryer for any reason between tests.

5-B.3 AHAM DE-IDENTIFIED CLOTHES DRYER DATA – COLLECTED DECEMBER 2007 FOR DOE RULEMAKING

AHAM supplied shipments, market share efficiency data, and data on the effects of remaining moisture content (RMC) on residential clothes dryer energy factor, representing the aggregated inputs from manufacturers which produce the significant majority of residential clothes dryers. Table 5-B.3.1 through Table 5-B.3.3 reproduces the tables of clothes dryer data submitted to DOE by AHAM.

Table 5-B.3.1 Residential Clothes Dryer Shipments (in Thousands of Units)

Year	Clothes Dryers				
	Electric	Standard Electric	Compact Electric	Gas	Total
2006	6,360	6,246	114	1,614	7,974
2005	6,408	6,330	78	1,707	8,115
2004	6,262	6,159	103	1,660	7,922
2003	5,718	5,622	96	1,616	7,334
2002	5,402			1,490	6,892
2001	5,117			1,384	6,501
2000	5,095			1,480	6,575
1999	4,865			1,444	6,309
1998	4,482			1,307	5,789
1997	4,115			1,195	5,310
1996	3,947			1,193	5,140
1995	3,823			1,169	4,992
1994	3,838			1,239	5,077
1993	3,674			1,156	4,830

* Original version of Table 5-B.3.1 was sent on April 11, 2008, but was revised on Aug. 20, 2008 (shown above).
** AHAM Note: Compact Electric shipments are not available prior to 2003. Standard electric shipments are determined from the difference in overall electric shipments and compact electric shipments.

Table 5-B.3.2 Residential Clothes Dryer Market Share Efficiency Data

Vented Electric Standard			Vented Gas		
EF Range, *lb/kWh*	**Market Share for 2005 *(%)***	**Market Share for 2006 *(%)***	**EF Range, *lb/kWh***	**Market Share for 2005 *(%)***	**Market Share for 2006 *(%)***
3.01-3.09	26	33	2.67-2.74	25	28
3.10-3.29	74	67	2.75-2.84	42	44
3.20-3.29			>2.85	32	27
>3.29					

Table 5-B.3.3 Effect of RMC on Residential Clothes Dryer Energy Factor

Test	RMC into Dryer (%) Target	RMC into Dryer (%) Actual	Baseline Model
1	70	70	3.1
2		70.08	3.08
3		70.08	2.99
4		70.24	3.11
5		70.33	3.08
6		70.17	3.07
7		69.7	3.07
8		71.6	3.27
9		70.5	3.03
10		70.9	3.13
11		70	3.04
12	56	56	3.77
13		55.99	3.73
14		55.99	3.85
15		55.99	3.74
16		58.43	3.73
17		58.58	3.8
18		58.58	3.82
19		55.4	3.8
20		55.8	3.78
21		55.7	3.83
22		56	3.59

Target RMC into Dryer	**70**	**56**
Average RMC into Dryer	70.3	56.6
Average EF	3.09	3.77
Standard Deviation	0.07	0.07
Percent EF Change		**22%**

5-B.4 DOE RESIDENTIAL CLOTHES DRYER ENGINEERING ANALYSIS DATA REQUESTS – AHAM DATA SUBMITTAL

AHAM supplied shipments, average energy and water use, and incremental cost data to DOE, representing the aggregated inputs from manufacturers which produce the significant majority of residential clothes dryers. Table 5-B.4.1 through Table 5-B.4.4 reproduces the tables of residential clothes dryer data submitted to DOE by AHAM in response to DOE's engineering analysis data request (See appendix 5A).

Table 5-B.4.1 Residential Clothes Dryer Shipment and Shipment-Weight Average Efficiency Data

	Shipments, Domestic + Imports (Thousands of Units)						Shipment-Weighted Average Efficiency (EF, *cycles/kWh*)			
	Vented				Vent-less		Vented			
	Electric				Electric		Electric			
Year	**All Electric**	**Standard**	**All Compact**	**Gas**	**Compact 240 V**	**Combo**	**Standard**	**Compact 120 V**	**Compact 240 V**	**Gas**
1993	3,674			1,156						
1994	3,838			1,239						
1995	3,823			1,169						
1996	3,947			1,193						
1997	4,115			1,195						
1998	4,482			1,307						
1999	4,865			1,444						
2000	5,095			1,480						
2001	5,117			1,384						
2002	5,402			1,490						
2003	5,718	5,622	96	1,616						
2004	6,262	6,159	103	1,660						
2005	6,408	6,330	78	1,707			3.10			2.70
2006	6,360	6,246	114	1,614			3.10			2.70

Comments to Table 5-B.4.1 from AHAM:

1. Shipments are from AHAM Fact Book. AHAM only collects shipment data on Standard Electric and Standard Gas vented residential clothes dryers. These are shown as All Electric and Gas.
2. Members provided information on compact shipments, but this is a small market and aggregated data for both compact classes is not available. Therefore, compact shipments include shipments of both 120V and 240V vented residential dryers after 2003. These values are slightly different than those provided in August 2008, as I had not incorporated both classes into the total.
3. The Standard column shows the difference between the aggregated member-supplied compact shipments (120V and 240V) and the All Electric published in the AHAM Fact Book. The source of and breakdown of the shipment information is slightly different, but we believe it is consistent.
4. Aggregated shipment weighted average efficiencies are only available for 2005 and 2006 for Standard Electric and Gas dryers. We did not receive enough input to provide data for years earlier than 2005 or for compact vented units.

Table 5-B.4.2 Residential Clothes Dryer Market Share Efficiency Data: Vented Electric Standard

Vented Electric Standard			Vented Gas		
EF Range, *lb/kWh*	**Market Share for 2005** *(%)*	**Market Share for 2006** *(%)*	**EF Range, *lb/kWh***	**Market Share for 2005** *(%)*	**Market Share for 2006** *(%)*
3.01-3.09 (Baseline = 3.01)	26	33	2.67-2.74 (Baseline = 2.67)	25	28
3.10-3.29	74	67	2.75-2.84	42	44
3.20-3.29			>2.85	32	27
>3.29					

* AHAM Note: Total Market Share percentages should equal 100%.

<u>Comments to Table 5-B.4.2 from AHAM:</u>

1. To maintain confidentiality, market share between EF of 3.20 and 3.29 have been incorporated into the EF range between 3.10 and 3.19.
2. To maintain confidentiality, market share for EF > 2.94 have been incorporated into EF > 2.85.
3. We were not able to obtain sufficient data for Vented compact 120V and 240V.
4. We have provided data for both 2005 and 2006.
5. Values have not changed from original submission.

Table 5-B.4.3 Residential Clothes Dryer Manufacturer Cost Data: Vented Electric Standard and Electric Compact 120V

Product Class →	Vented Electric Standard			Vented Electric Compact 120V		
Efficiency Level	1	2	3	1	2	3
EF (lb/KWh)	3.10	3.16	3.39	-	-	3.79
Design Options						
Average Incremental Costs ($ Per Unit)						
Material	9	42	140			
Labor	2	11	45			
Overhead#	2	4	12			
Minimum Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Maximum Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Conversion Capital Expenditures ($, Millions)						
Building CAPX	0.25	9.02	50.18			
Tooling/ Equipment CAPX	5.25	37.68	118.93			
One-Time Product Conversion Expenses ($, Millions)						
R&D	3.62	15.87	58.97			
Marketing						

+Manufacturer respondents should suggest the design option or design option combinations that they believe should be associated with each efficiency level.
++ DOE was unable to obtain data for any clothes dryers with efficiencies between the standard level of EF = 3.13 and the max available level of EF = 3.79. Therefore, manufacturer respondents should suggest representative intermediate efficiency levels.
# 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 current federal standard for residential clothes dryers.

Comments on Table 5-B.4.3 from AHAM:

1. Shaded cells indicate that AHAM did not receive enough input to aggregate incremental cost data. No data are available for vented electric compact 120V, minimum/maximum incremental costs or marketing expenses.
2. Values are shipment weighted.
3. AHAM members provided the incremental cost to obtain the requested EF. To determine these costs, design options would have been considered, but these were not shared with AHAM. AHAM recommends that DOE talk to manufacturers individually to further understand the design options available for reaching these efficiency targets.

Table 5-B.4.4 Residential Clothes Dryer Manufacturer Cost Data: Vented Electric Compact 240V and Gas

Product Class →	Vented Electric Compact 240 V			Vented Gas		
Efficiency Level	1	2	3	1	2	3
EF (lb/KWh)	2.98	3.09	3.2	2.75	2.85	3.44
Design Options						
	Average Incremental Costs ($ Per Unit)*					
Material				20	60	81
Labor				2	6	32
Overhead#				2	4	12
	Minimum Incremental Costs ($ Per Unit)*					
Material						
Labor						
Overhead#						
	Maximum Incremental Costs ($ Per Unit)*					
Material						
Labor						
Overhead#						
	Conversion Capital Expenditures ($, Millions)					
Building CAPX				0.46	29.83	
Tooling/ Equipment CAPX				2.62	37.24	16.15
	One-Time Product Conversion Expenses ($, Millions)					
R&D				2.99	15.46	12.91
Marketing						

Depreciation on the conversion capital expenditure should NOT be included in the incremental overhead.
***** Incremental costs per unit should be reported relative to the baseline unit's cost. The baseline unit complies with the current federal standard for residential clothes dryers. The Average Incremental Cost should be reported as a shipment weighted average value. The Minimum and Maximum Incremental Costs presumably reflect the costs associated with changes to different product platforms.

Other Information:
1. What depreciation method would your company use to depreciate the conversion capital expenditures? ____.

Direct material – Costs of raw materials including scrap that can be traced to final or end products. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process but are not assigned to final products (*e.g*., lubricating oil for production machinery).
Direct labor – The earnings of workers who assemble parts into a finished good for operate machines in the production process. Direct labor includes the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor does not include indirect labor which is defined as the earnings of employees who do not work directly in assembling a product, such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.
Overhead – Factory overhead excluding depreciation. Factory overhead includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A); research and development (R&D); interest; or profit (accounted for by DOE separately).
Full Production Cost = Direct Material + Direct Labor + Overhead (factory) + Depreciation
Full Cost of Product = Full Production Cost + Non-production Costs (SG&A, R&D, interest, and profit)

<u>Comments on Table 5-B.4.4 from AHAM:</u>

1. Shaded cells indicate that AHAM did not receive enough input to aggregate incremental cost data. No data are available for vented electric compact 240V, minimum/maximum incremental costs or marketing expenses or Building CAPX for EF 3.02 vented gas.
2. Values are shipment weighted.
3. AHAM members provided the incremental cost to obtain the requested EF. To determine these costs, design options would have been considered, but these were not shared with AHAM. AHAM recommends that DOE talk to manufacturers individually to further understand the design options available for reaching these efficiency targets.
4. One respondent stated that design options were not available to reach an EF of 3.02 on vented gas dryers, therefore, no incremental cost data were provided. Values shown are calculated without this respondent – but weighted basis is different. While all members use straight-line depreciation, AHAM was not able to obtain a consistent response on the years used in the calculation.

5-B.5 DOE ROOM AIR CONDITIONER ENGINEERING ANALYSIS DATA REQUESTS – AHAM DATA SUBMITTAL

AHAM supplied market share data, shipment-weighted efficiency data, and market share efficiency data to DOE, representing the aggregated inputs from manufacturers which produce the significant majority room air conditioners. Figure 5-B.5.1 through Figure 5-B.5.2 reproduces Table A2-1 through Table A2-6 of the room air conditioner data submitted to DOE by AHAM in response to DOE's engineering analysis data request (See appendix 5A).

Figure 5-B.5.1 AHAM Room Air Conditioner Market Share, Shipment-Weight Efficiency Data, Market Share Efficiency Data Submittal

Table A2-1 Room Air Conditioner Market Share Product Class Data (percent)*

	Without Reverse Cycle (RC) and With Louvered Sides (LS)					Without Reverse Cycle (RC) and Without Louvered Sides (LS)					With RC and With LS		With RC and Without LS		Casement	
Year	<6k	6-8k	8-14k	14-20k	>20k	<6k	6-8k	8-14k	14-20k	>20k	<20k	>20k	<14k	>14k	Only	Slider
2001																
2002																
2003																
2004																
2005	37	19	30	3	2	7					0.7	0.1	0.4		0.4	
2006	23	19	34	5.5	3.9	12					1.0		0.6		0.6	
2007	32	16	36	6	2.6	7					**	**	**	**	0.4	

* Total market share percentages for each year should equal 100%.

Table A2-2 Room Air Conditioner Shipment-Weighted Efficiency Data (EER)

	Without Reverse Cycle (RC) and With Louvered Sides (LS)					Without Reverse Cycle (RC) and Without Louvered Sides (LS)					With RC and With LS		With RC and Without LS		Casement	
Year	<6k	6-8k	8-14k	14-20k	>20k	<6k	6-8k	8-14k	14-20k	>20k	<20k	>20k	<14k	>14k	Only	Slider
2001																
2002																
2003																
2004																
2005	9.5	10.2	10.3	10.3	9.0		**	9.5	**		10.6	**	9.6	**	**	9.9
2006	9.8	10.4	10.4	10.5	9.2		**	9.5	**		10.5	**	9.6	**	**	**
2007	9.8	9.9	10.1	10.3	9.1		**	9.4	9.0		**	**	**	**	**	9.5

Table A2-3 Room Air Conditioner Market Share Efficiency Data: Without Reverse Cycle and With Louvered Sides

Less than 6,000 Btu/h		6,000 to 7,999 Btu/h		8,000 to 13,999 Btu/h		14,000 to 19,999 Btu/h		20,000 Btu/h and more	
Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)
9.7-10.0	94	9.7-10.5	79	9.8-10.5	76	9.7-10.0	42	8.5-8.9	37
10.1-10.5	0					10.1-10.5	2	9.0-9.4	52
10.6-11.0	6	>10.6	21	> 10.6	24	10.6-11.0	56	9.5-9.9	11
> 11.0	0					> 11.0	0	> 9.9	0

* Total market share percentage should equal 100%.

Figure 5-B.5.2 AHAM Room Air Conditioner Market Share Efficiency Data Submittal

Table A2-4 Room Air Conditioner Market Share Efficiency Data: Without Reverse Cycle and Without Louvered Sides

Less than 6,000 Btu/h		6,000 to 7,999 Btu/h		8,000 to 13,999 Btu/h		14,000 to 19,999 Btu/h		20,000 Btu/h and more	
Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)
9.0-9.4	**	9.0-9.4	**	8.5-9.4	39	8.5-9.4	100	8.5-8.9	**
9.5-9.9	**	9.5-9.9	**					9.0-9.4	**
10.0-10.4	**	10.0-10.4	**	> 9.5	61	9.5-9.9	0	9.5-9.9	**
> 10.4	**	> 10.4	**			> 9.9	0	10.0-10.4	**
								>10.4	**

* Total market share percentage should equal 100%.

Table A2-5 Room Air Conditioner Market Share Efficiency Data: With Reverse Cycle

With Louvered Sides, Less than 20,000 Btu/h		With Louvered Sides, 20,000 Btu/h and more		Without Louvered Sides, Less than 14,000 Btu/h		Without Louvered Sides, 14,000 Btu/h and more	
Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)
9.0-9.4	**	8.5-8.9	**	8.5-8.9	**	8.0-8.4	**
9.5-9.9	**	9.0-9.4	**	9.0-9.4	**	8.5-8.9	**
10.0-10.4	**	9.5-9.9	**	9.5-9.9	**	9.0-9.4	**
10.5-10.9	**	> 9.9	**	> 9.9	**	9.5-9.9	**
> 10.9	**					>9.9	**

* Total market share percentage should equal 100%.

Table A2-6 Room Air Conditioner Market Share Efficiency Data: Casement Units

Casement-Only		Casement-Slider	
Efficiency Bins (EER)	Market Share for 2007* (percent)	Efficiency Bins (EER)	Market Share for 2007* (percent)
8.7-9.0	**	9.5-9.9	100
9.1-9.5	**	10.0-10.4	0
9.6-10.0	**	10.5-10.9	0
> 10.0	**	> 10.9	0

* Total market share percentage should equal 100%.

Comments on Figure 5-B.5.1 and Figure 5-B.5.2 from AHAM:

Comments on Table A2-1:

1. Shipment data by product class is not available prior to 2005. Only overall shipments of room air conditioners are available.
2. Shipments for units without reverse cycle and without louvered sides were combined, as there were not sufficient data for each capacity range to maintain confidentiality.
3. Shipments for units with RC and without LS are combined, as are shipments for units with RC and with LS in 2006, as there were not sufficient data for each capacity range to report and maintain confidentiality.
4. No data can be provided for with RC and with/without LS in 2007.

Comments on Table A2-2:

1. As noted above, shipment data by product class is not available prior to 2005; therefore, no shipment-weighted EER information can be provided for these years.
2. A double asterisk (**) indicates that AHAM cannot provide data for these capacity ranges and or product classes since there is not enough data.

Comments on Tables A2-3 through A2-5:

1. In several cases, efficiency bins were combined to provide as much information as possible, while maintaining confidentiality.
2. When efficiency bins could not be combined, no data are provided. This is indicated by a double asterisk (**).

Additional Comments from AHAM on Tables A2-7 through A2-10 in DOE's Engineering Analysis Data Request:

Comments on Tables A2-7 through A2-8:

AHAM was not able to obtain room air conditioner incremental cost data from members for aggregation. In addition, many of our members purchase and sell their brands through OEMs, and do not have access to this type of cost information.

Comments on Table A2-9:

While AHAM collected data on Portable Air Conditioner shipments, we do not feel our information is representative of actual shipments. We are currently assuming that PAC shipments are roughly 10 percent of RAC shipments. Shipment values received were substantially lower than this estimate. We will begin collecting PAC shipment data in 2009.

Comments on Table A2-10:

AHAM does not feel it is appropriate to provide capacity values for Portable Air Conditioners at this time. There is not currently a standard that measures "true" PAC capacity – as the procedures currently being used for testing are not designed for small, residential units. AHAM has developed a Portable Air Conditioner standard (AHAM PAC-1), which is in its final stages of approval. In January 2009, AHAM will commence a PAC certification program, in which capacities will be reported and verified for both single and dual ducted units. These data will be available on a public website.

5-B.6 DOE DATA REQUESTS FOR RESIDENTIAL CLOTHES DRYERS AND ROOM AIR CONDITIONERS – AHAM DATA SUBMITTAL 01/09/2009

AHAM submitted the following data and responses to DOE on Jan. 9, 2009 in response to DOE's data request (See appendix 5A).

Data Requests for Standards Rulemaking for Residential Clothes Dryers and Room Air-Conditioners – 01/09/2009

Clothes Dryers

1. Shipment-weighted average remaining moisture content (RMC) over time for residential clothes washers for top-loading units, front-loading units, and combined.

   The file attached below [reproduced in Table 5-B.6.1] summarizes total shipments for front-loading and top-loading units from 2002 through 2008. Shipment-weighted RMC values are also shown for the front-load and top-load configurations. Note that the total shipments shown in this table were the shipments used to calculate the weighted RMC values. These shipments will be lower than those typically reported, as members did not provide RMC values for all units.

Table 5-B.6.1 AHAM Weighted RMC for Front-Load and Top-Load Clothes Washer Units, 2000-2008

Year	Clothes Washer Shipments for Which RMC was Reported			Shipment-Weighted RMC *(%)*		
	Front-Loading	Top-Loading	Total	Front-Loading	Top-Loading	Overall
2000	232,714	686,440	919,154	43.6	57.4	53.9
2001	235,989	473,629	709,618	41.3	57.7	52.2
2002	280,667	529,265	809,932	41.5	58.1	52.3
2003	351,411	1,676,877	2,028,288	43.1	54.5	52.5
2004	1,179,813	5,270,285	6,450,098	42.2	52.8	50.9
2005	1,563,108	5,394,511	6,957,619	40.8	52.7	50.1
2006	1,851,218	15,528,279	17,379,497	39.3	51.8	50.5
2007	1,973,825	15,271,142	17,244,967	38.3	51.8	50.2
2008	2,043,024	4,492,059	6,535,083	38.1	51.0	47.0

* Original version of Table 5-B.6.1 was sent on Jan. 9, 2009, but was revised on July 7, 2009 (shown above).

2. Data regarding consumer usage patterns for residential clothes dryers- the # of annual use cycles. Preferably the number of dryer use cycles independent of wash cycles. If not, then the percent of loads washed that are machine dried.

   AHAM does not collect data on patterns of residential clothes dryer use. Confidential industry data suggests that DOE's proposed value of 329 cycles per year is more representative than the current 416 cycles per year, but still on the high end. While dated, 1997 information from Natural Resources Canada (NRCan) on winter dryer use (5.8

loads per week; 302 cycles per year) is a realistic value for the United States. (http://www.oee.nrcan.gc.ca/publications/infosource/pub/energy_use/sheu_e/sheu_5.cfm).

3. Has AHAM made any progress on the development of a clothes dryer test procedure which tests dryer operation using automatic termination?

   AHAM HLD-1 is currently undergoing revision. We expect the standard to be finalized in 2nd quarter 2009. The revised standard addresses automatic termination by terminating the test immediately prior to the start of the cool down period. Timer-dryers are set to a specific time. Heat and total energy are both measured.

4. Is AHAM developing test methodology for condensing dryers?

   AHAM is not currently developing a test methodology for condensing dryers. There is an IEC standard for this technology; however, we expect that it would need to be modified for use in the U.S. (effect on HVAC is one area of concern).

Room Air Conditioners

1. Data regarding consumer usage patterns – room air-conditioner annual hours of operation.

   AHAM does not collect data on consumer usage patterns of room air conditioners or hours of operation.

APPENDIX 5-C. ENGINEERING QUESTIONNAIRES

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APPENDIX 5-C. ENGINEERING QUESTIONNAIRES

5-C.1 RESIDENTIAL CLOTHES DRYER ENGINEERING QUESTIONNAIRE

The engineering questionnaire used as a guide for engineering discussions during preliminary

manufacturer interviews is shown in this section. Some of the information provided in the questionnaire has been redacted to protect vendor information.

DESIGN FOR ENERGY IMPROVEMENT INFORMATION REQUEST

The United States Department of Energy (DOE) is currently reviewing energy conservation standards for residential clothes dryers. DOE would like to confirm information on the incremental costs of increasing product efficiency by understanding the design options involved in the efficiency improvement.

1. Market Share of products you sell

To help DOE discover manufacturer sub-groups and the relative importance of various product classes to specific manufacturers, please disaggregate your annual unit shipments for each product category as shown below. Please also indicate whether you purchase these products from other manufacturers (i.e. private label), and whether the factory that supplies the product is located in the United States.

Product Class	% Private Label	% Made in US	Yearly Unit Shipments
Vented Electric Standard			
Vented Electric Compact, 120V			
Vented Electric Compact, 240V			
Vented Gas			
Vent-less Electric Compact, 240V			
Vent-less Electric Combination Washer/Dryer			

2. Product Design Features

The following series of exhibits and questions address technical characteristics of key residential clothes dryer components for both baseline and improved-efficiency products.

Baseline Clothes Dryers

- Which design features impacting energy use are generally incorporated into a "baseline" clothes dryer (i.e. one that just meets existing energy factor standards, if any) in the following product classes:
    - Vented Electric Standard?
    - Vented Electric Compact, 120V?
    - Vented Electric Compact, 240V?
    - Gas?
    - Vent-less Electric Compact, 240V?
    - Vent-less Electric Combination Washer/Dryer?

Vented Clothes Dryers
DOE has updated the efficiency levels for the vented clothes dryer analysis that were presented in the Framework Document, based upon the more recent November 2008 California Energy Commission (CEC) directory and 2008 Natural Resources Canada (NRCAN) directory (for electric compact (240V) only). Values that are different than those in the Framework Document are highlighted in blue in the table below.

Since insufficient product data was available for electric compact (120V) clothes dryers, the efficiency levels for this product class were generated by applying a scaling factor developed using the relationship between the current standards for the electric standard and electric compact (120V) product classes (equal to 3.13/3.01 = 1.04).

- Are the updated maximum available efficiency levels appropriate?
- Do you agree with the methodology that was used to generate the electric compact (120 V) efficiency levels?
- Do you believe that the gap-fill efficiency levels defined by DOE for vented electric standard, electric compact, and gas clothes dryers are representative? If not, can you suggest appropriate gap-fill values?

Level	Efficiency Level Source	Efficiency Level (lb/kWh)			
		Electric Standard	Electric Compact (120V)	Electric Compact (240V)	Gas
baseline	DOE Standard	3.01	3.13	2.90	2.67
1	Gap Fill	3.10	**3.22***	2.98	2.75
2	Gap Fill	3.16	**3.29***	**3.09**	**2.85**
3	Maximum Available	**3.4**	**3.54***	**3.2**	**3.44**

* Estimated by scaling from electric standard clothes dryer efficiency levels.

- What design changes are associated with converting a baseline unit to the updated efficiency levels for each vented clothes dryer product class (see Tables below)? What are the costs of the individual design options selected? When considering energy efficiency improvements, do different product classes take different pathways or are pathways similar?
- Are the aggregated industry costs submitted by AHAM (highlighted in red in the Tables below) for the efficiency levels presented in the framework document representative of your firm's costs? Please edit these values as appropriate.
- Are there fundamental differences between required design changes that make the cost increment much higher for some product classes than others?
- Would you help DOE understand and estimate the conversion capital investments that would be necessary at each candidate standard level? What is the nature of the capital investments?

Product Class ➔	Vented Electric Standard			Vented Electric Compact 120V		
Efficiency Level	1	2	3	1	2	3
Updated EF (lb/KWh)	3.10	3.16	3.4	3.22	3.29	3.54
Framework Document EF (lb/KWh)	3.10	3.16	3.39	-	-	3.79
Design Options						
	Average Incremental Costs ($ Per Unit)					
Material	9	42	140			
Labor	2	11	45			
Overhead#	2	4	12			
	Minimum Incremental Costs ($ Per Unit)*					
Material						
Labor						
Overhead#						
	Maximum Incremental Costs ($ Per Unit)*					
Material						
Labor						
Overhead#						
	Conversion Capital Expenditures ($, Millions)					
Building CAPX	0.25	9.02	50.18			
Tooling/ Equipment CAPX	5.25	37.68	118.93			
	One-Time Product Conversion Expenses ($, Millions)					
R&D	3.62	15.87	58.97			
Marketing						

Depreciation on the conversion capital expenditure should NOT be included in the incremental overhead.
* Incremental costs per unit should be reported relative to the baseline unit's cost. The baseline unit complies with the current federal standard for residential clothes dryers. The Average Incremental Cost should be reported as a shipment weighted average value. The Minimum and Maximum Incremental Costs presumably reflect the costs associated with changes to different product platforms.
Red highlighted text indicates AHAM submitted data for the efficiency levels presented in the framework document.

Other Information:
1. What depreciation method would your company use to depreciate the conversion capital expenditures? ____.

Direct material – Costs of raw materials including scrap that can be traced to final or end products. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process but are not assigned to final products (*e.g.*, lubricating oil for production machinery).
Direct labor – The earnings of workers who assemble parts into a finished good for operate machines in the production process. Direct labor includes the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor does not include indirect labor which is defined as the earnings of employees who do not work directly in assembling a product, such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.
Overhead – Factory overhead excluding depreciation. Factory overhead includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A); research and development (R&D); interest; or profit (accounted for by DOE separately).
Full Production Cost = Direct Material + Direct Labor + Overhead (factory) + Depreciation
Full Cost of Product = Full Production Cost + Non-production Costs (SG&A, R&D, interest, and profit)

Product Class →	Vented Electric Compact 240 V			Vented Gas		
Efficiency Level	1	2	3	1	2	3
Updated EF (lb/KWh)	2.98	3.09	3.2	2.75	2.85	3.44
Framework Document EF (lb/kWh)	2.98	3.07	3.23	2.75	2.77	3.02
Design Options						
	Average Incremental Costs ($ Per Unit)*					
Material				20	60	81
Labor				2	6	32
Overhead#				2	4	12
	Minimum Incremental Costs ($ Per Unit)*					
Material						
Labor						
Overhead#						
	Maximum Incremental Costs ($ Per Unit)*					
Material						
Labor						
Overhead#						
	Conversion Capital Expenditures ($, Millions)					
Building CAPX				0.46	29.83	
Tooling/ Equipment CAPX				2.62	37.24	16.15
	One-Time Product Conversion Expenses ($, Millions)					
R&D				2.99	15.46	12.91
Marketing						

Depreciation on the conversion capital expenditure should NOT be included in the incremental overhead.
* Incremental costs per unit should be reported relative to the baseline unit's cost. The baseline unit complies with the current federal standard for residential clothes dryers. The Average Incremental Cost should be reported as a shipment weighted average value. The Minimum and Maximum Incremental Costs presumably reflect the costs associated with changes to different product platforms.
Red highlighted text indicates AHAM submitted data for the efficiency levels presented in the framework document.

Other Information:
1. What depreciation method would your company use to depreciate the conversion capital expenditures? ____.

Direct material – Costs of raw materials including scrap that can be traced to final or end products. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process but are not assigned to final products (*e.g.*, lubricating oil for production machinery).
Direct labor – The earnings of workers who assemble parts into a finished good for operate machines in the production process. Direct labor includes the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor does not include indirect labor which is defined as the earnings of employees who do not work directly in assembling a product, such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.
Overhead – Factory overhead excluding depreciation. Factory overhead includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A); research and development (R&D); interest; or profit (accounted for by DOE separately).
Full Production Cost = Direct Material + Direct Labor + Overhead (factory) + Depreciation
Full Cost of Product = Full Production Cost + Non-production Costs (SG&A, R&D, interest, and profit)

Vent-less Clothes Dryers
DOE derived efficiency levels for the analysis of vent-less electric compact (240V) and vent-less combination (washer/dryer) product classes using existing test data and available data from the CEC 2008 directory. DOE believes that the data derived from each of these sources was obtained using the DOE test procedure with the requirement for the exhaust simulator eliminated.

- Are the baseline and maximum available levels for vent-less electric clothes dryers representative? Can you suggest baseline, gap-fill, and max-tech efficiency levels for vent-less electric clothes dryers?

Level	Efficiency Level Source	Efficiency Level (lb/kWh)	
		Vent-less Electric Compact (240V)	Vent-less Combination (Washer/Dryer)
baseline	Baseline	2.37*	1.95*
1	Gap Fill	2.39**	3.23††
2	Gap Fill	2.49	3.51
3	Maximum Available	2.59†	3.79††

*Based on DOE test data.
**Determined by scaling the existing standard for vented electric compact (240V) based on Miele's voluntary plan to maintain its condenser clothes dryer EF within 82.5 percent of the existing non-condenser clothes dryer standard. 60 FR 9332.
† Based on NIST test data.[1]
†† Based on CEC model data.

- What design changes are implemented to achieve higher efficiency levels for vent-less electric compact clothes dryers? Are these design changes comparable for vent-less electric combination washer/dryers? What are the costs of the individual design options selected?
- Are there fundamental differences between required design changes that make the cost increment much higher for some product classes than others?
- Would you help DOE understand and estimate the conversion capital investments that would be necessary at each candidate standard level? What is the nature of the capital investments?

[1] Kao, J. "Energy Test Results of a Conventional Clothes Dryer and a Condenser Clothes Dryer", National Institute of Standards and Technology, Gaithersburg, MD, 1998.

Product Class →	Vent-less Electric Compact (240V)			Vent-less Combination (Washer/Dryer)		
Efficiency Level	1	2	3	1	2	3
EF (lb/KWh)	2.39	2.49	2.59	3.23	3.51	3.79
Design Options						
Average Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Minimum Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Maximum Incremental Costs ($ Per Unit)*						
Material						
Labor						
Overhead#						
Conversion Capital Expenditures ($, Millions)						
Building CAPX						
Tooling/ Equipment CAPX						
One-Time Product Conversion Expenses ($, Millions)						
R&D						
Marketing						

Depreciation on the conversion capital expenditure should NOT be included in the incremental overhead.
* Incremental costs per unit should be reported relative to the baseline unit's cost. The baseline unit complies with the current federal standard for residential clothes dryers. The Average Incremental Cost should be reported as a shipment weighted average value. The Minimum and Maximum Incremental Costs presumably reflect the costs associated with changes to different product platforms.

Other Information:

1. What depreciation method would your company use to depreciate the conversion capital expenditures? ____.

Direct material – Costs of raw materials including scrap that can be traced to final or end products. Direct material costs do not include indirect material costs which are attributed to supplies that may be used in the production process but are not assigned to final products (*e.g*., lubricating oil for production machinery).
Direct labor – The earnings of workers who assemble parts into a finished good for operate machines in the production process. Direct labor includes the fringe benefits of direct laborers such as group health care, as well as overtime pay. Direct labor does not include indirect labor which is defined as the earnings of employees who do not work directly in assembling a product, such as supervisors, janitors, stockroom personnel, inspectors, and forklift operators.
Overhead – Factory overhead excluding depreciation. Factory overhead includes indirect labor, downtime, set-up costs, indirect material, expendable tools, maintenance, property taxes, insurance on assets, and utility costs. Factory overhead does not include selling, general, and administrative costs (SG&A); research and development (R&D); interest; or profit (accounted for by DOE separately).
Full Production Cost = Direct Material + Direct Labor + Overhead (factory) + Depreciation
Full Cost of Product = Full Production Cost + Non-production Costs (SG&A, R&D, interest, and profit

Fans and Motors

- Is there any room for further, significant energy efficiency improvement via fan blade/air flow design improvements? If so, how much improvement can be achieved?
- What types of fan/drum motors do you currently employ in your clothes dryers?
- Do any of your fan motors run at multiple speeds, for example to match the output of a modulating burner or heater?
- Have you considered improved fan/drum motor efficiency as a design option? If so, how much improvement can be achieved?
- What are the manufacturing costs associated with improved fan/drum motor efficiency?

Automatic Termination Technologies

- What percentage of your clothes dryer shipments for each product class use automatic termination? What percentage of your shipments for each product class use moisture sensors? Temperature sensors? What drives your decision of what sensor technology to incorporate in a given platform?
- Are consumers aware of the specific sensor technology being used inside a clothes dryer?
    - If so, are consumers demanding specific sensor technologies?
    - If not, are they drawn principally to the presence of an automatic termination system and care less about how it is achieved?
- How are the sensor functions implemented by consumers on your clothes dryers? Are they enabled by default for some drying operations?
- For what percentage of dry cycles do consumers use automatic termination? How many of these cycles are actively selected as sensor drying?
- Do certain sensor technologies have better performance characteristics than others? If so, please elaborate on which sensor types?
- Have you performed or are you aware of any research/studies that show the effects on energy efficiency or annual energy consumption associated with the use of automatic termination sensors? In particular, is there any data indicating that one sensor technology performs better than another?
- What are the manufacturing costs associated with each of your automatic termination sensor technologies?
- What are the standby power requirements for the sensor that you use? Do the sensors that you use have a warm-up time, and if so, what is the warm-up time? Are you aware of any automatic termination sensors that do not consume standby power? If not, what would you consider to be the lowest achievable standby power level associated with these sensors?
- Are you aware of any other sensor or alternative technologies you would consider for automatically terminating the drying cycle?
- How wide of a supplier base can you choose from when sourcing sensors, or do you make your own?
- Are you aware of any intellectual property or patent infringement issues that might affect your choice of sensor technologies?

Other Dryer Control or Drum Upgrades

- Have you considered increased insulation as a design option? If so, what thicknesses and insulation materials have you considered? How much efficiency improvement can be achieved? What would be the incremental manufacturing cost?
- Have you explored any ways of improving the air circulation in your dryers (i.e. directing and maintaining heat more efficiently)? If so, how much efficiency improvement can be achieved? What would be the incremental manufacturing cost?
- Do you have any data showing any efficiency improvements associated with reverse tumble (during the drying cycle, as opposed to after the cycle as wrinkle prevention)? What is the incremental manufacturing cost of this design option?
- DOE's research showed that the efficiency of a clothes dryer can be improved slightly by the design of the drum (e.g., internal vane design or enhanced surface textures). Have you considered improvements to the drum design? If so how much efficiency improvement can be achieved? What would be the incremental manufacturing cost?

Exhaust Heat Recovery and Infiltration Abatement (vented models)

- Do you manufacture vented clothes dryers with an outdoor air supply? If not, what are the reasons? If you do offer models with an outdoor air supply option, do they feature sealed combustion?
- Do you manufacture any dryers that recycle exhaust heat? If so, please elaborate on how this is done? For example, is some of the exhaust air recycled to the inlet during a certain portion of the drying cycle or is a heat exchanger used to recover exhaust heat energy and to preheat inlet air? How much efficiency improvement can be achieved? What is the incremental manufacturing cost?

Modulating Heater Designs

- Do any of your gas dryer models use modulating gas burners? Have you considered this design option?
- Do you have any data showing the efficiency improvements associated with modulating gas burners? DOE's research shows that a modulating gas dryer design can reduce energy consumption by up to 25% for small and medium sized loads, and 10% for larger loads. Would you consider this accurate?
- Do any of your clothes dryers use a multi-step or modulating electric heater? What is the associated efficiency improvement with using a modulating or stepped electric heater versus a standard on/off electric heater?

Heat Pump Dryers

- Do you manufacture heat pump dryers? If not, have you considered this technology?
- What type of refrigerant is used? What type of compressor? What types of heat exchangers are used?
- DOE's research shows that this design option can achieve 50-68% efficiency improvement compared to conventional electric dryers. Would you consider this accurate?

- What are the manufacturing costs associated with this design option?

Standby Power

- What are the consumer utilities associated with each type of display used in clothes dryers? (Example, cycle/temperature selection, delay start time, cycle time, etc.)
- What types of display technologies do you use in your clothes dryer product line? What are the standby power requirements for each display type assuming a comparable display (size and capability)?
- Are you aware of consumers demanding specific display types or is it other clothes dryer features that attract them?
- What are the manufacturing costs associated with various display technologies?
- What drives the costs for each display technology?
- What would be the manufacturing costs associated with adding a feature to dim or turn off the displays? How much could this potentially decrease power consumption?
- What clothes dryer features other than displays contribute to standby power, and what is the standby power requirement associated with each of them?

3. Test Procedure Issues

- Have you observed significant test-to-test variation in EF measurements for a given clothes dryer unit? If so, how much is this variation?
- Do you have any data showing the effects of altering the ambient conditions on the measured EF for a give clothes dryer unit? The current DOE test procedure requires an ambient temperature of 75 ± 3°C and relative humidity of 50 ± 10%.
- Have you tested your clothes dryers with lower starting RMC of the test cloth load than is currently specified in the DOE test procedure (nominally 70%)? If so, how did EF vary with RMC?

5-C.2 ROOM AIR CONDITIONER ENGINEERING QUESTIONNAIRE

The engineering questionnaire used as a guide for engineering discussions during manufacturer interviews is shown in this section. Some of the information provided in the questionnaire has been redacted to protect vendor information.

DESIGN FOR ENERGY IMPROVEMENT INFORMATION REQUEST
ROOM AIR CONDITIONERS

DOE would like to confirm information on the incremental costs of increasing product efficiency by understanding the design options involved in the efficiency improvement.

1. **Market Share of products you sell**

To help DOE discover manufacturer sub-groups and the relative importance of various product classes to specific manufacturers, please disaggregate your annual unit shipments for each product category as shown below. Please also indicate whether you purchase these products from other manufacturers (i.e. private label), and whether the factory that supplies the product is located in the USA.

Product Class	% Private Label?	% Made in USA?	Yearly Unit Shipments
1. Without reverse cycle, with LS, and less than 6,000 Btu/h			
2. Without reverse cycle, with LS and 6,000 to 7,999 Btu/h			
3. Without reverse cycle, with LS and 8,000 to 13,999 Btu/h			
4. Without reverse cycle, with LS and 14,000 to 19,999 Btu/h			
5. Without reverse cycle, with LS and 20,000 Btu/h or more			
6. Without reverse cycle, without LS, and less than 6,000 Btu/h			
7. Without reverse cycle, without LS and 6,000 to 7,999 Btu/h			
8. Without reverse cycle, without LS and 8,000 to 13,999 Btu/h			
9. Without reverse cycle, without LS and 14,000 to 19,999 Btu/h			
10. Without reverse cycle, without LS and 20,000 Btu/h or more			
11. With reverse cycle, with LS, and less than 20,000 Btu/h			
12. With reverse cycle, without LS, and less than 14,000 Btu/h			
13. With reverse cycle, with LS, and 20,000 Btu/h or more			
14. With reverse cycle, without LS, and 14,000 Btu/h or more			
15. Casement-Only			
16. Casement-Slider			

2. Product Technical Descriptions

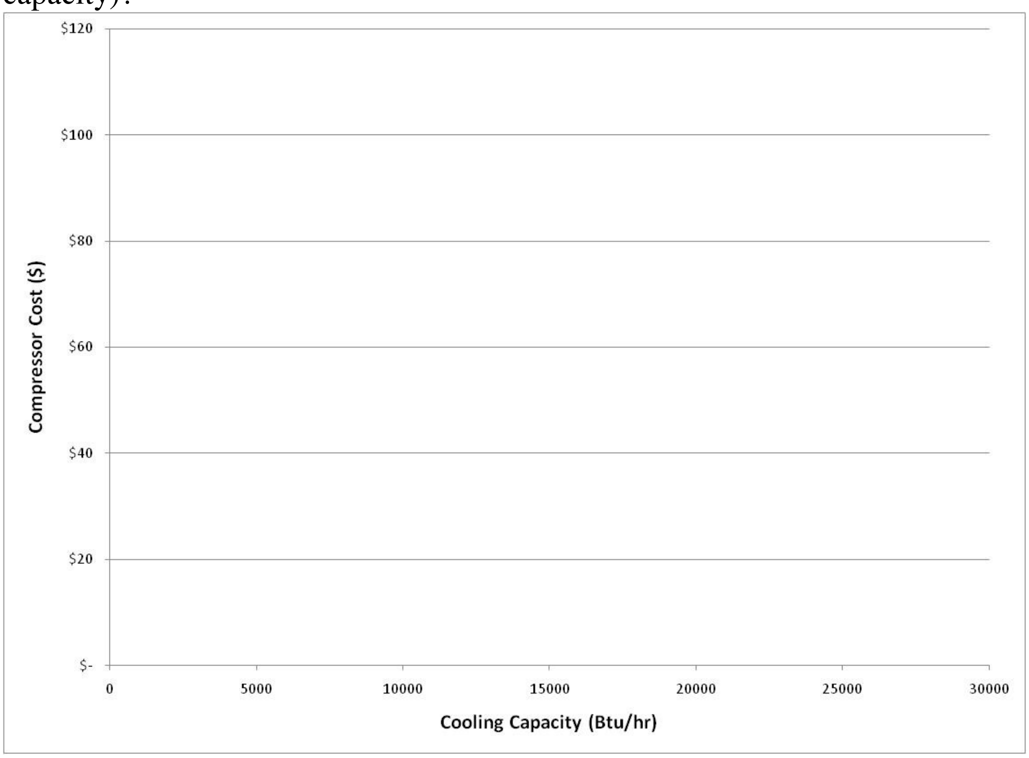
The following series of exhibits and questions address technical characteristics of key refrigerator and freezer components for both baseline and improved-efficiency products.

Compressors

Are the suggested compressor EERs representative for the Product Class and Efficiency?

Product Class	Typical Nominal Compressor EER for Minimum Efficiency	Typical Nominal Compressor EER for EnergyStar
1. Without reverse cycle, with LS, and less than 6,000 Btu/h	10 to 11	11
3. Without reverse cycle, with LS and 8,000 to 13,999 Btu/h	10 to 11	11
5. Without reverse cycle, with LS and 20,000 Btu/h or more	10.5	11
8. Without reverse cycle, without LS and 8,000 to 13,999 Btu/h	10	10.5 to 11

Is the Illustrated Typical Cost vs. Capacity for HCFC-22 Baseline Product compressors (10 EER) accurate (note that the plot is based on RAC capacity, not compressor rating point capacity)?



- Is 15% a good estimate of cost premium for 11 EER as compared with 10 EER compressors?

- Do any room air-conditioners use variable-speed compressors? Any other modulating or part-loading approaches?
- What are reasonable impacts for use of R-410 on **compressor** characteristics?
    - Cost premium 10%? Expected trend in coming years?
    - Rating point EER range 9.5 to 10.5 rather than 10 to 11?
    - Different performance trends than HCFC-22 at varying condensing or evaporating temperatures?
    - Maturity of product offerings?

R-410a Conversion
- Expected change in EER of room air conditioners designed with refrigerant velocities appropriate for R-410A but with equivalent heat exchanger core sizes and air flow?
- Cost impacts of conversion (compressor, refrigerant, other?)?

Evaporator and Condenser Heat Exchanger Characteristics
Please comment on the typical key details of heat exchangers.

	Evaporators	**Condensers**
Tube Outer Diameter (inch)	0.28	0.25
Tube Wall (inch)	0.015	0.020
Tubes Always Rifled?	Yes	Yes
Fin Type?	Louvered or Lanced	Louvered or Lanced
Fins per inch?	18	18
Standard-Efficiency Air flow (cfm/ton)?	275	800
Standard-Efficiency Air face velocity (fpm)?	450	500

- Tubes always copper? Fins always aluminum?
- Limitations of boosting fin density?
- Trends in Air flow variation by capacity, efficiency level, product class differences: window vs. thru-wall vs. reversible-cycle vs. casement/slider?
- Are you aware of any further significant system improvements that may be possible through heat exchanger changes?
- Benefits of reduced tube diameters?
- In spite of efforts to minimize room air conditioner size, typical coil depth is two rows: does the fan power increase with greater depth make additional rows counterproductive?
- Benefits of microchannel heat exchangers?
- Benefits of coil coatings to improve efficiency?
- Coil fabrication usually outsourced or in-house?
- Is air flow through the condenser always from inside out to assure cooling benefit of the condensate?

- At rating conditions, is all of the condensate evaporated prior to air leaving the coil, with no spillage from the pan?

Subcoolers using Condensate for Cooling
- Are these standard on Energy Star products?
- Do their designs take full advantage of possible pan counterflow?

Evaporator Blowers and Condenser Fans
- Typical blower geometry: backward-inclined blades using plug fan arrangement, using Styrofoam "scroll" to direct air from lower part of blower?
- Typical blower efficiency? Typical fan efficiency?
- Power requirement associated with water slinging function at design rating conditions? Are there more efficient ways to distribute the condensate?
- Is there any room for significant energy efficiency improvement via blower or fan design improvements?

Blower/Fan Motors
Please comment on blower/fan motor characteristics.
- Generally use double-shafted PSC? Typical number of speeds?
- Shaft Power output 8W per 1000 Btu/hr capacity?
- Typical efficiency roughly 60% for standard-efficiency products?
- Motor cost $X for 75W shaft output? Variation vs. shaft output?
- Higher efficiency PSC levels up to 65% for Energy Star? What is the peak efficiency commonly available for RAC-sized PSC motors? What is the cost premium?
- Brushless DC motor efficiency for RAC size 80%? Does this technology provide a viable option for efficiency improvement? What is the efficiency improvement, cost impact, and size/weight impact? Typical motor vendor/model?
- Are there any other motor technologies which could contribute to efficiency improvement?

Partition Insulation
- Usually ¼ inch Styrofoam or 1/10 inch polystyrene?

Air Leakage
- Is this a factor in rating point performance?

Expansion Devices:
- Is there any performance improvement potential with expansion devices other than capillary tube?
- Do you use any expansion device besides capillary tubes? If so, what are the benefits and the cost impacts?

Energy Efficiency Conversion Costs

- What design changes are typically associated with converting baseline products to Energy Star?
- When considering energy efficiency improvements to achieve or exceed Energy Star, do different product classes take different pathways or are pathways similar?
- Are the cost increments higher for some classes than others for a given performance improvement over baseline?

APPENDIX 5-D. ROOM AIR CONDITIONER ENGINEERING DATA

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APPENDIX 5-D. ENGINEERING DATA

5-D.1 INTRODUCTION

Chapter 5 presents incremental cost curves describing costs to attain each analyzed efficiency level for the six products analyzed in detail. The U.S. Department of Energy (DOE) developed the curves using design option analysis based on energy use modeling using the MarkN program and manufacturing cost modeling.

The tables in section 5-D.2 show the costs associated which each of the design configurations analyzed. The tables identify the design options associated with each design configuration and show the key elements comprising the cost impacts, including materials, labor, overhead, and depreciation. The tables also present total manufacturing production cost (MPC), total manufacturer sales price (MSP), and shipping cost associated with each design configuration. These costs represent the costs from the final rule analysis.

Details of the energy modeling are presented in section 5-D.3. Tables in this section identify for each analyzed design configuration the MarkN input file name, the compressor data file name, the MarkN key program output (energy efficiency ratio (EER) and capacity), standby energy use, and integrated efficiency (combined energy efficiency ratio (CEER)). These tables represent the analysis from the final rule analysis.

Details of two aspects of the engineering analysis are presented in section 5-D.4. Section 5-D.4.1 describes the airflow analysis that DOE used to account for changes in the airflow system, including changes to fans and heat exchangers. Section 5-D.4.2 describes the data collection and analysis used to develop the incremental cost estimates associated with increasing motor efficiency, both with higher-efficiency permanent split capacitor (PSC) motors and with brushless direct current (BLDC) motors.

5-D.2 MANUFACTURING COST MODELING DETAILS

The tables in this section itemize the results of the manufacturing cost analysis. The tables identify for each of the analyzed products the analyzed design configurations and their associated EER and CEER. The successive design configurations represent baseline designs with increasing numbers of design options. The total and incremental costs associated with each of the design configurations are presented in the tables as well, with separate identification of the key cost elements: materials, labor, overhead, depreciation, and shipping cost. The incremental manufacturing costs represent increases in MPC. The tables also show total MPC and MSC calculated for each design configuration. Chapter 5 describes the conversion of this data into incremental costs for specified efficiency levels (rather than by design configuration). The efficiency level format of the data is used in the downstream analyses (*i.e.*, life-cycle cost (LCC), national impact analysis (NIA), etc.)

Table 5-D.2.1 Incremental Cost Detail for 5,000 Btu/h Louvered, No Reverse Cycle Room Air Conditioner (Product Class 1) – Final Rule Analysis

Design Configuration Description	EER	IEER	Incremental Costs (MPC)						Total Cost		
			Material	Labor	OH	Depre-ciation	Increase	Cumulative Increase	MPC	MSP*	Shipping
R-410A Baseline	8.94	8.79	-	-	-	-	-	-	$ 146.63	$ 184.76	$3.86
1 Add Subcooler	9.18	9.02	$0.57	$0.25	$0.10	$0.02	$0.80	$0.80	$ 147.43	$ 185.77	$3.86
2 Increase Evap Circuits	9.37	9.20	$0.75	-	-	-	$0.75	$1.55	$ 148.18	$ 186.71	$3.86
3 Increase Compressor Efficiency	9.72	9.54	$1.80	-	-	-	$1.80	$3.35	$ 149.98	$ 188.98	$3.86
4 Stand-by Reduction	9.72	9.63	$0.75	-	-	-	$0.75	$4.10	$ 150.73	$ 189.92	$3.86
5 Increase Evap Width	9.89	9.80	$0.65	$0.21	$1.31	$0.00	$2.17	$6.27	$ 152.90	$ 192.66	$3.86
6 Increase Chassis to Medium Size	10.59	10.48	$6.74	$1.06	-$0.31	$0.01	$7.50	$13.77	$ 160.40	$ 202.10	$5.72
7 Increase Chassis to Large Size	10.80	10.69	$2.67	-$0.46	$3.14	$0.01	$5.36	$19.13	$ 165.76	$ 208.86	$8.39
8 Increase Condenser Tube Rows	11.23	11.12	$5.58	$1.17	$0.09	$0.00	$6.85	$25.98	$ 172.61	$ 217.49	$8.39
9 Increase PSC Efficiency	11.49	11.37	$8.11	-	-	-	$8.11	$34.09	$ 180.72	$ 227.71	$8.39
10 Increase Fin Thickness	11.51	11.38	$1.49	-	-	-	$1.49	$35.58	$ 182.21	$ 229.59	$8.39
11 DC Brushless Motor	11.80	11.67	$43.50	-	-	-	$43.50	$79.08	$ 225.71	$ 284.40	$8.39

*MSP is equal to MPC times the manufacturer markup of 1.26.

- (1) Add subcooler with 0.25 inches (in) outer diameter (OD), 24.25 in. length, and condensate temperature of 95º F
- (2) Increase total refrigerant circuits in evaporator from 1 circuit to 2 circuits
- (3) Improve rotary R-410A compressor efficiency to 10.0 EER
- (4) Change Main Control Board to a Switching Power Supply.
- (5) Increase evaporator width by 2 in. by redesigning the unit's user interface placement.
- (6) Increase Baseline Chassis Size by: Width 3 in., Height 0.75 in., Depth 2 in.
- (7) Increase Baseline Chassis Size by: Width 4.2 in., Height 1.9 in., Depth 5.7 in.
- (8) Convert Condenser to 3-tube row heat exchangers from 2-tube rows
- (9) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor
- (10) Increase evaporator fin thickness from 0.005 in to 0.006 in.
- (11) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.2.2 Incremental Cost Detail for 8,000 Btu/h Louvered, No Reverse Cycle Room Air Conditioner (Product Class 3) – Final Rule Analysis

Design Option Step	EER	IEER	Incremental Costs						Total Cost		
			Material	Labor	OH	Depre-ciation	Increase	Cumulative Increase	MPC	MSP	Shipping
R-410A Baseline	9.30	9.19	-	-	-	-	-	-	$179.60	$226.30	$6.32
1 Add Subcooler	9.60	9.50	$0.81	$0.00	$0.00	$0.00	$0.81	$0.81	$180.41	$227.32	$6.32
2 Increase Evap Width	9.76	9.65	$0.88	$0.31	$0.00	$0.00	$1.20	$2.01	$181.61	$228.83	$6.32
3 Increase Compre. Efficiency	10.17	10.05	$3.60	-	-	-	$3.60	$5.61	$185.21	$233.36	$6.32
4 Stand-by Reduction	10.17	10.11	$11.36	-	-	-	$0.75	$6.36	$185.96	$234.31	$6.32
5 Increase Chassis to Medium Size	10.87	10.80	$8.27	$1.00	$0.46	$0.00	$9.73	$16.09	$195.69	$246.57	$9.58
6 Increase PSC Efficiency	11.49	11.41	$13.70	-	-	-	$13.70	$29.79	$209.39	$263.83	$9.58
7 Increase Chassis to Large Size	11.84	11.76	$10.74	$0.97	$1.56	$0.04	$13.32	$43.11	$222.71	$280.61	$14.63
8 DC Brushless Motor	12.05	11.96	$63.14	-	-	-	$63.14	$106.25	$285.85	$360.17	$14.63

- (1) Add subcooler with 0.25 in. OD, 24.25 in. length, and condensate temperature of 95º F
- (2) Increase evaporator width by 3 in. by redesigning the unit's user interface placement
- (3) Improve rotary R-410A compressor efficiency to 10.0 EER
- (4) Change Main Control Board to a Switching Power Supply.
- (5) Increase baseline chassis size by: Width 0.81 in., Height 3.13 in., Depth 2.5 in.
- (6) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (7) Increase baseline chassis size by: Width 4 in., Height 3.13 in., Depth 8.1 in.
- (8) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.2.3 Incremental Cost Detail for 12000 Btu/h Louvered, No Reverse Cycle Room Air Conditioner (Product Class 3) – Final Rule Analysis

Design Option Step	EER	IEER	Incremental Costs						Total Cost		
			Material	Labor	OH	Depre-ciation	Increase	Cumulative Increase	MPC	MSP	Shipping
R-410A Baseline	9.76	9.68	-	-	-	-	-	-	$ 211.36	$ 266.31	$10.33
1 Add Subcooler	10.20	10.12	$0.75	$0.36	$0.14	$0.00	$1.25	$1.25	$ 212.61	$ 267.89	$10.33
2 Increase Compressor Efficiency	11.05	10.95	$9.03	-	-	-	$9.03	$10.28	$ 221.64	$ 279.27	$10.33
3 Standby Reduction	11.05	11.00	$0.75				$0.75	$11.03	$ 222.39	$ 280.21	$10.33
4 Increase PSC Efficiency	11.54	11.49	$18.00	-	-	-	$18.00	$29.03	$ 240.39	$ 302.89	$10.33
5 Increase Evaporator Tube Rows	11.66	11.60	$3.37	$0.92	$0.11	$0.00	$4.40	$33.43	$ 244.79	$ 308.43	$10.33
6 Increase Chassis Size to Medium Size	11.97	11.92	$9.49	$1.11	$1.79	$0.01	$12.41	$45.83	$ 257.19	$ 324.06	$15.30
7 Increase Chassis Size to Large Size	12.27	12.21	$10.65	$0.73	$2.27	$0.73	$13.65	$59.49	$ 270.85	$ 341.27	$20.37
8 DC Brushless Motor	12.44	12.38	$73.26	-	-	-	$73.26	$132.75	$ 344.11	$ 433.58	$20.37

- (1) Add subcooler with 0.315 in. OD, 32 in. length, and condensate temperature of 95º F
- (2) Improve rotary R-410A compressor efficiency to 10.0 EER
- (3) Change Main Control Board to a Switching Power Supply.
- (4) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (5) Increase number of evaporator tube rows from 3 rows to 4 rows
- (6) Increase baseline chassis size by: Width 4.5 in., Height 1.125 in., Depth 2.3 in.
- (7) Increase baseline chassis size by: Width 7 in., Height 1.125 in., Depth 7.2 in.
- (8) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.2.4 Incremental Cost Detail for 24000 Btu/h Louvered, No Reverse Cycle Room Air Conditioner (Product Class 5A) – Final Rule Analysis

Design Option Step	EER	IEER	Incremental Costs						Total Cost		
			Material	Labor	OH	Depre-ciation	Increase	Cumulative Increase	MPC	MSP	Shipping
R-410A Baseline	7.87	7.84	-	-	-	-	-	-	$ 336.81	$ 424.38	$23.10
1 Add Subcooler	8.17	8.14	$1.61	$0.00	$0.00	$0.00	$1.61	$1.61	$ 338.42	$ 426.41	$23.10
2 Increase Chassis size to Medium Size	8.98	8.95	$11.31	$0.57	$0.81	$0.01	$12.70	$14.31	$ 351.13	$ 442.42	$27.22
3 Increase Condenser Tube Rows	9.42	9.38	$8.28	$1.57	$0.94	$0.01	$10.80	$25.12	$ 361.93	$ 456.03	$27.22
4 Stand-by Reduction	9.42	9.40	$0.75	-	-	-	$0.75	$25.87	$ 362.68	$ 456.98	$27.22
5 Increase Compressor Efficiency	9.68	9.66	$15.00	-	-	-	$15.00	$40.87	$ 377.68	$ 475.88	$27.22
6 Increase PSC Efficiency	10.05	10.03	$44.25	-	-	-	$44.25	$85.12	$ 421.93	$ 531.63	$27.22
7 DC Brushless Motor	10.18	10.15	$126.33	-	-	-	$126.33	$211.45	$ 548.26	$ 690.81	$27.22

- (1) Add subcooler with 0.282 in OD, 63 in. length, and condensate temperature of 95º F
- (2) Increase baseline chassis size by: Width 1.75 in., Height 0.25 in., Depth 2.53 in.
- (3) Increase number of condenser tube rows from 3 rows to 4 rows
- (4) Change Main Control Board to a Switching Power Supply.
- (5) Improve rotary R-410A compressor efficiency to 10.3 EER
- (6) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (7) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.2.5 Incremental Cost Detail for 28000 Btu/h Louvered, No Reverse Cycle Room Air Conditioner (Product Class 5B) – Final Rule Analysis

Design Option Step	EER	IEER	Incremental Costs						Total Cost		
			Material	Labor	OH	Depre-ciation	Increase	Cumulative Increase	MPC	MSP	Shipping
R-410A Baseline	7.48	7.46	-	-	-	-	-	-	$366.81	$462.18	$23.10
1 Add Subcooler	7.74	7.72	$1.61	$0.00	$0.00	$0.00	$1.61	$1.61	$368.42	$464.21	$23.10
2 Increase Chassis size to Medium Size	8.29	8.26	$11.31	$0.57	$0.81	$0.01	$12.70	$14.31	$381.13	$480.22	$27.22
3 Increase Chassis size to Large Size	9.05	9.03	$24.51	$2.85	$6.81	$0.02	$34.18	$48.50	$415.31	$523.29	$36.46
4 Stand-by Reduction	9.05	9.04	$0.75	-	-	-	$0.75	$49.25	$416.06	$524.24	$36.46
5 Increase Compressor Efficiency	9.37	9.36	$16.50	-	-	-	$16.50	$65.75	$432.56	$545.03	$36.46
6 Increase Condenser Tube Rows	9.46	9.44	$14.48	$2.04	$0.00	$0.01	$16.53	$82.28	$449.09	$565.86	$36.46
7 Increase PSC Efficiency	9.73	9.71	$44.25	-	-	-	$44.25	$126.53	$493.34	$621.61	$36.46
8 DC Brushless Motor	9.81	9.80	$126.33	-	-	-	$126.33	$252.86	$619.67	$780.79	$36.46

- (1) Add subcooler with 0.282 in OD, 63 in. length, and condensate temperature of 95º F
- (2) Increase baseline chassis size by: Width 1.75 in., Height 0.25 in., Depth 2.53 in.
- (3) Increase baseline chassis size by: Width 3.81 in., Height 4.69 in., Depth 2.53 in.
- (4) Change Main Control Board to a Switching Power Supply.
- (5) Improve rotary R-410A compressor efficiency to 10.3 EER
- (6) Increase number of condenser tube rows from 3 rows to 4 rows
- (7) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (8) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.2.6 Incremental Cost Detail for 8000 Btu/h Non-Louvered, No Reverse Cycle Room Air Conditioner (Product Class 8A) – Final Rule Analysis

Design Option Step	EER	IEER	Incremental Costs						Total Cost		
			Material	Labor	OH	Depre-ciation	Increase	Cumulative Increase	MPC	MSP	Shipping
R-410A Baseline	8.43	8.34	-	-	-	-	-	-	$ 210.70	$ 265.49	$12.26
1 Increase Evap Width	9.44	9.34	$4.74	$0.43	$0.00	$0.01	$5.17	$5.17	$ 215.88	$ 272.01	$12.26
2 Add Subcooler	9.59	9.48	$0.80	$0.00	$0.00	$0.00	$0.80	$5.97	$ 216.68	$ 273.01	$12.26
3 Improve Compressor Efficiency	9.78	9.66	$1.65	-	-	-	$1.65	$7.62	$ 218.33	$ 275.09	$12.26
4 Stand-by Reduction	9.78	9.72	$0.75	-	-	-	$0.75	$8.37	$ 219.08	$ 276.04	$12.26
5 Increase PSC Efficiency	10.26	10.20	$14.68	-	-	-	$14.68	$23.05	$ 233.76	$ 294.53	$12.26
6 DC Brushless Motor	10.42	10.35	$65.77	-	-	-	$65.77	$88.82	$ 299.53	$ 377.40	$12.26

- (1) Increase evaporator width by 4 inches by redesigning the unit's user interface placement.
- (2) Add subcooler with 0.25 in. OD, 24.25 in. length, and condensate temperature of 95º F
- (3) Improve rotary R-410A compressor efficiency to 10.0 EER
- (4) Change Main Control Board to a Switching Power Supply
- (5) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (6) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Incremental Cost Detail for 12000 Btu/h Non-Louvered, No Reverse Cycle Room Air Conditioner (Product Class 8B) – Final Rule Analysis

Design Option Step	EER	IEER	Incremental Costs						Total Cost		
			Material	Labor	OH	Depre-ciation	Increase	Cumulative Increase	MPC	MSP	Shipping
R-410A Baseline	8.37	8.32	-	-	-	-	-	-	$ 236.54	$ 298.04	$12.26
1 Add Subcooler	8.57	8.51	$0.68	$0.36	$0.14	$0.00	$1.18	$1.18	$ 237.72	$ 299.53	$12.26
2 Improve Compressor Efficiency	9.09	9.03	$6.30	-	-	-	$6.30	$7.48	$ 244.02	$ 307.47	$12.26
3 Increase Evap width	9.59	9.52	$7.61	$1.14	$0.20	$0.01	$8.95	$16.43	$ 252.97	$ 318.74	$12.26
4 Stand-by Reduction	9.59	9.55	$0.75	-	-	-	$0.75	$17.18	$ 253.72	$ 319.69	$12.26
5 Increase PSC Efficiency	9.94	9.90	$13.70	-	-	-	$13.70	$30.88	$ 267.42	$ 336.95	$12.26
6 DC Brushless Motor	10.06	10.02	$63.23	-	-	-	$63.23	$94.11	$ 330.65	$ 416.62	$12.26

- (1) Add subcooler with 0.315 in. OD, 32 in. length, and condensate temperature of 95º F
- (2) Improve rotary R-410A compressor efficiency to 10.0 EER
- (3) Increase evaporator width by 6 inches by redesigning the unit’s user interface placement.
- (4) Change Main Control Board to a Switching Power Supply
- (5) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (6) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

5-D.3 ENERGY MODELING DETAILS

The tables in this section identify the analyzed design configurations for the analyzed products. For each design configuration, the tables present the key MarkN outputs (capacity and EER), the standby energy use, the IEER, and the MarkN input and compressor files used in the analysis. The MarkN program, a MarkN user manual, and the input and compressor files will be made available on the website for this rulemaking.

Table 5-D.3.7 MarkN Results for 5000 Btu/h Louvered, No Reverse Cycle Room Air Conditioner (Product Class 1) – Final Rule Analysis

Design Configuration Description	MarkN Input Filename	Compressor Map (EER, Capacity)	MarkN Outputs		Stand-by Power	IEER
			EER	Capacity		
R-410A Baseline	In_PC1_Baseline_R410A.dat	9.7 EER 4.6 kBtu/h	8.94	4,624	1.4	8.79
1 Add Subcooler	In_PC1_Step1.dat	9.7 EER 4.6 kBtu/h	9.18	4,689	1.4	9.02
2 Increase Evap Circuits	In_PC1_Step2.dat	9.7 EER 4.6 kBtu/h	9.37	4,834	1.4	9.20
3 Increase Compressor Efficiency	In_PC1_Step3.dat	10 EER 4.6 kBtu/h	9.72	4,842	1.4	9.54
4 Stand-by Reduction	In_PC1_Step4.dat	10 EER 4.6 kBtu/h	-	-	0.7	9.63
5 Increase Evap Width	In_PC1_Step5.dat	10 EER 4.6 kBtu/h	9.89	4,934	0.7	9.80
6 Increase Chassis to Medium Size	In_PC1_Step6.dat	10 EER 4.6 kBtu/h	10.59	5,066	0.7	10.48
7 Increase Chassis to Large Size	In_PC1_Step7.dat	10 EER 4.6 kBtu/h	10.80	5,215	0.7	10.69
8 Increase Condenser Tube Rows	In_PC1_Step8.dat	10 EER 4.6 kBtu/h	11.23	5,324	0.7	11.12
9 Increase PSC Efficiency	In_PC1_Step9.dat	10 EER 4.6 kBtu/h	11.49	5,325	0.7	11.37
10 Increase Fin Thickness	In_PC1_Step10.dat	10 EER 4.6 kBtu/h	11.51	5,338	0.7	11.38
11 DC Brushless Motor	In_PC1_Step11.dat	10 EER 4.6 kBtu/h	11.80	5,339	0.7	11.67

- (1) Add subcooler with 0.25 inches (in) outer diameter (OD), 24.25 in. length, and condensate temperature of 95º F
- (2) Increase total refrigerant circuits in evaporator from 1 circuit to 2 circuits
- (3) Improve rotary R-410A compressor efficiency to 10.0 EER
- (4) Change Main Control Board to a Switching Power Supply.
- (5) Increase evaporator width by 2 in. by redesigning the unit's user interface placement.
- (6) Increase Baseline Chassis Size by: Width 3 in., Height 0.75 in., Depth 2 in.
- (7) Increase Baseline Chassis Size by: Width 4.2 in., Height 1.9 in., Depth 5.7 in.
- (8) Convert Condenser to 3-tube row heat exchangers from 2-tube rows
- (9) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor
- (10) Increase evaporator fin thickness from 0.005 in to 0.006 in.
- (11) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.3.8 MarkN Results for 8000 Btu/h Louvered, No Reverse Cycle Room Air Conditioner (Product Class 3) – Final Rule Analysis

Design Option Step	MarkN Filename	Compressor Map (EER, Capacity)	MarkN Outputs		Stand-by Power	IEER
			EER	Capacity		
R-410A Baseline	In_PC3_12k_Baseline_R410A.dat	9.39 EER 7.6 kBtu/h	9.30	7,688	1.4	9.19
1 Add Subcooler	In_PC3_8k_Step1.dat	9.39 EER 7.6 kBtu/h	9.60	7,816	1.4	9.50
2 Increase Evap Width	In_PC3_8k_Step2.dat	9.39 EER 7.6 kBtu/h	9.76	8,001	1.4	9.65
3 Increase Compre. Efficiency	In_PC3_8k_Step3.dat	10 EER 7.6 kBtu/h	10.17	8,005	1.4	10.05
4 Stand-by Reduction	In_PC3_8k_Step4.dat	10 EER 7.6 kBtu/h	-	-	0.7	10.11
5 Increase Chassis to Medium Size	In_PC3_8k_Step5.dat	10 EER 7.6 kBtu/h	10.87	8,425	0.7	10.80
6 Increase PSC Efficiency	In_PC3_8k_Step6.dat	10 EER 7.6 kBtu/h	11.49	8,431	0.7	11.41
7 Increase Chassis to Large Size	In_PC3_8k_Step7.dat	10 EER 7.6 kBtu/h	11.84	8,633	0.7	11.76
8 DC Brushless Motor	In_PC3_8k_Step8.dat	10 EER 7.6 kBtu/h	12.05	8,635	0.7	11.96

- (1) Add subcooler with 0.25 in. OD, 24.25 in. length, and condensate temperature of 95º F
- (2) Increase evaporator width by 3 in. by redesigning the unit's user interface placement
- (3) Improve rotary R-410A compressor efficiency to 10.0 EER
- (4) Change Main Control Board to a Switching Power Supply.
- (5) Increase baseline chassis size by: Width 0.81 in., Height 3.13 in., Depth 2.5 in.
- (6) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (7) Increase baseline chassis size by: Width 4 in., Height 3.13 in., Depth 8.1 in.
- (8) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.3.9 MarkN Results for 12000 Btu/h Louvered, No Reverse Cycle Room Air Conditioner (Product Class 3) – Final Rule Analysis

Design Option Step	MarkN Filename	Compressor Map (EER, Capacity)	MarkN Outputs		Stand-by Power	IEER
			EER	Capacity		
R-410A Baseline	In_PC3_12k_Baseline_R410A.dat	9.14 EER 11.3 kBtu/h	9.76	12,607	1.4	9.68
1 Add Subcooler	In_PC3_12k_Step1.dat	9.14 EER 11.3 kBtu/h	10.20	12,913	1.4	10.12
2 Increase Compressor Efficiency	In_PC3_12k_Step2.dat	10 EER 10.9 kBtu/h	11.05	12,928	1.4	10.95
3 Standby Reduction	In_PC3_12k_Step3.dat	10 EER 10.9 kBtu/h	11.05	-	0.7	11.00
4 Increase PSC Efficiency	In_PC3_12k_Step4.dat	10 EER 10.9 kBtu/h	11.54	12,935	0.7	11.49
5 Increase Evaporator Tube Rows	In_PC3_12k_Step5.dat	10 EER 10.9 kBtu/h	11.66	13,206	0.7	11.60
6 Increase Chassis Size to Medium Size	In_PC3_12k_Step6.dat	10 EER 10.9 kBtu/h	11.97	13,607	0.7	11.92
7 Increase Chassis Size to Large Size	In_PC3_12k_Step7.dat	10 EER 10.9 kBtu/h	12.27	13,850	0.7	12.21
8 DC Brushless Motor	In_PC3_12k_Step8.dat	10 EER 10.9 kBtu/h	12.44	13,854	0.7	12.38

- (1) Add subcooler with 0.315 in. OD, 32 in. length, and condensate temperature of 95º F
- (2) Improve rotary R-410A compressor efficiency to 10.0 EER
- (3) Change Main Control Board to a Switching Power Supply.
- (4) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (5) Increase number of evaporator tube rows from 3 rows to 4 rows
- (6) Increase baseline chassis size by: Width 4.5 in., Height 1.125 in., Depth 2.3 in.
- (7) Increase baseline chassis size by: Width 7 in., Height 1.125 in., Depth 7.2 in.
- (8) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.3.10 MarkN Results for 24000 Btu/h Louvered, No Reverse Cycle Room Air Conditioner (Product Class 5A) – Final Rule Analysis

Design Option Step	MarkN Filename	Compressor Map (EER, Capacity)	MarkN Outputs		Stand-by Power	IEER
			EER	Capacity		
R-410A Baseline	In_PC5A_Baseline_R410A.dat	9.79 EER 24.1 kBtu/h	7.87	22,477	1.4	7.84
1 Add Subcooler	In_PC5A_Step1.dat	9.79 EER 24.1 kBtu/h	8.17	23,007	1.4	8.14
2 Increase Chassis size to Medium Size	In_PC5A_Step2.dat	10.0 EER 23.1 kBtu/h	8.98	22,998	1.4	8.95
3 Increase Condenser Tube Rows	In_PC5A_Step3.dat	10.0 EER 23.1 kBtu/h	9.42	23,725	1.4	9.38
4 Stand-by Reduction	In_PC5A_Step4.dat	10.0 EER 23.1 kBtu/h	-	-	0.7	9.40
5 Increase Compressor Efficiency	In_PC5A_Step5.dat	10.3 EER 23.1 kBtu/h	9.68	23,740	0.7	9.66
6 Increase PSC Efficiency	In_PC5A_Step6.dat	10.3 EER 23.1 kBtu/h	10.05	23,766	0.7	10.03
7 DC Brushless Motor	In_PC5A_Step7.dat	10.3 EER 23.1 kBtu/h	10.18	23,775	0.7	10.15

- (1) Add subcooler with 0.282 in OD, 63 in. length, and condensate temperature of 95° F
- (2) Increase baseline chassis size by: Width 1.75 in., Height 0.25 in., Depth 2.53 in.
- (3) Increase number of condenser tube rows from 3 rows to 4 rows
- (4) Change Main Control Board to a Switching Power Supply.
- (5) Improve rotary R-410A compressor efficiency to 10.3 EER
- (6) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (7) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.3.11 MarkN Results for 28000 Btu/h Louvered, No Reverse Cycle Room Air Conditioner (Product Class 5B) – Final Rule Analysis

Design Option Step	MarkN Filename	Compressor Map (EER, Capacity)	MarkN Outputs		Stand-by Power	IEER
			EER	Capacity		
R-410A Baseline	In_PC5B _Baseline_R410A.dat	9.79 EER 27.1 kBtu/h	7.48	27,326	1.4	7.46
1 Add Subcooler	In_PC5B _Step1.dat	9.79 EER 27.1 kBtu/h	7.74	27,963	1.4	7.72
2 Increase Chassis size to Medium Size	In_PC5B _Step2.dat	10.0 EER 27.1 kBtu/h	8.29	28,024	1.4	8.26
3 Increase Chassis size to Large Size	In_PC5B _Step3.dat	10.0 EER 27.1 kBtu/h	9.05	27,400	1.4	9.03
4 Stand-by Reduction	In_PC5B _Step4.dat	10.0 EER 27.1 kBtu/h	-	-	0.7	9.04
5 Increase Compressor Efficiency	In_PC5B _Step5.dat	10.3 EER 27.1 kBtu/h	9.37	27,424	0.7	9.36
6 Increase Condenser Tube Rows	In_PC5B _Step6.dat	10.3 EER 27.1 kBtu/h	9.46	27,647	0.7	9.44
7 Increase PSC Efficiency	In_PC5B _Step7.dat	10.3 EER 27.1 kBtu/h	9.73	27,662	0.7	9.71
8 DC Brushless Motor	In_PC5B_Step7.dat	10.3 EER 27.1 kBtu/h	9.81	27,666	0.7	9.80

- (1) Add subcooler with 0.282 in OD, 63 in. length, and condensate temperature of 95º F
- (2) Increase baseline chassis size by: Width 1.75 in., Height 0.25 in., Depth 2.53 in.
- (3) Increase baseline chassis size by: Width 3.81 in., Height 4.69 in., Depth 2.53 in.
- (4) Change Main Control Board to a Switching Power Supply.
- (5) Improve rotary R-410A compressor efficiency to 10.3 EER
- (6) Increase number of condenser tube rows from 3 rows to 4 rows
- (7) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (8) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.3.12 MarkN Results for 8000 Btu/h Non-Louvered, No Reverse Cycle Room Air Conditioner (Product Class 8A) – Final Rule Analysis

Design Option Step	MarkN Filename	Compressor Map (EER, Capacity)	MarkN Outputs		Stand-by Power	IEER
			EER	Capacity		
R-410A Baseline	In_PC8A_8k_Baseline_R410A.dat	9.78 EER 7.2 kBtu/h	8.43	7,968	1.4	8.34
1 Increase Evap Width	In_PC8A _8k_Step1.dat	9.78 EER 7.2 kBtu/h	9.44	8,275	1.4	9.34
2 Add Subcooler	In_PC8A _8k_Step2.dat	9.78 EER 7.2 kBtu/h	9.59	8,348	1.4	9.48
3 Improve Compressor Efficiency	In_PC8A_8k_Step3.dat	10 EER 7.2 kBtu/h	9.78	8,352	0.7	9.66
4 Stand-by Reduction	In_PC8A_8k_Step4.dat	10 EER 7.2 kBtu/h	-	-	0.7	9.72
5 Increase PSC Efficiency	In_PC8A_8k_Step5.dat	10 EER 7.2 kBtu/h	10.26	8,360	0.7	10.20
6 DC Brushless Motor	In_PC8A_8k_Step6.dat	10 EER 7.2 kBtu/h	10.42	8,362	0.7	10.35

- (1) Increase evaporator width by 4 inches by redesigning the unit's user interface placement.
- (2) Add subcooler with 0.25 in. OD, 24.25 in. length, and condensate temperature of 95° F
- (3) Improve rotary R-410A compressor efficiency to 10.0 EER
- (4) Change Main Control Board to a Switching Power Supply
- (5) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (6) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

Table 5-D.3.13 MarkN Results for 12000 Btu/h Non-Louvered, No Reverse Cycle Room Air Conditioner (Product Class 8B) – Final Rule Analysis

Design Option Step	MarkN Filename	Compressor Map (EER, Capacity)	MarkN Outputs		Stand-by Power	IEER
			EER	Capacity		
R-410A Baseline	In_PC8B_Baseline_R410A.dat	9.03 EER 11.5 kBtu/h	8.37	11,869	1.4	8.32
1 Add Subcooler	In_PC8B_Step1.dat	9.03 EER 11.5 kBtu/h	8.57	12,037	1.4	8.51
2 Improve Compressor Efficiency	In_PC8B_Step2.dat	10 EER 11.5 kBtu/h	9.09	12,068	1.4	9.03
3 Increase Evap width	In_PC8B_Step3.dat	10 EER 11.1 kBtu/h	9.59	12,233	1.4	9.52
4 Stand-by Reduction	In_PC8B_Step4.dat	10 EER 11.1 kBtu/h	-	-	0.7	9.55
5 Increase PSC Efficiency	In_PC8B_Step5.dat	10 EER 11.1 kBtu/h	9.94	12,247	0.7	9.90
6 DC Brushless Motor	In_PC8B_Step6.dat	10 EER 11.1 kBtu/h	10.06	12,252	0.7	10.02

- (1) Add subcooler with 0.315 in. OD, 32 in. length, and condensate temperature of 95º F
- (2) Improve rotary R-410A compressor efficiency to 10.0 EER
- (3) Increase evaporator width by 6 inches by redesigning the unit’s user interface placement.
- (4) Change Main Control Board to a Switching Power Supply
- (5) Replace 50 percent efficiency PSC Motor with 70 percent efficiency PSC Motor.
- (6) Replace PSC Motor with an 80 percent efficiency Brushless DC Motor

5-D.4 DESCRIPTION OF SUPPORTING ANALYSES

This section presents additional description of two aspects of the engineering analysis for room air conditioners:

- Airflow modeling
- Motor pricing analysis

5-D.4.1 Room Air Conditioner Airflow Modeling

DOE introduced the room air conditioner airflow modelling analysis during the preliminary analysi phase of the rulemaking, and continued the use of this analysis (developed during the preliminary analysis phase) to support the energy modelling analysis performed during the final rule analysis. DOE did not receive comments on the airflow modeling analysis from stakeholders during the stakeholder comment period.

Many factors influence the airflow characteristics of a room air conditioner. The flow passages, heat exchangers, motor and fans all influence the airflow behavior within the room air conditioner. The MarkN model treats the heat exchanger dimensions, airflows, and motor power as separate, decoupled inputs, so the effect of physical changes in the airflow system on the airflow and motor power must be calculated separately from the model. DOE conducted an airflow calculation for each distinct airside design configuration.

DOE calculated the system airflow using an iterative approach with the following steps.

1. Select an airflow rate
2. Calculate fan or blower pressure rise
3. Calculate heat exchanger pressure drops using MarkN
4. Calculate other system pressure drops using spreadsheet calculation.
5. Add pressure drops and compare to fan or blower pressure rise.
    a. If fan pressure rise is higher than total pressure drop, increase is airflow rate and return to step 2
    b. If fan pressure rise is lower than total pressure drop, reduce airflow rate and return to step 2
    c. If fan pressure rise and total pressure drop are equal within reasonable tolerance, airflow calculation is complete.

The airflow modeling was based on calculating the pressure drops for the separate components of the room air conditioner and the pressure rise associated with the condenser fan or the evaporator blower. The approaches for calculating the pressure characteristics of the key component are listed in Table 5-D.4.1 below.

Table 5-D.4.14 Components Modeled to Calculate Room Air Conditioner Airflow

Component	Pressure Drop Value or Calculation Method	Sources
Evaporator Blower	Total Pressure Curve, adjusted using Fan Laws to match observed baseline unit performance.	Comair Rotron Fan Company Ltd 2008 ASHRAE Handbook: HVAC Systems and Equipment
Condenser Fan	Static Pressure Curve, adjusted using Fan Laws to match observed baseline unit performance.	Sofasco International 2008 ASHRAE Handbook: HVAC Systems and Equipment
Filter	0.25 inches of water	Filter vendors
Grilles and Louvers	Loss coefficient times velocity pressure	2005 ASHRAE Handbook: Fundamentals
Ducts and Transitions	Loss coefficient times velocity pressure	2005 ASHRAE Handbook: Fundamentals
Inflow to Condenser (transition from fan outlet to condenser)	50 percent of Condenser Pressure Drop	Estimate
Heat Exchangers	MarkN Outputs	MarkN Model

Fan performance curves provided a relationship between fan static pressure rise and airflow delivered by the fan. DOE obtained fan performance curves for fans similar in size and geometry to those used in the teardown units. The fan performance curves were adjusted as needed to match the sizes, rotational speed, and performance of the modeled room air conditioner fans using the fan laws.

On the evaporator side, DOE accounted for the airside pressure losses of the evaporator, the entry and exit grilles, the filter, and the impeller exit transition. On the condenser side, DOE accounted for the pressure losses of the condenser, the airflow path from the louvers to the fan inlet, and the fan exit plenum geometry.

The evaporator and condenser pressure drops were calculated by the MarkN model based on assumed airflow rate.

5-D.4.2 Room Air Conditioner Motor Analysis

DOE introduced the room air conditioner motor analysis during the preliminary analysi phase of the rulemaking, and continued the use of the analysis (developed during the preliminary analysis phase) to support the manufacturing cost modelling analysis performed during the final rule analysis. DOE did not receive comments on the motoranalysis from stakeholders during the stakeholder comment period.

Through examination of the teardown units and interviews with room air conditioner manufacturers, DOE determined that PSC motors are the primary motor technology used in room air conditioners to power the fan and blower assemblies. DOE examined improvement in motor efficiency, including higher efficiency PSC motors and brushless DC motors as design options for improving the energy-efficiency of the room air conditioners.

For all of the teardown units, DOE measured the power consumption of the motor at the available fan speeds. In accordance with the current test procedure, DOE used the data for the highest fan setting in its energy models, by using the energy consumption of each fan as a model input. Changes in the technology of the fan motor from design options are expressed in the model through changes in the fan motor energy consumption.

Figure 5-D.4.1 below shows the steps taken to develop the incremental costs for the PSC motor efficiency increases. DOE researched motor characteristics and prices and established a room air conditioner motor database. DOE developed separate correlations for price and efficiency as functions of motor weight and extended this analysis to develop a relationship for incremental costs for increases in efficiency for PSC motors.

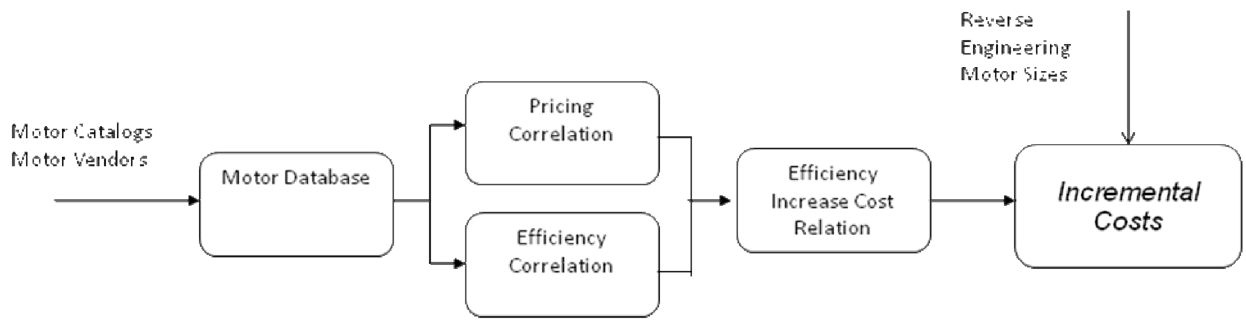

Figure 5-D.4.1 **Motor Incremental Cost Steps**

Teardown Unit Motor Sizes

The costs associated with increasing efficiency varied by motor shaft output rating. DOE examined the motor shaft output ratings associated with each of the different product classes, and used the baseline PSC shaft output rating as the basis of its efficiency analysis. Figure 5-D.4.2 shows the shaft output power of the motors that were examined during the reverse engineering work, identified by product class and room air conditioner efficiency level (baseline or high).

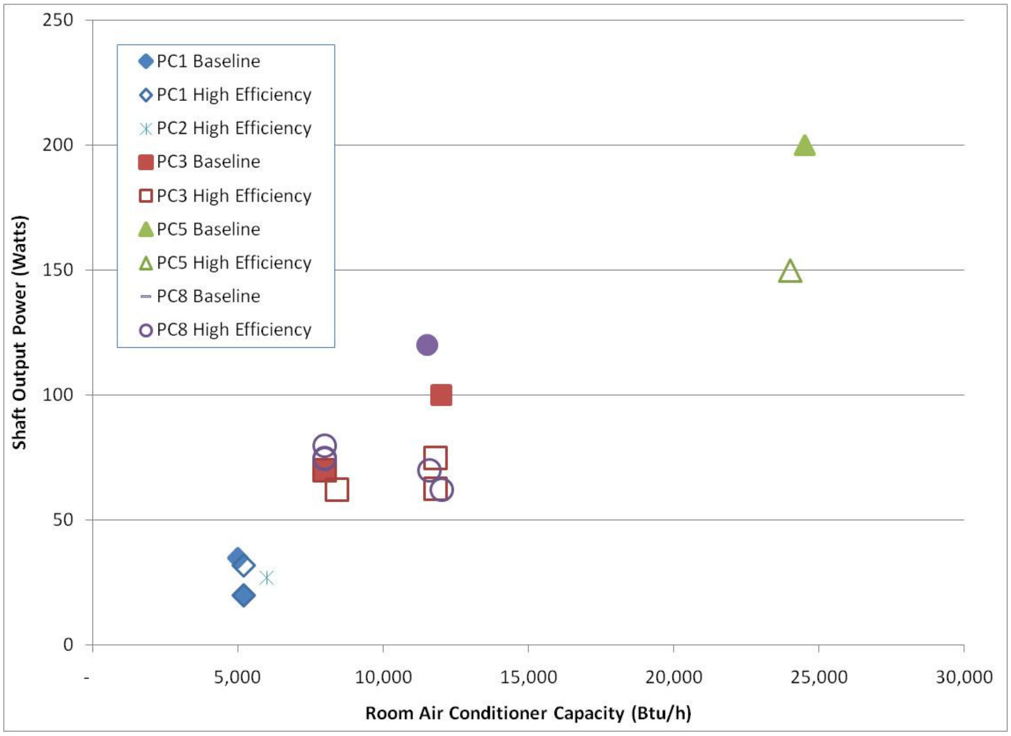

Figure 5-D.4.2 **Motor Shaft Output Ratings by Capacity for Different Product Classes**

Motor Efficiencies

DOE obtained PSC motor efficiency data from discussions with motor vendors, review of motor catalogs, and discussions with room air conditioner manufacturers. Most PSC motors found in room air conditioners have a full-load efficiency between 45 percent and 60 percent. High efficiency PSC motors can reach up to 70 percent efficiency. DOE selected an efficiency of 50 percent as the baseline for the room air conditioner PSC motors, and an efficiency of 70 percent for high efficiency PSC motors.

Cost as a Function of Weight

The DOE examined motor prices for a range of power ratings from a variety of motor vendors. DOE examined the correlation of motor prices with weights, incoming electrical current, incoming electrical voltage and shaft power for both single-shafted and double-shafted HVAC PSC motors.

DOE noted that, across motors of similar shaft output, motor frame size, and voltage, motor weight consistently increases as the efficiency increases. DOE found a strong correlation between motor pricing and motor weight across all motor data, and used a subset of this data to establish a basis for pricing PSC efficiency improvements. DOE established a statistically significant correlation between motor price and motor weight using data from two motor vendors, for motors with rated shaft output up to 0.25 horsepower (186.5 Watts (W)). Figure 5-D.4.3 below shows the motor data used to establish this relationship.

The correlation establishes the increased cost of a motor per increase in weight, for PSC motors within the range of established room air conditioner motors. It was established as statistically significant through statistical t-tests and DOE used the ratio of cost per weight increase to help calculate the cost of increasing the motor efficiency by a given amount.

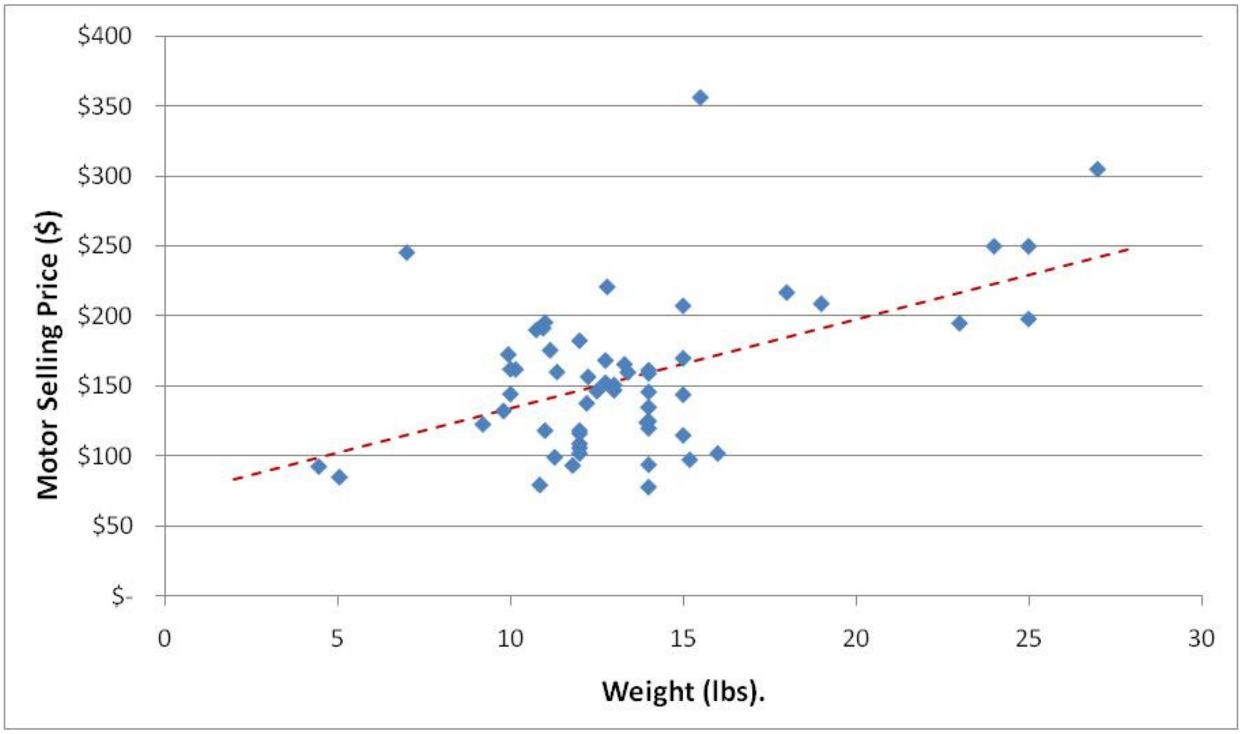

Figure 5-D.4.3 **Motor Pricing Increase with Weight Increase**

Efficiency as a Function of Weight

Available motor data did not generally included efficiency. However, full-load current data was available for most motor entries. Current is an indicator of efficiency, assuming that power factor does not change significantly among motors that are compared. The relationships between current and motor weight for a range of applicable motor sizes is illustrated in Figure 5-D.4.4 below. These relationships were developed from the available motor data.

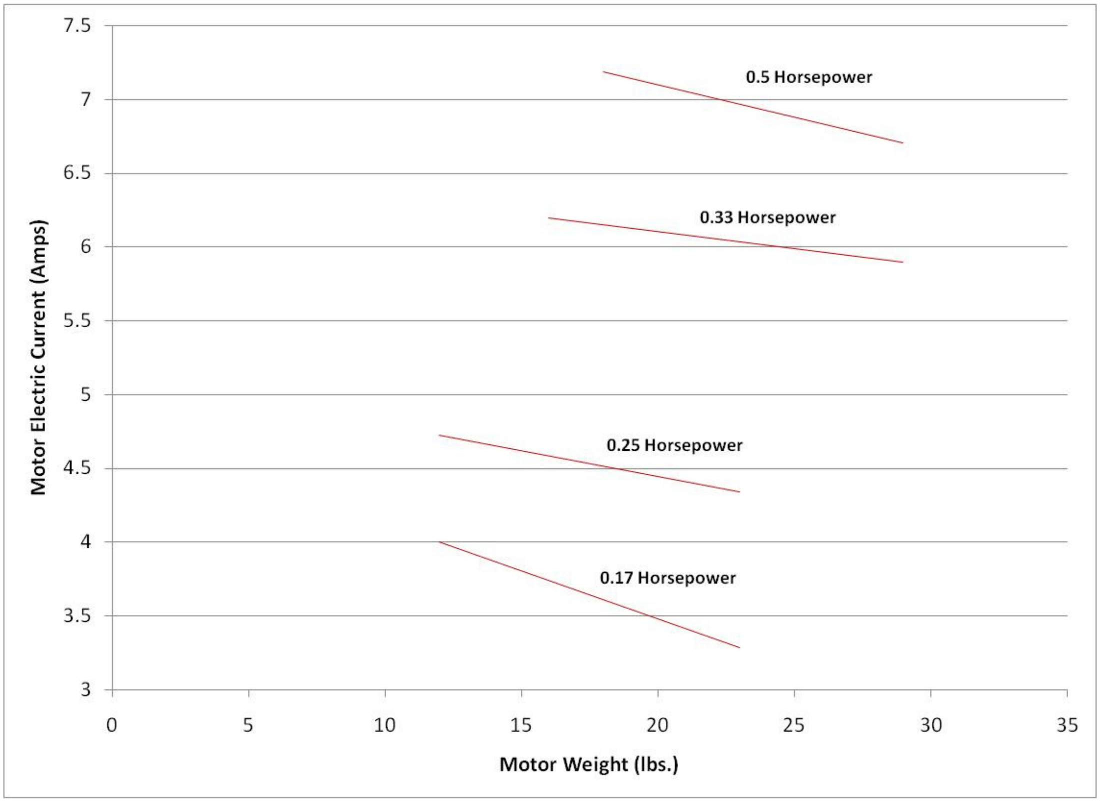

Figure 5-D.4.4 **Weight-Current Curves for room air conditioner PSC motors, grouped by shaft output**

Cost as Function of Efficiency

DOE combined the cost/weight and the current/weight relationships to develop a relationship for the cost of increasing motor efficiency from 50 percent to 70 percent as a function of shaft output power. DOE determined the incremental cost for this efficiency increase for the shaft output power levels of interest using the equation below.

$$Cost_{Efficiency} = (Current_{High-Eff} - Current_{Baseline}) \times \left(\frac{\Delta Weight}{\Delta Current}\right) \times \left(\frac{\Delta Cost}{\Delta Weight}\right)$$

The curve shown in Figure 5-D.4.5 below illustrates the resulting cost increase as a function of shaft power. This relationship was developed for shaft power up to roughly 100W. The high end of the relationship was extrapolated linearly to 200W to represent the cost of a high efficiency PSC motor for a product class 5 product. DOE expects that the linear extrapolation is conservative, since the curve's slope decreases as shaft power increases.

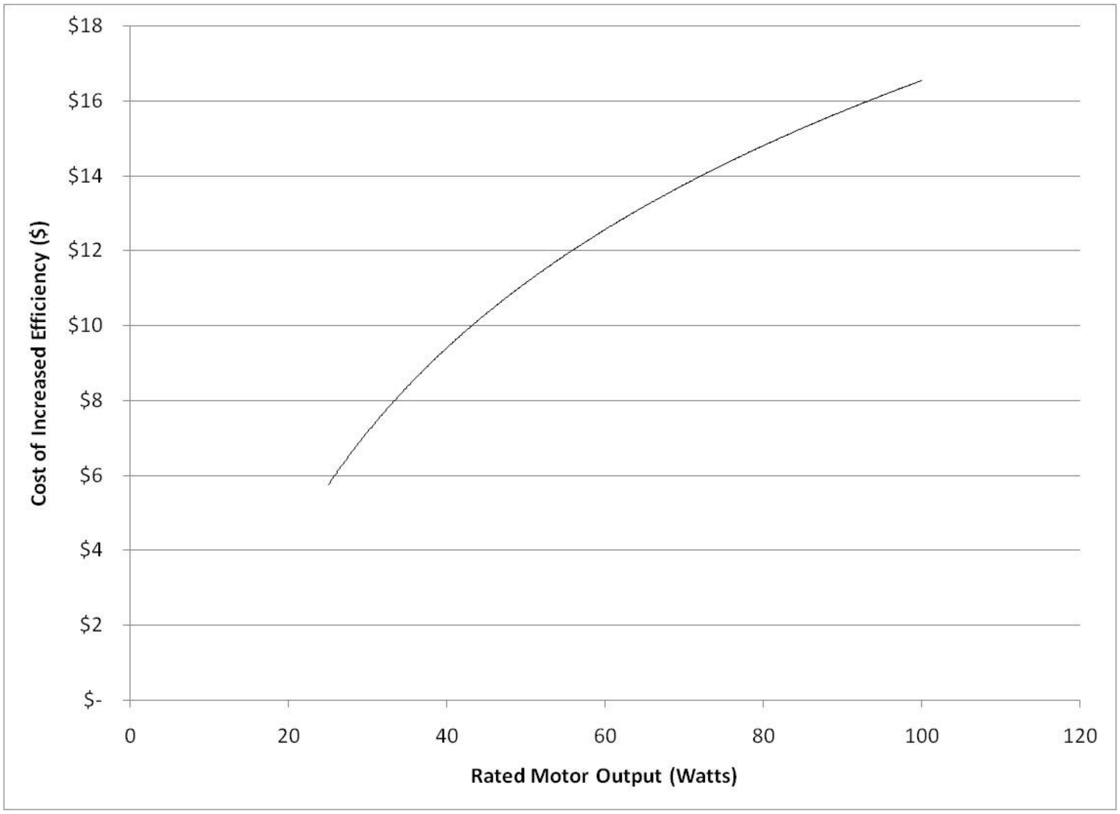

Figure 5-D.4.5 **Cost of Increased Efficiency for Different Motor Output Ratings**

Brushless DC Motors

BLDC motors are a more efficient alternative to PSC motors, and are already in use in products such as in PTACs. BLDC motors provide the same output power as PSC motors at higher efficiencies. DOE obtained BLDC motor efficiency data from discussions with motor vendors, review of motor catalogs, and discussions with room air conditioner manufacturers. Typical BLDC motors have efficiencies between 70 percent and 90 percent. However, in searching for replacement motors for room air conditioners, DOE found that the average efficiency of these motors is approximately 80 percent; motors with 90 percent efficiency are not very common. DOE selected a BLDC motor efficiency of 80 percent for the analysis.

DOE searched motor catalogs and contacted motor vendors to develop a database of BLDC motor characteristics. Using this data, DOE developed a representative relationship for the cost premium of BLDC motors as a function of shaft power. This is shown in Figure 5-D.4.6.

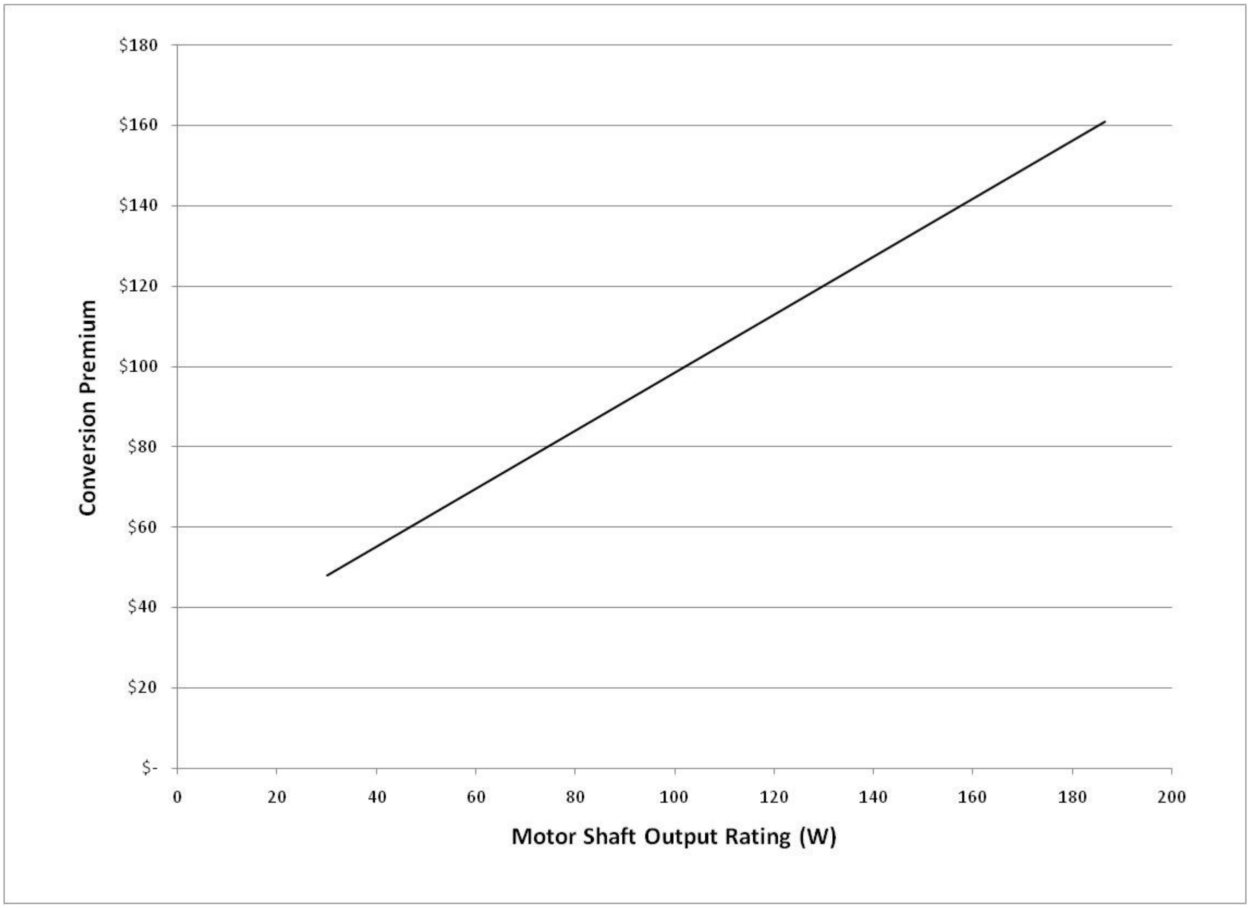

Figure 5-D.4.6 **Brushless DC Motor Cost Curve by Shaft Output Rating**

APPENDIX 6-A. DETAILED DATA FOR PRODUCT COST MARKUPS

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APPENDIX 6-A. DETAILED DATA FOR PRODUCT COST MARKUPS

6-A.1 MARKUPS VALIDATION

This appendix provides further details on the markups validation presented in chapter 6, Markups to Determine Product Cost. As part of its market data collection, DOE assembled a data base with retail Internet prices for a large number of clothes dryer models at baseline efficiency. Additionally, DOE used detailed sales data from NPD Group, a market research firm, to estimate room air conditioner retail prices at baseline efficiency for three of the product classes.[a]

For each model, DOE divided the retail price by the estimated manufacturer cost for the appropriately-sized clothes dryer or room air conditioner (estimated as described in chapter 5) to derive an implicit markup. This markup would include the manufacturer markup and the retail markup. To be comparable with the overall markups shown in Table 6.6.1, DOE added U.S.-average sales tax values for each product. Table 6-A.1.1 and Table 6-A.1.2 provide details of the baseline markup validation for select clothes dryer and room air conditioner product classes, as defined in the Framework Document.[1] Room air conditioner product classes are defined by louvered or non-louvered sides, and by Btu per hour cooling capacity. Clothes dryer product classes are defined by drum capacity. Because the manufacturer production costs differ by product class, a separate markup is estimated for each product class.

In chapter 6, Markups to Determine Product Cost, DOE estimates an overall baseline markup of 1.95 for both room air conditioners and clothes dryers. As illustrated by Table 6-A.1.1 and Table 6-A.1.2, DOE's markup validation of detailed sales data arrives at similar markup estimates for most product class, ranging between 1.71 and 2.40.

Some product classes were omitted due to an inconsistency between the efficiency levels used to estimate manufacturer cost and the levels found in the retail price data. The Internet retail data for natural gas clothes dryers included only models significantly more efficient than the baseline efficiency of 2.67 lbs/kWh defined for this product class, and would thus not be appropriate for the estimation of a baseline markup. The NPD data set for room air conditioners reports efficiency in increments of 0.5 EER. Manufacturer production costs for less than 20,000 Btu/h units with louvered sides are reported for units with base efficiencies of 9.7 and 9.8 EER. These categories could not be satisfactorily matched to NPD retail price data.

[a] For the other product classes, there was an imperfect match between efficiency levels of retail data and those used to estimate manufacturing cost.

Table 6-A.1.1 Clothes Dryer Markup Validation (Prices in 2008$)

Clothes Dryer Type	Units in Price Data Set	Energy Efficiency (lbs/kWh)	Mfr. Production Cost[b]	Average Retail Price	Implied Retail Markup	Sales Tax	Total Markup
Electric, 4.4 or more cu. ft.	119	3.01	$438	$987	2.25	6.53%	**2.40**
Electric, less than 4.4 cu. ft.	70	3.13	$379	$608	1.61	6.53%	**1.71**

Table 6-A.1.2 Room Air Conditioner Markup Validation (Prices in 2008$)

Air Conditioner Type	Units in Price Data Set	Energy Efficiency (EER)	Mfr. Production Cost	Average Retail Price	Implied Retail Markup	Sales Tax	Total Markup
Louvered sides, 20,000 Btu/h or more	186	8.5	$346	$577	1.43	6.83%	**1.78**
No louvered sides, 8,000–9,999 Btu/h	86	8.5	$217	$362	1.67	6.83%	**1.79**
No louvered sides, 10,000–14,999 Btu/h	67	8.5	$238	$471	1.67	6.83%	**2.11**

[b] Manufacturer cost is an average of vent-less and vented, so as to be representative of the models in the Internet retail data for clothes dryers.

REFERENCES

1 U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy Building Technologies Program. *Energy Conservation Standards Rulemaking Framework Document for Residential Clothes Dryers and Room Air Conditioners.* October 24, 2007. pp. 13-15.

APPENDIX 7-A. RECS 2005 VARIABLES AND VALUES

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APPENDIX 7-A. RECS 2005 VARIABLES AND VALUES

7-A.1 INTRODUCTION

The U.S. Department of Energy (DOE) created a database containing a subset of the records and variables from DOE's Energy Information Administration (EIA)'s RECS 2005.[1] DOE used this RECS subset in the life-cycle cost (LCC) analysis of the Room Air Conditioners and Clothes Dryers Rulemaking. This appendix explains the variable name abbreviations and provides definitions of the variable values. For the entire RECS 2005 dataset, refer to http://www.eia.doe.gov/emeu/recs/recspubuse05/pubuse05.html.

7-A.2 SAMPLE DETERMINATION

7-A.2.1 Clothes Dryers

The subset of RECS households used for clothes dryers met all of the following criteria:

- The household had a clothes dryer.
- The household had and used a clothes washer.
- Clothes dryer fuel was electricity, natural gas, or LPG.
- Clothes dryer use was greater than zero.

The RECS 2005 variables used to match the selection criteria are listed in Table 7-A.2.1.

Table 7-A.2.1 Selection of RECS 2005 Records for Clothes Dryers

Product Class	Selection Criterion	# of Records	# of US Households Represented *(million)*
Electric	WASHLOAD ≠ 9 DRYRFUEL = 5 DRYRUSE > 0	2655	67.0
Gas	WASHLOAD ≠ 9 DRYRFUEL = 1 OR 2 DRYRUSE > 0	756	20.3
Electric Ventless	WASHLOAD ≠ 9 DRYRFUEL = 5 DRYRUSE > 0 Type of Housing = Mobile home, multifamily, or single family (≤1000 sq. ft., no attached garage, no basement)	570	14.3

Table 7-A.2.2 RECS 2005 Variables Used for Clothes Dryers

Variable	Description
Location Variables	
REGIONC	Census region
DIVISION	Census division
DIVISION + LRG STATE*	Combined large state (LRGSTATE) and census division (DIVISION)
Household Characteristics Variables	
DOEID	DOE 4-digit identification number
NWEIGHT	Final weight
YEARMADE	Year residence built
WASHLOAD	Average number of wash loads per week in household clothes washer
DRYRUSE	Clothes dryer usage frequency
BTUELCDR	Electricity used for drying clothes
DRYRFUEL	Clothes dryer fuel
BTUNGAPL	Natural gas appliance use
BTULPAPL	LPG appliance use
TYPEHUQ	Type of housing unit
TOTSQFT	Household square footage
CELLAR	Household has a basement
PRKGPLC1	Household has attached garage

* Not part of RECS 2005 variables.

7-A.2.2 Room Air Conditioners

The subset of RECS 2005 records used for room air conditioners in this analysis met all of the following criteria:

- A room air conditioner was present in the household.
- Room air conditioner energy consumption was greater than zero.

To divide the subset of RECS records into the appropriate product classes, DOE used Energy Star sizing guidelines for room air conditioners[2] as shown in Table 7-A.2.3 and the cooling square footage area from RECS 2005 for each household. For households with multiple air conditioners, DOE divided the square footage by the number of room air conditioners to derive the average cooling square footage area per room air conditioner. DOE made adjustments to the guidelines for records where more than two people lived in the household. For each of these households this resulted in adding 600 Btu/h to the capacity needed for each additional person. The RECS 2005 variables used to match the selection criteria are listed in Table 7-A.2.4. DOE used the same RECS 2005 subset to characterize both product classes 3 and 8.

Table 7-A.2.3 Energy Star Sizing Guidelines for Room Air Conditioners

Area to be cooled	Capacity Needed (BTUs per hour)	Room Air Conditioner product class Assignment
100–150	5,000	<6,000 Btu/h with louvers
150–250	6,000	
250–350	7,000	8,000–13,999 Btu/h with louvers and without louvers
300–350	8,000	
350–400	9,000	
400–450	10,000	
450–550	12,000	
550–700	14,000	
700–1,000	18,000	≥ 20,000 Btu/h with louvers
1,000–1,200	21,000	
1,200–1,400	23,000	
1,400–1,500	24,000	
1,500–2,0000	30,000	
2,000–2,500	34,000	

Table 7-A.2.4 Selection of RECS 2005 Records for Room Air Conditioners

Product Class	Selection Criterion	# of Records	# of US Households Represented *(million)*	# of Room AC Units Represented *(million)*
1	COOLTYPE = 2 USEWWAC ≠ 0 Average adjusted capacity ≤ 6,000 Btu/h	266	9.2	16.9
3 and 8	COOLTYPE = 2 USEWWAC ≠ 0 Average adjusted capacity > 6,000 Btu/h and ≤ 14,000 Btu/h	890	38.9	97.1
5	COOLTYPE = 2 USEWWAC ≠ 0 Average adjusted capacity ≥ 18,000 Btu/h	66	2.5	5.4

Table 7-A.2.5 RECS 2005 Variables Used for Room Air Conditioners

Variable	Description
Location Variables	
DIVISION	Census division
DIVISION + LRG STATE*	Combined large state (LRGSTATE) and census division (DIVISION)
CD65	Cooling degree-days to base 65, 1-04 TO 12-04
Household Characteristics Variables	
DOEID	DOE 4-digit identification number
NWEIGHT	Final weight
TYPEHUQ	Type of housing unit
COOLTYPE	Type of air conditioning equipment
ACHOUSE	Central AC cooling usage
ACROOMS	Number of rooms cooled by central AC during the summer
NUMBERAC	Number of window or wall air conditioning units
WWACAGE	Approximate age of window or wall air conditioning unit
USEWWAC	Usage description for most-used window or wall air conditioner
TOTCSQFT	Household square footage
BTUELCOL	Electricity used for household cooling
LocationID*	Not part of RECS, added to link to weather data (See App. 7-E)

* Not part of RECS 2005 variables.

7-A.3 RECS 2005 DATABASE VARIABLE RESPONSE CODES

Table 7-A.3.1 provides the response codes for all RECS 2005 variables used in the Room Air Conditioner and Clothes Dryer samples.

Table 7-A.3.1 RECS 2005 Variable Response Codes

Variable	Definition
Common Variables (Alphabetical)	
CDD65	Cooling degree-days to base 65, 1-04 TO 12-04
DIVISION	Census division 1 = New England 2 = Middle Atlantic 3 = East North Central 4 = West North Central 5 = South Atlantic 6 = East South Central 7 = West South Central 8 = Mountain 9 = Pacific
DIVISION + LRG STATE*	Combined large state (LRGSTATE) and census division (DIVISION) 1 = New England 2 = Middle Atlantic (not including New York) 3 = East North Central 4 = West North Central 5 = South Atlantic (not including Florida) 6 = East South Central 7 = West South Central (not including Texas) 8 = Mountain 9 = Pacific (not including California) 10 = New York 11 = California 13 = Texas 14 = Florida
DOEID	DOE 4-digit identification number
LRGSTATE	Large state designation 0 = Other 1 = New York 2 = California 3 = Texas 4 = Florida
NHSLDMEM	Number that live in household
NWEIGHT	Final weight
REGIONC	Census region 1 = Northeast 2 = Midwest 3 = South 4 = West
TOTSQFT	Household square footage
TYPEHUQ	Type of housing unit 1 = Mobile Home 2 = Single-family detached 3 = Single-family attached 4 = Apartment building with 2-4 units 5 = Apartment building with 5 or more units

YEARMADE	Year home built 1 = Before 1940 2 = 1940-49 3 = 1950-59 4 = 1960-69 5 = 1970-79 6 = 1980-84 7 = 1985-89 8 = 1990-94 9 = 1995-99 10 = 2000-2002 11 = 2003 12 = 2004 13 = 2005
Sample Variables (Alphabetical)	
ACHOUSE	Central AC cooling usage 1 = All of the rooms 2 = Only some of the rooms 0 = None of the rooms cooled
ACROOMS	Number of rooms cooled by central AC during the summer
ADQINSUL	Home/Apartment insulation 1 = Well insulated 2 = Adequately insulated 3 = Poorly insulated 4 = No insulation
AGECENAC	Central air conditioning equipment age 1 = Less than 2 years old 2 = 2 to 4 years old 3 = 5 to 9 years old 4 = 10 to 19 years old 5 = 20 years or older 6 = As old as the home
ATTCCOOL	How much of attic air-conditioned during summer months? 1 = All 2 = Part 3 = None
BASECOOL	How much of basement air-conditioned during summer months? 1 = All 2 = Part 3 = None
BEDROOMS	Number of bedrooms in the home
BTUELCDR	Electricity clothes dryer use estimated (thousands of BTU) 9999999=Not Applicable
BTUELCOL	Electricity cooling use estimated (thousands of BTU) 9999999=Not Applicable
BTULPAPL	LPG appliance use estimated (thousands of BTU) 9999999=Not Applicable
BTUNGAPL	Natural gas appliance use estimated (thousands of BTU) 9999999=Not Applicable

CATHCEIL	Any cathedral ceilings in the home/apartment? 1 = Yes 2 = No
CELLAR	Household has a basement 1 = Yes 0 = No 9 = Skip
CENACHP	Is your central air-conditioning system a heat pump? 1 = Yes 0 = No
COOLTYPE	Type of air conditioning equipment 1 = Central system 2 = Individual units in the windows or wall 3 = Both central and individual units
DRYRFUEL	Clothes dryer fuel 1 = Natural gas from underground pipes 2 = Bottled Gas (LPG or Propane) 5 = Electricity 99 = No Answer/Not Applicable
DRYRUSE	Clothes dryer usage frequency 1 = Use it every time you wash clothes 2 = Use it for some, but not all, loads of wash 3 = Use it infrequently
ESWWAC	Energy Star AC unit? 1 = Yes 0 = No
FINATTRMS	Number of finished rooms in the attic
FINBASERMS	Number of finished rooms in the basement
GARGCOOL	Garage air-conditioned during the summer months? 1 = Yes 0 = No
HIGHCEIL	Unusually high ceilings in home? 1 = Yes 0 = No
LocationID*	Not part of RECS, added to link to weather data (See App. 7-E)
NUMBERAC	Number of window or wall air conditioning units
PRKCPLC1	Household has attached garage 0 = No 1 = Yes
TREESHAD	Home shaded by trees from afternoon summer sun? 1 = Yes 0 = No
TOTATTCSQFT	Square footage of attic
TOTBASESQFT	Square footage of basement
TOTGARGSQFT	Square footage of garage

TYPEGLASS	Type of glass in windows in home/apartment 1 = Single-pane glass 2 = Double-pane glass 3 = Double-pane glass with Low-e coating 4 = Triple-pane glass 5 = Triple-pane glass with Low-e coating
USECENAC	Central AC usage during summer 0 = Not used at all 1 = Turned on only a few days or nights when really needed 2 = Turned on quite a bit 3 = Turned on just about all summer
USEWWAC	Usage description for most-used window or wall air conditioner 0 = Not used at all 1 = Turned on only a few days or nights when really needed 2 = Turned on quite a bit 3 = Turned on just about all summer
WASHLOAD	Average number of wash loads per week in household clothes washer 1 = 1 load or less each week 2 = 2 to 4 loads 3 = 5 to 9 loads 4 = 10 to 15 loads 5 = More than 15 loads
WINDOWS	Approximate number of windows (not including unheated areas) 10 = 1 or 2 20 = 3 to 5 30 = 6 to 9 41 = 10 to 15 42 = 16 to 19 50 = 20 to 29 60 = 30 or more 00 = None
WWACAGE	Approximate age of window or wall air conditioning unit 1 = Less than 2 years old 2 = 2 to 4 years old 3 = 5 to 9 years old 4 = 10 to 19 years old 5 = 20 years or older 6 = As old as the home (if volunteered)

* Not part of RECS 2005 variables.

REFERENCES

1. U.S. Department of Energy - Energy Information Administration, *Residential Energy Consumption Survey: 2005 Public Use Data Files,* 2005. <http://www.eia.doe.gov/emeu/recs/recspubuse05/pubuse05.html>

2. Energy Star, Properly Sized Room Air Conditioners. <http://www.energystar.gov/index.cfm?c=roomac.pr_properly_sized>

APPENDIX 7-B. CBECS 2003 VARIABLES AND VALUES

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APPENDIX 7-B. CBECS 2003 VARIABLES AND VALUES

7-B.1 INTRODUCTION

The U.S. Department of Energy (DOE) created a database containing a subset of the records and variables from DOE's Energy Information Administration (EIA)'s CBECS 2003.[1] DOE used this CBECS subset in the life-cycle cost (LCC) analysis of the Room Air Conditioners (RAC) and Clothes Dryers Rulemaking. This appendix explains the variable name abbreviations and provides definitions of the variable values. For the entire CBECS 2003 dataset, refer to http://www.eia.doe.gov/emeu/cbecs/cbecs2003/public_use_2003/cbecs_pudata2003.html.

7-B.2 SAMPLE DETERMINATION

7-B.2.1 Room Air Conditioners

The subset of CBECS records used for room air conditioners met all of the following criteria:

1) A room air conditioner served as a source of air conditioning.[a]
2) Building is not vacant,
3) A room air conditioner is used as the primary equipment to cool at least a portion of the building.[b]

The CBECS 2003 variables used to match the selection criteria are listed in Table 7-B.2.1. Buildings were assigned to the sub-samples based on the amount of cooling area per room air conditioner, with similar reasoning as for residential room air conditioners (see appendix 7-A). CBECS 2003 provides for the total cooling square footage and the fraction of cooling by the room air conditioner for each building record, but it does not provide the number of room air conditioners used by the building, so all of the total room air conditioner cooling square footage is used to determine the subsamples.

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[a] Packaged Terminal Air Conditioner (PTAC) systems could also be listed as room air conditioners, therefore DOE tried to select buildings with only room air conditioners by selecting buildings that did not have a PTAC type heating system.

[b] Sum of the fraction of all other cooling equipment is less than 100 percent.

Table 7-B.2.1 Selection of CBECS 2003 Records for Room Air Conditioners

Product Class	Algorithm	# of Records	# of Commercial Buildings Represented *(million)*
Total sample		440	0.4
>6000 Btu/h	Total RAC Cooling sq. ft. > 0 (Cooling sq. ft. per unit < 300)	440	0.4
8,000 to 13,999 Btu /h	Total RAC Cooling sq. ft. > 300 (Cooling sq. ft. per unit between 300 and 900)	400	0.3
≥ 20,000 Btu /h	Total RAC Cooling sq. ft. > 900 (Cooling sq. ft. per unit > 900)	352	0.3

Table 7-B.2.2 CBECS 2003 Variables Used for Room Air Conditioners

Variable	Description
Location Variables	
CENDIV8	Census division
HDD658	Heating degree days (base 65)
CDD658	Cooling degree days (base 65)
Household Characteristics Variables	
PUBID8	CBECS building identifier
ADJWT8	Final full sample building weight
SQFT8	Building square footage
MAINCL8	Main building cooling equipment
COOLP8	Percent of building cooled
ACWNWP8	Percent of building cooled by individual room air conditioner(s)
OPEN248	Building open 24 hours a day
OPNMF8	Building open during week
OPNWE8	Building open on weekend
WKHRS8	Building total weekly operating hours
AdjRACpct*	Determined using CBECS variables as follows: [COOLP8] * [ACWNWP8]
CLIMATE8	Climate zone (30-year average)
ELCNS8	Annual electricity consumption (kWh)
ELEXP8	Annual electricity expenditures ($)

* Not part of CBECS 2003 variables.

7-B.3 CBECS 2003 DATABASE VARIABLE RESPONSE CODES

Table 7-B.3.1 provides the response codes for all CBECS 2003 variables used in the Room Air Conditioner and Clothes Dryer samples.

Table 7-B.3.1 CBECS 2003 Variable Response Codes

Variable	Definition
ACWNWP8	Percent of building cooled by individual room air conditioner(s)
AdjRACpct*	Determined using CBECS variables as follows: [COOLP8] * [ACWNWP8]
ADJWT8	Final full sample building weight
CDD658	Cooling degree days (base 65)
CENDIV8	Census division 1 = New England 2 = Middle Atlantic 3 = East North Central 4 = West North Central 5 = South Atlantic 6 = East South Central 7 = West South Central 8 = Mountain 9 = Pacific
CLIMATE8	Climate zone (30-year average) 1 = < 2,000 CDD, > 7,000 HDD 2 = < 2,000 CDD, 5,500-7,000 HDD 3 = < 2,000 CDD, 4,000-5,499 HDD 4 = < 2,000 CDD, < 4,000 HDD 5 = ≥ 2,000 CDD, < 4,000 HDD 7 = Withheld to protect confidentiality
COOLP8	Percent of building cooled
ELCNS8	Annual electricity consumption (kWh)
ELEXP8	Annual electricity expenditures ($)
HDD658	Heating degree days (base 65)
MAINCL8	Main building cooling equipment 1 = Packaged A/C units 2 = Residential-type central A/C 3 = Individual room A/C 4 = Heat pumps for cooling 5 = District chilled water piped in 6 = Central chillers inside the building 7 = "Swamp" coolers or evaporative coolers 8 = Other cooling equipment
OPEN248	Building open 24 hours a day 1 = Yes 2 = No 7 = Not ascertained 8 = Refused 9 = Don't know

OPNMF8	Building open during week 1 = Yes 2 = No 7 = Not ascertained 8 = Refused 9 = Don't know
OPNWE8	Building open on weekend 1 = Yes 2 = No 7 = Not ascertained 8 = Refused 9 = Don't know
PUBID8	CBECS building identifier
SQFT8	Building square footage
WKHRS8	Building total weekly operating hours

* Not part of CBECS 2003 variables.

REFERENCES

1. U.S. Department of Energy - Energy Information Administration, *Commercial Buildings Energy Consumption Survey*, 2003. <http://www.eia.doe.gov/emeu/cbecs/>

APPENDIX 7-C. LCC ENERGY USE CALCULATIONS

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APPENDIX 7-C. LCC ENERGY USE CALCULATIONS

7-C.1 INTRODUCTION

This appendix contains the calculation methodology for calculating the energy use of clothes dryers and room air conditioners (RAC) in the life-cycle cost (LCC) analysis.

7-C.2 CLOTHES DRYERS

DOE determined the annual energy consumption by-products that would meet a potential future standard by multiplying the number of cycles per year by the energy use per cycle.

7-C.2.1 Number of Cycles

DOE estimated the number of clothes dryer cycles per year for each sample home using data given by RECS on the number of laundry loads (clothes washer cycles) washed per week and the frequency of clothes dryer use. The responses in RECS fall into one of the bins shown in Tables 7-C.2.1 and 7-C.2.2. For each question, DOE assumed a uniform distribution within the boundaries of each bin and randomly assigned a value from within the appropriate range to each sample household.

Table 7-C.2.1 Number of Loads Washed per Week Based on RECS Sample

Bin	Loads per Week	Derived Loads per Year*	
		Min	Max
1	1 load or less	0	78
2	2 to 4 loads	78	234
3	5 to 9 loads	234	494
4	10 to 15 loads	494	806
5	More than 15 loads	806	1118

* The ranges reflect the inclusion of values in between the given bin boundaries.

Table 7-C.2.2 RECS Sample Clothes Dryer Usage

Bin	Description	Fraction of Washer Cycles When Dryer is used	
		Min	Max
1	Use it every time wash clothes	1	1
2	Use it for some, but not all, loads of wash	0.50	1
3	Use it infrequently	0.00	0.50

The responses to the above questions vary among sample households using different clothes dryer products, so they yield somewhat different values for the average annual number of clothes dryer cycles for each product class (see Table 7-C.2.3).

Table 7-C.2.3 RECS Sample Clothes Dryers Utilization

	Product Class		
	Electric Standard	**Gas**	**Vent-less**
Washer loads per year	301	292	268
Clothes dryer frequency*	0.95	0.93	0.94
Clothes dryer loads per year	283	274	251

* Fraction of washer loads
** Accounts for fraction of households that have a clothes washer, but no clothes dryer

7-C.2.2 Energy Use Calculation

For each considered efficiency level, DOE derived the field energy use by separately estimating the active mode and standby mode energy use and then adding them together. The DOE test procedure calculates active mode energy consumption by dividing the weight (lbs) of clothes dried per cycle (8.45 lbs for standard and 3 lbs for compact clothes dryers) by the Combined Energy Factor (CEF) (lbs/kWh) and subtracting standby power.[a] DOE adjusted the test procedure energy use to reflect field conditions by making an adjustment for clothes dryer load weight and moisture removal factor.

For each household, DOE determined the per-cycle test procedure clothes dryer energy use during active mode by using the following formula:

$$TP_{Active} = \left[\left(\frac{avgLoadWeight_{TP}}{CEF} * CD\_Cycles_{TP}\right) - \left(Stby\_hrs_{TP} * \frac{Stby}{1000}\right)\right] / CD\_Cycles_{TP}$$

Where:

$avgLoadWeight_{TP}$ =	average load weight in the test procedure, lbs,
CEF =	efficiency of the clothes dryer during active mode, lbs per kWh,
CD_Cycles_{TP} =	test procedure clothes dryer cycles per year,
$Stby\_hrs_{TP}$ =	test procedure standby hours, and,
$Stby$ =	clothes dryers standby power usage, watts.

For each household, DOE determined the field adjustment for clothes dryer energy use during active mode by using the following formula:

[a] See chapter 5 for more information on how to convert from CEF to EF.

$$EnergyUse_{Active} = \left[\left(TP_{Active} - RMC_{adj} \right) * \left(\frac{avgLoadWeight_{Field}}{avgLoadWeight_{TP}} \right) * \left(\frac{RMC_{Field} - RMC_{Field,Enc}}{RMC_{TP} - RMC_{TP,End}} \right) + RMC_{Adj} \right] * CD\_Cycles$$

Where:

TP_{Active} =	test procedure energy use per cycle, kWh per cycle,
RMC_{adj} =	RMC adjustment factor for the fixed energy use, kWh per cycle,
$avgLoadWeight_{TP}$ =	average load weight in the test procedure, lbs,
$avgLoadWeight_{Field}$ =	average load weight for each household, lbs,
RMC_{TP} =	remaining moisture content in the test procedure, 57.5 percent,
$RMC_{TP,Enc}$ =	remaining moisture content at the end of the cycle in the test procedure, 5 percent,
RMC_{Field} =	remaining moisture content for the household, percent,
$RMC_{Field,End}$ =	remaining moisture content at the end of the cycle for the household, percent,
CD_Cycles =	clothes dryer cycles per year.

DOE assigned a fixed energy use adjustment (RMC_{adj}) equal to 0.25 kWh/cycle to account for energy required to heat the clothes dryer cabinet.

To assign a field average load weight ($avgLoadWeight_{Field}$) for each household, DOE developed a distribution of load weights by matching the listed tub sizes for models in the July 2010 California Energy Commission (CEC) directory with the correlations between tub size and average pounds in the DOE test procedure. To account for a wider distribution of households that do not wash the average pounds in the DOE test procedure, DOE added a ±25 percent adjustment factor. The average load weights for standard-size units range from 3.8 lbs. to 13.7 lbs., with a mean value of 8.45 lbs, which matches DOE's proposed clothes dryer procedure value.

To assign a field remaining moisture content (RMC_{Field}) value for each household, DOE used the 2008 shipment weighted values provided by AHAM for front loader and top loader washers. The shipment weighted value is 38.1 percent for front loaders and 51 percent for top loaders, with an overall shipment weighted RMC value of 47 percent. In 2008, front loaders represented 31 percent of shipments, while top loaders represented the remaining 69 percent, so the overall RMS shipment weighted value is 47-percent. This shipment weighted average RMC value in the AHAM data is based on the clothes washer RMC which uses a correction factor to normalize testing results from different lots of test cloth. As a result, DOE determined that an initial clothes dryer RMC of 57.5 percent more accurately represents the moisture content of current laundry loads after a wash cycle and therefore adjusted the shipment weighted value for front loaders and top loaders accordingly. In order to get a distribution of values, DOE used the number of models listed at each unadjusted RMC in the July 1010 CEC directory.[1] The adjusted RMC values used in the analysis range from 36 percent to 64 percent for front loaders, with an average of 47 percent, and from 42 percent to 75 percent for front loaders, with an average of 62 percent. The overall average value of 57.5 percent matches DOE's proposed clothes dryer procedure value.

To assign a field remaining moisture content at the end of the cycle ($RMC_{Field,End}$) value for each household, DOE used a uniform distribution of 0 to 5 percent. In comparison, the DOE test procedure uses 5 percent.

Using the above approach, DOE calculated a unique value for the clothes dryer annual active mode energy consumption for each sample household with an electric clothes dryer using the number of dryer cycles specified for that household. For gas clothes dryers, DOE used a similar approach as for electric clothes dryers, but added an estimate of the energy use of the electric components. An estimate of 0.107 kWh per cycle, which was derived from tests done by DOE, was applied for all efficiency levels except for the max-tech level. For the latter, which has a more efficient motor, the tests found a value of 0.091 kWh.

For each household, DOE determined the field-adjusted clothes dryer energy use during standby mode by using the following formula:

$$ClothesDryerEnergyUse_{S\tan dby} = \left[8760 - CD\_Cycles * \left(\frac{CD\_Time}{60}\right)\right] * S\tan dby\_Power$$

Where:

8760 = number of hours in one year, hrs,
CD_Time = clothes dryer time to complete one cycle, min/cycle,
60 = number of minutes in one hour, min/hr,
Standby_Power = standby power, kW, and
CD_Cycles = clothes dryer cycles per year.

DOE assumed that clothes dryers take 60 minutes on average to complete a cycle. Standby power varies by efficiency level as discussed in chapter 5.

DOE also considered the impact of clothes dryer operation on home heating and cooling loads. A clothes dryer releases heat to the surrounding environment. If the dryer is located indoors, its use will tend to slightly reduce the heating load during the heating season and slightly increase the cooling load during the cooling season. To calculate this impact, DOE first estimated whether the clothes dryer in a RECS sample home is located in conditioned space (referred to as indoors) or in unconditioned space (such as garages, unconditioned basements, outdoor utility closets, or attics). Based on the 2005 RECS[2] and the 2009 American Housing Survey (AHS)[3], DOE assumed that 50 percent of vented standard electric and gas dryers are located indoors, while 100 percent of compact and ventless clothes dryers are located indoors. For these installations, DOE utilized the results from a European Union study about the impacts of clothes dryers on home heating and cooling loads to determine a the appropriate factor to apply to the total clothes dryer energy use.[4] This study reported that for vented dryers there is a factor of negative 3 to 9 percent (average 6 percent) and for ventless dryers there is a factor of positive 7 to 15 percent (average 11 percent). DOE believes that this effect is the same for all of the considered efficiency levels because the amount of air passing through the clothes dryer does not vary.

7-C.3 ROOM AIR CONDITIONERS

7-C.3.1 General Approach

DOE calculated the annual energy consumption of a room air conditioner using the following equation:

$$RAC_{ENERGY} = \frac{Capacity * OH}{IEER}$$

Where:

RAC_{ENERGY} =	Room air conditioner annual energy consumption (kWh/year),
Capacity =	rated capacity in Btu/h,
OH =	operating hours per year,
CEER =	Combined Energy Efficiency Ratio in Btu/h/W.

DOE used the same representative capacities for each product class (PC) as it did in the engineering analysis: 5 kBtu/h for < 6000 Btu/h product classes (PC 3 and 8), 8 and 12 kBtu/h for 8000–13,999 Btu/hr product class (PC 1)[b], and 24 kBtu/h product class (PC 5). The *CEER* is also determined in the engineering analysis and is a new energy factor descriptor that incorporates standby power. The CEER is calculated as capacity times active mode hours (equal to 750) divided by the sum of active mode annual energy use and inactive mode annual energy use. The number of hours associated with this standby mode for room air conditioners is 5,115 hours per year. See chapter 5 for details.

For residential room air conditioners, the operating hours of the RAC are determined using the data reported by RECS 2005 on the annual energy consumption (field energy consumption) for room air conditioning, as well as assumed EER and capacity values for the existing room air conditioner. For commercial-sector room air conditioners, CBECS does not report annual energy consumption for room air conditioning, so DOE estimated the energy consumption using variables specific to each building in the sample and data on cooling degree-days. The following section provides a detailed explanation of the methodology for estimating the number of room air conditioner operating hours for each household or commercial building in the samples.

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[b] The fraction of 8 and 12 kBtu/h units was assumed to be equal, so each are assigned to a specific household 50 percent of the time.

7-C.3.2 Operating Hours

7-C.3.2.1 Residential

DOE calculated the annual room air conditioner operating hours for each residential sample unit using the following formula:

$$OH = \frac{FEC_{RECS} * EER_{RECS}}{Capacity} * BldgShellAdj * CDDAdj$$

Where:

OH = operating hours per year,
FEC_{RECS} = field energy consumption for a room air conditioner,
EER_{RECS} = the estimated EER of the room air conditioner in the sample home,
$Capacity$ = the room air conditioner capacity in Btu/h,
$BldgShellAdj$ = adjustment to building shell efficiency in 2014, precent,
$CDDAdj$ = cooling degree days (CDD) adjustment in Btu/h.

DOE used the same representative capacities for each class as it did in the engineering analysis.[c]

To ensure that the estimated operating hours are representative of future conditions, DOE used the building shell index factor from *AEO2010* in 2014 for space cooling in all homes of 0.96 and 115 year historical average CDD by census division. The building shell index factor decreased energy use by 4 percent, while the CDD adjustment factor decreased energy use by 10 percent on average.

To estimate the energy consumption of a single room air conditioner, referred to as $FEC_{RECS,}$ DOE divided the RECS 2005 reported annual energy consumption (field energy consumption) for room air conditioning, referred to as $FEC(all)_{RECS}$, by the reported number of room air conditioners. Although in reality the utilization of each of the room air conditioners in a home may vary, DOE has no way to estimate such variation. The reported RECS 2005 end-use quantities were not based on metering of individual appliances, rather, EIA used a regression technique to estimate how much of the total annual electricity consumption for each household can be attributed to each end-use category.[d] The reported field energy consumption refers to the

[c] In conducting the analysis of energy use by-products that would meet some future standard, DOE effectively substituted the room air conditioners in the sample residential and commercial buildings with a new product of identical product class (capacity) that the household or building owner would purchase if their room air conditioner failed.

[d] The desire to use a large number of independent variables without using a large number of interaction terms and the desire to adapt the regression procedures to account for heteroscedastic error terms led to the use of a nonlinear regression technique. For more information, see: http://www.eia.doe.gov/pub/consumption/residential/append_c.pdf

consumption of all of the room air conditioners in a home. RECS also reports the number of room air conditioners in the home. Of all homes that use a room air conditioner, 35 percent have two room air conditioners and 14 percent have three or more room air conditioners.

In RECS 2005, some households are identified as having purchased ENERGY STAR air conditioners in the last 4 years. For these households, DOE applied the appropriate ENERGY STAR EER. For the rest of the sample, DOE estimated the EER of the existing room air conditioner in each sample household by matching the age of the room air conditioner given by RECS with the average EER for the specific product class in the year of its vintage. In RECS, the age of a room air conditioner is given in one of the five bins shown in Table 7-C.3.1. DOE assumed a uniform distribution within each vintage bin and assigned an age to the room air conditioner in each sample household. Once the vintage year was determined, DOE assigned an EER to the unit equal to the average EER for the appropriate capacity for that year.

Table 7-C.3.1 RECS Vintage Bins for Room Air Conditioner

Bin	Age of unit
1	Less than 2 years old
2	2 to 4 years old
3	5 to 9 years old
4	10 to 19 years old
5	20 years or older

To derive a time series of average EER by capacity, DOE began with data from AHAM on total shipment-weighted average EER for 1972–2008 (See Figure 7-C.3.1). AHAM also provided average EER data by product class (capacity) for 2005–2007.[5] To develop the EER values by product class (capacity) for earlier years, DOE first assumed that all of the products shipped in each product class had the minimum efficiency required by the standard in each particular year.

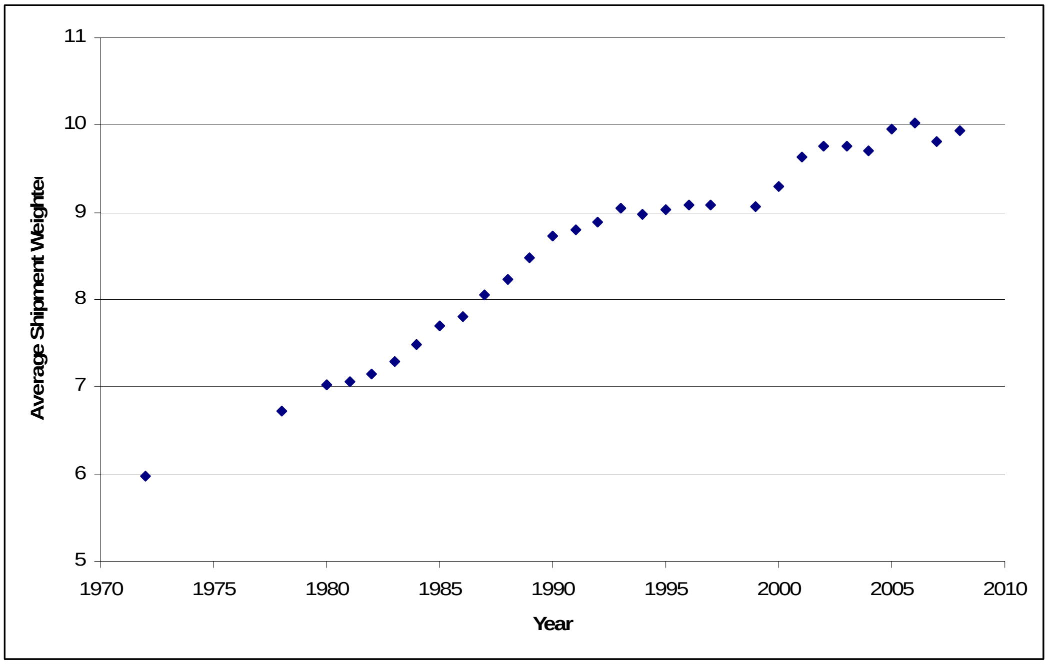

Figure 7-C.3.1 1972–2008 Average Shipment Weighted EER for Room Air Conditioners

DOE then estimated the shares of total shipments by product class in each year using data for 1989, 1992, and 2005–2007, and calculated a total shipment-weighted EER (See Table 7-C.2.2). DOE then calculated scalars for each year from the ratio of the actual total shipment-weighted EER to the calculated EER, and then applied the scalars to the minimum efficiency required for each product class in each year.

Table 7-C.3.2 Fraction of Shipments of Room Air Conditioner by Product Class

Product Class			2007	2006	2005	1992	1989
1	Without reverse cycle and with louvered sides	Less than 6,000 Btu/h	32.0%	23.0%	37.0%	26.7%	27.7%
2		6,000 to 7,999 Btu/h	16.0%	19.0%	19.0%	14.4%	17.7%
3		8,000 to 13,999 Btu/h	36.0%	34.0%	30.0%	32.8%	29.7%
4		14,000 to 19,999 Btu/h	6.0%	5.5%	3.0%	13.1%	13.2%
5		20,000 Btu/h and more	2.6%	3.9%	2.0%	6.3%	7.0%
6	Without reverse cycle and without louvered sides	Less than 6,000 Btu/h	7.0%	12.0%	7.0%		
7		6,000 to 7,999 Btu/h				2.1%	3.2%
8		8,000 to 13,999 Btu/h				2.1%	
9		14,000 to 19,999 Btu/h					
10		20,000 Btu/h and more					
11	With reverse cycle and with louvered sides	Less than 20,000 Btu/h	**	1.0%	0.7%	2.1%	1.5%
12		20,000 Btu/h and more			0.1%		
13	With reverse cycle and without louvered sides	Less than 14,000 Btu/h	**	0.6%	0.4%	0.5%	
14		14,000 Btu/h and more					
15	Casement	Casement Only	0.4%	0.6%	0.4%		
16		Casement Slider					

Table 7-C.3.3 shows the AHAM data on total shipment-weighted average EER and the average EER estimated for the representative product classes.

Table 7-C.3.3 Average Room Air Conditioner EER by Product Class and Year Sold

Year	Shipment Weighted EER	Derived Average EER*			
		< 6000 Btu/h	8000–13,999 Btu/hr (PC 3)	≥ 20,000 Btu/hr	8000–13,999 Btu/hr (PC 8)
2007	9.81	9.80	10.10	9.10	9.50
2006	10.02	9.80	10.40	9.20	9.50
2005	9.95	9.80	10.10	9.10	9.40
2004	9.71	9.70	9.86	8.83	9.15
2003	9.75	9.70	9.92	8.89	9.21
2002	9.75	9.70	9.92	8.88	9.21
2001	9.63	9.70	9.80	8.50	8.73
2000**	9.3	9.03	9.70	8.50	8.73
1999	9.07	8.56	9.63	8.50	8.73
1998	NA	8.56	9.63	8.50	8.73
1997	9.09	8.57	9.64	8.50	8.73
1996	9.08	8.55	9.62	8.50	8.73
1995	9.03	8.49	9.55	8.50	8.73
1994	8.97	8.42	9.47	8.50	8.73
1993	9.05	8.50	9.56	8.50	8.73
1992	8.88	8.31	9.35	8.50	8.73
1991	8.8	8.24	9.27	8.45	8.73
1990**	8.73	8.18	9.20	8.39	8.69
1989	8.48	7.95	8.95	8.15	8.45
1988	8.23	7.72	8.68	7.91	8.20
1987	8.06	7.56	8.51	7.75	8.03
1986	7.8	7.32	8.23	7.50	7.77
1985	7.7	7.22	8.13	7.40	7.67
1984	7.48	7.02	7.89	7.19	7.45
1983	7.29	6.84	7.69	7.01	7.27
1982	7.14	6.70	7.53	6.86	7.12
1981	7.06	6.62	7.45	6.79	7.04
1980	7.02	6.58	7.41	6.75	7.00
1978	6.72	6.44	7.25	6.60	6.85
1972	5.98	6.30	7.09	6.46	6.70

* Shaded area values were provided by AHAM[5]
** Years in which standards became effective

7-C.3.2.2 Commercial

DOE calculated the annual operating hours for each sample commercial-sector room air conditioner by establishing a relationship between cooling degree-days and operating hours for a number of building type and building schedule combinations. DOE assumed that the room air conditioner is operated when the outdoor air conditions are above the comfort zone described by ANSI/ASHRAE Standard 55-2004 Thermal Environmental Conditions for Human Occupancy (see figure 7-C.3.2).[6] To estimate how often this occurs, DOE used the following general equation:

$$OH55 = (a * CDD) + b$$

Where:

OH55 = Average annual hours when the outdoor air conditions are above the ASHRAE Standard 55 comfort zone;
CDD = the number of annual cooling degree-days (65 F) for a given location; *a* and *b* are linear fit parameters.

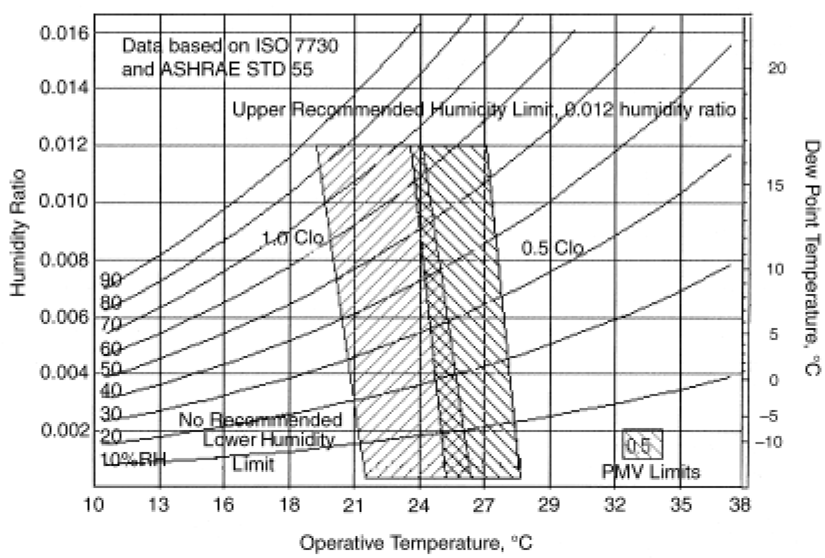

Figure 7-C.3.2 ANSI/SHRAE Standard 55-2004: Thermal Environmental Conditions for Human Occupancy

ANSI/ASHRAE Standard 55 assumes that metabolic rates of 1.1 met, (engaged in near sedentary physical activity), 0.5 clo of clothing insulation, insulation levels typical of clothing worn when the outdoor environment is warm, air speeds are not greater than 0.20 m/s (40 ft/min), upper recommended humidity limit, and 0.012 humidity ratio. The range of operative temperatures presented in Figure 7-C.3.2 are for 80 percent occupant acceptability. This is based on a 10 percent dissatisfaction criteria for general (whole body) thermal comfort based on the PMV-PPD index, plus an additional 10 percent dissatisfaction that may occur on average from local (partial body) thermal discomfort. Predicted mean vote (PMV) index is an index that predicts the mean value of the votes of a large group of persons on the seven point thermal sensation scale. The predicted percentage of dissatisfied (PPD) index is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people determined from PMV. The room air conditioner is assumed to operate if the outdoor conditions are outside comfort zone if W (humidity ratio)>0.012 or T>Tcomf for that humidity ratio. Tcomf is given by the following equation: $Tcomf = -117.7081 \times W + 28.25491422$, where W is the humidity ratio at the outdoor conditions for that hour.

DOE used data on cooling degree-days from the National Solar Radiation Database (NSRDB).[7] The 1991–2005 NSRDB is an update of the 1961–1990 NSRDB. This updated NSRDB dataset is an hourly ground-based data set of solar and meteorological fields for 1454 stations, which are subdivided into three classes of stations (see figure 7-C.3.3). A total of 858 sites have a complete 15-year period of record.

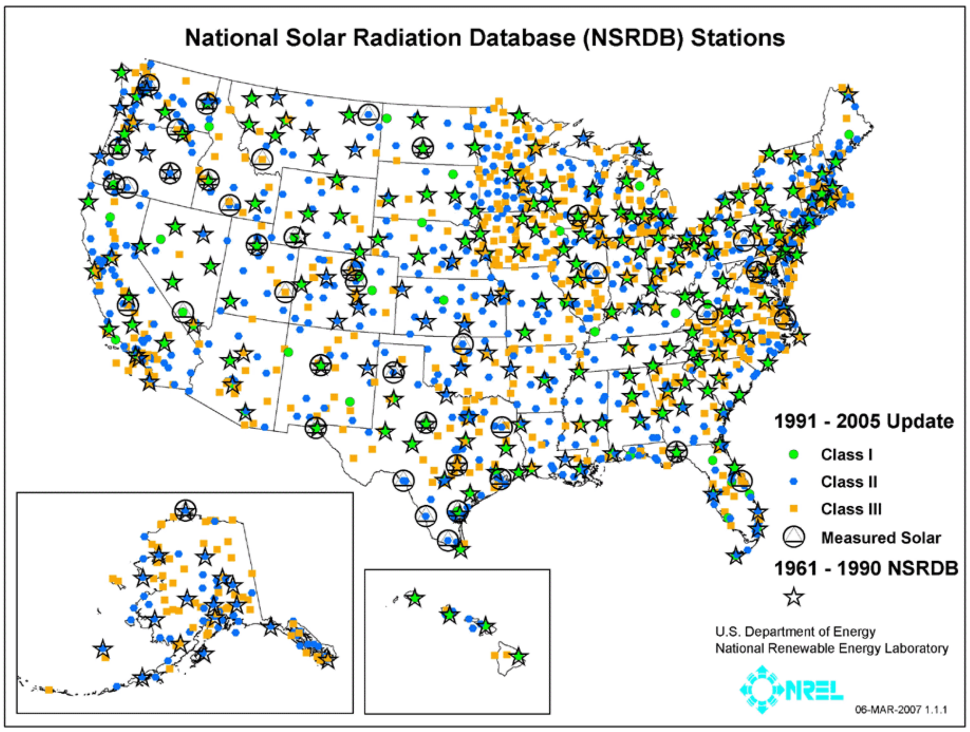

Figure 7-C.3.3 National Solar Radiation Database (NSRDB) Stations

Stations are identified with a USAF number as follows:

- Class I Stations have a complete period of record (all hours 1991–2005) for solar and key meteorological fields and have the highest-quality solar modeled data (221 sites).
- Class II Stations have a complete period of record but significant periods of interpolated, filled, or otherwise lower-quality input data for the solar models (637 sites).
- Class III Stations have some gaps in the period of record but have at least 3 years of data that might be useful for some applications (596 sites).

The NSRDB has complete measured hourly Dry Bulb Temperature, Dew Point Temperature, Relative Humidity, and Atmospheric Pressure for all Class I & Class II Stations. The Dry Bulb Temperature, Relative Humidity, and Atmospheric Pressure fields were used to calculate the humidity ratio for each hour. The humidity ratio was calculated using procedures from the 2005 ASHRAE Handbook-Fundamentals, Chapter 6 Psychrometrics. Under the section on Numerical Calculation of Moist Air Properties, Situation 3 describes the process to calculate humidity ratio (W) from Dry Bulb Temperature, Relative humidity, and Pressure. The saturation pressure for the dry bulb temperature is calculated using the following equation:

$$\ln(Pws) = \frac{C_8}{T} + C_9 + C_{10} \times T + C_{11} \times T^2 + C_{12} \times T^3 + C_{13} \times \ln(T)$$

where:

C8 = -5.8002206 E+03
C9 = 1.3914993 E+00
C10 = -4.8640239 E-02
C11 = 4.1764768 E-05
C12 = -1.4452093 E-08
C13 = 6.5459673 E+00
Pws = saturation pressure, Pa
T = absolute temperature, K = °C + 273.15

The water vapor partial pressure is the saturation pressure multiplied by the relative humidity.

$$Pw = \varphi \times Pws$$

The humidity ratio, W, is defined as the ratio of the mass of water vapor to the mass of dry air contained in the sample. It can be calculated from the pressure and the water vapor partial pressure as:

$$W = 0.62198 \times \frac{Pw}{(P - Pw)}$$

The testing the conditions for that hour against the criteria from Std 55, we can determine if the room air conditioner would have operated during that hour.

Figure 7-C.3.4 shows the hours (2281 hours) in 1991 that were above the comfort zone for Palm Springs.

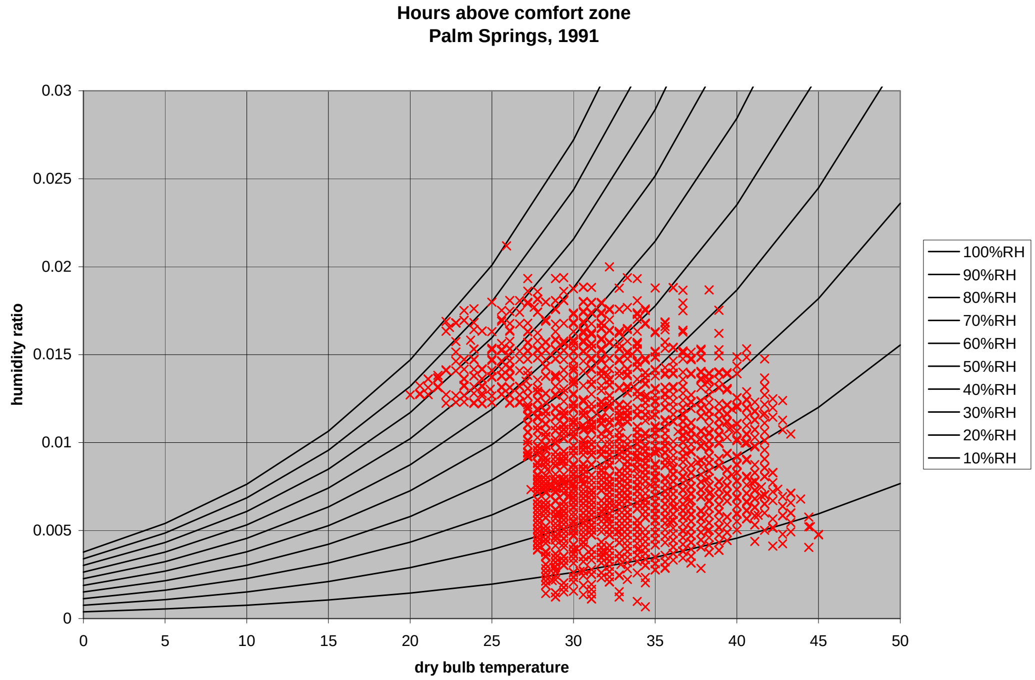

Figure 7-C.3.4 Hours Above Comfort Zone in Palm Springs (1991)

Figure 7-C.3.5 shows hours above the Standard 55 comfort zone compared to CLDD for 15 years (1991-2005) for all Class 1 & II weather stations.

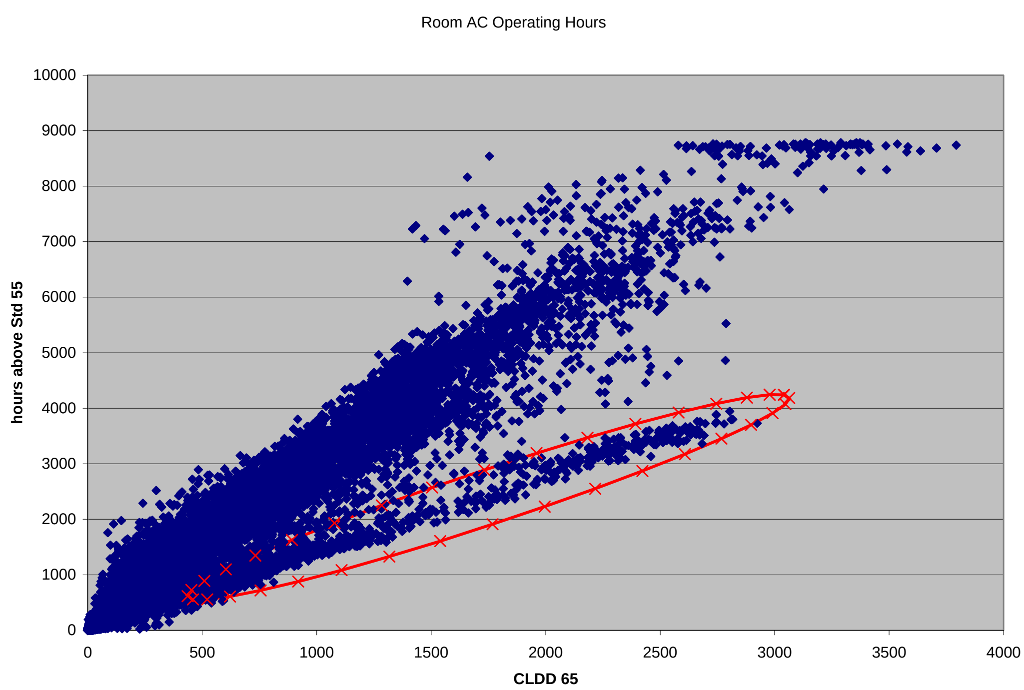

Figure 7-C.3.5 Hours Above the Standard 55 Comfort Zone Compared to CLDD

The lower 'branch' in the 'hours above Std 55' vs 'CLDD 65' is from low desert locations. After examining the data, the following sites were classified as desert.

Table 7-C.3.4 Average Room Air Conditioner EER by Product Class and Year Sold

STATION	ST
DAVIS MONTHAN AFB	AZ
DEER VALLEY/PHOENIX	AZ
DOUGLAS BISBEE-DOUGLAS INTL A	AZ
KINGMAN (AMOS)	AZ
LUKE AFB	AZ
PHOENIX SKY HARBOR INTL AP	AZ
SCOTTSDALE MUNI	AZ
TUCSON INTERNATIONAL AP	AZ
YUMA INTL ARPT	AZ
YUMA MCAS	AZ
BAKERSFIELD MEADOWS FIELD	CA
BLYTHE RIVERSIDE CO ARPT	CA
CHINA LAKE NAF	CA
DAGGETT BARSTOW-DAGGETT AP	CA
EDWARDS AFB	CA
IMPERIAL	CA
LANCASTER GEN WM FOX FIELD	CA
NEEDLES AIRPORT	CA
PALM SPRINGS INTL	CA
PALM SPRINGS THERMAL AP	CA
PALMDALE AIRPORT	CA
TWENTYNINE PALMS	CA
CARLSBAD CAVERN CITY AIR TERM	NM
DEMING MUNI	NM
HOLLOMAN AFB	NM
LAS CRUCES INTL	NM
ROSWELL INDUSTRIAL AIR PARK	NM
TRUTH OR CONSEQUENCES MUNI AP	NM
LAS VEGAS MCCARRAN INTL AP	NV
MERCURY DESERT ROCK AP [SURFRAD]	NV
NELLIS AFB	NV
EL PASO INTERNATIONAL AP [UT]	TX
SAINT GEORGE (AWOS)	UT

In Figure 7-C.3.6, the desert and tropical sites are shown. The uppermost points on the original chart (Figure 7-C.3.5) represent data from stations in Hawaii, Guam and the Caribbean.

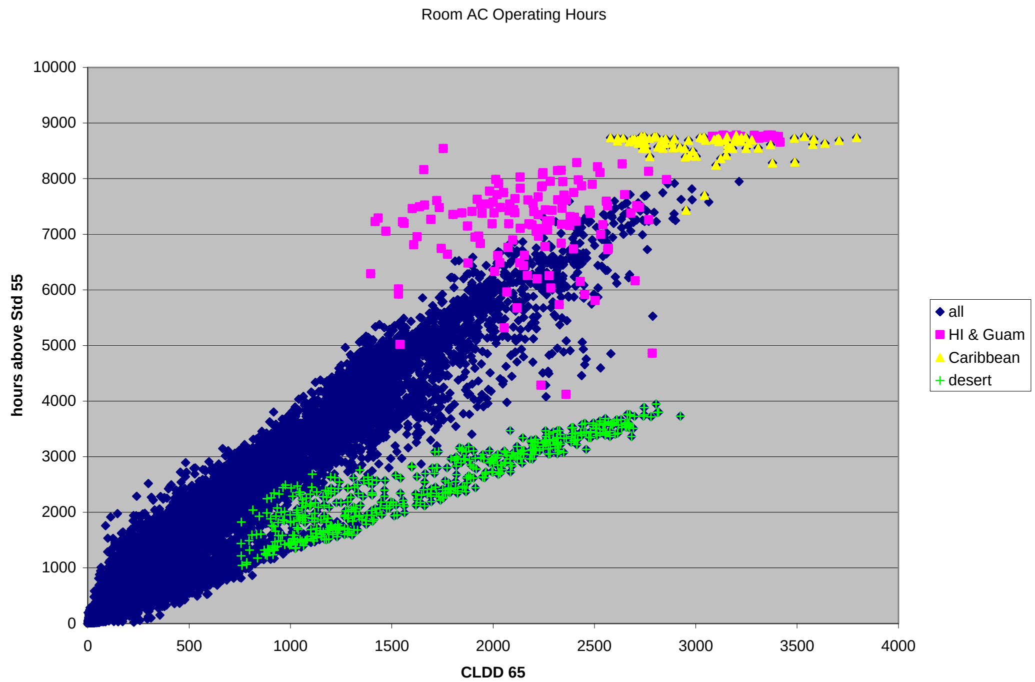

Figure 7-C.3.6 Hours Above the Standard 55 Comfort Zone versus CLDD with Different Regions Highlighted

After removing the sites in Hawaii, Guam, and the Caribbean islands, regressions were done to predict the hours per year above Standard 55 from the number of cooling degree-days for each year. The data points and regression lines are shown in Figure 7-C.3.7 for all hours of the year. This represents 842 sites for 15 years each in the continental United States.

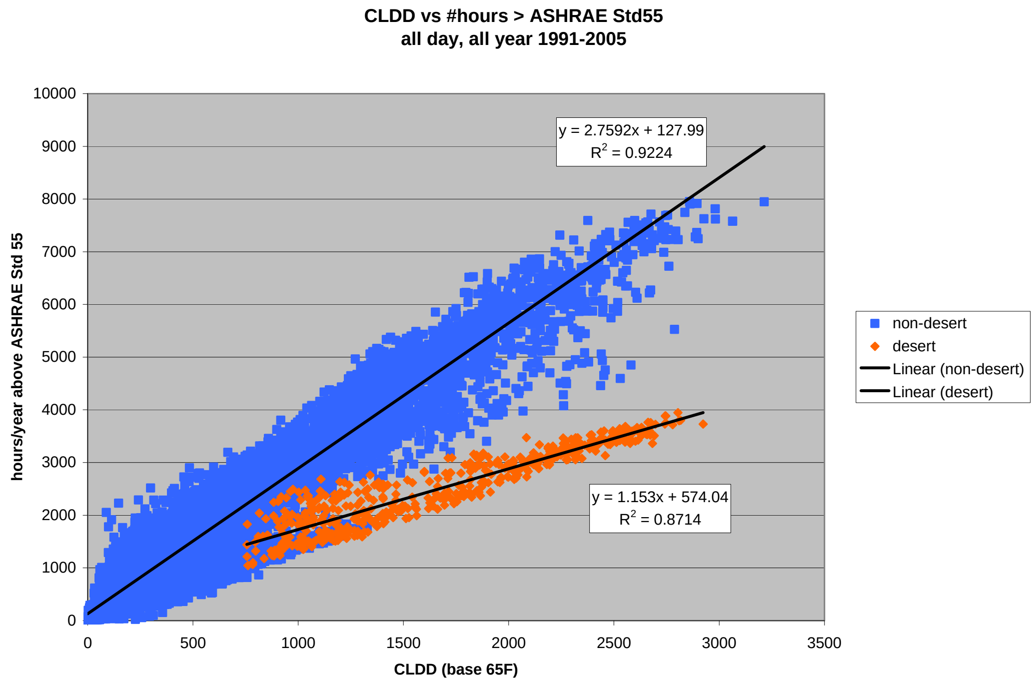

Figure 7-C.3.7 Hours Above ANSI/ASHRAE Standard 55-2004 as a Function of Cooling Degree-Days

As can be seen in the graph above, the data patterns are different for desert locations, where humidity is not a present factor affecting comfort. The regression equations used to derive the average annual hours when the outdoor air conditions are above the ASHRAE Standard 55 comfort zone (OH55) are shown in Table 7-C.3.5.

Table 7-C.3.5 Regression Equations

Region	Equation	R^2	# sites
Non-desert	OH55 = 2.759 x CLDD + 127.99	0.9224	809
Desert	OH55 = 1.153 x CLDD + 574.04	0.8714	33

The number of annual hours above the ASHRAE Standard 55 comfort zone varies by schedule, which refers to the time that a building is open. Thus, DOE performed the regression for a number of combinations of building type and building schedule, yielding somewhat different equations for each combination. The building types included are: Assembly, Education, Food Service, Office, Retail, and Warehouse. For each building type, DOE estimated operating hours for each of the following building schedules: (1) open 24 hours a day and seven days a week (24/7); (2) open business hours Monday through Friday; (3) open business hours Monday through Saturday; (4) open business hours Monday through Friday and Sunday; (5) open business hours all week. The building types and schedule abbreviations are shown in table 7-C.3.6 and 7-C.3.7. An assumption was made that if the occupancy rate was greater than 20% of full occupancy, the room air-conditioner would operate if the outdoor air conditions were above the ASHRAE standard 55 comfort zone.

Table 7-C.3.6 Building Type and Abbreviation

Building Type	Abbreviation
Assembly	ASM
Education	EDU
Food Service	FDS
Lodging	LOD
Medical	MED
Office	OFF
Outdoor	OUT
Retail	RET
Warehouse	WHS

Table 7-C.3.7 Building Schedules and Abbreviation

Building Schedules	Abbreviation
24/7 hours	247
Monday-Friday	M-F
Monday - Friday and Saturday and Sunday	ALL

The equations to predict the hours per year the outdoor air conditions are above the ASHRAE Standard 55 comfort zone for various building types and schedules for non-desert locations are shown table 7-C.3.8.

Table 7-C.3.8 Room Air Conditioner Operating Hour Equations By Building Type and Schedule

building type	open schedule	equation	R2
ALL	247	ROH55 = 2.759 x CLDD + 127.99	0.9224
OUT	M_F	ROH55 = 1.974 x CLDD + 93.29	0.9458
OUT	ALL	ROH55 = 2.759 x CLDD + 127.99	0.9430
ASM	M_F	ROH55 = 0.751 x CLDD + 119.67	0.9458
ASM	ALL	ROH55 = 1.396 x CLDD + 169.18	0.9430
EDU	M_F	ROH55 = 1.001 x CLDD + 117.11	0.9412
EDU	ALL	ROH55 = 1.398 x CLDD + 163.52	0.9424
FDS	M_F	ROH55 = 1.243 x CLDD + 112.91	0.9354
FDS	ALL	ROH55 = 1.510 x CLDD + 166.44	0.9408
LOD	M_F	ROH55 = 1.471 x CLDD + 17.11	0.9428
LOD	ALL	ROH55 = 2.206 x CLDD + 40.94	0.9408
MED	M_F	ROH55 = 1.001 x CLDD + 128.06	0.9428
MED	ALL	ROH55 = 1.151 x CLDD + 148.72	0.9408
OFF	M_F	ROH55 = 0.918 x CLDD + 119.76	0.9428
OFF	ALL	ROH55 = 1.510 x CLDD + 166.44	0.9408
RET	M_F	ROH55 = 0.751 x CLDD + 119.67	0.9458
RET	ALL	ROH55 = 1.281 x CLDD + 170.57	0.9450
WHS	M_F	ROH55 = 0.836 x CLDD + 109.17	0.9422
WHS	ALL	ROH55 = 1.514 x CLDD + 178.06	0.9419

The highlighted rows are the same. This is because the occupancy rates were above 20 percent for 24 hours per day for all building types operating under the 24/7 schedule. The analysis does not account for differences in building operation schedules due to holidays.

The equations to predict the hours per year the outdoor air conditions are above the ASHRAE Standard 55 comfort zone for various building types and schedules for desert locations are shown table 7-C.3.9.

Table 7-C.3.9 Room Air Conditioner Operating Hour Equations By Building Type and Schedule (Desert)

building type	open schedule	equation	R2
ALL	247	ROH55 = 1.153 x CLDD + 574.04	0.9224
OUT	M_F	ROH55 = 1.974 x CLDD + 93.29	0.8353
OUT	ALL	ROH55 = 2.759 x CLDD + 127.99	0.8925
ASM	M_F	ROH55 = 0.289 x CLDD + 546.12	0.8353
ASM	ALL	ROH55 = 0.600 x CLDD + 721.20	0.8925
EDU	M_F	ROH55 = 0.409 x CLDD + 532.56	0.8723
EDU	ALL	ROH55 = 0.572 x CLDD + 741.06	0.8794
FDS	M_F	ROH55 = 0.553 x CLDD + 449.33	0.8914
FDS	ALL	ROH55 = 0.663 x CLDD + 690.02	0.8985
LOD	M_F	ROH55 = 0.642 x CLDD + 40.06	0.8260
LOD	ALL	ROH55 = 0.951 x CLDD + 157.74	0.8985
MED	M_F	ROH55 = 0.402 x CLDD + 603.12	0.8260
MED	ALL	ROH55 = 0.458 x CLDD + 706.19	0.8985
OFF	M_F	ROH55 = 0.353 x CLDD + 573.23	0.8260
OFF	ALL	ROH55 = 0.663 x CLDD + 690.02	0.8985
RET	M_F	ROH55 = 0.289 x CLDD + 546.12	0.8353
RET	ALL	ROH55 = 0.534 x CLDD + 749.00	0.8813
WHS	M_F	ROH55 = 0.317 x CLDD + 524.97	0.8087
WHS	ALL	ROH55 = 0.612 x CLDD + 837.58	0.8682

To estimate the room air conditioner operating hours for each of the buildings in the CBECS 2003 room air conditioner sample, DOE identified the building type (see Table 7-C.3.10) and the building schedule using information provided by CBECS, and used the appropriate equation (non-desert or desert) combined with the number of cooling degree-days for the location of the building. It adjusted the results with a scaling factor to account for the difference between the number of building operating hours assumed to derive the equations and the actual building operating hours reported by CBECS.

Table 7-C.3.10 CBECS 2003 Building Code Match to Room Air Conditioner Equation Building Type

CBECS 2003 PBA Code	Definition	Building Type Match	Fraction of CBECS 2003 RAC Sample
1	Vacant	Not Applicable	
2	Office	OFF	18.3%
4	Laboratory	MED	0.2%
5	Nonrefrigerated warehouse	WHS	5.9%
6	Food sales	RET	2.9%
7	Public order and safety	OFF	4.1%
8	Outpatient health care	MED	0.6%
11	Refrigerated warehouse	WHS	0.0%
12	Religious worship	ASM	8.7%
13	Public assembly	ASM	5.5%
14	Education	EDU	12.7%
15	Food service	FDS	4.5%
16	Inpatient health care	MED	0.2%
17	Nursing	MED	1.4%
18	Lodging	LOD	3.5%
23	Strip shopping mall	RET	0.0%
24	Enclosed mall	RET	0.0%
25	Retail other than mall	RET	11.8%
26	Service	RET	17.3%
91	Other	OFF	2.3%

The above approach provides a 'best guess' of the room air conditioner operating hours for a particular CBECS building. However, operating hours are affected by some factors not included in the analysis, such as interior heat gains from equipment or people and solar gains. To develop a distribution of the number of operating hours for each sample building, DOE added an error band to the value derived using the regression equation. The error band includes values that are ± 10% from the regression line for the appropriate building type/schedule combination.

The commercial sector operating hours were estimated based on the cooling climate in 2003. To match the 115 year CDD average values, DOE decreased the estimated commercial sector operating hours by 2 percent on average.

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APPENDIX 7-D. WEATHER DATA AND TEMPERATURE PARAMETERS

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APPENDIX 7-D. WEATHER DATA AND TEMPERATURE PARAMETERS

7-D.1 INTRODUCTION

To facilitate more precise analyses, DOE matched RECS households with National Oceanic and Atmospheric Administration (NOAA) weather station locations. This match allowed DOE to determine monthly cooling and heating degree-days, compared to the yearly averages available from the RECS survey. These values were used for a variety of purposes.

7-D.2 OUTDOOR TEMPERATURE DERIVATION

RECS 2005 provides yearly averages for heating and cooling degree-days but no data on a monthly scale. To find more precise temperature information for the households in the RECS sample, DOE developed an approach to assign a physical location to each RECS household. The following steps were performed:

1. DOE assembled weather data from 282 weather stations that provide annual average outdoor air temperatures.[1, 2] The annual average outdoor air temperatures represent 30-year averages. DOE also gathered the heating and cooling degree-days at base temperature 65 ^{o}F for year 2005 for these weather stations.[3] The 2005 heating and cooling degree days match the period used to determine the degree-days in RECS 2005.
2. RECS reports both heating degree-days (HDD) and cooling degree-days (CDD) to base temperature 65 ^{o}F for each housing record. DOE assigned each RECS household to one of the 282 weather stations by calculating which weather station (within the appropriate census region or large state) gave the best linear least squares fit of the RECS data to the weather data.

Figures 7-D.2.1 and 7-D.2.2 show the relationship between the gathered mean temperature values and the HDD and CDD values.

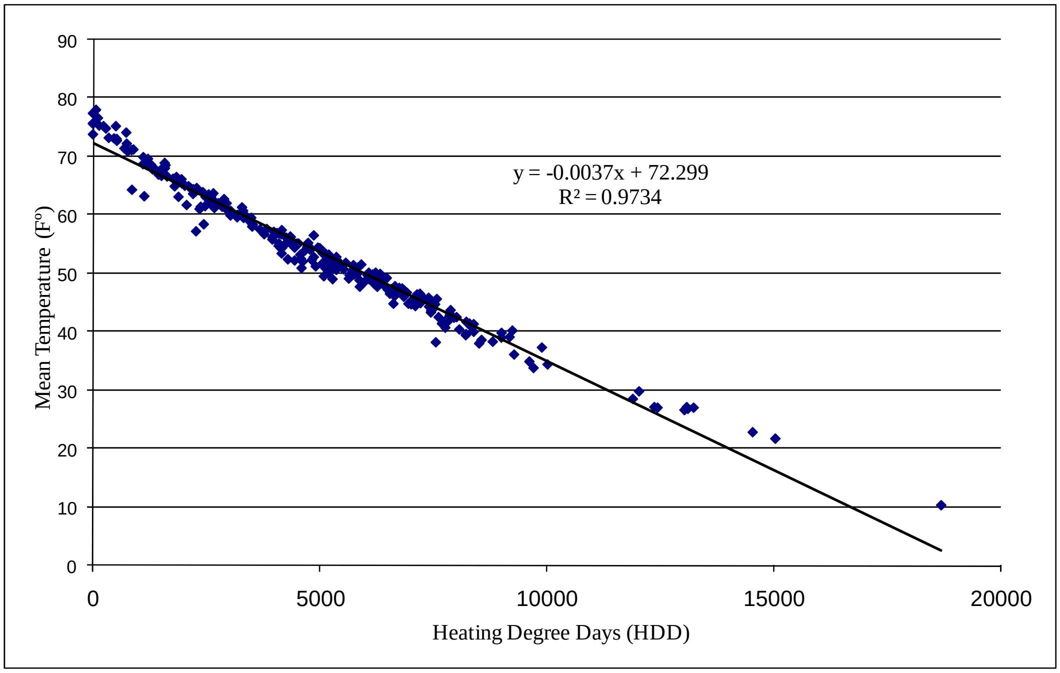

Figure 7-D.2.1 Heating Degree Days (HDD) Compared to Mean Temperature

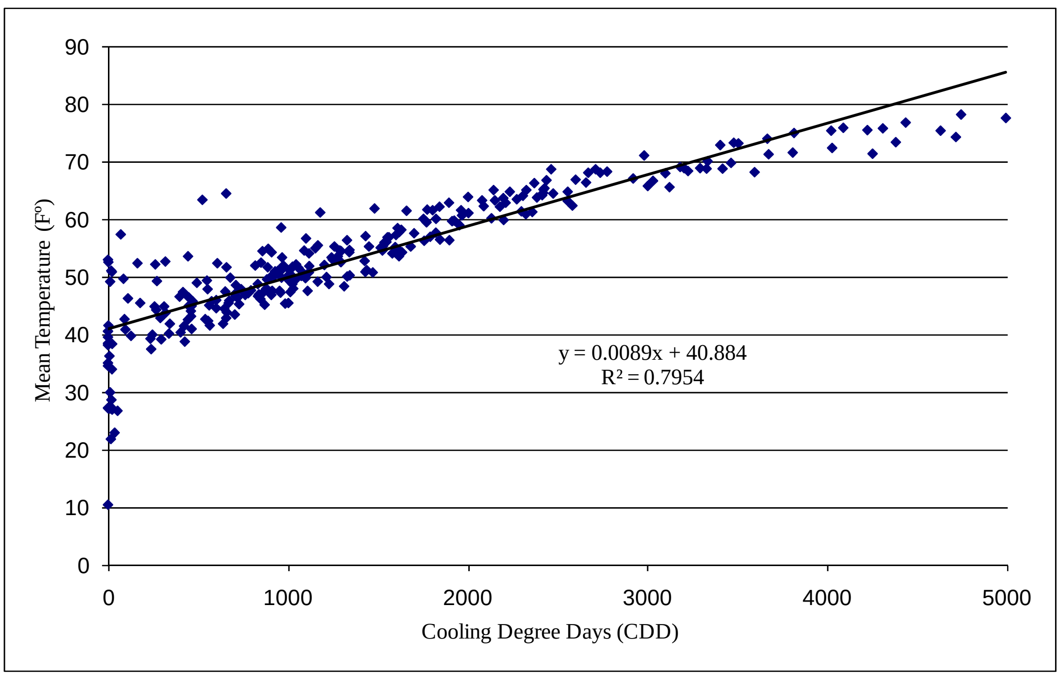

Figure 7-D.2.2 Cooling Degree Days (CDD) Compared to Mean Temperature

7-D.2.1 Imputation Method

To determine household location, DOE matched the RECS 2005 combinations (255 individual combinations of Census Divisions plus 4 large states, together with the HDD and CDD data) to U.S. weather data. DOE used the U.S. weather station closest (or with minimum "distance") from the RECS 2005 data combination. The following equation calculates the "distance" between the U.S. weather data and RECS 2005 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 2005 data,
CDD_1 = cooling degree days from U.S. weather data, and
CDD_2 = cooling degree days from RECS 2005 data.

Figures 7-D.2.3 and 7-D.2.4 show the relationship between the imputed mean outdoor air temperature values and the RECS 2005 HDD values.

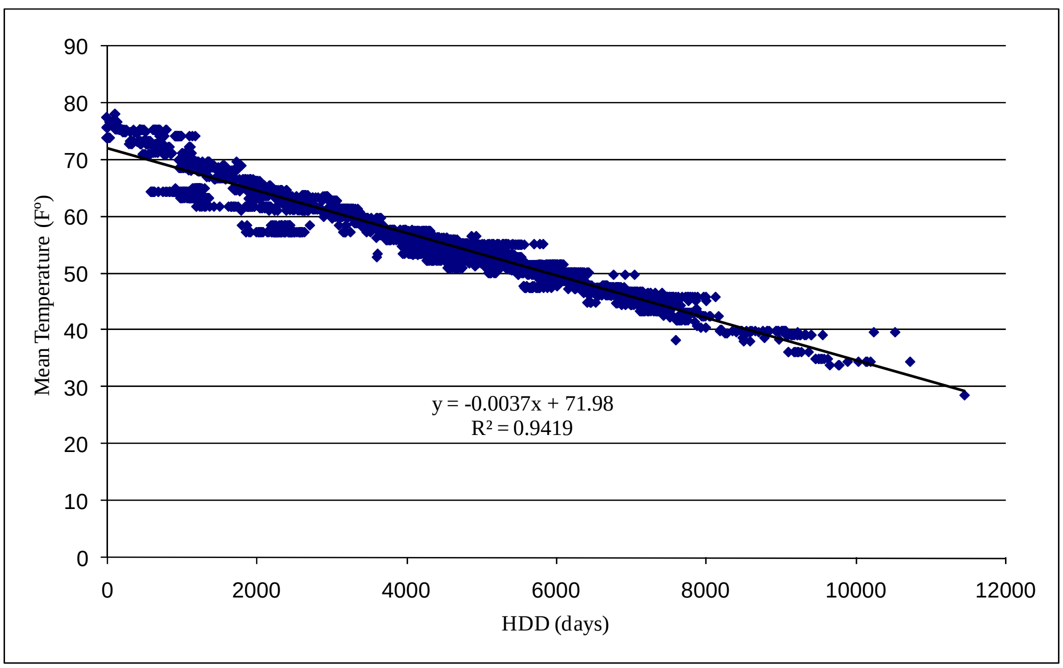

Figure 7-D.2.3 Heating Degree Days (HDD) Compared to Imputed Mean Temperature Values

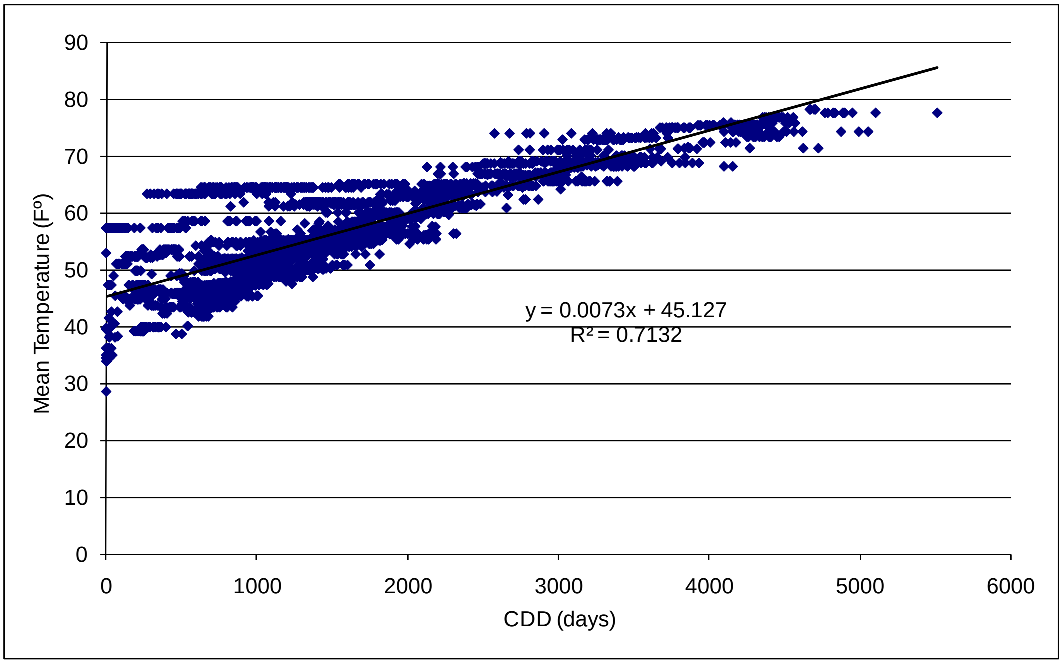

Figure 7-D.2.4 Cooling Degree Days (CDD) Compared to Imputed Mean Temperature Values

Table 7-D.2.1 shows the imputation results for all RECS locations. Note that some weather station data matches with several of the RECS 2005 255 HDD & CDD combinations. Table 7-D.2.2 shows a subset of the data matches.

Table 7-D.2.1 Weather Station Data

Station Location		Code	Mean Temp	HDD (2005)	CDD (2005)
State	City				
AK	KODIAK	BDL	50.2	6219	1003
AK	KING SALMON	BDR	52.1	5361	1046
AK	ANCHORAGE	BOS	51.6	5902	888
AK	BETHEL	ORH	47.2	6670	714
AK	BIG DELTA	CAR	39.2	9166	236
AK	BARROW	HUL	39.9	8989	247
AK	BETTLES	PWM	45.7	7218	471
AK	COLD BAY	CON	45.9	7385	602
AK	FAIRBANKS	MWN	27.2	13063	0
AK	GULKANA	PVD	51.1	5824	1010
AK	HOMER	BTV	45.2	7425	729
AK	JUNEAU	ACY	53.5	5109	1278
AK	MCGRATH	EWR	54.5	4949	1526
AK	NOME	ABE	50.6	5704	1085
AK	KOTZEBUE	CXY	53.3	5187	1243
AK	ST PAUL ISLAND	ERI	50.0	6318	907
AK	TALKEETNA	IPT	49.8	6038	965
AK	UNALAKLEET	PHL	55.3	4735	1530
AK	VALDEZ	PIT	50.9	5765	929

AK	YAKUTAT	MLI	50.2	5750	1344
AL	BIRMINGHAM	ORD	49.1	6076	1166
AL	HUNTSVILLE	PIA	50.8	5514	1431
AL	MONTGOMERY	RFD	47.9	6421	1030
AL	MOBILE	SPI	52.7	5168	1427
AL	MUSCLE SHOALS	EVV	56.0	4317	1548
AL	TUSCALOOSA	FWA	49.9	6153	1008
AR	FORT SMITH	IND	52.5	5263	1295
AR	FAYETTEVILLE	SBN	49.5	6243	1044
AR	LITTLE ROCK	ANJ	40.1	8375	339
AZ	DOUGLAS	APN	42.5	7941	444
AZ	FLAGSTAFF	DTW	49.7	6189	1098
AZ	WINSLOW	FNT	46.8	6906	763
AZ	PHOENIX	GRR	47.6	6642	891
AZ	TUCSON	HTL	43.1	7858	462
AZ	YUMA	LAN	46.8	6585	908
CA	BAKERSFIELD	MKG	47.1	6583	780
CA	BLYTHE	SAW	38.7	8548	427
CA	EUREKA	CAK	49.5	6215	884
CA	FRESNO	CLE	49.6	6067	997
CA	LOS ANGELES	CMH	52.9	5355	1250
CA	MT SHASTA	CVG	54.2	4981	1342
CA	PASO ROBLES	DAY	51.5	5730	1059
CA	REDDING	FDY	50.2	6067	1020
CA	SACRAMENTO	MFD	48.7	6320	833
CA	SAN DIEGO	TOL	49.5	6210	1031
CA	STOCKTON	YNG	48.5	6328	711
CA	SAN FRANCISCO	GRB	44.4	7392	647
CO	ALAMOSA	LSE	47.3	6754	1014
CO	COLORADO SPRINGS	MKE	47.5	6612	954
CO	DENVER	MSN	46.1	6837	848
CO	GRAND JUNCTION	ALO	47.2	6845	862
CO	PUEBLO	DBQ	46.9	6791	839
CO	TRINIDAD	DSM	50.0	5817	1330
CT	HARTFORD	SUX	48.3	6189	1313
CT	BRIDGEPORT	CNK	53.5	5057	1618
DC	WASHINGTON	DDC	55.2	4488	1683
DE	WILMINGTON	GLD	50.7	5353	1117
FL	DAYTONA BEACH	ICT	56.4	4342	1846
FL	KEY WEST	TOP	54.3	4803	1627
FL	FT LAUDERDALE	DLH	39.1	8985	296
FL	FORT MYERS	INL	37.4	9876	240
FL	GAINESVILLE	MSP	45.4	7003	1003
FL	JACKSONVILLE	RST	43.4	7434	705
FL	ORLANDO	STC	41.8	7797	640
FL	MIAMI	COU	54.0	4663	1581
FL	WEST PALM BEACH	MCI	54.2	4777	1635
FL	PENSACOLA	SGF	56.2	4254	1758

FL	TALLAHASSEE	STL	56.3	4352	1898
FL	TAMPA	BIS	42.3	7795	557
FL	VERO BEACH	DIK	41.8	8215	344
GA	ALBANY	FAR	41.5	8283	566
GA	AUGUSTA	GFK	40.3	9227	404
GA	ATHENS	ISN	40.9	8326	465
GA	ATLANTA	JMS	41.4	8376	423
GA	WAYCROSS	BFF	47.8	6254	741
GA	BRUNSWICK	GRI	49.9	5748	1215
GA	COLUMBUS	LBF	48.7	6228	1025
GA	MACON	LNK	51.1	5762	1439
GA	SAVANNAH	OFK	48.7	5979	1229
HI	HONOLULU-OAHU	OMA	50.7	5749	1472
HI	HILO-HAWAII	VTN	47.2	6558	959
HI	LIHUE-KAUAI	ABR	43.8	7868	660
HI	KAHULUI-MAUI	ATY	42.8	7847	657
IA	WATERLOO	FSD	45.1	6999	871
IA	DUBUQUE	HON	45.3	7173	985
IA	DES MOINES	PIR	47.5	6802	1110
IA	SIOUX CITY	RAP	46.6	6533	834
ID	BOISE	DCA	57.5	4154	1702
ID	LEWISTON	ILG	54.4	4991	1296
ID	POCATELLO	ABY	66.3	1763	2658
IL	MOLINE	AGS	63.2	2475	2151
IL	CHICAGO	AHN	61.5	2841	1805
IL	PEORIA	ATL	62.1	2754	1843
IL	ROCKFORD	AYS	66.7	1630	2438
IL	SPRINGFIELD	BQK	68.6	1596	2464
IN	EVANSVILLE	CSG	65.1	2019	2421
IN	FORT WAYNE	MCN	63.7	2202	2385
IN	INDIANAPOLIS	SAV	66.2	1948	2370
IN	SOUTH BEND	BWI	54.6	4714	1343
KS	CONCORDIA	SBY	56.6	4858	1101
KS	DODGE CITY	AVL	54.8	4083	891
KS	GOODLAND	CLT	61.4	3279	1660
KS	WICHITA	GSO	58.1	3504	1631
KS	TOPEKA	HAT	62.8	2884	1896
KY	BOWLING GREEN	ILM	63.8	2650	2002
KY	JACKSON	RDU	59.6	3314	1913
KY	LEXINGTON	CAE	63.6	2545	2198
KY	PADUCAH	CHS	65.3	2003	2427
KY	LOUISVILLE	GSP	60.0	3024	1754
LA	BATON ROUGE	LYH	55.4	4375	1167
LA	LAKE CHARLES	ORF	59.6	3484	1767
LA	LAFAYETTE	RIC	57.6	3674	1823
LA	NEW ORLEANS	ROA	56.3	3948	1329
LA	SHREVEPORT	BKW	51.6	5360	659
MA	BOSTON	CRW	54.5	4436	1289

MA	WORCESTER	EKN	49.8	5644	680
MD	BALTIMORE	HTS	55.0	4375	1516
MD	SALISBURY	MRB	54.0	5044	1118
ME	CARIBOU	BHM	62.2	2587	2089
ME	HOULTON	HSV	60.6	3007	1968
ME	PORTLAND	MGM	65.0	2104	2326
MI	SAULT ST MARIE	MOB	66.8	1507	2600
MI	ALPENA	MSL	61.0	2956	2004
MI	DETROIT	TCL	64.0	2416	2307
MI	FLINT	BWG	57.2	3980	1601
MI	GRAND RAPIDS	JKL	55.9	3946	1537
MI	HOUGHTON LAKE	LEX	55.2	4525	1451
MI	LANSING	PAH	56.8	4145	1554
MI	MUSKEGON	SDF	56.9	4085	1792
MI	MARQUETTE	JAN	64.1	2257	2414
MN	DULUTH	MEI	64.7	2283	2234
MN	INT'L FALLS	TUP	61.3	2669	2298
MN	MINNEAPOLIS	BNA	58.9	3459	1954
MN	ROCHESTER	CHA	60.0	3140	1824
MN	SAINT CLOUD	CSV	54.5	4166	1091
MO	COLUMBIA	MEM	62.3	2629	2582
MO	KANSAS CITY	MKL	59.4	3443	1771
MO	SPRINGFIELD	TRI	54.9	4201	1153
MO	SAINT LOUIS	TYS	58.4	3517	1610
MS	JACKSON	FSM	61.2	2920	2359
MS	MERIDIAN	FYV	57.7	3825	1619
MS	TUPELO	LIT	62.1	2941	2179
MT	BILLINGS	BTR	67.0	1443	2920
MT	CUT BANK	LCH	67.9	1312	3099
MT	KALISPELL	LFT	68.3	1292	3225
MT	GLASGOW	MSY	68.8	1102	3203
MT	GREAT FALLS	SHV	65.7	1868	3001
MT	HELENA	HBR	59.8	3379	2200
MT	MILES CITY	OKC	60.1	3178	2132
MT	MISSOULA	TUL	60.8	3303	2323
NC	ASHEVILLE	DUG	61.5	2369	1963
NC	CHARLOTTE	FLG	46.2	6634	111
NC	GREENSBORO	INW	55.2	4096	1259
NC	CAPE HATTERAS	PHX	74.2	732	4714
NC	WILMINGTON	TUS	68.7	1207	3417
NC	RALEIGH DURHAM	YUM	75.3	504	4629
ND	BISMARCK	ALS	40.8	7751	97
ND	DICKINSON	COS	47.8	5870	554
ND	FARGO	DEN	50.1	5730	925
ND	GRAND FORKS	GJT	51.8	5047	1119
ND	WILLISTON	PUB	51.7	5217	1026
ND	JAMESTOWN	TAD	51.0	5110	945
NE	SCOTTSBLUFF	BOI	51.9	5424	975

NE	GRAND ISLAND	LWS	52.4	4814	851
NE	NORTH PLATTE	PIH	46.5	7131	398
NE	LINCOLN	BIL	47.4	6560	652
NE	NORFOLK	CTB	39.7	8206	128
NE	OMAHA	FCA	42.6	7603	92
NE	VALENTINE	GGW	42.6	8000	541
NH	CONCORD	GTF	43.7	7443	320
NH	MT WASHINGTON	HLN	44.0	7478	461
NJ	ATLANTIC CITY	MLS	46.3	7217	720
NJ	NEWARK	MSO	44.8	7527	312
NM	ALBUQUERQUE	ABQ	56.8	3767	1562
NM	CLAYTON	CAO	53.3	4563	968
NM	CARLSBAD	CNM	62.8	2619	2211
NM	ROSWELL	ROW	60.8	3028	1974
NV	ELKO	EKO	46.4	7169	448
NV	ELY	ELY	44.8	7001	259
NV	LAS VEGAS	LAS	68.1	1582	3595
NV	LOVELOCK	LOL	50.1	5181	1075
NV	RENO	RNO	51.3	4900	970
NV	WINNEMUCCA	WMC	49.3	6464	550
NY	ALBANY	SLC	52.0	5321	1203
NY	WATERTOWN	CPR	44.9	6939	465
NY	BINGHAMTON	CYS	44.9	6610	449
NY	BUFFALO	LND	45.0	7203	563
NY	NEW YORK	RKS	42.8	7849	291
NY	ROCHESTER	SHR	44.5	7091	602
NY	SYRACUSE	WRL	45.4	7214	671
NY	UTICA	ADQ	40.5	8058	0
OH	AKRON CANTON	AKN	34.5	10001	0
OH	CLEVELAND	ANC	36.2	9265	8
OH	COLUMBUS	BET	29.9	12013	12
OH	CINCINNATI	BIG	28.6	11876	19
OH	DAYTON	BRW	10.4	18659	0
OH	FINDLAY	BTT	22.9	14513	37
OH	MANSFIELD	CDB	38.4	8794	0
OH	TOLEDO	FAI	26.7	13011	53
OH	YOUNGSTOWN	GKN	27.1	12420	2
OK	HOBART	HOM	38.1	8496	0
OK	OKLAHOMA CITY	JNU	41.5	7676	2
OK	TULSA	MCG	26.9	13086	23
OR	ASTORIA	OME	27.1	13214	12
OR	BAKER	OTZ	21.8	15012	16
OR	BURNS	SNP	35.0	9601	0
OR	EUGENE	TKA	33.9	9692	22
OR	MEDFORD	UNK	27.2	12349	21
OR	NORTH BEND	VWS	38.3	7542	23
OR	PENDLETON	YAK	39.5	8201	0
OR	PORTLAND	HNL	77.5	0	4992

OR	SALEM	ITO	73.9	0	3666
PA	ALLENTOWN	LIH	75.7	0	4308
PA	HARRISBURG	OGG	75.8	0	4088
PA	ERIE	AST	51.0	4588	18
PA	WILLIAMSPORT	BKE	45.4	7453	179
PA	PHILADELPHIA	BNO	44.2	7450	268
PA	PITTSBURGH	EUG	52.1	4612	263
RI	PROVIDENCE	MFR	54.4	4133	859
SC	COLUMBIA	OTH	52.5	4288	2
SC	CHARLESTON	PDT	52.3	5258	608
SC	GREENVILLE	PDX	53.5	4150	445
SD	ABERDEEN	SLE	52.6	4574	319
SD	WATERTOWN	ALW	54.2	4770	910
SD	SIOUX FALLS	BLI	50.8	5269	22
SD	HURON	EAT	51.9	5562	819
SD	PIERRE	GEG	47.3	6485	417
SD	RAPID CITY	OLM	49.6	5078	86
TN	NASHVILLE	SEA	52.3	4437	164
TN	CHATTANOOGA	UIL	49.1	5272	12
TN	CROSSVILLE	YKM	48.9	5867	494
TN	MEMPHIS	ALB	47.5	6607	913
TN	JACKSON	ART	45.7	7565	576
TN	BRISTOL	BGM	45.8	7089	674
TN	KNOXVILLE	BUF	47.9	6644	880
TX	ABILENE	LGA	55.1	4707	1597
TX	WACO	ROC	47.6	6735	795
TX	ALICE	SYR	47.4	6636	909
TX	AMARILLO	UCA	46.6	7195	709
TX	AUSTIN	BFL	65.0	1797	2144
TX	BROWNSVILLE	BLH	71.3	889	4251
TX	CORPUS CHRISTI	EKA	52.9	4857	0
TX	DALLAS FT WORTH	FAT	63.2	1881	2080
TX	DEL RIO	LAX	63.3	1128	525
TX	EL PASO	MHS	49.2	5629	272
TX	GALVESTON	PRB	58.5	2437	963
TX	HOUSTON	RDD	61.6	2466	1775
TX	LUBBOCK	SAC	61.1	2345	1180
TX	MIDLAND ODESSA	SAN	64.4	858	657
TX	SAN ANTONIO	SCK	61.8	2061	1482
TX	SAN ANGELO	SFO	57.3	2267	71
TX	WICHITA FALLS	ABI	64.4	2316	2475
TX	VICTORIA	ACT	66.6	1837	3030
UT	SALT LAKE CITY	ALI	72.3	743	4026
VA	LYNCHBURG	AMA	57.0	4045	1432
VA	NORFOLK	AUS	69.0	1578	3181
VA	RICHMOND	BRO	73.3	346	4380
VA	ROANOKE	CRP	71.5	690	3807
VT	BURLINGTON	DFW	65.5	1953	3122

WA	WALLA WALLA	DRT	69.7	1210	3464
WA	BELLINGHAM	ELP	64.7	2146	2556
WA	WENATCHEE	GLS	71.2	848	3673
WA	SPOKANE	IAH	68.8	1221	3292
WA	OLYMPIA	LBB	59.7	3173	1925
WA	SEATTLE TACOMA	MAF	63.4	2604	2273
WA	QUILLAYUTE	SAT	68.7	1277	3328
WA	YAKIMA	SJT	64.5	2209	2420
WI	GREEN BAY	SPS	63.1	2597	2556
WI	LACROSSE	VCT	70.0	1108	3334
WI	MILWAUKEE	DAB	71.0	763	2981
WI	MADISON	EYW	78.1	68	4743
WV	BECKLEY	FLL	75.4	135	4222
WV	CHARLESTON	FMY	74.9	284	3814
WV	ELKINS	GNV	68.6	1193	2711
WV	HUNTINGTON	JAX	68.0	1358	2670
WV	MARTINSBURG	MCO	72.8	527	3404
WY	CASPER	MIA	76.7	109	4435
WY	CHEYENNE	PBI	75.3	232	4021
WY	LANDER	PNS	68.2	1305	2775
WY	ROCK SPRINGS	TLH	68.0	1520	2737
WY	SHERIDAN	TPA	73.1	522	3505
WY	WORLAND	VRB	73.2	463	3479

Table 7-D.2.2 Sample RECS Household Matches

Location	DOE ID	HDD	CDD	Division
BOS	2977	5771	839	1
BOS	43	5788	900	1
BOS	396	5791	834	1
BOS	703	5796	833	1
BOS	2389	5817	828	1
BOS	1470	5874	894	1
BOS	385	5874	894	1
BOS	4354	5879	902	1
BOS	3952	5885	876	1
BOS	1529	5899	888	1
BOS	2381	5911	885	1
BOS	825	5913	894	1
BOS	2005	5922	880	1
BOS	2064	5931	801	1
BOS	4040	5933	879	1
BOS	1428	5933	879	1
BOS	535	5951	884	1
BOS	894	5956	873	1
BOS	2211	5958	873	1
BOS	1548	5959	873	1
BOS	3239	5965	871	1
BOS	620	5968	864	1
BOS	2533	5975	853	1
BOS	697	5979	865	1

BOS	4067	5980	865	1
BOS	3506	5983	866	1
BOS	1369	5994	864	1
BOS	4113	5994	932	1
BOS	1726	5997	861	1
BOS	1671	5998	861	1
BOS	328	6012	918	1
BOS	3790	6018	856	1
BOS	3890	6020	841	1
BOS	2587	6024	854	1
BOS	281	6028	839	1
BOS	87	6028	855	1
BOS	1440	6052	847	1
BOS	2152	6057	832	1
BOS	4140	6059	831	1
BOS	2949	6061	845	1
BOS	675	6062	876	1
BOS	1079	6071	843	1
BOS	178	6072	801	1
BOS	2487	6072	842	1
BOS	3111	6084	825	1
BOS	1797	6097	821	1
BOS	3333	6107	694	1

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APPENDIX 8-A. USER INSTRUCTIONS FOR THE LIFE-CYCLE COST ANALYSIS SPREADSHEET

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APPENDIX 8-A. USER INSTRUCTIONS FOR THE LIFE-CYCLE COST ANALYSIS SPREADSHEET

8-A.1 USER INSTRUCTIONS

The results obtained in this analysis can be examined and reproduced using the Microsoft Excel spreadsheets available on DOE's Home Appliances Rulemaking website: http://www.eere.energy.gov/buildings/appliance_standards/. From that page, follow the links to the NOPR phase and then to Analytical Tools.

8-A.2 STARTUP

DOE's spreadsheets enable users to perform Life-Cycle Cost (LCC) and Payback Period (PBP) analyses for each product class. A separate spreadsheet exists for each product class. Table 8-A.2.1 lists the LCC spreadsheets used in this rulemaking.

Table 8-A.2.1 List of LCC Spreadsheets

Filename	Product Class
LCC_RoomAir.xls	Room Air Conditioners
LCC_ClothesDryer.xls	Clothes Dryers

To examine the spreadsheets, DOE assumes that the user has access to a personal computer with a hardware configuration capable of running Windows NT/2000/XP. All LCC spreadsheets require Microsoft Excel 2000 or later installed under the Windows operating system. Because certain variables inside the spreadsheets are defined as distributions, the user's computer requires a copy of Crystal Ball (a commercially available add-on program).

8-A.3 DESCRIPTION OF LIFE-CYCLE COST WORKSHEETS

For both of the products, DOE created one spreadsheet containing a collection of worksheets. Each worksheet represents a conceptual component within the LCC calculation. To facilitate navigability and identify how worksheets are related, each worksheet contains an area on the extreme left showing variables imported to and exported from the current worksheet. Each LCC spreadsheet contains the following worksheets:

Summary The *Summary* worksheet contains LCC and PBP simulation results for each design option and product class.

Statistics The *Statistics* worksheet contains statistics for each design option and product class.

LCC & PB Calcs The *LCC&PB Calcs* worksheet shows LCC calculation results for different efficiency levels for single Residential Energy Consumption Survey (RECS) households and Commercial Buildings Energy Consumption Survey (CBECS) buildings, if applicable.[1, 2]

Rebuttable Payback	The *Rebuttable Payback* worksheet contains the total and incremental manufacturer costs, retail prices, installation costs, repair and maintenance costs, energy use calculations, and simple payback period calculations for each efficiency level.
Equipment (and Installation) Cost	This worksheet calculates retail price values used as inputs in the LCC calculations in the *Summary* worksheet. In the Clothes Dryers LCC spreadsheet, installation costs were included in this worksheet.
Maintenance	These worksheets calculate maintenance costs used as inputs in the LCC calculations.
RECS Households	The *RECS Households* worksheet contains the RECS 2005 household data for each residential product class.
CBECS Households	The *CBECS Households* worksheet contains the CBECS 2003 building data for each commercial product class.
Energy Use Adjustment Factors	This worksheet calculates energy adjustment factors used in the energy use calculations for room air conditioners.
CW Models	This worksheet includes information on clothes washer models.
CD Models	This worksheet includes information on clothes dryer models.
RAC Models	This worksheet includes information on room air conditioner models.
Commercial and Residential Weather Station Data	These worksheets include temperature data.
Base Case Eff Dist	The *Base Case EF* worksheet determines the efficiency of the base case unit.
(Per Cycle) Energy Use	The *(Per Cycle) Energy Use* worksheet calculates annual energy use by fuel type, depending on product class.
Energy Prices	The *Energy Prices* worksheet calculates energy prices, depending on a number of variables.
Energy Price Trends	The *Energy Price Trends* worksheet shows the future price trends of the different heating fuels.
Discount Rate	The *Discount Rate* worksheet contains the distributions of discount rates

for replacement and new units.

Lifetime The *Lifetime* worksheet contains the distribution of lifetimes for equipment of that product class.

8-A.4 BASIC INSTRUCTIONS FOR OPERATING THE LIFE-CYCLE COST SPREADSHEETS

Basic instructions for operating the LCC spreadsheet are as follows:

1. Once the LCC spreadsheet has been downloaded, open the file using Excel. Click “Enable Macro” when prompted and then click on the tab for the *Summary* worksheet.

2. Use Excel's View/Zoom commands at the top menu bar to change the size of the display to fit your monitor.

3. The user can change the parameters listed under USER INPUT on the *Summary* worksheet. There are four drop-down boxes and one command button. The default parameters are:

    a. Energy Price Trend: Defaults to “AEO 2010 - Reference.” To change the input, use the drop-down menu and select the desired trend (Reference, Low, or High).

    b. Start Year: Defaults to “2014.” To change the value, use the drop-down menu and select the desired year.

    c. # of Trials: Defaults to “10,000.” To change the value, use the drop-down menu and select the desired number of trials (1,000, 2,000, 3,000, 5,000, or 10,000).

    d. Analysis Group: Defaults to “National.” To analyze a subgroup, use the drop-down menu and select the desired subgroup.

4. To run the Crystal Ball simulation, click the “run” button (you must re-run after changing any parameters). The spreadsheet will then be minimized. You can monitor the progress of the simulation by watching the count of iterations in the left bottom corner of the screen. When the simulation is finished, the spreadsheet will re-open.

5. Additional information can be found in the *Statistics* and *Summary* worksheets.

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APPENDIX 8-B. UNCERTAINTY AND VARIABILITY

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APPENDIX 8-B. UNCERTAINTY AND VARIABILITY

8-B.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.

8-B.2 UNCERTAININTY

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. room air conditioner or clothes dryer) 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.

8-B.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, the number of hours an air conditioner is operated by a household depends upon the specific circumstances and behaviors of the occupants (e.g., number of persons, personal habits about how comfortable the person wants to be). Variability makes specifying an appropriate population value more difficult in as much as any one value may not be representative of the entire population. Surveys can be helpful here, and analysis of surveys can relate the variable of interest (e.g., hours of use) to other variables that are better known or easier to forecast (e.g., persons per household).

8-B.4 APPROACHES TO UNCERTAINTY AND VARIABILITY

This section describes two approaches to uncertainty and variability:

- scenario analysis, and
- probability analysis.

Scenario analysis uses a single numerical value for each quantity in a calculation, then changes one (or more) of the numerical values and repeats the calculation. 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.

8-B.5 PROBABILITY ANALYSIS AND THE USE OF CRYSTAL BALL

To quantify the uncertainty and variability that exist in inputs to the engineering, LCC, and payback period (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., product lifetime, discount rate, and installation cost).

For each uncertain variable (one that has a range of possible values), possible values are defined with a probability distribution. The type of distribution selected is based on the conditions surrounding that variable. Probability distribution types include:

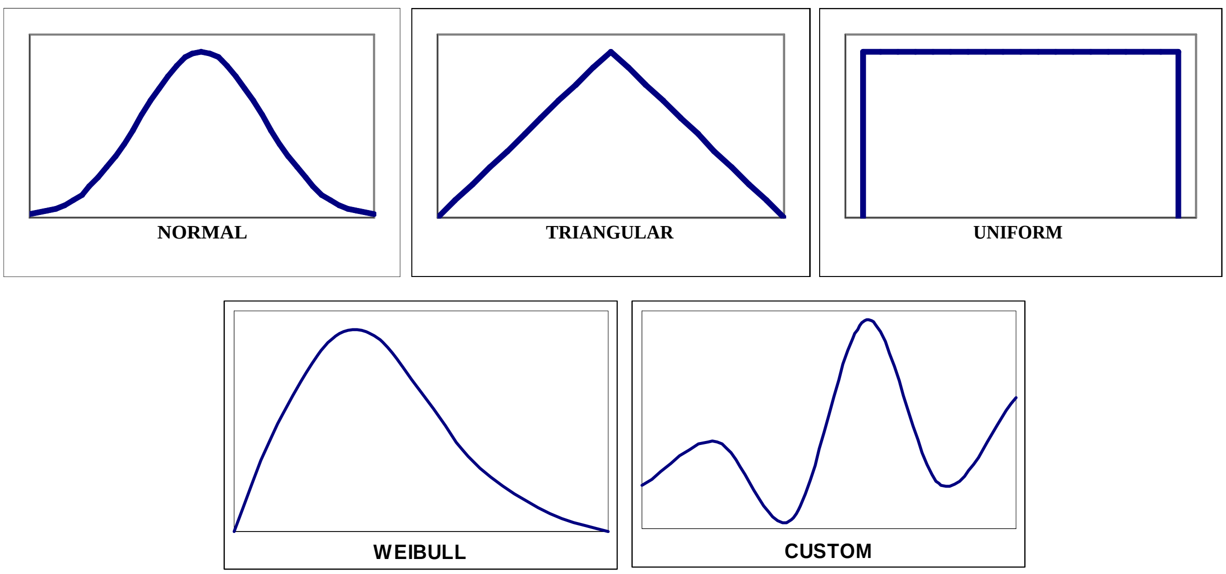

Figure 8-B.5.1 Normal, Triangular, Uniform, Weibull, and Custom Probability Distributions

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 8-C. LIFETIME DISTRIBUTIONS

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APPENDIX 8-C. LIFETIME DISTRIBUTIONS

8-C.1 INTRODUCTION

For each product class, DOE characterized the product lifetime using a Weibull probability distribution that ranged from the minimum to maximum lifetime estimates described in chapter 8, Life Cycle Cost and Payback Period Analyses. The Weibull distribution is recommended for application to lifetime data because it can be shaped to match low, average, and high values while still allowing some probability of exceeding the high value.[1, 2]

8-C.1.1 Product Lifetime

The product lifetime is the age at which the product is retired from service. *Appliance* magazine provides estimates of the low, high, and average years of an appliance's lifetime. The estimates, which are based on first-owner use of the product, represent the expert judgment of *Appliance* staff based on input obtained from various sources. DOE also identified other sources that give lifetimes for room air conditioners and clothes dryers (see Tables 8.C.1.1 and 8.C.1.2). Because the basis for the estimates in the literature was uncertain, DOE developed a method using household survey data to estimate the distribution of room air conditioner and clothes dryer lifetimes in the field.

Table 8-C.1.1 Room Air Conditioners: Product Lifetime Estimates and Sources

Typical Lifetime or Range (years)		Source
Original Sources		
Average = 9; Low = 7		Appliance Magazine, September 2008[3]
12.5		ASHRAE 2008[4]
15		CEC 2005[5]
12		European Rulemaking Draft Report[6]
Average = 15; High = 20		NRDC[7]
Other Sources		
Lifetime	*Source*	
9	Appliance Magazine, 1997	ENERGY STAR Savings Calculator[a]
18	EnerGuide 2005	Natural Resources Canada, 2008[8]
15	NA	New Mexico Market Assessment, Itron 2006[9]
18	NA	Nebraska Public Power District[10]
12	See endnote	NYSERDA SBC, 2002[11]
9	NA	RTF (Northwest), 2002[12]
12.5	DOE TSD 1997	NCEP report, LBNL 2004[13]
19	Aspen Memo, 2002	NYSERDA Deemed Savings Database: ENERGY STAR[14]
13 (TTW)	DOE TSD 2005	NYSERDA Deemed Savings Database: ENERGY STAR[13]
Low = 8, High =16		NEMS Residential Demand Module, 2008[15]
13		LBNL 2008[16]
Average = 10–15, Low = 8–12, High = 14-18		LBNL 1994[17]
10		Consortium for Energy Efficiency[18]
10–12		American Council for an Energy Efficient Economy, 2007[19]

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

[a] ENERGY STAR Savings Calculator, Products, Room AC. Efficient and conventional models.

Table 8-C.1.2 Clothes Dryers: Product Lifetime Estimates and Sources

Typical Lifetime or Range (years)		Source
Original Sources		
Average = 12; Low = 8; High = 15		Appliance Magazine, September 2008[3]
15		CEC 2005[5]
18		CALMAC 2000[20]
Other Sources		
Lifetime	*Source*	
Average = 12; Low = 8; High = 15	Appliance Magazine, 2006	BTS Core Databook, 2007[21]
18	EnerGuide 2005	Natural Resources Canada, 2007[22]
18	DOE Framework Document	Itron, Report to CEC, 2007
18	NA	CEC Consumer Energy Center website
18	See endnote	CEC Flex Your Power website
14	NA	Nebraska Public Power website
18	NA	New Mexico Market Assessment, Itron 2006[8]
12	Nexant, PECI	Questar Gas, Utah, from Deemed Savings Database, 2006
14		RTF (Northwest) CW/CD spreadsheet, 2008

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

8-C.2 ESTIMATION OF SURVIVAL FUNCTION.

The Residential Energy Consumption Survey (RECS) records the presence of various appliances in each household, and places the age of each appliance into bins comprising several years. Data from the U.S. Census's American Housing Survey (AHS),[23] which surveys all housing including vacant and second homes, enabled DOE to adjust the RECS data to reflect the presence of appliances outside of primary residences. By combining the results of both surveys with the known history of appliance shipments (collected from Appliance magazine or directly from manufacturer trade associations), DOE estimated the percentage of appliances of a given age still in operation. This survival function, which DOE assumed has the form of a cumulative Weibull distribution, provides an average and a median appliance lifetime.

The Weibull distribution is a probability distribution commonly used to measure failure rates.[b] Its form is similar to an exponential distribution, which models a fixed failure rate, except

[b] For reference on the Weibull distribution, see sections 1.3.6.6.8 and 8.4.1.3 of the *NIST/SEMATECH e-Handbook of Statistical Methods*, <www.itl.nist.gov/div898/handbook/>.

that a Weibull distribution allows for a failure rate that changes over time in a particular fashion. The cumulative Weibull distribution takes the form:

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

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

Where:

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

When $\beta = 1$, the failure rate is constant over time, giving the distribution the form of a cumulative exponential distribution. In the case of appliances, β commonly is greater than 1, reflecting an increasing failure rate as appliances age.

RECS is DOE's primary resource for appliance ages. For several appliances, including room air conditioners and clothes dryers, the survey asks respondents to identify the appliance's age as:

- less than 2 years old,
- 2 to 4 years old,
- 5 to 9 years old,
- 10 to 19 years old, or
- more than 20 years old.

The RECS has been conducted every three or four years for the past several decades. For this analysis, DOE used the surveys conducted in 1990, 1993, 1997, 2001, and 2005. DOE used the AHS count of housing units that contain room air conditioners or clothes dryers to scale the RECS data to better match the total installed stock. Table 8.C.2.1 shows the lifetime parameters for room air conditioners and clothes dryers.

Table 8-C.2.1 Lifetime Parameters

Product Class	Calculated Values				Weibull Parameters	
	Minimum *(years)*	**Average** *(years)*	**Maximum** *(years)*	**Maximum percentile** *(%)*	**Alpha (scale)**	**Beta (shape)**
Room Air Conditioner	3	10.5	30	97	7.47	1.00
Clothes Dryer	5	16.03	30	94	12.1	1.38

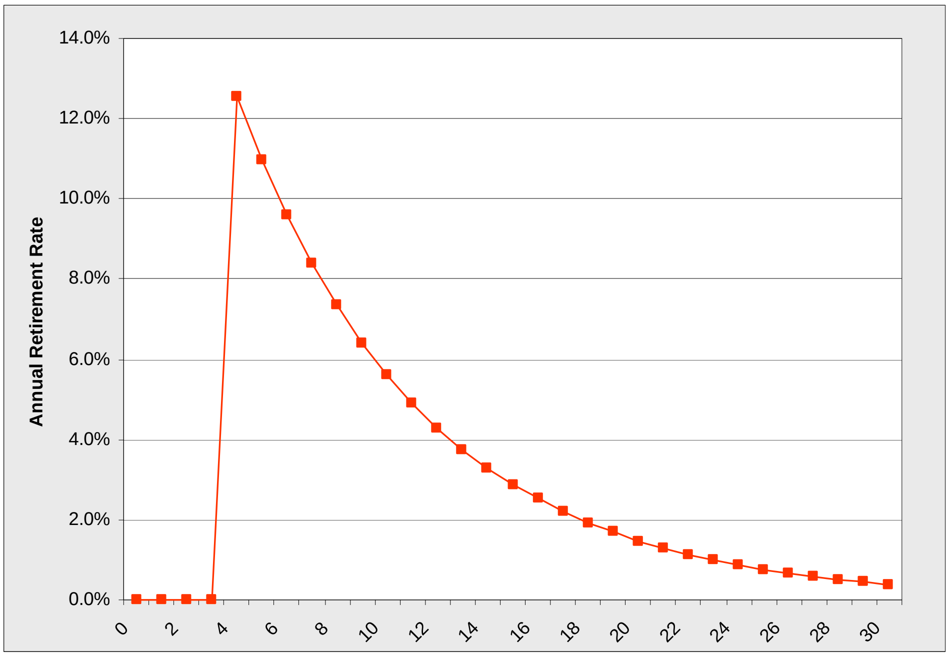

Figure 8-C.2.1 Room Air Conditioners: Lifetime Function

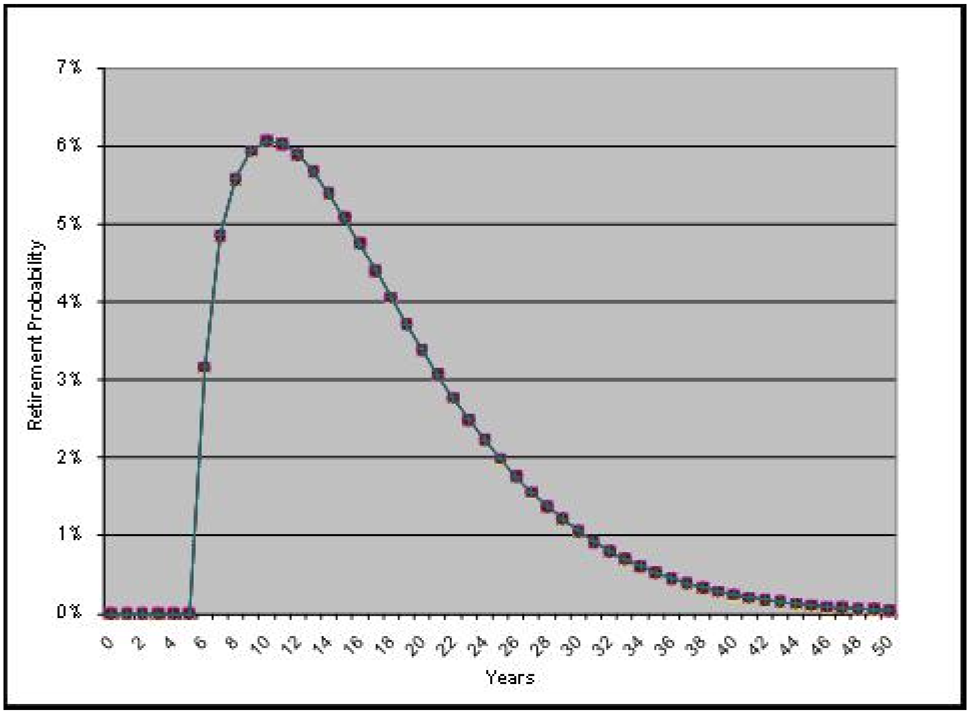

Figure 8-C.2.2 Clothes Dryers: Lifetime Function

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APPENDIX 8-D. DISTRIBUTIONS USED FOR DISCOUNT RATES

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APPENDIX 8-D. DISTRIBUTIONS USED FOR DISCOUNT RATES

8-D.1 INTRODUCTION

DOE derived discount rates for the LCC analysis using data on interest or return rates for various types of debt and equity. To account for variation among households in rates for each of the types, DOE sampled a rate for each household from a distribution of rates for each debt and equity type. This appendix describes the distributions used.

8-D.2 DISTRIBUTION OF MORTGAGE INTEREST RATES

Figure 8-D.2.1 shows the distribution of real interest rates for new home mortgages. The data source DOE used for mortgage interest rates is the Federal Reserve Board's *Survey of Consumer Finances (SCF)* in 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[1] Using the appropriate *SCF* data for each year, DOE adjusted the nominal mortgage interest rate for each relevant household in the *SCF* for mortgage tax deduction and inflation. In cases where the effective interest rate is equal to or below the inflation rate (resulting in a negative real interest rate), DOE set the real effective interest rate to zero.

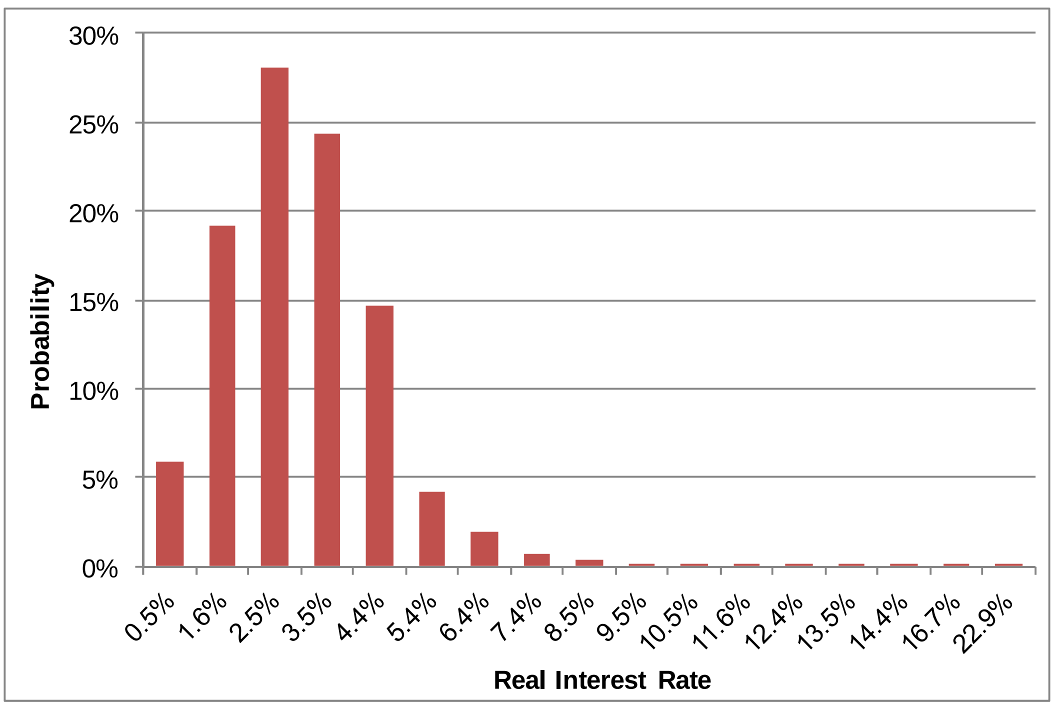

Figure 8-D.2.1 Distribution of New Home Mortgage Interest Rates

8-D.3 DISTRIBUTION OF RATES FOR DEBT CLASSES CONSIDERED FOR REPLACEMENT PRODUCTS

Figure 8-D.3.1 through Figure 8-D.3.5 show the distribution of real interest rates for different types of debt used to finance replacement clothes dryers and room air conditioners. The

data source for the interest rates for home equity loans, credit cards, installment loans, other residence loans, and other lines of credit is the Federal Reserve Board's *SCF* in 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[1] DOE adjusted the nominal rates to real rates using the annual inflation rate in each year. For home equity loans, DOE calculated effective interest rates in a similar manner as for mortgage rates, since interest on such loans is tax deductible.

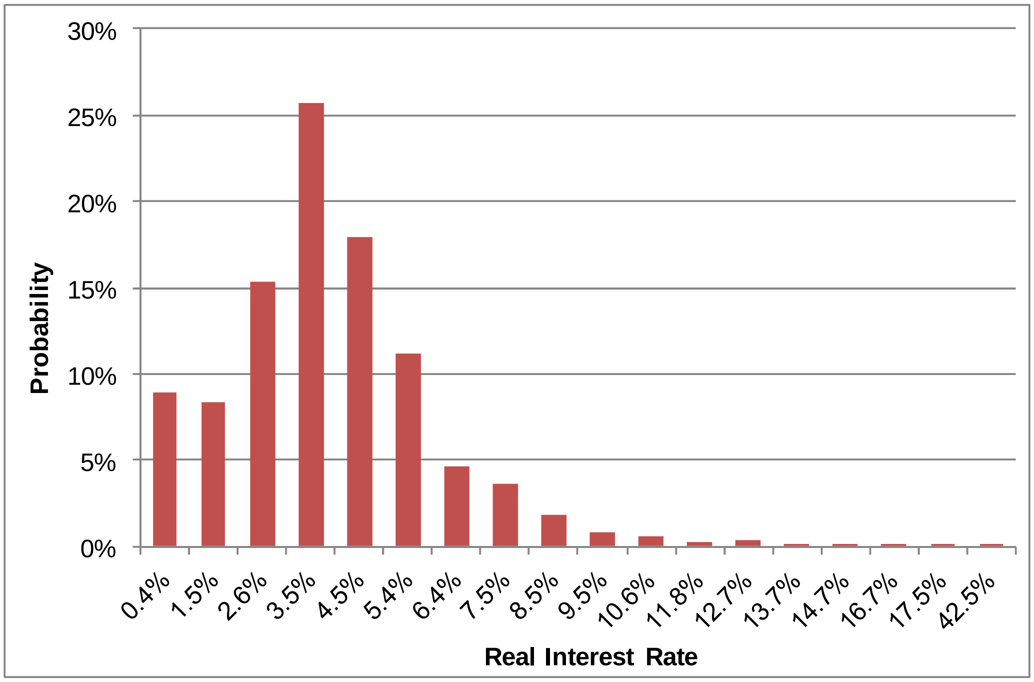

Figure 8-D.3.1 Distribution of Home Equity Loan Interest Rates

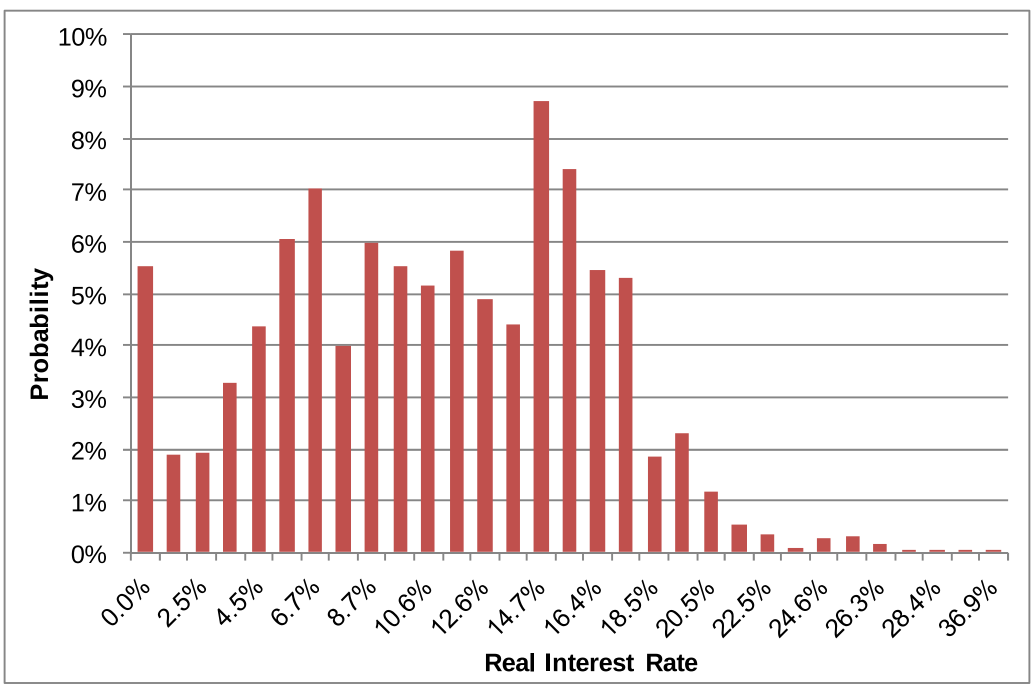

Figure 8-D.3.2 Distribution of Credit Card Interest Rates

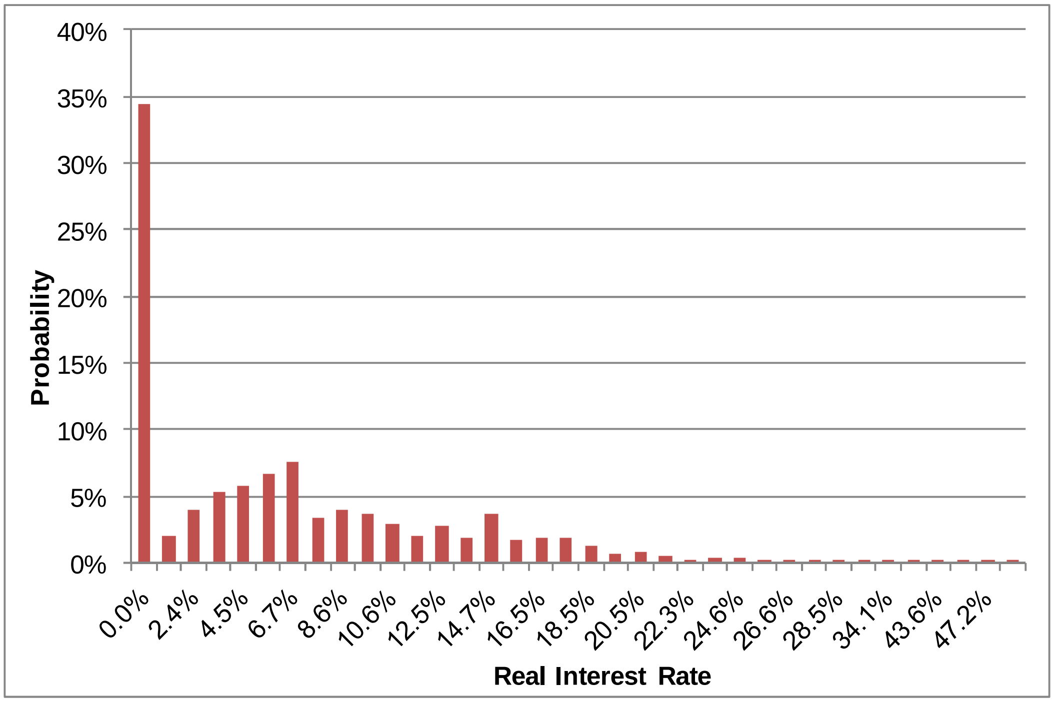

Figure 8-D.3.3 Distribution of Installment Loan Interest Rates

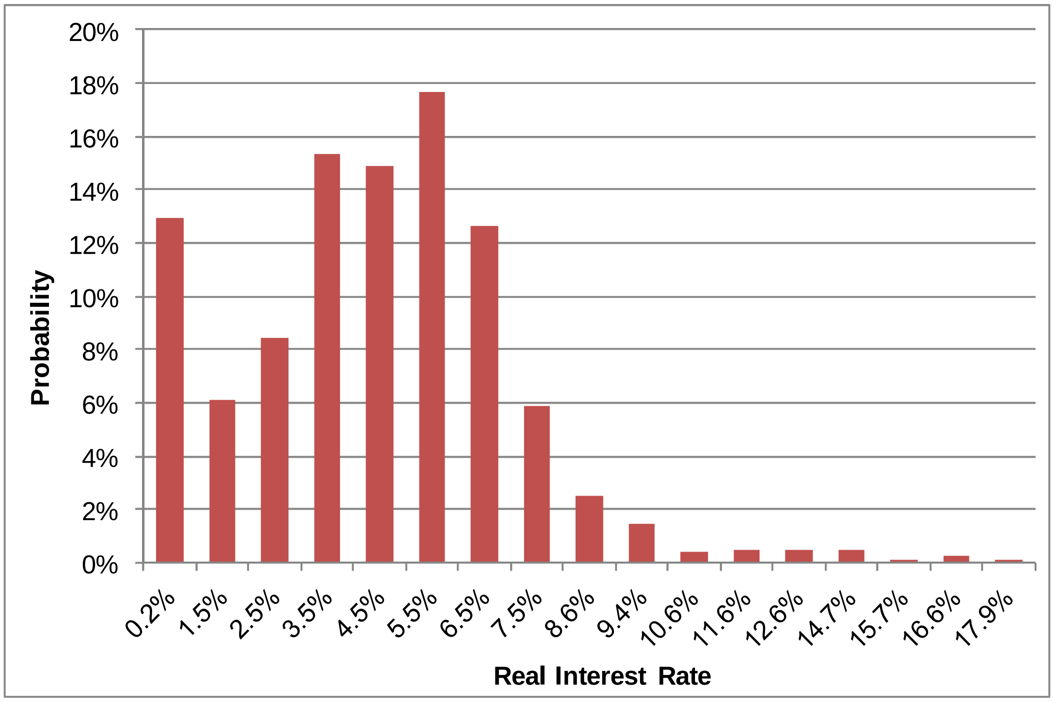

Figure 8-D.3.4 Distribution of Other Residence Loan Interest Rates

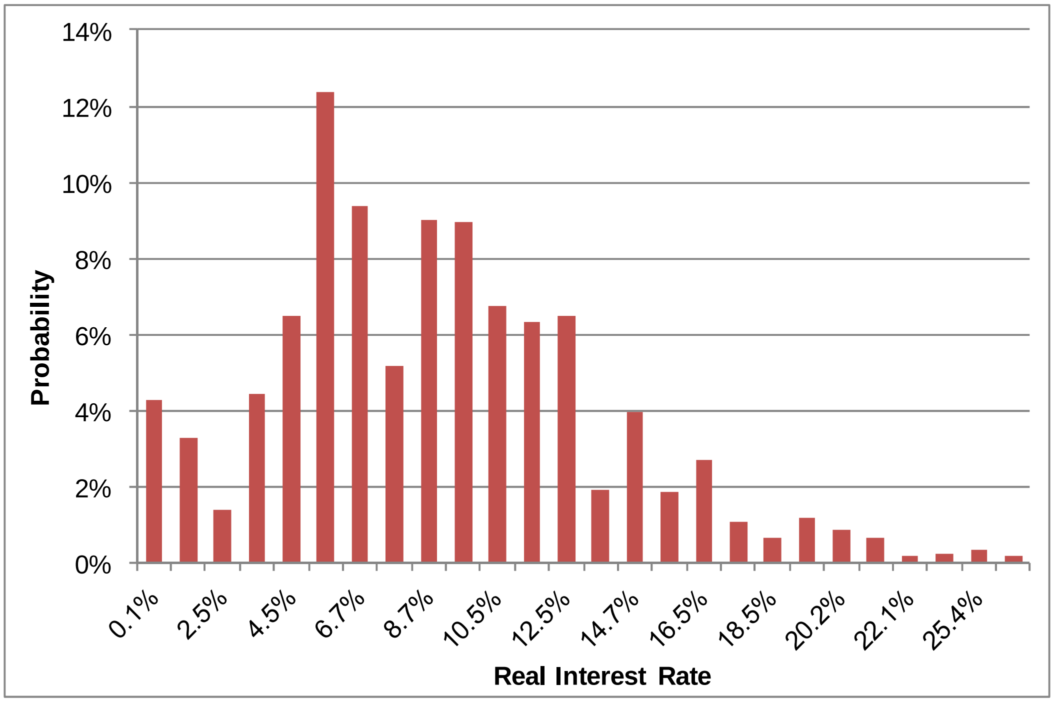

Figure 8-D.3.5 Distribution of Other Lines of Credit Loan Interest Rates

8-D.4 DISTRIBUTION OF RATES FOR EQUITY CLASSES CONSIDERED FOR REPLACEMENT PRODUCTS

Figure 8-D.4.1 through Figure 8-D.4.6 show the distribution of real interest rates for different types of equity used to finance replacement clothes dryers and room air conditioners. Data for equity classes are not available from the Federal Reserve Board's *SCF*, so DOE derived data for these classes from national-level historical data. The interest rates associated with certificates of deposit (CDs),[2] savings bonds,[3] and AAA corporate bonds[4] are from Federal Reserve Board time-series data covering 1977 to 2009. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts are from Cost of Savings Index data covering 1984 to 2009.[5] The rates for stocks are the annual returns on the Standard and Poor's (S&P) 500 from 1977 to 2009.[6] The mutual fund rates are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year from 1977 to 2009. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year.

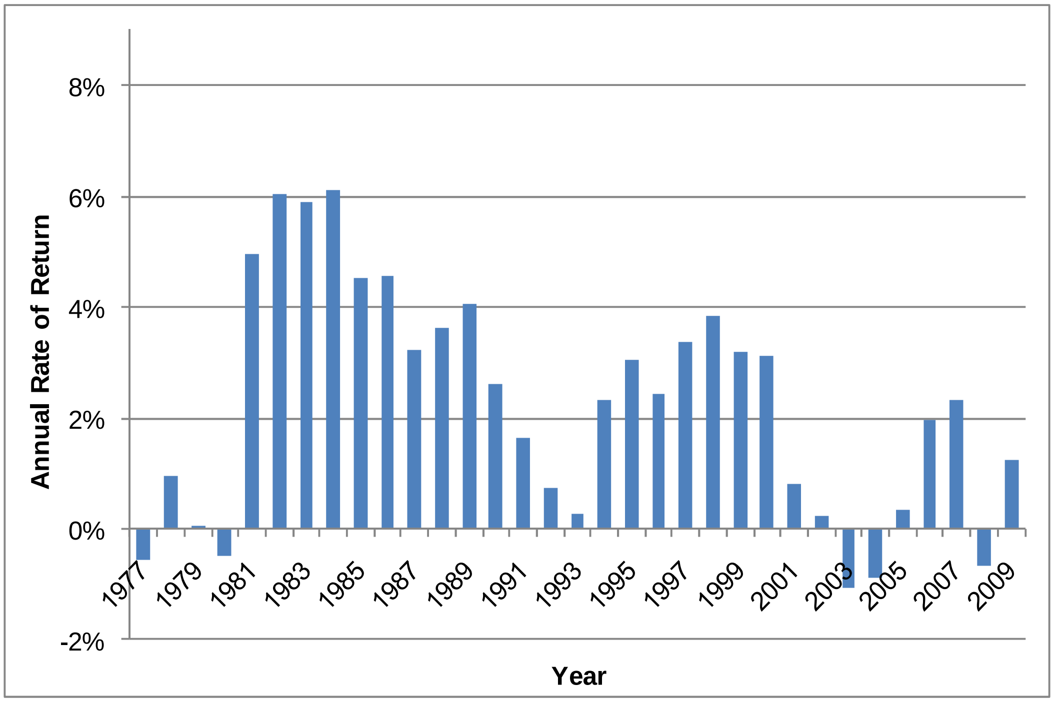

Figure 8-D.4.1 Distribution of Annual Rate of Return on CDs

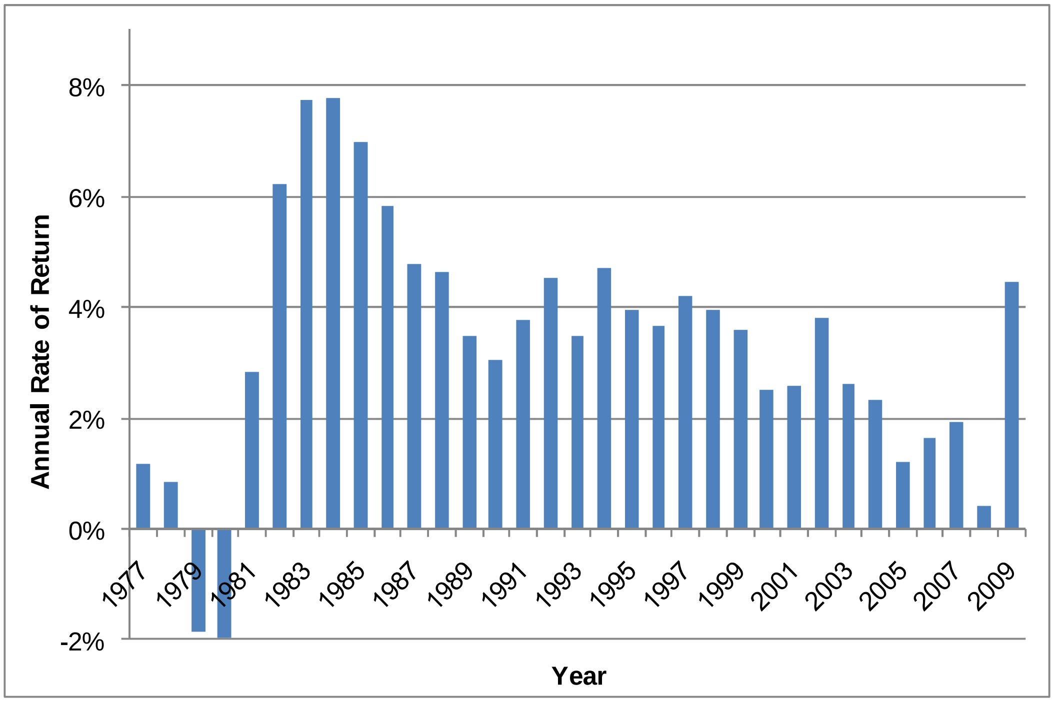

Figure 8-D.4.2 Distribution of Annual Rate of Return on Savings Bonds

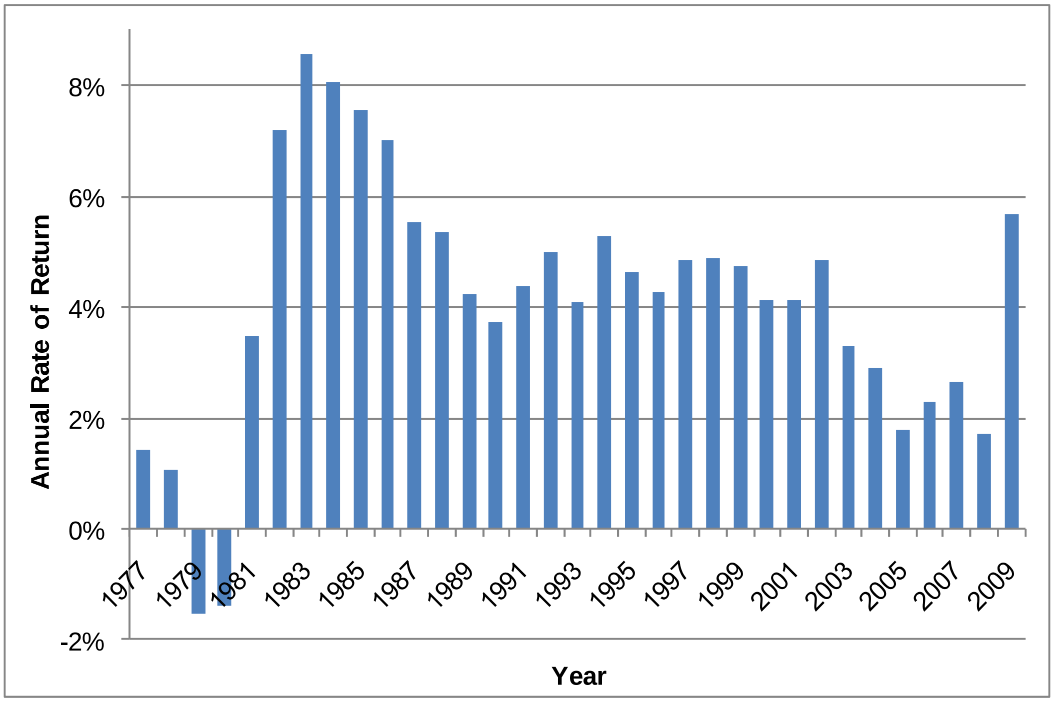

Figure 8-D.4.3 Distribution of Annual Rate of Return on Corporate AAA Bonds

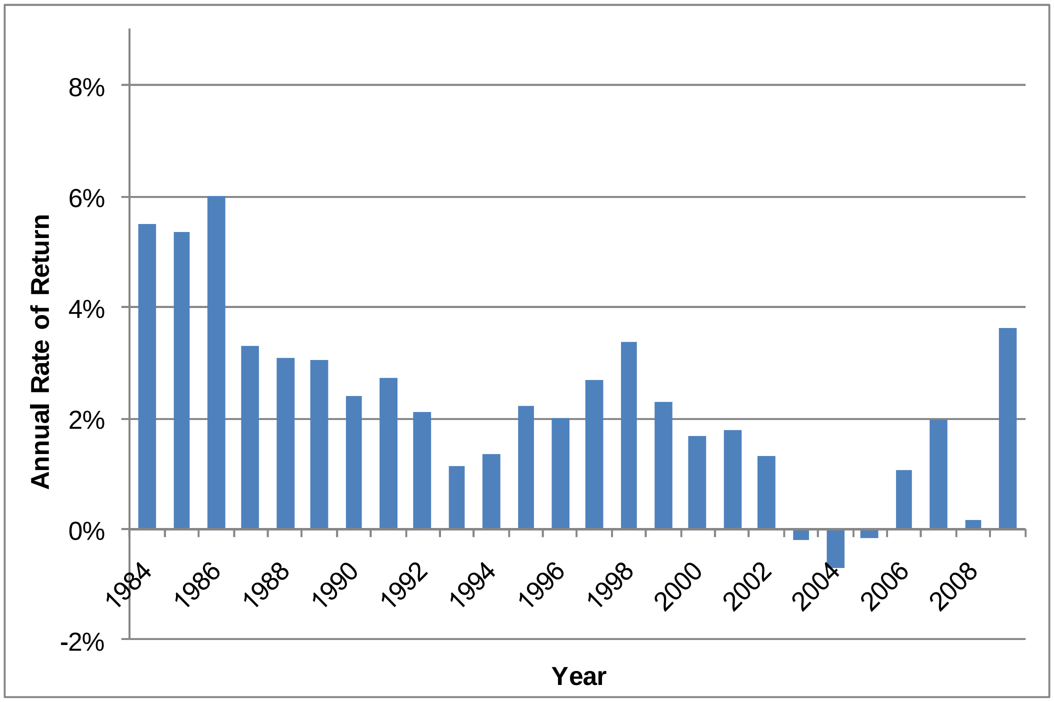

Figure 8-D.4.4 Distribution of Annual Rate of Savings Accounts

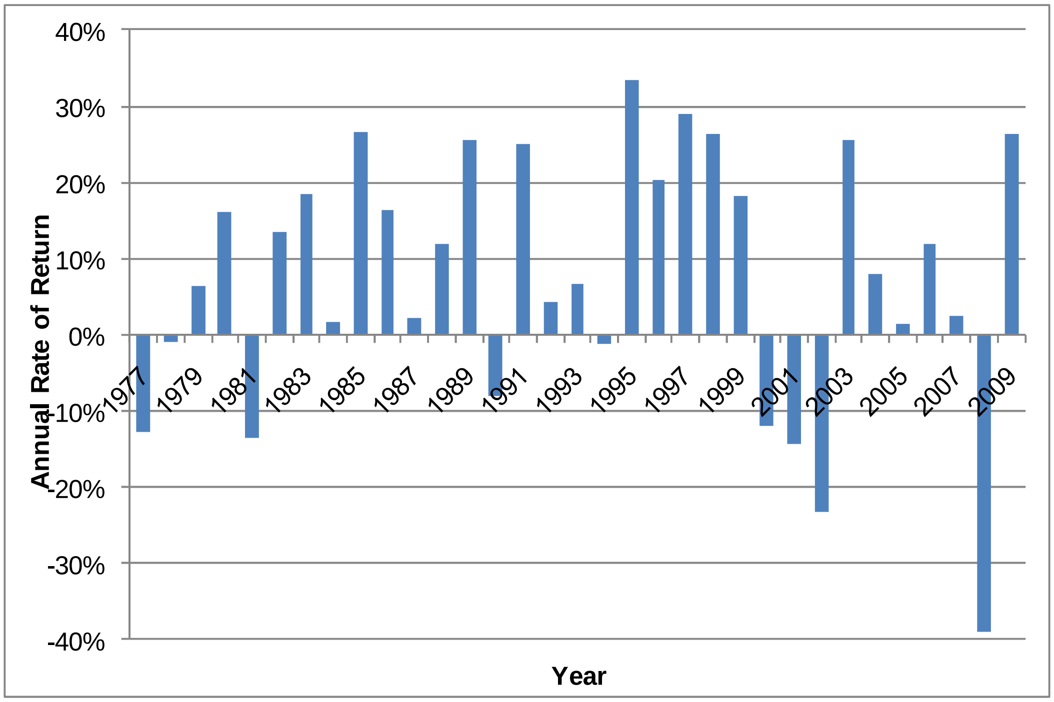

Figure 8-D.4.5 Distribution of Annual Rate of Return on S&P 500

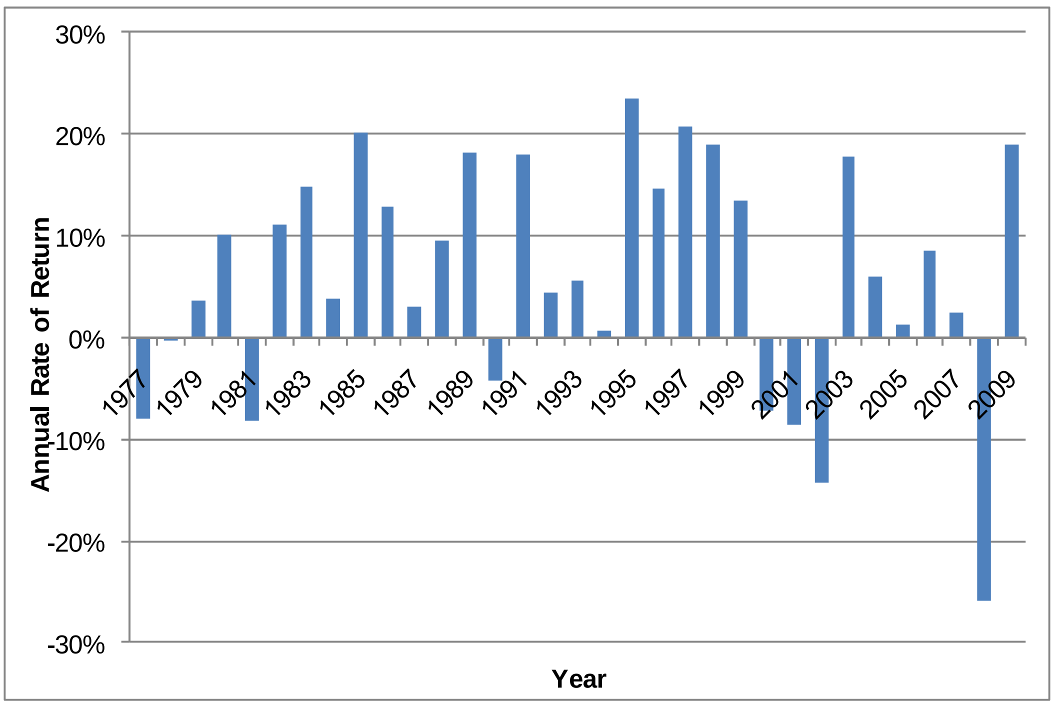

Figure 8-D.4.6 Distribution of Annual Rate of Return on Mutual Funds

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APPENDIX 8-E. TECHNICAL ASPECTS OF THE TARIFF-BASED APPROACH FOR ROOM AIR CONDITIONER ENERGY PRICES

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APPENDIX 8-E. TECHNICAL ASPECTS OF THE TARIFF-BASED APPROACH FOR ROOM AIR CONDITIONER ENERGY PRICES

8-E.1 REVIEW OF DATASETS AND CALCULATION METHODS

The methodology used to calculate electricity prices is dependent on the data set. Table 8-E.1.1 lists the data available for this analysis, and the type of methodology that goes with the data. The table includes information on the resolution of the data both geographically and in terms of the ability to distinguish customer type, and the degree of complexity and accuracy of the calculation methods.

Table 8-E.1.1 List of Data Sources That Could Be Used To Estimate Electricity Prices

Method	Data Source/Year		Resolution		Complexity	Accuracy
			Customer Type	Geographic		
Average price	EIA 861	2006[a]	Low	High	Low	Low
Price by consumption block	EEI	2007	Low	Medium	Low	Low
Average or marginal price by household/building	RECS/CBECS	2001	High	Low	Low	Low
Tariff-based prices using existing data (2004)	LBNL-TAP	2004	High	Medium	Low	Medium
Tariff-based prices using updated data (2008)	LBNL-TAP	2008	High	Medium	Medium	High

If EIA 861 or EEI data are used, only average prices can be estimated. Residential average prices are likely to be slightly above residential marginal prices due to the relatively large fixed charges on residential bills. However, many areas use ascending block rates, in which case the marginal price may be higher than the average price. Commercial average prices are typically lower than commercial marginal prices. Due to the complexity and diversity of commercial rate structures, it can be very difficult to relate an average electricity price to the actual bill savings that may occur under an efficiency scenario in which both the electricity consumption and demand are reduced. This is especially true for peak-coincident end uses. The only method that allows the direct estimation of marginal prices is the tariff-based approach.

Both the RECS and CBECS datasets provide monthly billing data (consumption and expenditures, and demand for commercial buildings) for some survey years (1992 and 1995 for CBECS, 1997 and 2001 for RECS). While these data can be used to estimate prices in principle, the age of the expenditure data and the size of recent price increases make this approach problematic. In particular, in many areas tariff *structures* (not just rates) may have changed significantly in the last 5–10 years. The EEI dataset covers only investor-owned utilities and does not include publicly-owned companies. In some regions, a significant fraction of consumers are served by publicly-owned utilities; EIA data show that on average residential prices tend to be lower, and commercial prices somewhat higher, for publicly-owned versus investor-owned utilities. It is therefore important to include these utilities in the analysis.

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[a] EIA Form 861 data for 2007 became available in May 2009, too late for use in this analysis.

Table 8-E.1.2 illustrates some of these points using EIA form 861 data[1] for the residential sector. In each of the years 2004, 2005 and 2006, the consumer-weighted average revenues divided by sales is calculated over all utilities in a given region, for different market sectors. These numbers are an estimate of the average price paid by a customer in the given sector. The table shows the average price using this estimation for 2006 (in nominal dollars) for publicly- and privately- owned utilities separately. The growth rate is calculated from the price ratios between year 2004 and 2005, 2005 and 2006, and the compound increase between 2004 and 2006. The table illustrates the variability in growth rates by region. Commercial prices show similar characteristics.

Table 8-E.1.2 Residential average prices estimated from EIA Form 861

Residential		**Average Price ¢/kWh (2006)**			**Increase 2004 to 2006**
Code	Area	All	Private	Public	All
1	New England	16.0	16.3	13.1	33.3%
2	Mid-Atlantic	14.1	13.9	16.6	12.4%
3	ENC	9.3	9.3	9.1	10.2%
4	WNC	8.3	8.3	8.3	7.6%
5	South Atlantic	9.8	9.7	10.0	17.2%
6	ESC	8.2	8.2	8.1	14.3%
7	WSC	11.5	12.4	9.6	26.9%
8	Mountain	9.0	9.1	8.9	8.4%
9	Pacific	12.6	13.8	9.2	15.3%
	HI & AK	20.6	22.8	17.2	25.5%

8-E.2 THE TARIFF ANALYSIS PROJECT DATABASE AND CALCULATION TOOLS

The core of the current Tariff Analysis Project (TAP) database is a statistically representative sample of approximately 90 electric utilities[2] that reflects the diversity of the geographic regions, ownership types, and company sizes in the industry. The finest level of regional variation is currently a set of seventeen regions, constructed from the intersection of Census Divisions with major climate zones.[3 4] The region definitions resolve three sources of variability: 1) For datasets such as CBECS and RECS, general demographic variability is represented at the Census Division level. To facilitate the use of these data in the tariff-based electricity price analysis, the TAP regions are defined as sub-sectors of Census Divisions. 2) Weather variability plays an important role in determining load characteristics, which in turn can influence prices, as utilities will try to encourage or discourage certain behaviors to make their system operations more efficient. Therefore, the Census Divisions are subdivided according to how they overlap with the nine climate regions defined by the National Climatic Data Center. (3) Since the onset of deregulation, different areas of the country can have very different electricity market structures, which can affect prices and billing practices. To capture this variability, States or regions with independent markets have been broken down into separate regions. In practice this means that California, New York, Texas and Florida are defined as separate regions. Within each region, the number of utilities chosen was determined by the relative population living in that area, and the proportion of customers served by privately- versus publicly- owned companies. With the current database, variability in prices is well-represented at the level of these seventeen regions. For the current analysis, regional variation is actually somewhat coarser, consisting of nine Census Divisions plus four large States as is used in RECS.

Electricity tariffs are typically classed as residential or non-residential. Non-residential may be further subdivided into general service and special-use tariffs such as street-lighting, agricultural, etc. For the general service category, some utilities explicitly distinguish between commercial and industrial, but most do not. There are usually several general-service tariffs for different customer sizes. Size is defined by the value of the annual peak load, and in each size class there is generally a default tariff. TAP currently contains the default residential and commercial tariffs for each customer size and market. Given the importance of residential tariffs for the current analysis, these data were updated in 2008. TAP also includes any optional time-of-use (TOU) residential tariffs that are offered by the utilities in the sample. On the commercial side, TOU tariffs are always included when they are the default tariff. Tariffs have been collected for both primary and secondary delivery voltage. Since commercial users of residential-style equipment are a small portion of the total customer base, it was not considered necessary to update the commercial data for this analysis. Therefore, the commercial tariffs collected in 2004 were used for analysis. The resulting prices are rescaled to reflect recent price increases.

Tariff data are collected using a series of spreadsheet forms which automatically populate the set of normalized tables that comprise the TAP database. Most of the tariff features (various types of block rates, TOU rates, seasonal rates, demand charges, etc.) are captured without approximation (see [5], [3] for a complete discussion of the level of detail in the data). Given a standardized data format, it is relatively straightforward to develop bill calculation tools. These tools use monthly electricity use data by TOU period if necessary for input, which consists of consumption and demand. The bill calculation then produces the monthly bill.

To validate the tariff data and bill calculation tools, a series of diagnostic tests were performed which make use of the electricity price information described above, particularly the EEI data. A detailed discussion is presented here of the validation for the residential data; the commercial data has been validated in a similar manner through previous work. EEI provides a "typical" bill at three monthly consumption levels (500 kWh, 750 kWh and 1,000 kWh for residential). These are reported by utility for summer and winter separately. It is straightforward to use TAP to calculate bills at each of these consumption levels, for the summer and winter seasonal rates as appropriate. The corresponding average prices can then be directly compared to the EEI data. The results for bills calculated at 750 kWh consumption are presented graphically in Figures 8-E.2.1 and 8-E.2.2, and are organized by State. The figures show the median average price calculated from the EEI data, and the range (high, low and median) of average prices for all the tariffs in TAP. Note the TAP data include publicly-owned utilities, making the data more variable than the EEI dataset.

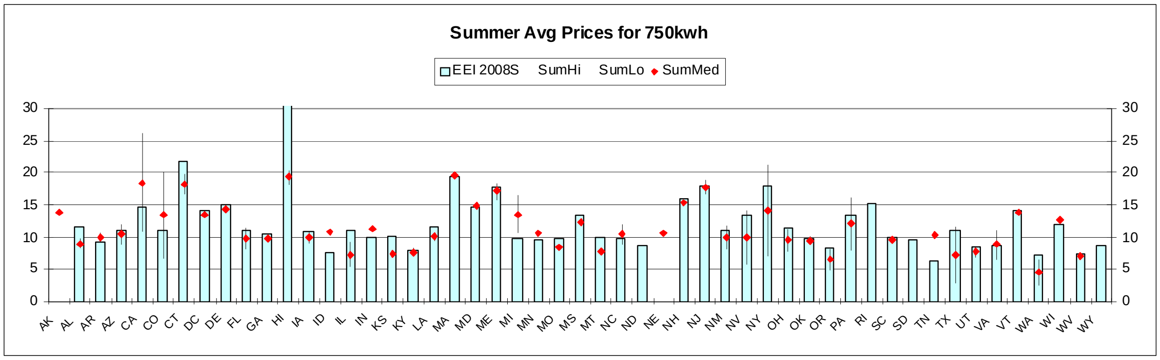

Figure 8-E.2.1 Comparison of average prices for summer (July) calculated using TAP and EEI data

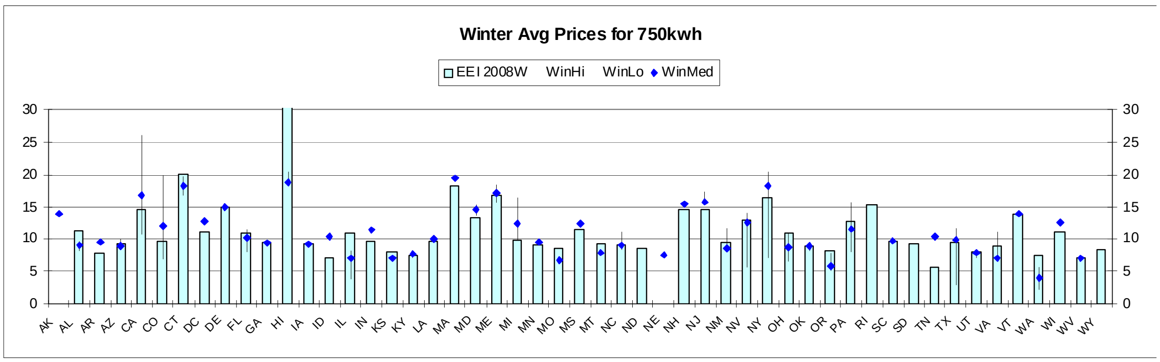

Figure 8-E.2.2 Comparison of average prices for winter (January) calculated using TAP and EEI data

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APPENDIX 8-F. DEVELOPMENT OF MONTHLY ALLOCATION FACTORS FOR RESIDENTIAL BASELINE ENERGY USE

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APPENDIX 8-F. DEVELOPMENT OF MONTHLY ALLOCATION FACTORS FOR RESIDENTIAL BASELINE ENERGY USE

8-F.1 INTRODUCTION

Utility bills for residential consumers frequently include block rates and/or seasonal rates for electricity use. For tariffs with block rates, the unit price per kilowatt-hour (kWh) varies according to how much electricity the consumer uses during the billing period. For tariffs with seasonal rates, these unit prices differ in summer and winter months, with the assignment of months to a particular season varying by utility. To correctly calculate marginal prices for this type of tariff, an estimation of a residential household's monthly baseline electricity consumption is required. This appendix describes the methodology used to make this estimation.

8-F.2 METHODOLOGY

The approach uses the monthly household billing data available for the RECS 2001 survey year to develop monthly allocation factors that define the fraction of annual energy use that occurs in each month.[1] The RECS 2001 survey included the collection of monthly electricity consumption and expenditure data for a large fraction of the total household sample. For this analysis, a minimum of eight bills for a calendar year, with a minimum of three for each season, were required for a record to be included in the data set. This results in monthly billing data for approximately 70–75 percent of all households by weight, as shown in Table 8-F.2.1.

Table 8-F.2.1 Fraction of RECS 2001 Records With Monthly Billing Data By Census Division

Census Division	All Records	Records with Bills	
	N	N	% by Weight
1	396	279	71%
2	691	482	69%
3	681	522	76%
4	366	269	72%
5	626	469	75%
6	409	289	70%
7	454	349	75%
8	407	310	76%
9	792	566	70%
Nation	4822	3535	73%

The billing periods for each RECS household are approximately one month long, but with varying start and end dates. The data were interpolated onto calendar months by (1) calculating the average daily electricity use during each billing period and (2) defining a total electricity use for the calendar month as the sum of the daily values. In cases where a household is missing one or more bills, the daily values for the missing periods were estimated as an average of the daily values for the preceding and following periods. This procedure leads to a set of twelve monthly electricity consumption values for 3535 of the RECS 2001 records. The percent of annual energy use that occurs in each month, which we call the *monthly allocation factor*, is then easily calculated for each household.

From this set, those RECS households having room air conditioners and with non-zero annual cooling energy use were chosen to represent the consumer population impacted by the current rulemaking. For these consumers, the monthly variability in electricity consumption depends primarily on three factors: geographic region (which incorporates both climate and building codes), the type of fuel used for space heating and the fuel used for water heating. Accordingly, the records were grouped according to four categorical variables: the two geographic variables Census Division (CD) and Large State (LS), a flag (1/0) for electric versus other space heating (EH in Table 8-F.2.2), and a flag (1/0) for electric versus other water heating (EWH in Table 2). For each category, weighted-average monthly allocation factor were calculated as a weighted sum over all households in that category, using the RECS “NWEIGHT” variable as the weight. Some categories in Census Division 2 did not contain enough records to calculate a weighted average. In these cases, the number of categories was reduced by dropping the water-heating flag, and the weighted averages calculated for the broader category. The resulting set of categories and allocation factors are presented in Table 2.

Table 8-F.2.2 Monthly Allocation Factors By Census Division (CD), Large State (LS), Space Heating Fuel Type (EH) and Water Heating Fuel Type (EWH).

CD	LS	EH	EWH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0.086	0.075	0.078	0.071	0.074	0.088	0.100	0.102	0.080	0.079	0.080	0.089
1	0	0	1	0.091	0.080	0.089	0.080	0.079	0.079	0.085	0.085	0.075	0.080	0.084	0.093
1	0	1	0	0.085	0.067	0.063	0.071	0.064	0.087	0.132	0.122	0.078	0.067	0.075	0.088
1	0	1	1	0.131	0.116	0.118	0.074	0.054	0.049	0.056	0.053	0.057	0.069	0.094	0.128
2	0	0	0	0.087	0.073	0.077	0.070	0.074	0.092	0.111	0.113	0.080	0.073	0.072	0.081
2	0	0	1	0.087	0.078	0.081	0.076	0.080	0.087	0.102	0.101	0.076	0.071	0.075	0.087
2	0	1	n/a	0.114	0.099	0.108	0.095	0.070	0.062	0.073	0.067	0.060	0.067	0.075	0.110
2	1	0	0	0.082	0.069	0.076	0.069	0.077	0.089	0.110	0.112	0.087	0.074	0.075	0.080
2	1	0	1	0.090	0.084	0.078	0.070	0.079	0.091	0.094	0.090	0.070	0.081	0.083	0.090
2	1	1	n/a	0.125	0.089	0.086	0.087	0.074	0.062	0.065	0.082	0.066	0.069	0.075	0.120
3	0	0	0	0.083	0.071	0.074	0.067	0.074	0.093	0.121	0.109	0.076	0.071	0.076	0.086
3	0	0	1	0.090	0.079	0.082	0.073	0.072	0.081	0.106	0.098	0.079	0.077	0.078	0.087
3	0	1	0	0.114	0.102	0.084	0.054	0.048	0.081	0.127	0.102	0.069	0.064	0.069	0.085
3	0	1	1	0.120	0.101	0.095	0.064	0.058	0.069	0.094	0.083	0.062	0.063	0.078	0.115
4	0	0	0	0.086	0.072	0.070	0.064	0.072	0.093	0.130	0.109	0.074	0.066	0.077	0.088
4	0	0	1	0.086	0.082	0.077	0.069	0.067	0.087	0.103	0.092	0.073	0.080	0.090	0.095
4	0	1	0	0.132	0.112	0.109	0.068	0.051	0.053	0.063	0.060	0.044	0.056	0.112	0.140
4	0	1	1	0.132	0.112	0.109	0.068	0.051	0.053	0.063	0.060	0.044	0.056	0.112	0.140
5	0	0	0	0.077	0.064	0.074	0.073	0.078	0.094	0.115	0.119	0.087	0.069	0.073	0.077
5	0	0	1	0.082	0.073	0.080	0.072	0.077	0.092	0.107	0.110	0.085	0.071	0.071	0.080
5	0	1	0	0.071	0.057	0.068	0.077	0.092	0.107	0.126	0.113	0.086	0.066	0.066	0.071
5	0	1	1	0.124	0.094	0.093	0.062	0.060	0.073	0.085	0.081	0.061	0.060	0.078	0.128

5	4	0	0	0.053	0.049	0.064	0.072	0.088	0.121	0.124	0.124	0.107	0.072	0.064	0.064
5	4	0	1	0.123	0.085	0.047	0.045	0.050	0.062	0.089	0.110	0.100	0.087	0.084	0.117
5	4	1	0	0.098	0.063	0.076	0.076	0.074	0.093	0.097	0.091	0.078	0.071	0.084	0.098
5	4	1	1	0.081	0.064	0.071	0.075	0.085	0.094	0.098	0.104	0.094	0.081	0.072	0.082
6	0	0	0	0.070	0.056	0.061	0.065	0.082	0.105	0.134	0.132	0.091	0.066	0.064	0.074
6	0	0	1	0.086	0.072	0.075	0.069	0.077	0.089	0.109	0.108	0.085	0.072	0.075	0.083
6	0	1	0	0.127	0.093	0.090	0.063	0.057	0.068	0.083	0.078	0.065	0.070	0.085	0.121
6	0	1	1	0.127	0.093	0.090	0.063	0.057	0.068	0.083	0.078	0.065	0.070	0.085	0.121
7	0	0	0	0.058	0.050	0.056	0.061	0.083	0.113	0.156	0.145	0.096	0.062	0.059	0.060
7	0	0	1	0.063	0.053	0.061	0.074	0.092	0.109	0.151	0.122	0.086	0.067	0.059	0.063
7	0	1	0	0.114	0.087	0.081	0.058	0.056	0.067	0.101	0.119	0.088	0.071	0.069	0.091
7	0	1	1	0.105	0.090	0.064	0.055	0.063	0.078	0.092	0.099	0.080	0.070	0.078	0.129
7	3	0	0	0.063	0.054	0.057	0.057	0.084	0.114	0.148	0.140	0.095	0.064	0.058	0.065
7	3	0	1	0.103	0.096	0.073	0.057	0.067	0.083	0.120	0.097	0.066	0.070	0.077	0.092
7	3	1	0	0.063	0.048	0.049	0.060	0.086	0.117	0.151	0.147	0.095	0.061	0.054	0.069
7	3	1	1	0.054	0.048	0.054	0.062	0.110	0.107	0.124	0.124	0.099	0.072	0.061	0.086
8	0	0	0	0.085	0.076	0.077	0.071	0.080	0.091	0.106	0.093	0.074	0.078	0.080	0.091
8	0	0	1	0.093	0.078	0.079	0.070	0.072	0.075	0.090	0.086	0.079	0.087	0.095	0.097
8	0	1	0	0.083	0.076	0.090	0.081	0.061	0.078	0.106	0.099	0.076	0.072	0.087	0.091
8	0	1	1	0.127	0.100	0.089	0.062	0.054	0.067	0.075	0.067	0.053	0.062	0.114	0.130
9	0	0	0	0.086	0.074	0.076	0.068	0.073	0.082	0.093	0.094	0.084	0.084	0.087	0.099
9	0	0	1	0.083	0.076	0.085	0.079	0.079	0.082	0.091	0.093	0.087	0.084	0.078	0.083
9	0	1	0	0.126	0.105	0.094	0.075	0.055	0.058	0.067	0.053	0.056	0.089	0.101	0.124
9	0	1	1	0.126	0.105	0.094	0.075	0.055	0.058	0.067	0.053	0.056	0.089	0.101	0.124
9	2	0	0	0.084	0.073	0.078	0.075	0.083	0.091	0.092	0.094	0.085	0.079	0.081	0.087
9	2	0	1	0.106	0.082	0.084	0.082	0.076	0.079	0.070	0.074	0.072	0.074	0.097	0.103
9	2	1	0	0.085	0.076	0.071	0.074	0.084	0.077	0.090	0.083	0.089	0.098	0.085	0.088
9	2	1	1	0.117	0.091	0.070	0.048	0.058	0.085	0.106	0.091	0.059	0.060	0.097	0.117

REFERENCES

1. U.S. Department of Energy - Energy Information Administration, *RECS 2001 Billing Data*, 2001. (Last accessed March, 2005.) Data provided electronically to LBNL.

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APPENDIX 8-G. REBUTTABLE PAYBACK ANALYSIS RESULTS

8-G.1 INTRODUCTION

This appendix contains the cost and efficiency tables described in chapter 8. DOE based the payback periods on the calculation methodology found in the DOE room air conditioner and clothes dryer test procedures; these payback periods may differ from those found under field conditions.

8-G.2 ENERGY CALCULATIONS

8-G.2.1 Clothes Dryers

The energy consumption in the LCC analysis is determined using the DOE test procedure. The DOE test procedure calculates annual energy consumption, E_{annual}, as follows:

$$E_F = Cycles \times (Lbs / CEF)$$

Where:

Cycles =	clothes dryer cycles per year, cycles/yr, (416 cycles/yr),
Lbs =	pounds of clothing, lbs, (7 lbs for standard and 3 lbs. for compact dryer) and
CEF =	clothes dryer efficiency.

8-G.2.2 Room Air Conditioners

The energy consumption in the LCC analysis is determined using the DOE test procedure. The DOE test procedure calculates annual energy consumption, E_{annual}, as follows:

$$E_{annual} = Capacity \times (Hrs / 1000) / CEER$$

Where:

Capacity =	room air conditioner input capacity,
Hrs =	room air conditioner operating hours (750 hrs), and
CEER =	room air conditioner efficiency.

8-G.3 RESULTS TABLES

Tables 8-G.3.1 to 8-G.3.10 show the rebuttable payback period calculation results for each product class.

8-G.3.1 Clothes Dryers

Table 8-G.3.1 Rebuttable Payback for Electric Standard Clothes Dryers

Efficiency Level	Combined Energy Factor	Design Option	Cost Data: Manufacturer Costs ($ per unit): Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Cost Data: Consumer Costs ($ per unit): Retail	Installation	Maintenance & Repair	Energy Use Data: Electricity	Summary Economics: Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	3.55	DOE Standard + 2.0 W Standby	$201	$254		$353	$94.77		674	$448	$73	
1	3.56	1.5 W Standby	$202	$255	$1	$354	$94.77		672	$449	$73	4.7
2	3.61	0.08 W Standby	$202	$255	$1	$354	$94.77		662	$449	$72	1.0
3	3.73	Gap Fill	$210	$265	$11	$365	$94.77		641	$460	$69	3.5
4	3.81	Gap Fill	$252	$318	$64	$425	$94.77		628	$519	$68	14.4
5	4.08	Max Available	$290	$366	$112	$479	$94.77		586	$573	$63	13.3
6	5.42	Heat Pump (Max Tech)	$482	$607	$353	$750	$114.73		441	$864	$48	16.6

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

Table 8-G.3.2 Rebuttable Payback for Electric Compact (120V) Clothes Dryers

Efficiency Level	Combined Energy Factor	Design Option	Cost Data: Manufacturer Costs ($ per unit): Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Consumer Costs ($ per unit): Retail	Installation	Maintenance & Repair	Energy Use Data: Electricity	Summary Economics: Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	3.43	DOE Standard + 2.0 W Standby	$211	$265		$369	$93.96		272	$463	$30	
1	3.48	Gap Fill	$211	$266	$1	$370	$93.96		269	$464	$29	2.6
2	3.61	Gap Fill	$211	$266	$1	$370	$93.96		260	$464	$28	0.8
3	3.72	Max Available	$232	$292	$27	$399	$93.96		253	$493	$28	14.3
4	3.80	1.5 W Standby	$273	$344	$79	$458	$93.96		244	$552	$27	28.9
5	4.08	0.08 W Standby	$320	$403	$138	$523	$93.96		236	$617	$26	39.0
6	5.41	Heat Pump (Max Tech)	$478	$602	$337	$747	$113.73		174	$861	$19	37.0

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

Table 8-G.3.3 Rebuttable Payback for Electric Compact (240V) Clothes Dryers

Efficiency Level	Combined Energy Factor	Design Option	Cost Data						Energy Use Data	Summary Economics		
			Manufacturer Costs (*$ per unit)*			Consumer Costs (*$ per unit)*						
			Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Retail	Installation	Maintenance & Repair	Electricity	Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	3.12	DOE Standard + 2.0 W Standby	$211	$265		$369	$93.96		248	$463	$27	
1	3.16	1.5 W Standby	$211	$266	$1	$370	$93.96		244	$464	$27	2.5
2	3.27	0.08 W Standby	$211	$266	$1	$370	$93.96		235	$464	$26	0.9
3	3.36	Gap Fill	$232	$292	$27	$399	$93.96		228	$493	$25	14.4
4	3.48	Gap Fill	$273	$344	$79	$458	$93.96		223	$552	$24	33.7
5	3.60	Max Available	$320	$403	$138	$523	$93.96		208	$617	$23	35.9
6	4.89	Heat Pump (Max Tech)	$478	$602	$337	$747	$113.73		157	$861	$17	40.2

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

Table 8-G.3.4 Rebuttable Payback for Gas Clothes Dryers

Efficiency Level	Combined Energy Factor	Design Option	Cost Data: Manufacturer Costs ($ per unit): Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Consumer Costs ($ per unit): Retail	Installation	Maintenance & Repair	Energy Use Data: Electricity	Gas	Summary Economics: Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*MMBtu/yr*	*$*	*$/yr*	*years*
0	3.14	DOE Standard + 2.0 W Standby	$227	$287		$398	$147.90		57	2.4	$546	$38	
1	3.16	1.5 W Standby	$228	$287	$1	$399	$147.90		57	2.4	$547	$38	4.5
2	3.20	0.08 W Standby (Max Tech)	$228	$288	$1	$400	$147.90		57	2.4	$548	$38	1.8
3	3.30	Gap Fill	$237	$298	$11	$411	$147.90		53	2.3	$559	$36	6.7
4	3.41	Gap Fill	$300	$378	$91	$501	$147.90		53	2.2	$649	$35	34.5
5	3.61	Max Available	$337	$425	$139	$554	$147.90		53	2.1	$702	$33	33.1

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

Table 8-G.3.5 Rebuttable Payback for Vent-less Electric Compact (240V) Clothes Dryers

Efficiency Level	Combined Energy Factor	Design Option	Cost Data: Manufacturer Costs ($ per unit): Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Consumer Costs ($ per unit): Retail	Installation	Maintenance & Repair	Energy Use Data: Electricity	Summary Economics: Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	2.55	Baseline + 2.0 W Standby	$559	$705		$980	$93.78		333	$1,074	$36	
1	2.59	1.5 W Standby	$560	$706	$1	$981	$93.78		328	$1,075	$36	2.3
2	2.69	0.08 W Standby	$560	$706	$1	$982	$93.78		316	$1,075	$34	0.8
3	2.71	Gap Fill	$586	$738	$33	$1,017	$93.78		313	$1,111	$34	17.4
4	2.80	Gap Fill	$617	$778	$73	$1,062	$93.78		303	$1,156	$33	25.2
5	4.03	Heat Pump (Max Tech)	$802	$1,010	$305	$1,323	$113.56		211	$1,436	$23	27.1

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.

** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

Table 8-G.3.6 Rebuttable Payback for Vent-less Electric Combination Washer/Dryers

Efficiency Level	Energy Factor	Design Option	Cost Data: Manufacturer Costs ($ per unit): Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Consumer Costs ($ per unit): Retail	Installation	Maintenance & Repair	Energy Use Data: Electricity	Summary Economics: Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	2.17	Baseline + 2.0 W Standby	$806	$1,015		$1,412	$93.78		391	$1,506	$43	
1	2.46	Gap Fill	$807	$1,017	$2	$1,414	$93.78		345	$1,508	$38	0.4
2	2.46	1.5 W Standby	$808	$1,019	$3	$1,416	$93.78		345	$1,509	$38	0.7
3	2.46	0.08 W Standby	$809	$1,019	$3	$1,416	$93.78		345	$1,510	$38	0.7
4	2.56	Gap Fill	$838	$1,055	$40	$1,457	$93.78		332	$1,551	$36	6.9
5	3.70	Heat Pump (Max Tech)	$1,103	$1,390	$375	$1,833	$113.56		229	$1,946	$25	24.9

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

8-G.3.2 Room Air Conditioners

Table 8-G.3.7 Rebuttable Payback for Room Air Conditioners, < 6,000 Btu/h with Louvers

Efficiency Level	Combined Energy Efficiency Ratio	Design Option	Cost Data						Energy Use Data	Summary Economics		
			Manufacturer Costs ($ per unit)			Consumer Costs ($ per unit)						
			Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Retail	Installation	Maintenance & Repair	Electricity	Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	9.5	DOE Standard	$150	$193		$271	$81.52		394	$352	$50	
1	10.1	Gap Fill	$156	$201	$9	$280	$81.52		371	$362	$47	3.4
2	10.6	Energy Star	$163	$213	$20	$294	$81.52		354	$375	$45	4.5
3	11.1	CEE Tier 1	$173	$226	$33	$308	$85.59		338	$394	$43	5.8
4	11.4	CEE Tier 2	$182	$238	$45	$322	$89.67		329	$411	$41	7.1
5	11.7	Max Tech	$226	$293	$100	$384	$89.67		321	$474	$40	13.0

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

Table 8-G.3.8 Rebuttable Payback for Room Air Conditioners, 8,000–13,999 Btu/h with Louvers

Efficiency Level	Combined Energy Efficiency Ratio	Design Option	Cost Data: Manufacturer Costs ($ per unit): Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Cost Data: Consumer Costs ($ per unit): Retail	Installation	Maintenance & Repair	Energy Use Data: Electricity	Summary Economics: Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	9.7	DOE Standard	$197	$256		$360	$118.03		774	$478	$103	
1	10.2	Gap Fill	$200	$261	$5	$365	$118.03		735	$483	$98	1.1
2	10.7	Energy Star	$207	$270	$14	$375	$118.03		701	$493	$93	1.6
3	10.9	CEE Tier 1	$209	$274	$18	$380	$118.03		688	$498	$92	1.8
4	11.5	Max Available	$227	$297	$40	$405	$120.45		652	$526	$87	3.0
5	12.0	Max Tech	$273	$359	$103	$476	$129.51		627	$605	$84	6.6

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

Table 8-G.3.9 Rebuttable Payback for Room Air Conditioners, 20,000-24,999 Btu/h with Louvers

Efficiency Level	Combined Energy Efficiency Ratio	Design Option	Cost Data: Manufacturer Costs ($ per unit): Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Consumer Costs ($ per unit): Retail	Installation	Maintenance & Repair	Energy Use Data: Electricity	Summary Economics: Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	8.5	DOE Standard	$344	$458		$643	$218.82		1992	$861	$288	
1	9.0	Gap Fill	$352	$471	$14	$658	$218.82		1875	$877	$271	0.9
2	9.4	Energy Star	$363	$484	$26	$672	$218.82		1795	$891	$260	1.1
3	9.8	CEE Tier 1	$394	$524	$66	$718	$218.82		1722	$936	$249	1.9
4	10.2	Max Tech	$548	$718	$260	$937	$226.88		1662	$1,164	$240	6.4

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

Table 8-G.3.10 Rebuttable Payback for Room Air Conditioners, ≥ 25,000 Btu/h with Louvers

Efficiency Level	Combined Energy Efficiency Ratio	Design Option	Cost Data: Manufacturer Costs ($ per unit): Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Consumer Costs ($ per unit): Retail	Installation	Maintenance & Repair	Energy Use Data: Electricity	Summary Economics: Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	8.5	DOE Standard	$391	$522		$733	$251.06		2301	$984	$333	
1	9.0	Gap Fill	$414	$558	$36	$774	$251.06		2167	$1,025	$313	2.1
2	9.4	Energy Star	$441	$592	$70	$812	$251.06		2074	$1,063	$300	2.4
3	9.8	Max Tech	$620	$817	$295	$1,067	$251.06		1990	$1,318	$288	7.4

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

Table 8-G.3.11 Rebuttable Payback for Room Air Conditioners, 8,000-10,999 Btu/h without Louvers

Efficiency Level	Combined Energy Efficiency Ratio	Design Option	Cost Data: Manufacturer Costs ($ per unit): Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Consumer Costs ($ per unit): Retail	Installation	Maintenance & Repair	Energy Use Data: Electricity	Summary Economics: Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	8.4	DOE Standard	$211	$278		$391	$98.52		847	$489	$113	
1	9.3	Energy Star	$216	$284	$6	$397	$98.52		766	$496	$102	0.6
2	9.6	Gap Fill	$218	$287	$8	$400	$98.52		742	$499	$99	0.7
3	10.0	CEE Tier 1	$228	$299	$21	$414	$98.52		713	$513	$95	1.3
4	10.4	Max Tech	$300	$390	$111	$517	$98.52		688	$615	$92	6.0

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

Table 8-G.3.12 Rebuttable Payback for Room Air Conditioners, ≥ 11,000 Btu/h without Louvers

Efficiency Level	Combined Energy Efficiency Ratio	Design Option	Cost Data: Manufacturer Costs ($ per unit): Manufacturer Production Cost (MPC)	Total Manufacturer Selling Price (MSP)	Incremental MSP	Consumer Costs ($ per unit): Retail	Installation	Maintenance & Repair	Energy Use Data: Electricity	Summary Economics: Total Installed Costs	Total Operating Costs	Simple Payback
			2009$	*2009$*	*2009$*	*$*	*$*	*$*	*kWh/yr*	*$*	*$/yr*	*years*
0	8.4	DOE Standard	$237	$311		$437	$137.37		1066	$574	$142	
1	9.3	Energy Star	$249	$326	$15	$454	$137.37		968	$591	$129	1.3
2	9.5	Gap Fill	$253	$331	$19	$459	$137.37		947	$596	$126	1.4
3	9.8	CEE Tier 1	$263	$344	$33	$474	$137.37		918	$611	$122	1.9
4	10.0	Max Tech	$331	$429	$118	$570	$137.37		898	$707	$120	6.0

* The manufacturing production cost (MPC) includes the direct labor, direct material, and direct overhead.
** The manufacturing selling price (MSP) includes manufacturer profit and non-production costs, such as selling, general and administrative expenses, research and development, and interest.

APPENDIX 8-H. DETERMINATION OF BASECASE EFFICIENCY DISTRIBUTIONS

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APPENDIX 8-H. DETERIMINATION OF BASECASE EFFICIENCY DISTRIBUTIONS

8-H.1 PRODUCT ENERGY EFFICIENCY IN THE BASE CASE

To estimate the percentage of consumers who would be affected by a standard at any of the potential efficiency levels, in its life-cycle cost (LCC) analysis the U.S. Department of Energy (DOE) considered the projected distribution of efficiencies for products that consumers purchase under the base case (the case without new energy efficiency standards). DOE refers to this distribution of product energy 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 sample household and commercial user. If a household is assigned a product efficiency that was greater than or equal to the efficiency of the standard level under consideration, the LCC calculation would show that this household would not be affected by that standard level. The energy efficiency distributions that DOE used in the LCC analysis are described below.

8-H.1.1 Clothes Dryers

To develop a base case energy efficiency distribution for clothes dryers, DOE began with data that AHAM provided showing the distribution of clothes dryer efficiencies sold by product class in 2005–2007.[1] Because there is no evidence of change in average efficiency in recent years, DOE assumed that the shares remain the same in 2014. The market shares in Tables 8-H.1.1 and 8-H.1.2 represent the products that households would be expected to purchase in 2014 in the absence of new standards.

Table 8-H.1.1 Vented Clothes Dryers Energy Efficiency: Base Case Market Shares

Electric, Standard		Electric, Compact (120V)		Electric, Compact (240V)		Gas	
CEF (lb/kWh)	**Share**	**CEF (lb/kWh)**	**Share**	**CEF (lb/kWh)**	**Share**	**CEF (lb/kWh)**	**Share**
3.55	2.6%	3.43	100.0%	3.12	59.4%	3.14	7.9%
3.56	18.9%	3.48	0.0%	3.16	0.0%	3.16	8.2%
3.61	53.5%	3.61	0.0%	3.27	15.6%	3.20	42.9%
3.73	17.9%	3.72	0.0%	3.36	16.7%	3.30	30.9%
3.81	6.1%	3.80	0.0%	3.48	4.2%	3.41	9.3%
4.08	1.0%	4.08	0.0%	3.60	4.2%	3.61	0.9%
5.42	0.0%	5.41	0.0%	4.89	0.0%		

Table 8-H.1.2 Vent-less Clothes Dryers Energy Efficiency: Base Case Market Shares

Electric, Compact (240V)		Electric, Combination Washer/Dryer	
CEF (lb/kWh)	Share	CEF (lb/kWh)	Share
2.55	100.0%	2.08	100.0%
2.59	0.0%	2.35	0.0%
2.69	0.0%	2.38	0.0%
2.71	0.0%	2.46	0.0%
2.80	0.0%	2.56	0.0%
4.03	0.0%	3.69	0.0%

8-H.1.2 Room Air Conditioners

To develop a base-case energy efficiency distribution for room air conditioners, DOE began with data that AHAM provided showing the distribution of room air conditioner efficiencies sold by product class in 2005–2007.[1] Using these data, DOE derived the shares in Table 8-H.1.1. Regarding change in energy efficiency in coming years, DOE used historical trends from 2005 to 2009, which give a 0.25 percent annual growth trend in energy star levels. Therefore, DOE assumed that the market shares of the efficiency levels in 2014 will be higher than in 2007. The market shares in Tables 8-H.1.3 and 8-H.1.4 represent the products that consumers would be expected to purchase in 2014 in the absence of new standards.

Table 8-H.1.3 Room Air Conditioners with Louvers: Base Case Market Shares

Less than 6,000 Btu/h		8,000–13,999 Btu/h		20,000-24,999 Btu/h		Greater than 25,000 Btu/h	
CEER	Share	CEER	Share	CEER	Share	CEER	Share
9.5	70.0%	9.7	38.4%	8.5	13.6%	8.5	12.9%
10.1	0.0%	10.2	2.4%	9.0	1.4%	9.0	2.1%
10.6	29.0%	10.7	57.9%	9.4	81.0%	9.4	85.0%
11.1	1.0%	10.9	1.5%	9.8	2.0%	9.8	0.0%
11.4	0.0%	11.5	0.2%	10.2	2.0%		
11.7	0.0%	12.0	0.4%				

Table 8-H.1.4 Room Air Conditioners without Louvers: Base Case Market Shares

8,000-10,999 Btu/h		Greater than 11,000 Btu/h	
CEER	Share	CEER	Share
8.4	10.0%	8.4	10.0%
9.3	65.2%	9.3	60.0%
9.6	19.2%	9.5	12.9%
10.0	3.7%	9.8	17.1%
10.4	1.9%	10.0	0.0%

DOE also assembled data for 2002–2009 on market shares of ENERGY STAR room air conditioners by State and organized them into Census Divisions and four large States. In assigning a product efficiency to each sample household and commercial user, DOE accounted for regional patterns in the efficiency distribution.

REFERENCES

1. Association of Home Appliance Manufacturers, AHAM Data on Room Air Conditioners and Clothes Dryers. 2008

APPENDIX 8-I. LIFE-CYCLE COST ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS

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APPENDIX 8-I. LIFE-CYCLE COST ANALYSIS RESULTS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS

8-I.1 INTRODUCTION

This appendix presents LCC results using energy price forecasts from alternative economic growth scenarios. The scenarios are based on the High Economic Growth case and the Low Economic Growth case from the May 2010 release of the *AEO2010*.[1] To estimate energy prices after 2035 in the high and low scenarios, DOE used the growth rate between 2020 and 2035.

The forecasts in these cases are shown in Appendix 10-B. Energy prices are higher in the High Economic Growth case and lower in the Low Economic Growth case. The energy price forecasts affect the energy savings at different efficiency levels.

8-I.2 HIGH ECONOMIC GROWTH RESULTS

8-I.2.1 Clothes Dryers

Table 8-I.2.1 Standard Electric Clothes Dryers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Median Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			
						Net Cost	No Impact	Net Benefit	
Baseline	3.55	$455	$902	$1,357	N/A	0%	100%	0%	N/A
1	3.56	$455	$900	$1,355	$0	1%	98%	2%	3.9
2	3.61	$456	$888	$1,344	$3	0%	79%	21%	0.2
3	3.73	$467	$860	$1,327	$15	18%	25%	57%	5.2
4	3.81	$528	$843	$1,371	-$25	78%	7%	15%	24.9
5	4.08	$583	$789	$1,372	-$27	74%	1%	25%	18.8
6	5.42	$879	$602	$1,481	-$136	80%	0%	20%	21.7

Table 8-I.2.2 Compact 120V Clothes Dryers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Median Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			
						Net Cost	No Impact	Net Benefit	
Baseline	3.43	$470	$398	$868	N/A	0%	100%	0%	N/A
1	3.48	$471	$394	$865	$4	4%	0%	96%	2.6
2	3.61	$471	$383	$854	$15	4%	0%	96%	0.9
3	3.72	$501	$371	$872	-$4	71%	0%	29%	14.7
4	3.80	$560	$363	$923	-$55	96%	0%	4%	33.8
5	4.08	$627	$337	$965	-$97	95%	0%	5%	35.4
6	5.41	$875	$252	$1,127	-$258	95%	0%	5%	39.3

Table 8-I.2.3 Compact 240V Clothes Dryers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Median Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			
						Net Cost	No Impact	Net Benefit	
Baseline	3.12	$470	$443	$913	N/A	0%	100%	0%	N/A
1	3.16	$471	$438	$909	$2	4%	41%	55%	2.7
2	3.27	$471	$427	$898	$9	2%	41%	56%	0.9
3	3.36	$501	$415	$916	-$5	56%	25%	18%	15.4
4	3.48	$560	$401	$961	-$46	86%	8%	5%	32.9
5	3.60	$627	$387	$1,015	-$97	93%	4%	3%	44.3
6	4.89	$875	$282	$1,158	-$240	94%	0%	6%	37.5

Table 8-I.2.4 Gas Clothes Dryers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Median Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			
						Net Cost	No Impact	Net Benefit	
Baseline	3.14	$554	$460	$1,014	N/A	0%	100%	0%	N/A
1	3.16	$555	$454	$1,009	$0	1%	93%	7%	2.1
2	3.20	$555	$442	$997	$2	0%	85%	15%	0.5
3	3.30	$567	$429	$997	$2	31%	42%	27%	11.6
4	3.41	$658	$417	$1,076	-$68	88%	11%	2%	72.2
5	3.61	$712	$393	$1,106	-$98	95%	1%	5%	48.6

Table 8-I.2.5 Vent-less Compact Clothes Dryers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)* Average Installed Price	Average Lifetime Operating Cost	Average LCC	Life-Cycle Cost Savings Average Savings *(2009$)*	Households with Net Cost	No Impact	Net Benefit	Median Payback Period *(years)*
Baseline	2.55	$1,093	$469	$1,562	N/A	0%	100%	0%	N/A
1	2.59	$1,094	$463	$1,556	$6	0%	0%	100%	2.4
2	2.69	$1,094	$447	$1,541	$21	0%	0%	100%	0.9
3	2.71	$1,131	$443	$1,574	-$12	84%	0%	17%	17.8
4	2.80	$1,176	$426	$1,602	-$40	92%	0%	8%	24.8
5	4.03	$1,462	$270	$1,732	-$170	87%	0%	13%	26.3

Table 8-I.2.6 Vent-less Combination Washer/Dryers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)* Average Installed Price	Average Lifetime Operating Cost	Average LCC	Life-Cycle Cost Savings Average Savings *(2009$)*	Households with Net Cost	No Impact	Net Benefit	Median Payback Period *(years)*
Baseline	2.08	$1,533	$586	$2,119	N/A	0%	100%	0%	N/A
1	2.35	$1,535	$506	$2,041	$78	2%	0%	98%	0.4
2	2.38	$1,536	$500	$2,037	$82	0%	0%	100%	0.6
3	2.46	$1,537	$486	$2,022	$96	0%	0%	100%	0.5
4	2.56	$1,579	$463	$2,042	$77	19%	0%	81%	5.2
5	3.69	$1,981	$292	$2,274	-$155	81%	0%	19%	21.9

8-I.2.2 Room Air Conditioners

Table 8-I.2.7 Room Air Conditioners, Less than 6,000 Btu/h, with Louvers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Median Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			
						Net Cost	No Impact	Net Benefit	
Baseline	9.52	$351	$392	$743	N/A	0%	100%	0%	N/A
1	10.1	$361	$368	$730	$9	20%	31%	49%	4.1
2	10.6	$374	$352	$726	$12	32%	31%	37%	5.8
3	11.1	$393	$337	$729	$8	64%	1%	35%	8.6
4	11.4	$410	$329	$739	-$2	73%	0%	27%	10.9
5	11.7	$472	$321	$794	-$56	90%	0%	10%	20.9

Table 8-I.2.8 Room Air Conditioners, 8,000-13,999 Btu/h, with Louvers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Median Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			
						Net Cost	No Impact	Net Benefit	
Baseline	9.69	$477	$632	$1,109	N/A	0%	100%	0%	N/A
1	10.2	$483	$601	$1,084	$10	4%	63%	33%	1.7
2	10.7	$493	$574	$1,067	$17	9%	60%	31%	0.0
3	10.9	$497	$563	$1,061	$23	33%	2%	65%	2.8
4	11.5	$525	$534	$1,059	$24	55%	1%	44%	7.1
5	12.0	$605	$514	$1,119	-$35	77%	0%	23%	14.7

Table 8-I.2.9 Room Air Conditioners, 20,000-24,999 Btu/h, with Louvers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Median Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			
						Net Cost	No Impact	Net Benefit	
Baseline	8.47	$857	$771	$1,628	N/A	0%	100%	0%	N/A
1	9.0	$872	$726	$1,598	$3	4%	87%	9%	4.3
2	9.4	$887	$691	$1,577	$6	5%	85%	10%	4.3
3	9.8	$932	$663	$1,595	-$9	86%	4%	10%	22.2
4	10.2	$1,159	$643	$1,802	-$212	98%	2%	0%	73.8

Table 8-I.2.10 Room Air Conditioners, Greater than 25,000 Btu/h, with Louvers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Median Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	
Baseline	8.48	$979	$846	$1,825	N/A	0%	100%	0%	N/A
1	9.00	$1,019	$798	$1,817	$1	9%	88%	4%	10.1
2	9.40	$1,058	$760	$1,818	$2	11%	85%	4%	10.3
3	9.80	$1,313	$732	$2,045	-$225	100%	0%	0%	107.7

Table 8-I.2.11 Room Air Conditioners, 8,000-10,999 Btu/h, without Louvers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Median Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	
Baseline	8.41	$489	$557	$1,045	N/A	0%	100%	0%	N/A
1	9.3	$495	$505	$1,000	$4	1%	90%	9%	1.5
2	9.6	$498	$490	$988	$14	12%	25%	63%	2.1
3	10.0	$512	$468	$980	$21	37%	6%	57%	4.9
4	10.4	$615	$453	$1,067	-$65	91%	2%	7%	25.2

Table 8-I.2.12 Room Air Conditioners, Greater than 11,000 Btu/h, without Louvers, High Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Median Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	
Baseline	8.44	$574	$790	$1,363	N/A	0%	100%	0%	N/A
1	9.30	$590	$719	$1,309	$5	2%	90%	8%	2.6
2	9.50	$596	$704	$1,299	$12	22%	31%	47%	3.7
3	9.80	$611	$680	$1,291	$19	35%	17%	47%	5.3
4	10.02	$707	$666	$1,373	-$63	92%	0%	8%	25.9

8-I.3 LOW ECONOMIC GROWTH RESULTS

8-I.3.1 Clothes Dryers

Table 8-I.3.1 Standard Electric Clothes Dryers, Low Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	Median
Baseline	3.55	$455	$835	$1,290	N/A	0%	100%	0%	N/A
1	3.56	$455	$833	$1,289	$0	1%	98%	2%	4.0
2	3.61	$456	$822	$1,278	$2	0%	79%	21%	0.2
3	3.73	$467	$796	$1,264	$13	20%	25%	56%	5.4
4	3.81	$528	$781	$1,308	-$28	80%	7%	13%	25.8
5	4.08	$583	$731	$1,313	-$34	77%	1%	22%	19.5
6	5.42	$879	$558	$1,436	-$157	82%	0%	18%	22.6

Table 8-I.3.2 Compact 120V Clothes Dryers, Low Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	Median
Baseline	3.43	$470	$369	$838	N/A	0%	100%	0%	N/A
1	3.48	$471	$364	$835	$3	5%	0%	95%	2.7
2	3.61	$471	$354	$825	$13	4%	0%	96%	0.9
3	3.72	$501	$343	$844	-$6	76%	0%	24%	15.3
4	3.80	$560	$336	$896	-$58	97%	0%	3%	35.1
5	4.08	$627	$312	$940	-$101	96%	0%	4%	36.8
6	5.41	$875	$233	$1,108	-$270	96%	0%	4%	40.9

Table 8-I.3.3 Compact 240V Clothes Dryers, Low Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median
						Net Cost	No Impact	Net Benefit	
Baseline	3.12	$470	$410	$879	N/A	0%	100%	0%	N/A
1	3.16	$471	$405	$876	$2	4%	41%	55%	2.8
2	3.27	$471	$395	$866	$8	2%	41%	56%	0.9
3	3.36	$501	$384	$885	-$6	59%	25%	16%	16.1
4	3.48	$560	$371	$931	-$48	87%	8%	4%	34.2
5	3.60	$627	$358	$986	-$101	94%	4%	2%	46.1
6	4.89	$875	$262	$1,137	-$252	95%	0%	5%	39.0

Table 8-I.3.4 Gas Clothes Dryers, Low Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median
						Net Cost	No Impact	Net Benefit	
Baseline	3.14	$554	$428	$982	N/A	0%	100%	0%	N/A
1	3.16	$555	$423	$978	$0	1%	93%	7%	2.2
2	3.20	$555	$411	$967	$2	0%	85%	15%	0.5
3	3.30	$567	$400	$967	$2	33%	42%	25%	11.9
4	3.41	$658	$389	$1,047	-$70	88%	11%	2%	74.3
5	3.61	$712	$367	$1,079	-$101	95%	1%	4%	50.3

Table 8-I.3.5 Vent-less Compact Clothes Dryers, Low Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median
						Net Cost	No Impact	Net Benefit	
Baseline	2.55	$1,093	$435	$1,527	N/A	0%	100%	0%	N/A
1	2.59	$1,094	$428	$1,522	$5	0%	0%	100%	2.5
2	2.69	$1,094	$414	$1,508	$19	0%	0%	100%	0.9
3	2.71	$1,131	$410	$1,541	-$14	87%	0%	13%	18.5
4	2.80	$1,176	$395	$1,571	-$44	93%	0%	7%	25.8
5	4.03	$1,462	$251	$1,712	-$185	89%	0%	11%	27.4

Table 8-I.3.6 Vent-less Combination Washer/Dryers, Low Economic Growth

Efficiency Level ID	CEF	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	Median
Baseline	2.08	$1,533	$543	$2,075	N/A	0%	100%	0%	N/A
1	2.35	$1,535	$469	$2,004	$72	2%	0%	98%	0.4
2	2.38	$1,536	$463	$2,000	$76	0%	0%	100%	0.6
3	2.46	$1,537	$450	$1,986	$89	0%	0%	100%	0.5
4	2.56	$1,579	$429	$2,007	$68	22%	0%	78%	5.4
5	3.69	$1,981	$271	$2,253	-$177	84%	0%	16%	22.8

8-I.3.2 Room Air Conditioners

Table 8-I.3.7 Room Air Conditioners, Less than 6,000 Btu/h, with Louvers, Low Economic Growth

Efficiency Level ID	CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	Median
Baseline	9.52	$351	$367	$718	N/A	0%	100%	0%	N/A
1	10.1	$361	$345	$706	$8	22%	31%	47%	4.1
2	10.6	$374	$329	$703	$10	34%	31%	36%	5.8
3	11.1	$393	$315	$708	$5	66%	1%	33%	8.6
4	11.4	$410	$308	$718	-$5	75%	0%	25%	10.9
5	11.7	$472	$301	$773	-$60	91%	0%	9%	20.9

Table 8-I.3.8 Room Air Conditioners, 8,000-13,999 Btu/h, with Louvers, Low Economic Growth

Efficiency Level ID	CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	Median
Baseline	9.69	$477	$592	$1,070	N/A	0%	100%	0%	N/A
1	10.2	$483	$563	$1,046	$9	4%	63%	33%	1.7
2	10.7	$493	$538	$1,031	$15	10%	60%	30%	0.0
3	10.9	$497	$528	$1,025	$21	34%	2%	63%	2.8
4	11.5	$525	$500	$1,026	$20	57%	1%	42%	7.1
5	12.0	$605	$482	$1,087	-$40	78%	0%	21%	14.7

Table 8-I.3.9 Room Air Conditioners, 20,000-24,999 Btu/h, with Louvers, Low Economic Growth

Efficiency Level ID	CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	Median
Baseline	8.47	$857	$723	$1,580	N/A	0%	100%	0%	N/A
1	9.0	$872	$681	$1,554	$2	5%	87%	9%	4.3
2	9.4	$887	$648	$1,535	$5	5%	85%	9%	4.3
3	9.8	$932	$622	$1,554	-$12	87%	4%	9%	22.2
4	10.2	$1,159	$603	$1,763	-$216	98%	2%	0%	73.8

Table 8-I.3.10 Room Air Conditioners, Greater than 25,000 Btu/h, with Louvers, Low Economic Growth

Efficiency Level ID	CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	Median
Baseline	8.48	$979	$794	$1,773	N/A	0%	100%	0%	N/A
1	9.0	$1,019	$749	$1,769	$1	9%	88%	3%	10.1
2	9.4	$1,058	$713	$1,771	$1	11%	85%	3%	10.3
3	9.8	$1,313	$687	$2,000	-$228	100%	0%	0%	107.7

Table 8-I.3.11 Room Air Conditioners, 8,000-10,999 Btu/h, without Louvers, Low Economic Growth

Efficiency Level ID	CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median
						Net Cost	No Impact	Net Benefit	
Baseline	8.41	$489	$521	$1,010	N/A	0%	100%	0%	N/A
1	9.3	$495	$473	$968	$4	1%	90%	9%	1.5
2	9.6	$498	$458	$957	$13	13%	25%	62%	2.1
3	10.0	$512	$438	$950	$19	39%	6%	55%	4.9
4	10.4	$615	$424	$1,039	-$68	92%	2%	6%	25.2

Table 8-I.3.12 Room Air Conditioners, Greater than 11,000 Btu/h, without Louvers, Low Economic Growth

Efficiency Level ID	CEER	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median
						Net Cost	No Impact	Net Benefit	
Baseline	8.44	$574	$740	$1,313	N/A	0%	100%	0%	N/A
1	9.3	$590	$673	$1,264	$5	2%	90%	8%	2.6
2	9.5	$596	$659	$1,255	$11	24%	31%	46%	3.7
3	9.8	$611	$637	$1,248	$17	37%	17%	46%	5.3
4	10.0	$707	$624	$1,331	-$66	93%	0%	7%	25.9

REFERENCES

1. Energy Information Administration, *Annual Energy Outlook 2010 with Projections to 2035*, 2010. Washington, DC. Report No. DOE/EIA-0383(2010). <http://www.eia.doe.gov/oiaf/aeo/>

APPENDIX 8-J. ESTIMATION OF EQUIPMENT PRICE TRENDS FOR RESIDENTIAL CLOTHES DRYERS AND ROOM AIR CONDITIONERS

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APPENDIX 8-J. ESTIMATION OF EQUIPMENT PRICE TRENDS FOR RESIDENTIAL CLOTHES DRYERS AND ROOM AIR CONDITIONERS

8-J.1 INTRODUCTION

In the standards established in today's direct final rule, DOE assumes that the manufacturer costs and retail prices of products meeting various efficiency levels may not remain fixed, in real terms, after 2010 (the year for which the engineering analysis estimated costs) and throughout the period of the analysis. In its Notice of Data Availability (NODA) published on February 22, 2011 (76 FR 9696), DOE stated that it may consider improving regulatory analysis by addressing equipment price trends. Consistent with the NODA, DOE examined historical producer price indices (PPI) for household laundry equipment and room air conditioners. For this equipment, DOE found consistent negative real price trends. Therefore, DOE concluded that the real prices of residential clothes dryers and room air conditioners have a different long term trend than prices in the economy as a whole. DOE maintained the constant real price trend as a sensitivity analysis to evaluate how the impact of potential standards might change under this scenario.

DOE stated in the NODA that examination of historical price data for certain appliances and equipment that have been subject to energy conservation standards indicates that the assumption of constant real prices and costs may, in many cases, over-estimate long-term appliance and equipment price trends. Economic literature and historical data suggest that the real costs of these products may in fact trend downward over time according to "learning" or "experience" curves, or alternatively that the price trends for certain sectors of the US economy may be different than the price trends for the economy as a whole. A draft paper, "Using the Experience Curve Approach for Appliance Price Forecasting," posted on the DOE web site at http://www1.eere.energy.gov/buildings/appliance_standards/supplemental_info_equipment_price_forecasting.html, provides a summary of the data and literature currently available to DOE that is relevant to price forecasts for selected appliances and equipment.

The extensive literature on the "learning" or "experience" curve phenomenon is typically based on observations in the manufacturing sector.[a] In the experience curve method, the real cost of production is related to the cumulative production or "experience" with a manufactured product. This experience is usually measured in terms of cumulative production. A common functional relationship used to model the evolution of production costs in this case is:

$$Y = aX^{-b}$$

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

where a is an initial price (or cost), b is a positive constant known as the learning rate parameter, X is cumulative production, and Y is the price as a function of cumulative production. Thus, as experience (production) accumulates, the cost of producing the next unit decreases. The percentage reduction in cost that occurs with each doubling of cumulative production is known as the learning rate (LR), given by:

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

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

8-J.2 PRICE, COST AND MARKET STRUCTURE

DOE uses a cost-based analysis in estimating equipment prices. To estimate equipment prices in both the standards and the baseline or no-standards case, DOE develops engineering cost estimates that DOE then uses to estimate manufacturer selling price. The manufacturer selling price includes direct manufacturing production costs (labor, material, and overhead estimated in DOE's manufacturer production costs) and all non-production costs (SG&A, R&D, and interest), along with profit. The process of the cost-based method for developing the manufacturer selling prices is described in the engineering analysis described in Chapter 5 of this TSD. To convert the manufacturer selling price to an equipment price for the consumer, DOE performs an analysis of distribution chain markups and estimates markups on both the baseline and incremental manufacture selling prices to determine equipment prices after distribution to the consumer.

In analyzing experience curves to estimate price trends, DOE uses producer price indices as a key data input and analyzes this data to estimate the experience curve exponent. This approach has only one model parameter to describe the price trend and assumes a simple relationship between producer price and retail equipment price. Specifically, the approach assumes that producer prices, distribution chain markups and equipment prices all scale proportionally over time for the same product.

DOE could have developed a more complex price trend forecasting model with more parameters that could explain different trends in different equipment price and cost components over time. But the relatively few available data points presents a risk that a fit with multiple parameters would "overfit" the data. Overfitting occurs when there are too many degrees of freedom in a statistical model compared to the data and the fits are sensitive to random noise unrelated to long term trends. Due to the risk of overfitting the available data, DOE has decided to not develop a more complex multi-parameter price trend estimation model at this time.

Due to the simple nature of the price trend estimation model, there are several well known economic and market phenomenon that will not be captured in detail by the price trend forecast. Some effects might lead to an overestimate of the long term price trend and other effects may lead to an underestimate.

For example, if there has been increasing market concentration historically on the part of manufacturers, this may have resulted in increasing manufacturer and wholesale markups over time. This would result in an observed historical producer price trend that did not decrease as fast as the underlying industrial learning rate. Depending on if market concentration accelerated or decelerated into the future this could lead to an over- or under-estimation of future price trends.

Similarly, if there are cost components that have relatively slow long term price trends that have an increasing impact on price over time, the decreasing share of costs that are declining rapidly can result in a change in the empirically estimated experience curve exponent over time.

8-J.3 DATA EVALUATION AND ANALYSIS

To derive a learning rate parameter for residential clothes dryers and room air conditioners, DOE obtained historical Producer Price Index (PPI) data for household laundry equipment and room air conditioners from the Bureau of Labor Statistics' (BLS). Because PPI data specific to residential clothes dryers were not available, DOE used PPI data for household laundry equipment as representative of residential clothes dryers. For household laundry equipment, DOE used PPI data spanning the time period 1980-2010, while for room air conditioners, DOE use data from 1990-2009. Inflation-adjusted price indices for household laundry equipment and room air conditioners were calculated by dividing the PPI series by the Consumer Price Index (CPI) "all items" index for the same years. These inflation-adjusted price indices (shown in Figure 8-J.3.1 and Figure 8-J.3.2) were used in subsequent analysis steps.

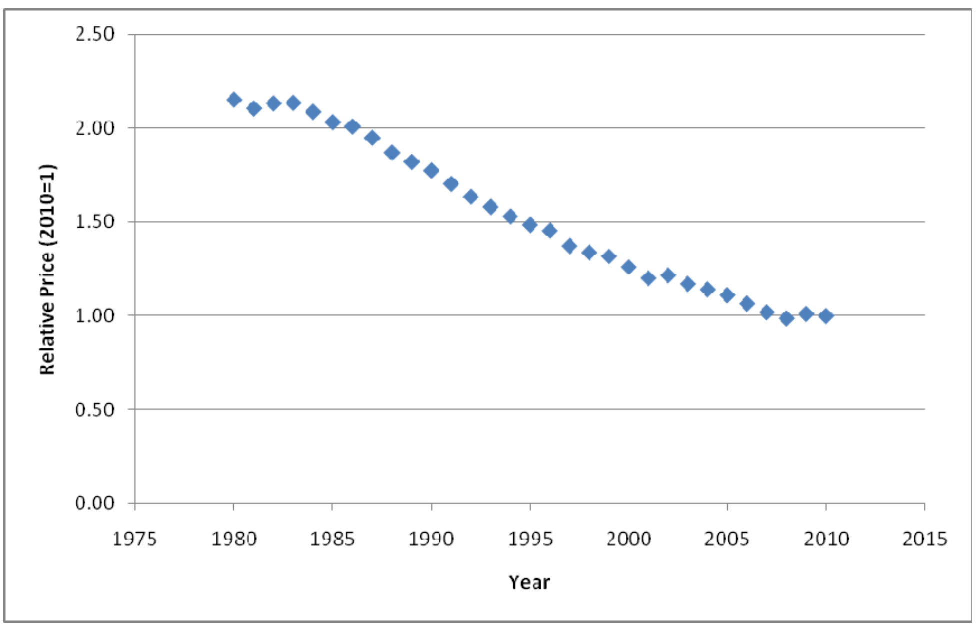

Figure 8-J.3.1 Historical Normalized Prices of Household Laundry Equipment

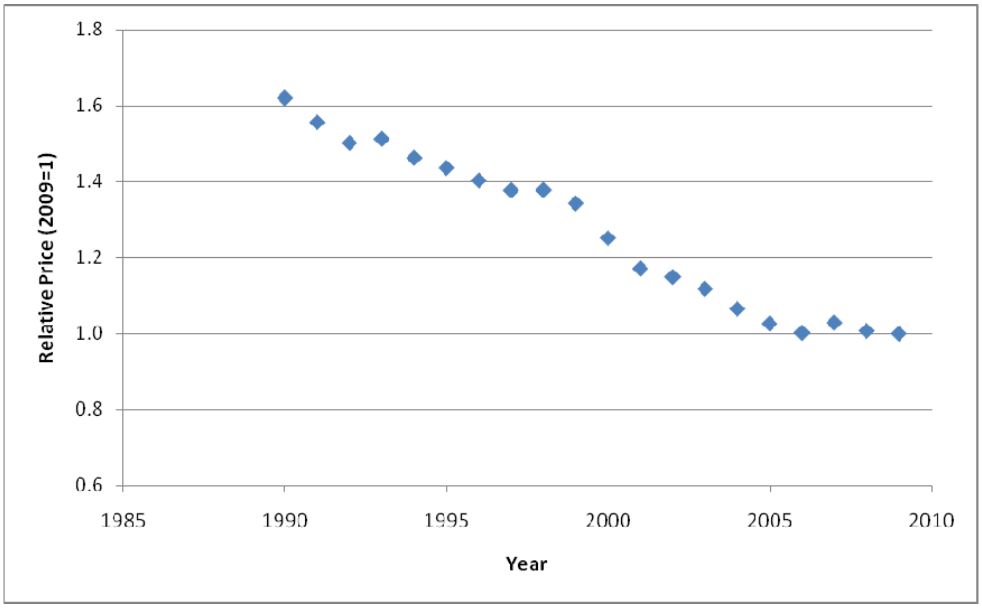

Figure 8-J.3.2 Historical Normalized Prices of Room Air Conditioners

DOE assembled a time-series of annual shipments for 1946-2009 for clothes dryers, 1972-2008 for clothes washers, and for 1946-2009 for room air conditioners from data submittals from AHAM, AHAM Fact Books, and Appliance Magazine. Decadal shipments up to 1979 for clothes washers were obtained from the 2005 AHAM Fact Book. Household laundry equipment is assumed to consist of only residential clothes washers and dryers. The annual and decadal shipments data were used to estimate cumulative shipments (production). Projected shipments after 2008/2009 were obtained from the base case projections made for the NIA (see chapter 9 of this TSD). Figure 8-J.3.3 and Figure 8-J.3.4 show the shipments time series used in the analysis.

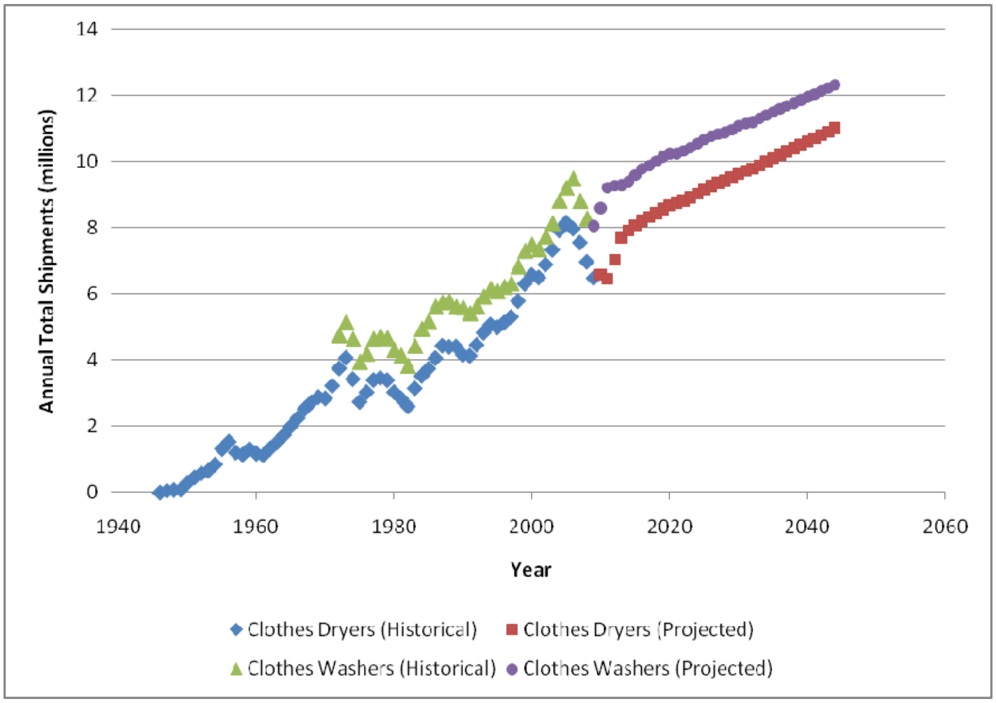

Figure 8-J.3.3 Historical and Projected Total Shipments of Household Laundry Equipment

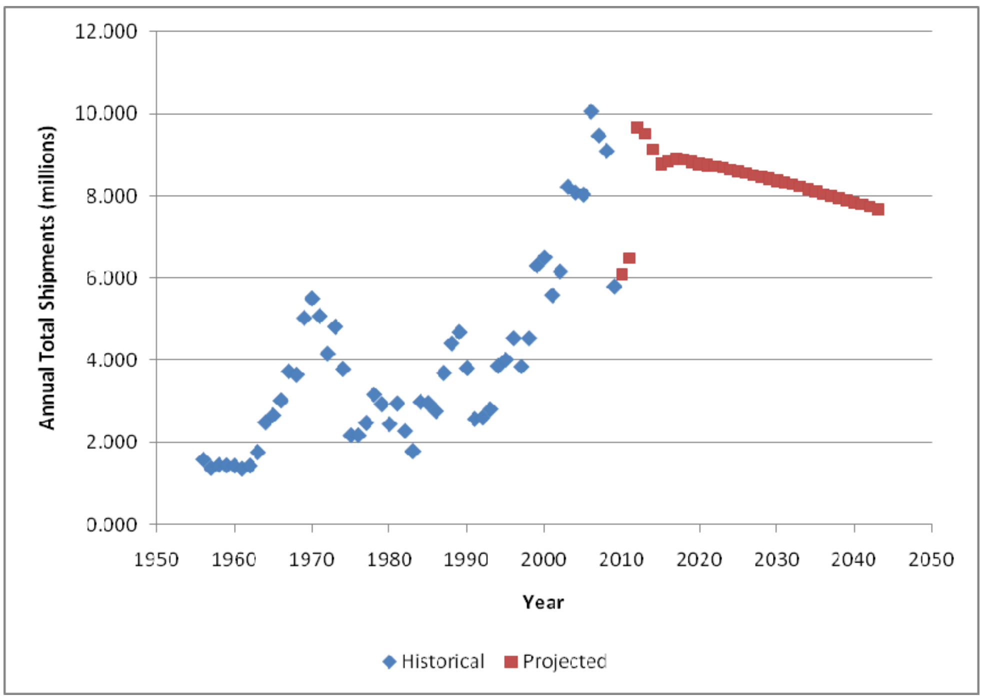

Figure 8-J.3.4 Historical and Projected Total Shipments of Room Air Conditioners

To estimate a learning rate parameter, a least-squares power-law fit was performed on the unified price index versus cumulative shipments.

See Figure 8-J.3.5 and Figure 8-J.3.6.

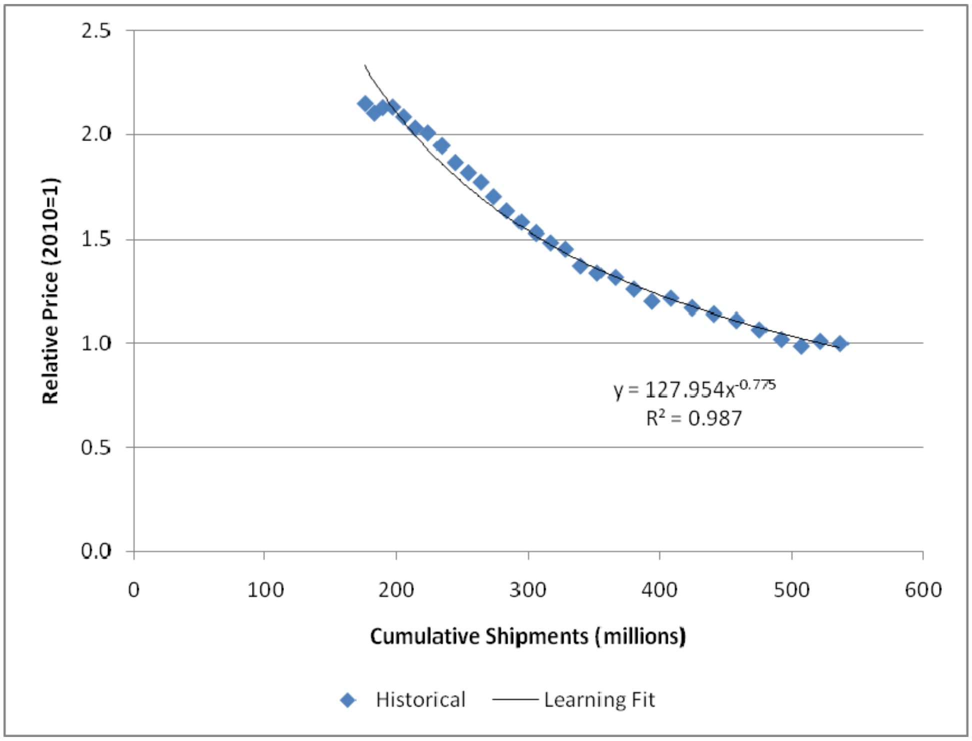

Figure 8-J.3.5 Relative Price versus Cumulative Shipments of Household Laundry Equipment, with Power Law Fit

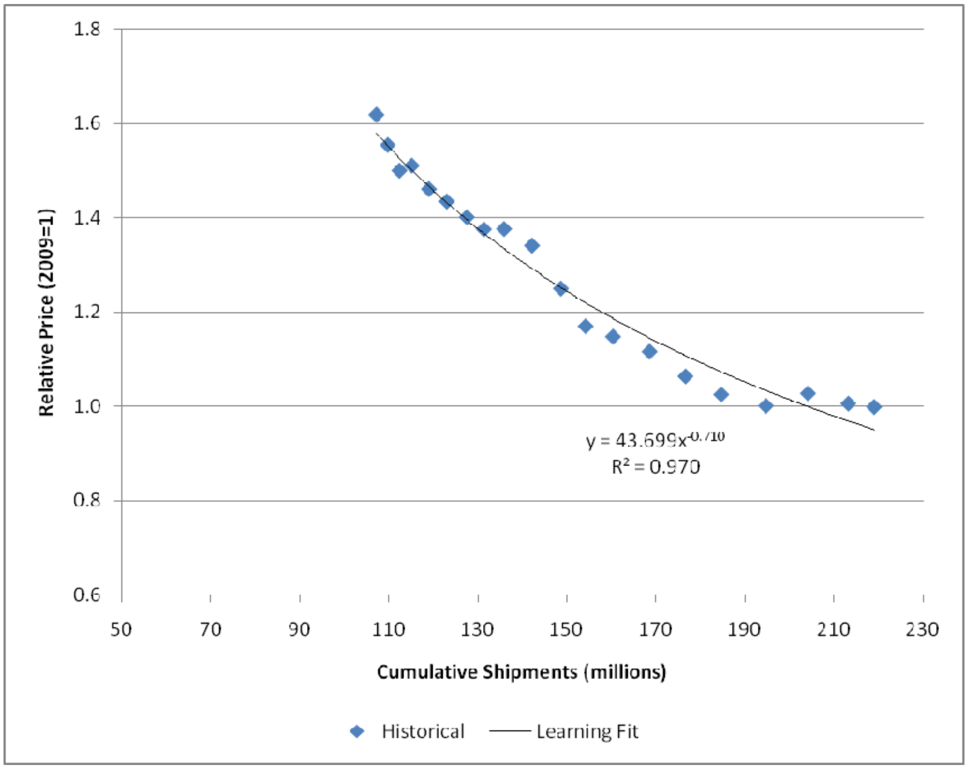

Figure 8-J.3.6 Relative Price versus Cumulative Shipments of Room Air Conditioners, with Power Law Fit

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.

The parameter values obtained are:

P_o = (95% confidence) for household laundry equipment and (95% confidence) for room air conditioners, and
b = 0.775±0.034 (95% confidence) for household laundry equipment and 0.710±0.062 (95% confidence) for room air conditioners.

For household laundry equipment, the estimated learning rate (defined as the fractional reduction in price expected from each doubling of cumulative production) is % (95% confidence). For room air conditioners, the estimated learning rate is % (95% confidence).

DOE then derived a price factor index, with 2010 equal to 1, to forecast prices in each future year in the analysis period. The index value in a given year is a function of the LR and the cumulative production forecast through that year. Table 1 shows the price factors used in the analysis. DOE applied the same value to forecast prices for each residential clothes dryer and room air conditioner product class at each considered efficiency level.

8-J.4 PRICE TRENDS FOR SENSITIVITY ANALYSES

DOE recognizes that there is uncertainty in its estimates of equipment price trends. Uncertainty arises from potentially systematic long term changes in the trend. To provide a potential indication of long term changes in the trend, DOE performed price trend fits to two component periods in the historical data. DOE analyzed years in which the historical efficiency standards for the product changed that were approximately in the middle of the time series of the available data. For household laundry equipment, the selected year was 1994, and for room air conditioners, the selected year was 2000.

Table 8-J.4.1 Learning parameter as a function of time period

Product	**Period**	**Learning Parameter (%)**
Household Laundry Equipment	1980-2010	41.6
Household Laundry Equipment	1980-1993	33.9
Household Laundry Equipment	1994-2010	42.0
Room Air Conditioners	1990-2009	38.9
Room Air Conditioners	1990-1999	34.7
Room Air Conditioners	2000-2009	31.0

DOE examined the impacts of a range of learning parameters on the range of net benefit impacts from potential standards using high, medium and low values of the learning rate parameter. DOE examined the range of estimates as sensitivities to the national impact analysis. The low learning rate is from the time period with the lowest value, or the low end of the 95% confidence range of the full period learning estimate. The medium value is the estimate for the full time period. The high value is the higher of the high time period estimate or upper range of the 95% confidence interval for the full time period estimate. In addition, DOE examined a constant real price scenario as a sensitivity calculation for its national impact analysis.

DOE considered another sensitivity calculation for residential clothes dryers. An effective PPI series for clothes dryers only was determined from the household laundry equipment PPI series, by factoring out the contribution from clothes washers. DOE used average selling prices from two sources: NPD (2004-2009 for clothes washers, 2007-2008 for clothes dryers), and Consumer Reports (1992, 1993, 1995, 1997, 1999 for clothes washers). Clothes washer prices were separated into top-loading and front-loading models. Market shares for top-loading clothes washers, front-loading clothes washers, and clothes dryers were available for all years. Using the 2007-2008 washer and dryer price data to normalize the relative household laundry PPI index to nominal dollars, DOE created an effective PPI series for clothes washers only for years 1992, 1993, 1995, 1997, 1999, and 2004-2009. Assuming the household laundry PPI series is dominated by clothes washers and clothes dryers only, and using the known market shares between clothes washers and dryers, DOE derived an effective clothes dryer PPI series from the household laundry PPI and the effective clothes washer PPI series. Learning parameters were calculated from the effective clothes dryer PPI series (using clothes dryer cumulative production) and used as another sensitivity estimate.

APPENDIX 10-A. USER INSTRUCTIONS FOR SHIPMENTS AND NATIONAL ENERGY SAVINGS SPREADSHEET MODEL

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APPENDIX 10-A. USER INSTRUCTIONS FOR SHIPMENTS AND NATIONAL IMPACT ANALYSIS SPREADSHEET MODEL

10-A.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) room air conditioner and clothes dryer Rulemaking page: http://www.eere.energy.gov/buildings/appliance_standards/. From that page, follow the links to the Final Rule phase and then to the Analytical Tools.

10-A.2 STARTUP

DOE named the spreadsheets for the product classes and subgroup analysis if applicable. The spreadsheets enable users to perform National Impact Analysis (NIA) of room air conditioners and clothes dryers. A separate spreadsheet exists for each of the products. Table 10-A.2.1 lists all national impact analysis spreadsheets used in this analysis.

Table 10-A.2.1 List of National Impact Analysis Spreadsheets

Filename	Description
NIA_RAC.xls	Room Air Conditioner Products
NIA_CD.xls	Clothes Dryer Products

To examine the spreadsheets, DOE assumes that the user has access to a personal computer with a hardware configuration capable of running Windows NT/2000/XP. The room air conditioner and clothes dryer NIA spreadsheets require Microsoft Excel 2000 or later installed under the Windows operating system.

10-A.3 DESCRIPTION OF NATIONAL IMPACT ANALYSIS WORKSHEETS

The NIA spreadsheets perform calculations to forecast the change in national energy use and net present value of financial impacts due to a revised energy conservation standard. The energy use and associated costs for a given standard are determined by first calculating the shipments and then by calculating the energy use and costs for all products shipped under that standard. The differences between the standards and base case can then be compared and the overall energy savings and net present values determined. The NIA spreadsheets consist of the following worksheets:

Introduction The *Introduction* sheet contains a list and description of all worksheets used in the analysis.

Flow Chart The *Flow Chart* sheet contains a diagram of the structure of the inputs and outputs used to derive the NIA.

Summary The *Summary* sheet contains energy savings results, net present value results, and emissions monetization results for each TSL considered.

National Impacts Summary	The *National Impacts Summary* sheet contains user input selections, source energy savings results matrix, net present value results matrix, a summary table for each product class and charts of national impacts for each product class.
Base Case Consumption	The *Base Case Consumption* sheet contains the base case consumption calculations.
NES	The *NES* worksheets contain detailed calculations for the base case and the shipments and stock energy savings and net present value at given candidate standard levels.
Base Case Shipments	The *Base Case Shipments* sheet contains a tabular summary and chart of the annual shipments forecasts for each product class at each trial standard level.
New Housing Market Share	The *New Housing Market Share* sheet contains the market share model calculations that determine the market shares for new housing market segment. (Clothes Dryer NIA spreadsheet only.)
Historical Market Share Data	The *Historical Market Share Data* sheet contains the market share model calculations that determine the market shares for each market segment.
Efficiency Dist.	The *Efficiency Dist.* sheet contains the efficiency trends model which captures the changing parameters due to changes in efficiency trends of equipment over time.
Efficiency Trends	The *Efficiency Trends* sheet contains the efficiency trends combined with the LCC inputs (Room Air Conditioner NIA spreadsheet only.)
LCC Inputs	The *LCC Inputs* sheet contains inputs from the LCC spreadsheet for each product class.
Lifetime	The *Lifetime* sheet calculates the lifetime expectancy distribution of room air conditioners and clothes dryers.
New Housing Forecast	The *New Housing Forecast* sheet provides projected new housing construction completions and manufactured home placements.
Fuel Prices and Heat Rates	The *Fuel Prices and Heat Rates* sheets contain projected energy price trends and site to source heat rates.

Shipments Forecast Charts	The *Shipments Forecast Charts* sheet contains charts of product shipments

10-A.4 BASIC INSTRUCTIONS FOR OPERATING THE NATIONAL IMPACT ANALYSIS SPREADSHEETS

Basic instructions for operating the NIA spreadsheets are as follows:

Once the NIA spreadsheet file has been downloaded from the Web, open the file using Excel. Click “Enable Macro” when prompted and then click on the tab for the worksheet National Impacts Summary Analysis.

1. Use Excel's View/Zoom commands at the top menu bar to change the size of the display to make it fit your monitor.
2. The user can change the parameters under the title “National Impacts Summary”. The default parameters are:

   a. Discount Rate: Set to 7 percent. To change value, click on cell C5 and interchange value (7 percent or 3 percent).

   b. Current Year: Set to 2011. To change value, click on cell C6 and interchange to desired year.

   c. Economic Growth: Set to Reference Case. To change value, use the pull down menu and select the desired level (Reference Case, Low Economic Growth or High Economic Growth).

In the case of clothes dryers, the results are automatically updated and are reported in the source energy savings matrix, net present value matrix, summary table for each product class and charts of national impacts for each product class.

In the room air conditioner spreadsheet, the user can visualize the automatically updated results for a given product class by using the pull down menu “select product class”. To see the results for the entire room air conditioner market, the user needs to update the results tables by clicking on the button “Update TSLs Results”. A macro will automatically generate the summary table results for all product classes.

APPENDIX 10-B. NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE USING ECONOMIC GROWTH SCENARIOS

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APPENDIX 10-B. NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE USING ECONOMIC GROWTH SCENARIOS

10-B.1 INTRODUCTION

This appendix presents national energy savings (NES) and net present value (NPV) results for alternative economic scenarios for room air conditioners and clothes dryers. DOE explained the calculations of NES and NPV using the reference installation costs and the default energy price forecast in chapter 10, National Impact Analysis.

10-B.2 ROOM AIR CONDITIONER RESULTS USING ECONOMIC GROWTH SCENARIOS

For each room air conditioner product class, DOE calculated NES and NPV using energy price scenarios from the High and Low Economic Growth cases. The NES results are the same in each energy price scenario. As one would expect, the NPV is most favorable using prices in the High Growth scenario, and least favorable using prices in the Low Growth scenario.

10-B.2.1 Room Air Conditioner NES and NPV Results Using High Economic Growth Scenario

Table 10-B.2.1 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 1 (High Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	10.10	0.08	0.15	0.42
2	10.60	0.08	0.15	0.42
3	10.10	0.05	0.13	0.31
4	11.10	0.13	0.02	0.34
5	11.10	0.13	0.02	0.34
6	11.67	0.17	-1.33	-1.71

Table 10-B.2.2 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 2 (High Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	10.70	0.11	0.48	0.98
2	10.70	0.14	0.25	0.72
3	10.90	0.08	0.23	0.53
4	10.90	0.23	0.04	0.58
5	11.50	0.23	0.04	0.58
6	11.96	0.29	-2.27	-2.93

Table 10-B.2.3 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 3 (High Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	9.40	0.001	-0.003	-0.002
2	9.40	0.11	0.20	0.58
3	8.47	0.06	0.18	0.42
4	9.40	0.18	0.03	0.47
5	8.47	0.18	0.03	0.47
6	10.15	0.23	-1.82	-2.35

Table 10-B.2.4 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 4 (High Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	9.40	0.00	-0.01	-0.01
2	9.40	0.08	0.15	0.42
3	8.48	0.05	0.13	0.31
4	9.00	0.13	0.02	0.34
5	8.48	0.13	0.02	0.34
6	9.80	0.17	-1.33	-1.71

Table 10-B.2.5 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 5 (High Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	9.30	0.01	0.03	0.05
2	9.30	0.09	0.17	0.47
3	9.60	0.05	0.15	0.35
4	9.60	0.15	0.03	0.38
5	10.00	0.15	0.03	0.38
6	10.35	0.19	-1.49	-1.92

Table 10-B.2.6 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 6 (High Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	9.30	0.00	0.01	0.03
2	9.30	0.09	0.17	0.48
3	9.50	0.05	0.15	0.35
4	9.50	0.15	0.03	0.38
5	9.50	0.15	0.03	0.38
6	10.02	0.19	-1.49	-1.93

10-B.2.2 Room Air Conditioner NES and NPV Results Using Low Economic Growth Scenario

Table 10-B.2.7 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 1 (Low Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	10.10	0.08	0.09	0.30
2	10.60	0.08	0.09	0.30
3	10.10	0.05	0.10	0.24
4	11.10	0.13	-0.07	0.14
5	11.10	0.13	-0.07	0.14
6	11.67	0.17	-1.45	-1.98

Table 10-B.2.8 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 2 (Low Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	10.70	0.11	0.40	0.82
2	10.70	0.14	0.16	0.51
3	10.90	0.08	0.17	0.41
4	10.90	0.23	-0.11	0.24
5	11.50	0.23	-0.11	0.24
6	11.96	0.29	-2.47	-3.37

Table 10-B.2.9 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 3 (Low Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	9.40	0.001	-0.003	-0.004
2	9.40	0.11	0.13	0.41
3	8.47	0.06	0.14	0.33
4	9.40	0.18	-0.09	0.19
5	8.47	0.18	-0.09	0.19
6	10.15	0.23	-1.98	-2.71

Table 10-B.2.10 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 4 (Low Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	9.40	0.000	-0.006	-0.009
2	9.40	0.08	0.09	0.30
3	8.48	0.05	0.10	0.24
4	9.00	0.13	-0.07	0.14
5	8.48	0.13	-0.07	0.14
6	9.80	0.17	-1.45	-1.98

Table 10-B.2.11 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 5 (Low Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	9.30	0.01	0.02	0.04
2	9.30	0.09	0.10	0.33
3	9.60	0.05	0.11	0.27
4	9.60	0.15	-0.07	0.16
5	10.00	0.15	-0.07	0.16
6	10.35	0.19	-1.62	-2.22

Table 10-B.2.12 Cumulative National Energy Savings and Consumer Net Present Value for Room Air Conditioners Group 6 (Low Growth)

Trial Standard Level (TSL)	CEER	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	9.30	0.004	0.011	0.021
2	9.30	0.09	0.10	0.33
3	9.50	0.05	0.11	0.27
4	9.50	0.15	-0.07	0.16
5	9.50	0.15	-0.07	0.16
6	10.02	0.19	-1.63	-2.22

10-B.3 ROOM AIR CONDITIONER RESULTS USING ECONOMIC GROWTH SCENARIOS COMPARISON

The following figures graphically display the NES and 7 percent NPV for all room air conditioner product classes under the low growth, the reference case, and the high growth economic growth scenarios. NES are not impacted by economic growth, so only one scenario is shown in the graphs.

10-B.3.1 Room Air Conditioner National Energy Savings (NES)

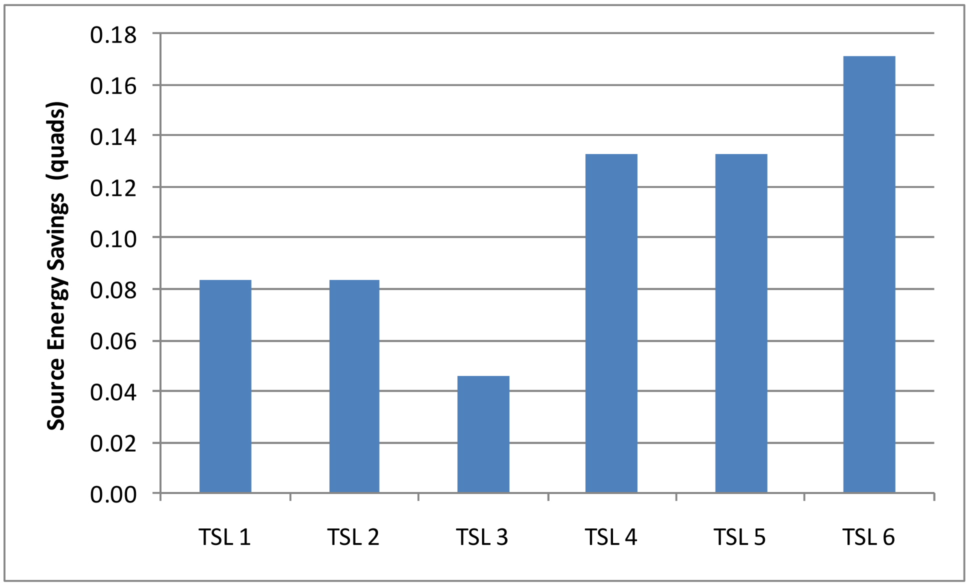

Figure 10-B.3.1 Room Air Conditioners Group 1 Energy Price Scenarios (NES)

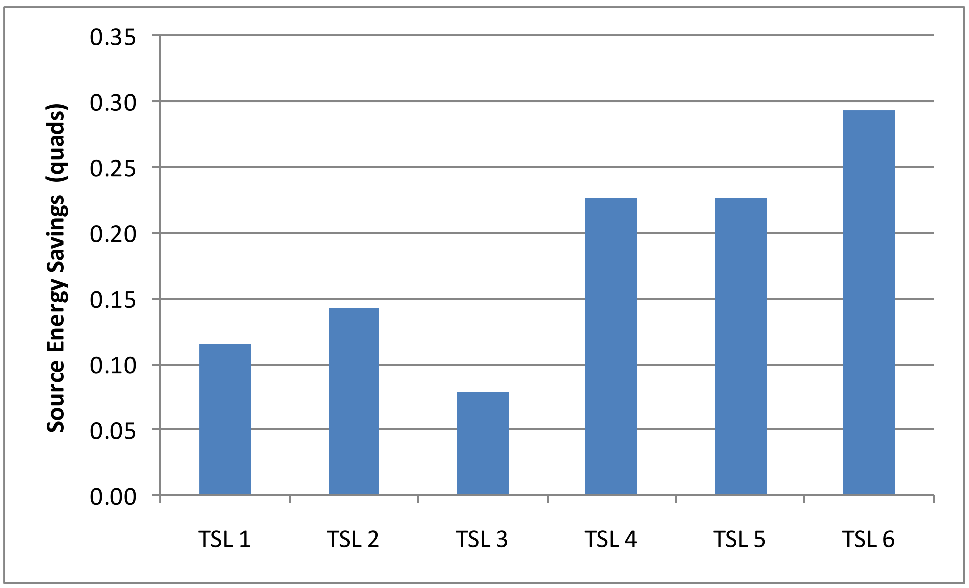

Figure 10-B.3.2 Room Air Conditioners Group 2 Energy Price Scenarios (NES)

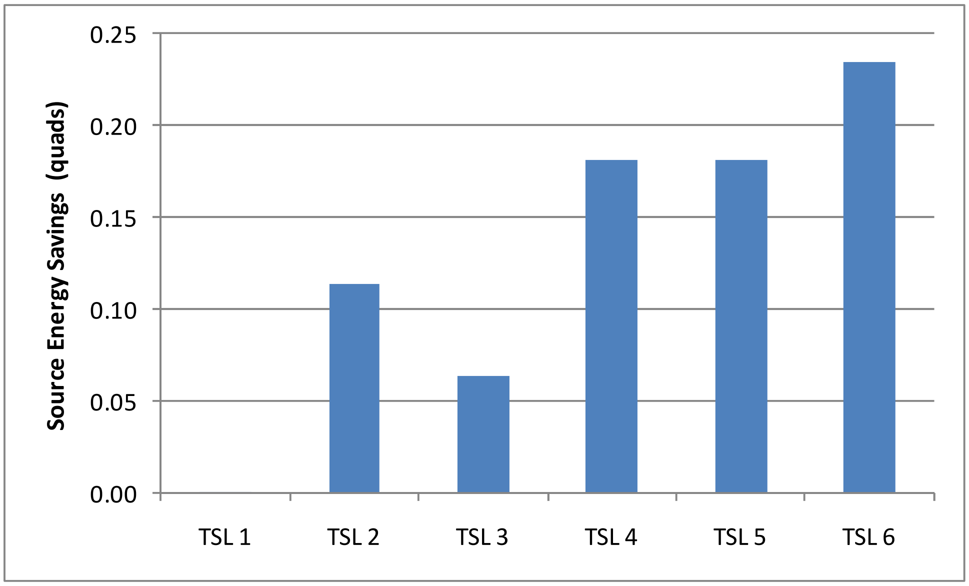

Figure 10-B.3.3 Room Air Conditioners Group 3 Energy Price Scenarios (NES)

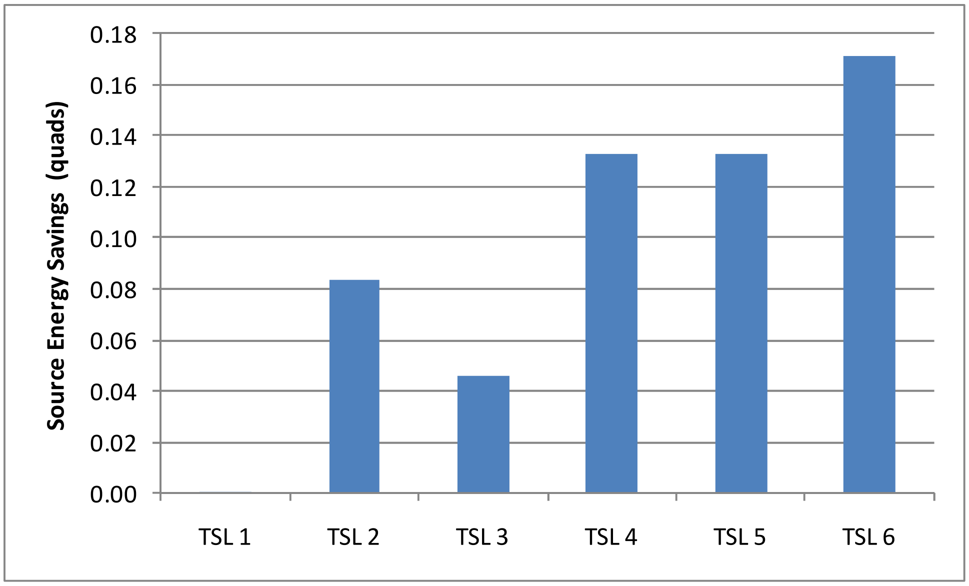

Figure 10-B.3.4 Room Air Conditioners Group 4 Energy Price Scenarios (NES)

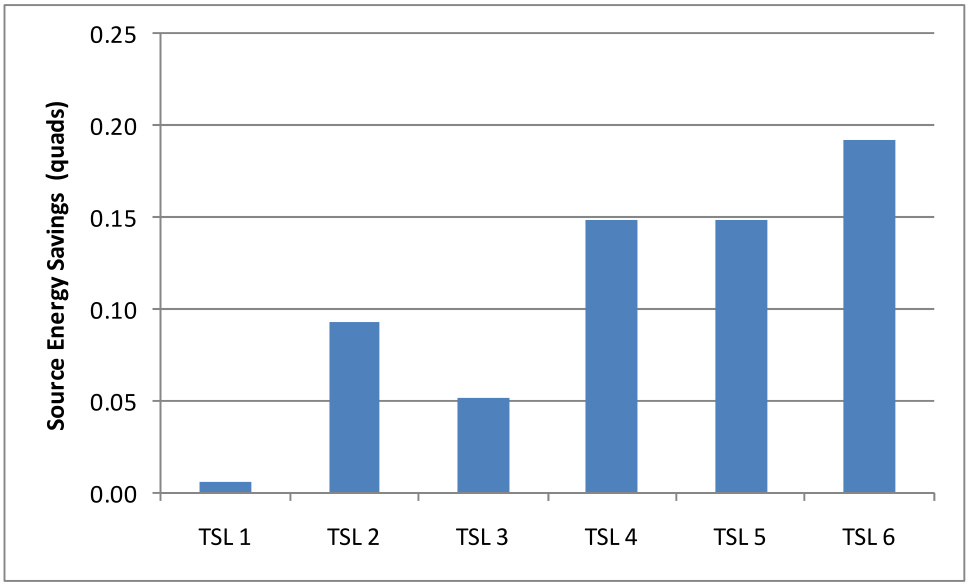

Figure 10-B.3.5 Room Air Conditioners Group 5 Energy Price Scenarios (NES)

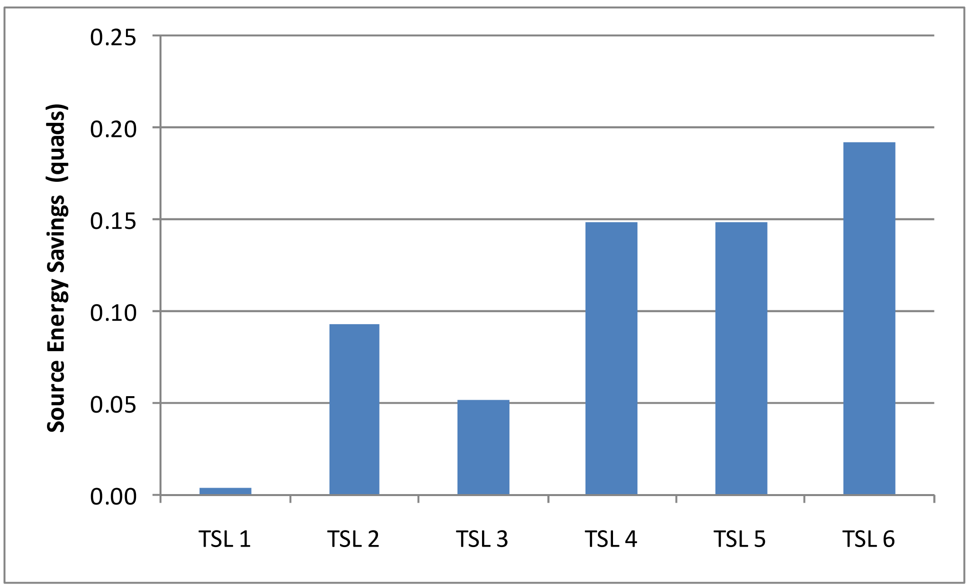

Figure 10-B.3.6 Room Air Conditioners Group 6 Energy Price Scenarios (NES)

10-B.3.2 Room Air Conditioner Net Present Values (NPV)

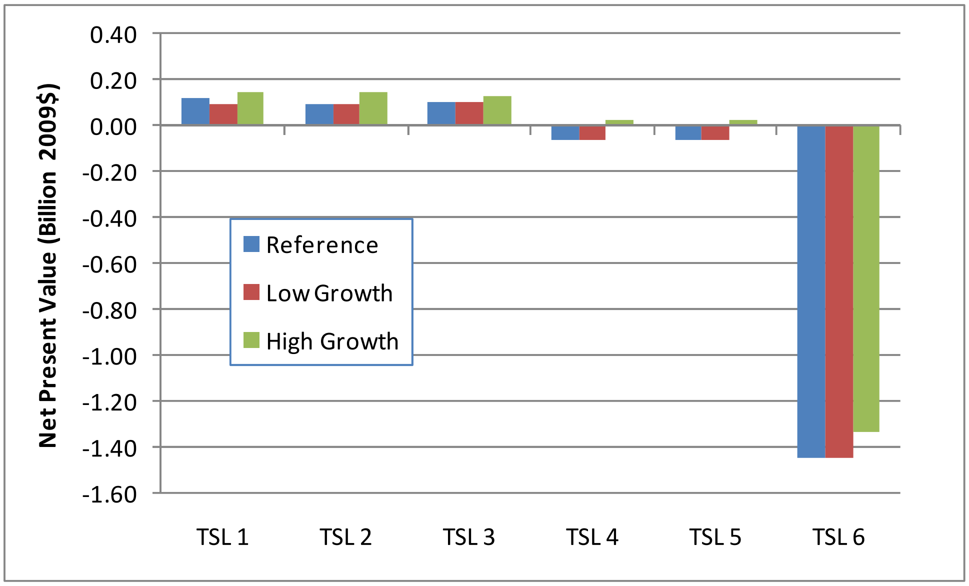

Figure 10-B.3.7 Room Air Conditioners Group 1 Energy Price Scenarios (NPV, 7% Discount Rate)

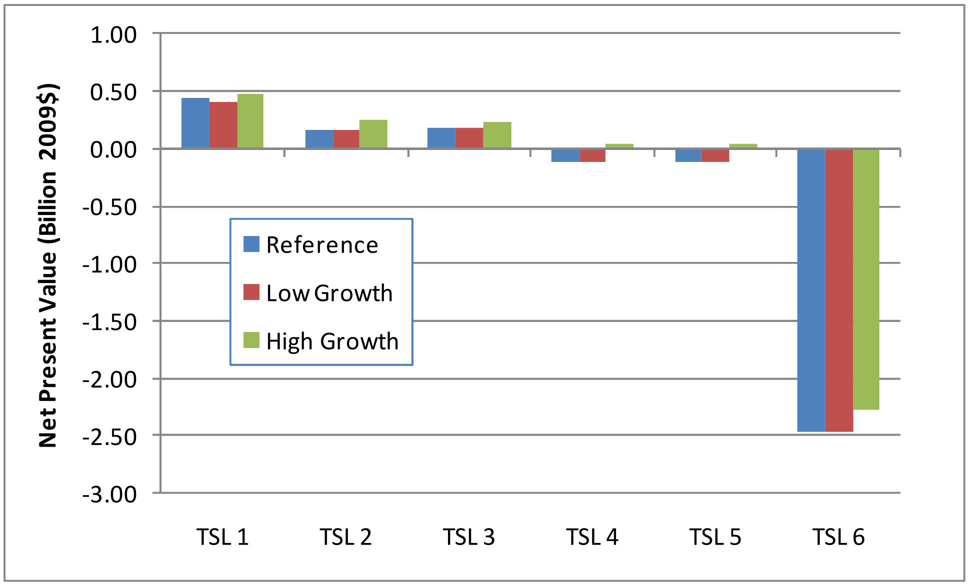

Figure 10-B.3.8 Room Air Conditioners Group 2 Energy Price Scenarios (NPV, 7% Discount Rate)

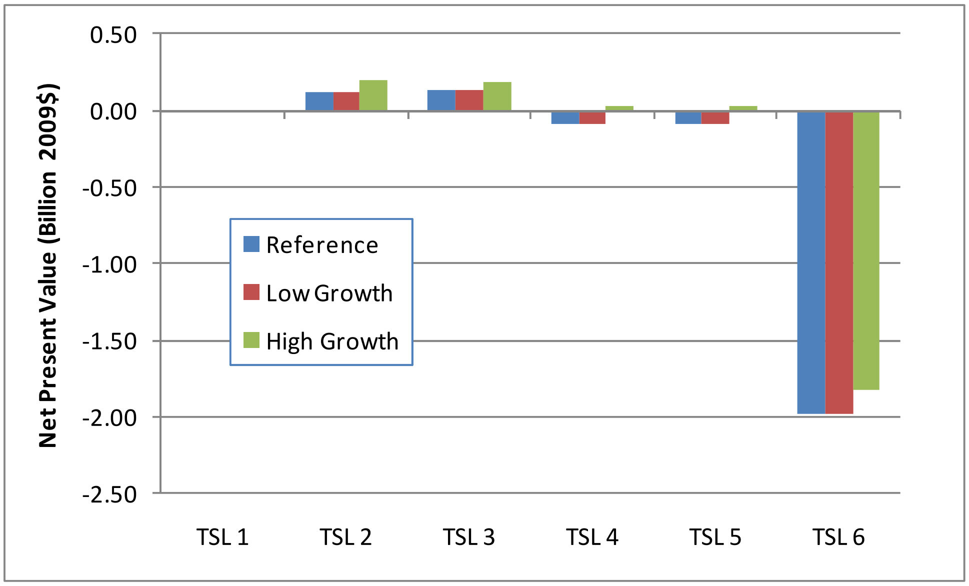

Figure 10-B.3.9 Room Air Conditioners Group 3 Energy Price Scenarios (NPV, 7% Discount Rate)

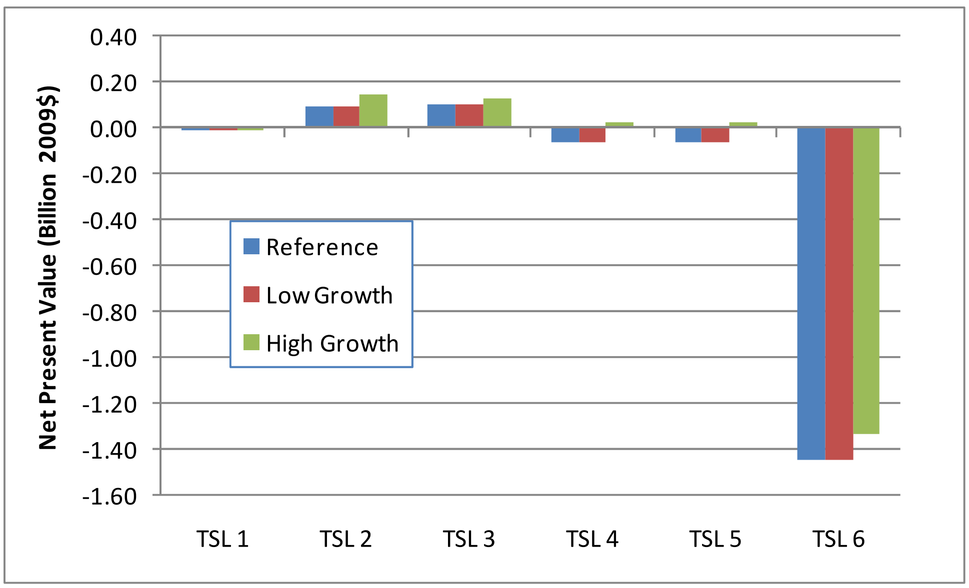

Figure 10-B.3.10 Room Air Conditioners Group 4 Energy Price Scenarios (NPV, 7% Discount Rate)

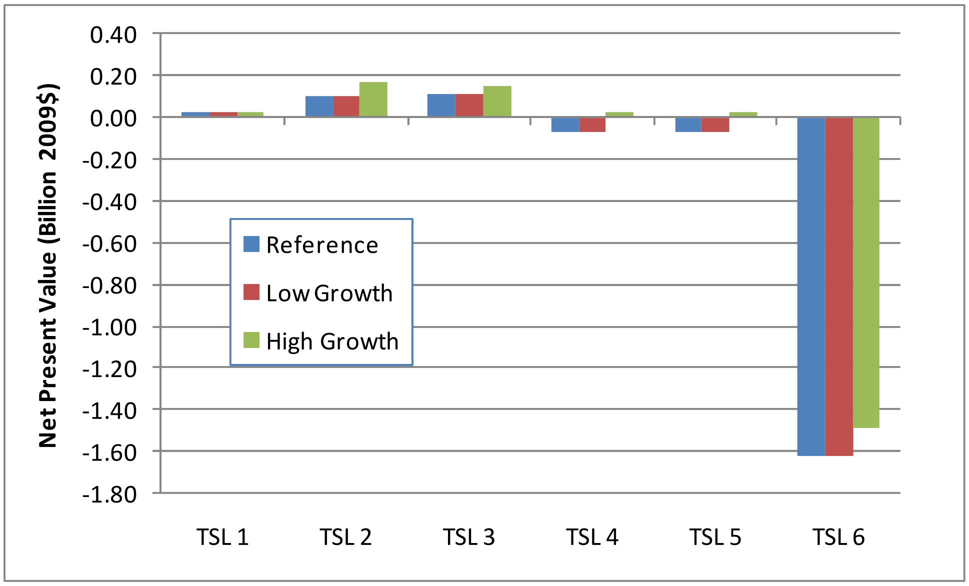

Figure 10-B.3.11 Room Air Conditioners Group 5 Energy Price Scenarios (NPV, 7% Discount Rate)

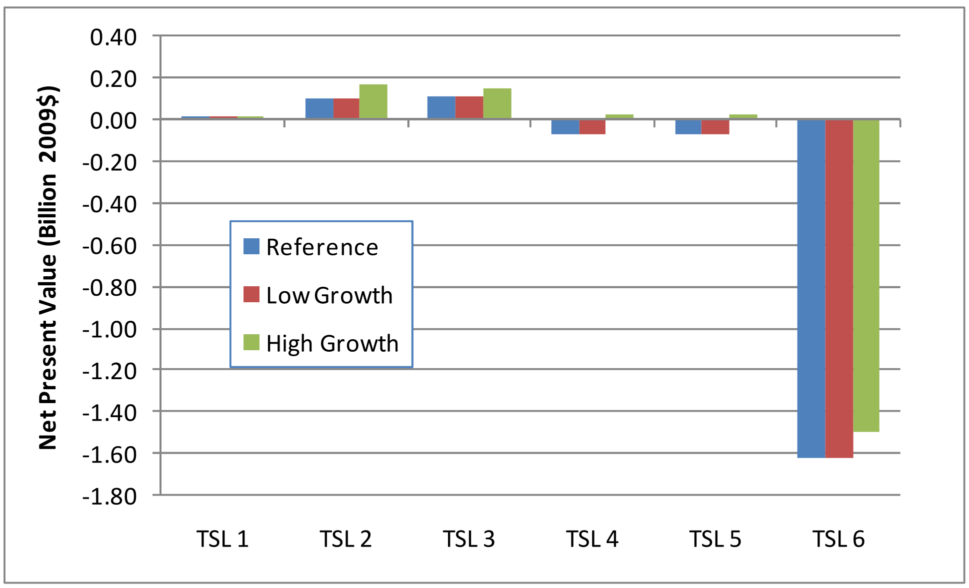

Figure 10-B.3.12 Room Air Conditioners Group 6 Energy Price Scenarios (NPV, 7% Discount Rate)

10-B.4 CLOTHES DRYER RESULTS USING ECONOMIC GROWTH SCENARIOS

For each clothes dryer product class, DOE calculated NES and NPV using the high growth, reference case, and low growth economic growth scenarios. The NES results are the same in each economic growth scenario. As one would expect, the NPV is most favorable using prices in the High Growth scenario, and least favorable using prices in the Low Growth scenario.

10-B.4.1 Clothes Dryer NES and NPV Results Using High Economic Growth Scenario

Table 10-B.4.1 Cumulative National Energy Savings and Consumer Net Present Value for Electric Standard Clothes Dryers (High Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	3.56	0.00	0.00	0.01
2	3.61	0.04	0.19	0.46
3	3.73	0.37	1.20	3.28
4	3.73	0.37	1.20	3.28
5	4.08	1.37	-0.76	3.33
6	5.42	3.15	-4.47	3.01

Table 10-B.4.2 Cumulative National Energy Savings and Consumer Net Present Value for Electric Compact 120V Clothes Dryers (High Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	3.43	0.000	0.00	0.00
2	3.61	0.001	0.00	0.01
3	3.61	0.001	0.00	0.01
4	3.61	0.001	0.00	0.01
5	4.08	0.002	-0.01	-0.01
6	5.41	0.004	-0.02	-0.03

Table 10-B.4.3 Cumulative National Energy Savings and Consumer Net Present Value for Electric Compact 240V Clothes Dryers (High Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	3.12	0.000	0.00	0.00
2	3.27	0.001	0.01	0.02
3	3.27	0.001	0.01	0.02
4	3.27	0.001	0.01	0.02
5	3.60	0.006	-0.05	-0.07
6	4.89	0.017	-0.10	-0.12

Table 10-B.4.4 Cumulative National Energy Savings and Consumer Net Present Value for Gas Clothes Dryers (High Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	3.16	0.00	0.01	0.02
2	3.20	0.01	0.04	0.11
3	3.20	0.01	0.04	0.11
4	3.30	0.04	0.07	0.26
5	3.61	0.18	-1.52	-1.91
6	3.61	0.18	-1.52	-1.91

Table 10-B.4.5 Cumulative National Energy Savings and Consumer Net Present Value for Electric Compact Ventless 240V Clothes Dryers (High Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	2.55	0.000	0.00	0.00
2	2.69	0.002	0.01	0.02
3	2.69	0.002	0.01	0.02
4	2.55	0.000	0.00	0.00
5	2.80	0.004	-0.01	-0.01
6	4.03	0.017	-0.05	-0.03

Table 10-B.4.6 Cumulative National Energy Savings and Consumer Net Present Value for Electric Combination Washer/Dryer (High Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	2.08	0.00	0.00	0.00
2	2.56	0.01	0.04	0.10
3	2.56	0.01	0.04	0.10
4	2.08	0.00	0.00	0.00
5	2.56	0.01	0.04	0.10
6	3.69	0.03	-0.04	0.02

10-B.4.2 Clothes Dryer NES/NPV Results Using Low Economic Growth Scenario

Table 10-B.4.7 Cumulative National Energy Savings and Consumer Net Present Value for Electric Standard Clothes Dryers (Low Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	3.56	0.00	0.00	0.01
2	3.61	0.04	0.15	0.34
3	3.73	0.32	0.85	2.29
4	3.73	0.32	0.85	2.29
5	4.08	1.17	-1.38	0.95
6	5.42	2.70	-5.53	-1.82

Table 10-B.4.8 Cumulative National Energy Savings and Consumer Net Present Value for Electric Compact 120V Clothes Dryers (Low Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	3.43	0.000	0.00	0.00
2	3.61	0.000	0.00	0.00
3	3.61	0.000	0.00	0.00
4	3.61	0.000	0.00	0.00
5	4.08	0.002	-0.01	-0.01
6	5.41	0.003	-0.02	-0.03

Table 10-B.4.9 Cumulative National Energy Savings and Consumer Net Present Value for Electric Compact 240V Clothes Dryers (Low Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	3.12	0.000	0.00	0.00
2	3.27	0.001	0.00	0.01
3	3.27	0.001	0.00	0.01
4	3.27	0.001	0.00	0.01
5	3.60	0.005	-0.05	-0.07
6	4.89	0.015	-0.10	-0.12

Table 10-B.4.10 Cumulative National Energy Savings and Consumer Net Present Value for Gas Clothes Dryers (Low Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	3.16	0.00	0.00	0.01
2	3.20	0.01	0.03	0.08
3	3.20	0.01	0.03	0.08
4	3.30	0.04	0.04	0.17
5	3.61	0.15	-1.43	-1.91
6	3.61	0.15	-1.43	-1.91

Table 10-B.4.11 Cumulative National Energy Savings and Consumer Net Present Value for Electric Compact Vent-less 240V Clothes Dryers (Low Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	2.55	0.000	0.00	0.00
2	2.69	0.002	0.01	0.02
3	2.69	0.002	0.01	0.02
4	2.55	0.000	0.00	0.00
5	2.80	0.003	-0.01	-0.01
6	4.03	0.014	-0.05	-0.05

Table 10-B.4.12 Cumulative National Energy Savings and Consumer Net Present Value for Electric Vent-less Combination Washer/Dryer (Low Growth)

Trial Standard Level (TSL)	Efficiency Level (CEF)	NES (Quads)	NPV (billion 2009$)	
			7% Discount Rate	3% Discount Rate
1	2.08	0.000	0.00	0.00
2	2.56	0.010	0.03	0.07
3	2.56	0.010	0.03	0.07
4	2.08	0.000	0.00	0.00
5	2.56	0.010	0.03	0.07
6	3.69	0.021	-0.05	-0.02

10-B.5 CLOTHES DRYER RESULTS USING ECONOMIC GROWTH SCENARIOS COMPARISON

The following figures graphically display the NES and 7 percent NPV for all clothes dryer product classes under the low growth, the reference case, and the high growth energy price scenarios.

10-B.5.1 Clothes Dryer National Energy Savings (NES)

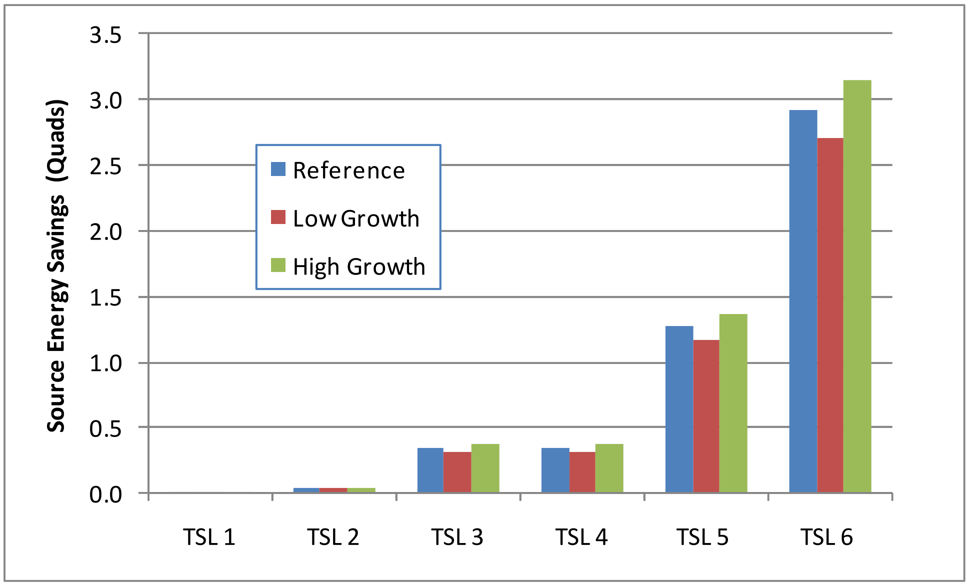

Figure 10-B.5.1 Electric Standard Clothes Dryers Energy Price Scenarios (NES)

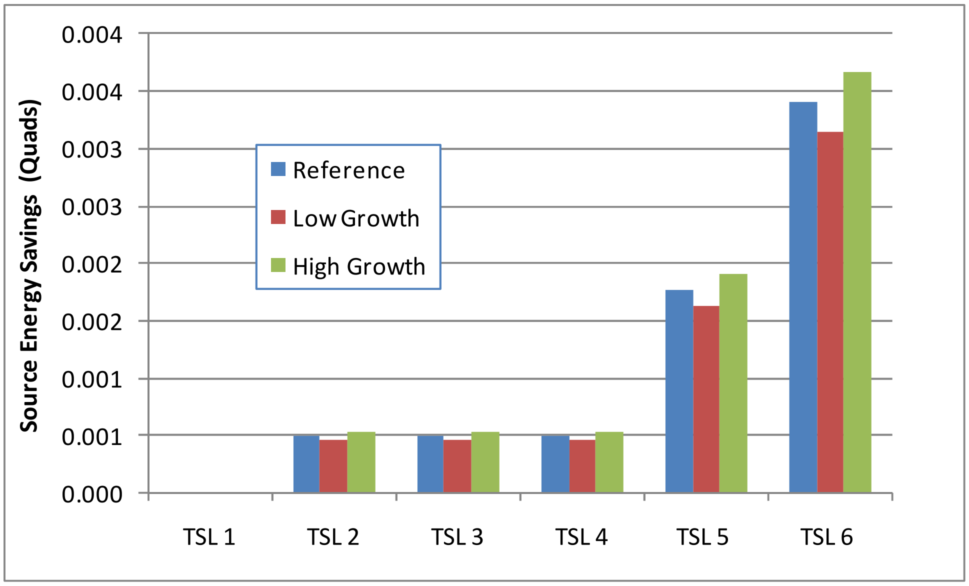

Figure 10-B.5.2 Electric Compact 120V Clothes Dryer Energy Price Scenarios (NES)

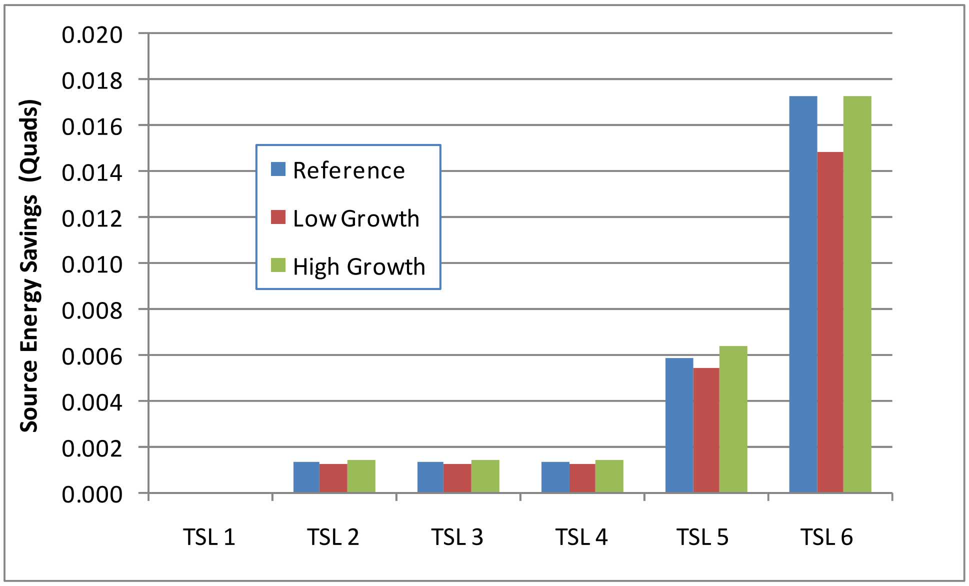

Figure 10-B.5.3 Electric Compact 240V Clothes Dryer Energy Price Scenarios (NES)

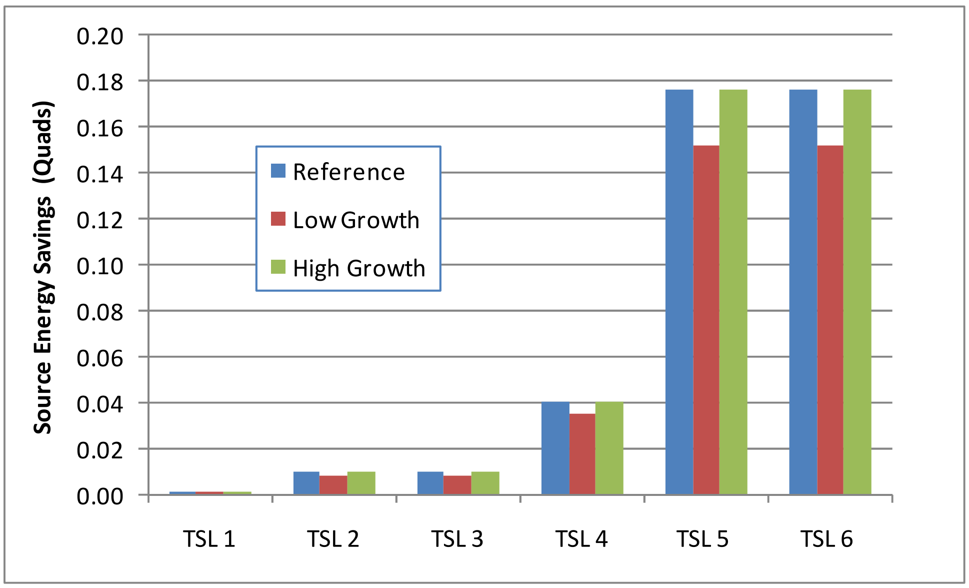

Figure 10-B.5.4 Gas Clothes Dryer Energy Price Scenarios (NES)

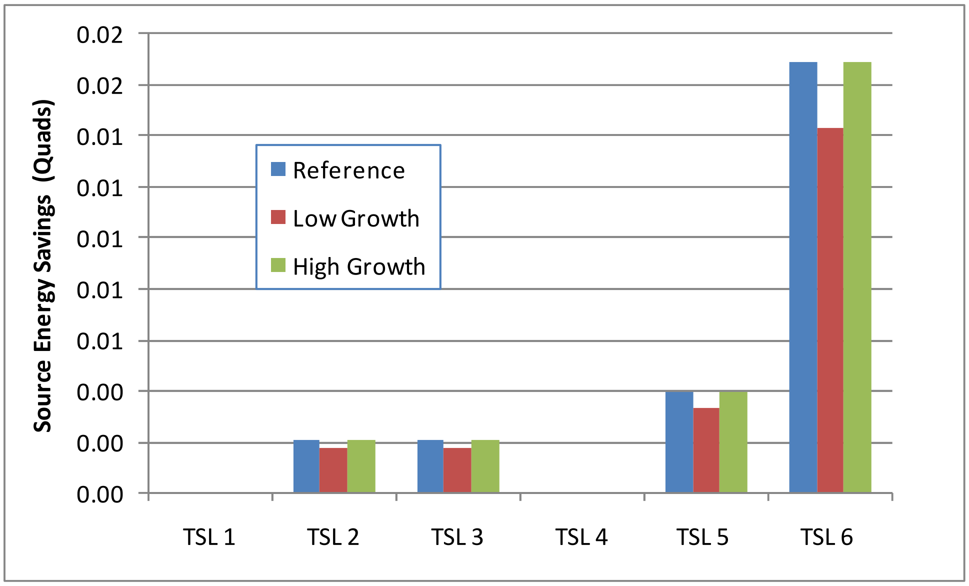

Figure 10-B.5.5 Electric Compact 240V Vent-less Clothes Dryer Energy Price Scenarios (NES)

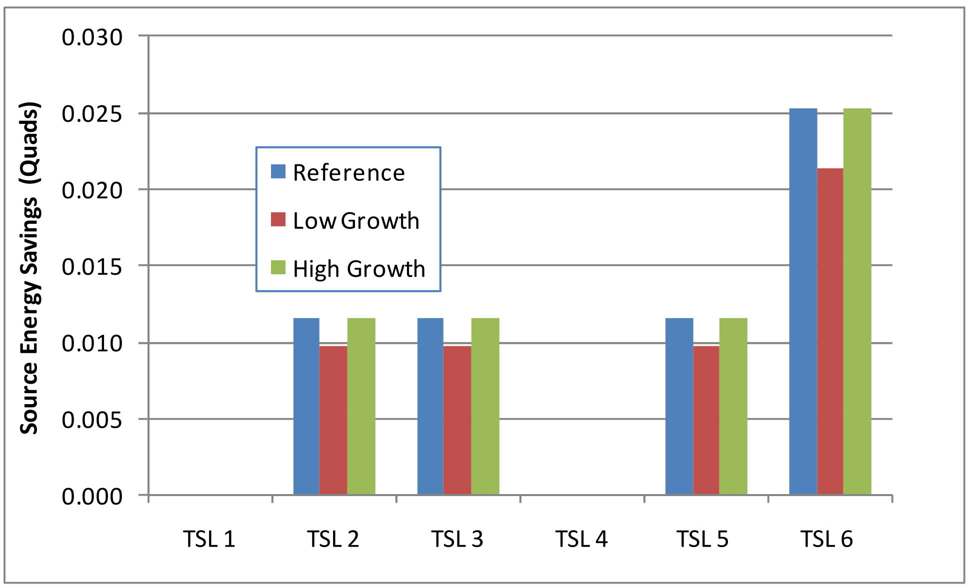

Figure 10-B.5.6 Electric Combination Washer/Dryer Energy Price Scenarios (NES)

10-B.5.2 Clothes Dryer Net Present Values (NPV)

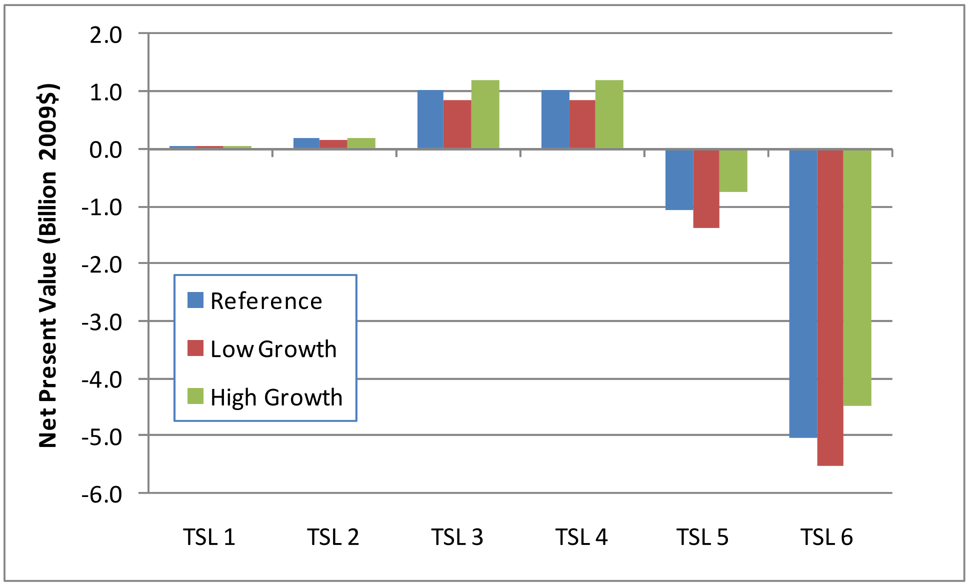

Figure 10-B.5.7 Electric Standard Clothes Dryer Energy Price Scenarios (NPV; 7% Discount Rate)

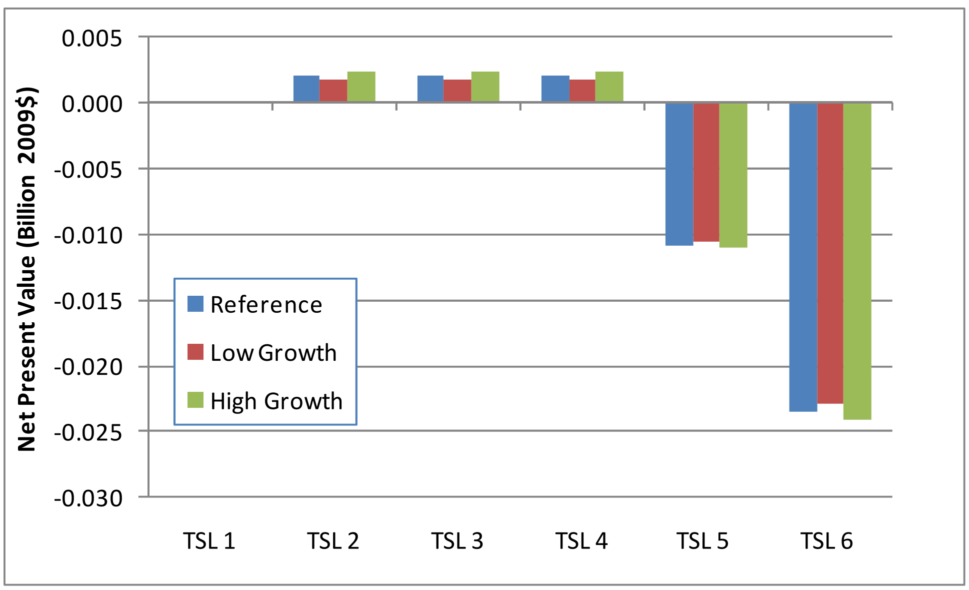

Figure 10-B.5.8 Electric Compact 120V Clothes Dryer Energy Price Scenarios (NPV; 7% Discount Rate)

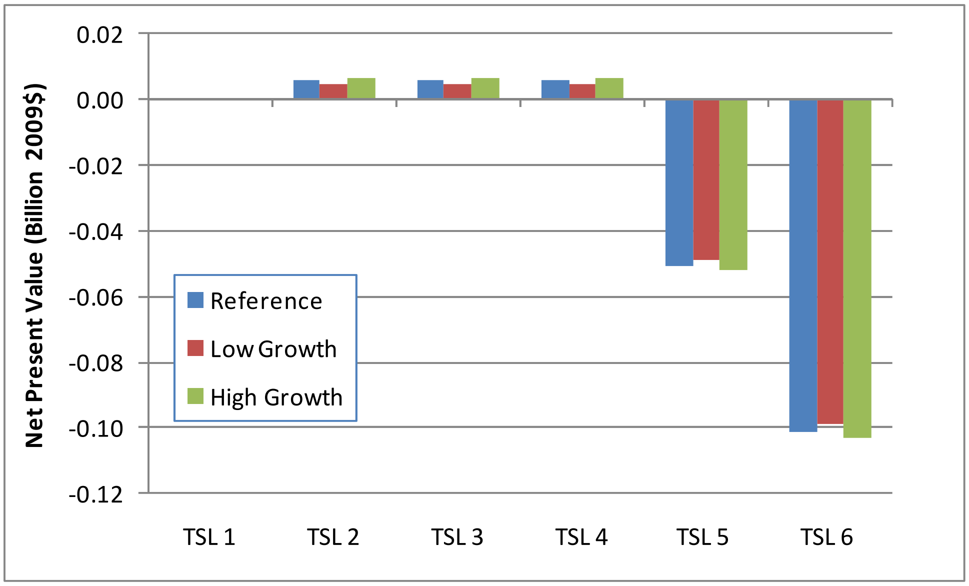

Figure 10-B.5.9 Electric Compact 240V Clothes Dryer Energy Price Scenarios (NPV; 7% Discount Rate)

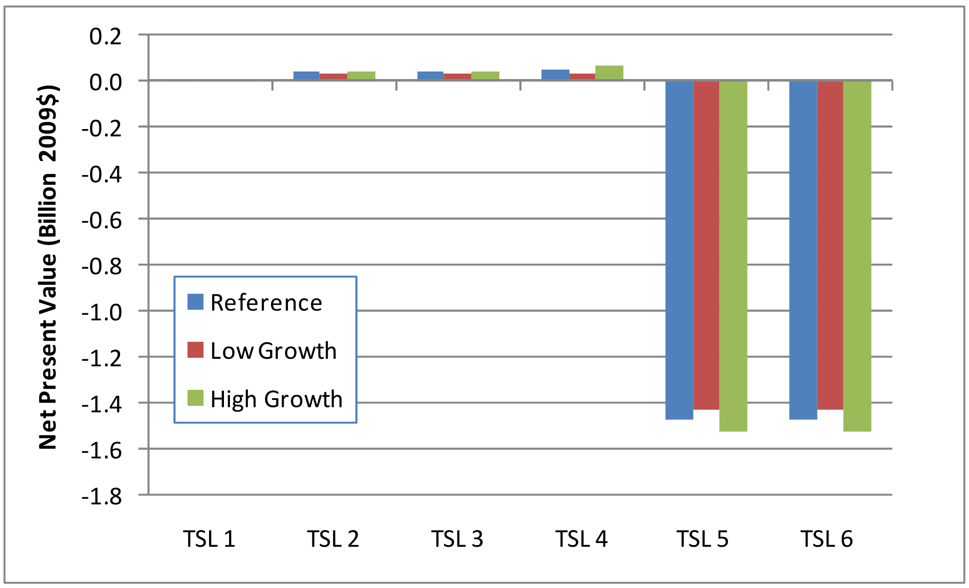

Figure 10-B.5.10 Gas Clothes Dryer Energy Price Scenarios (NPV; 7% Discount Rate)

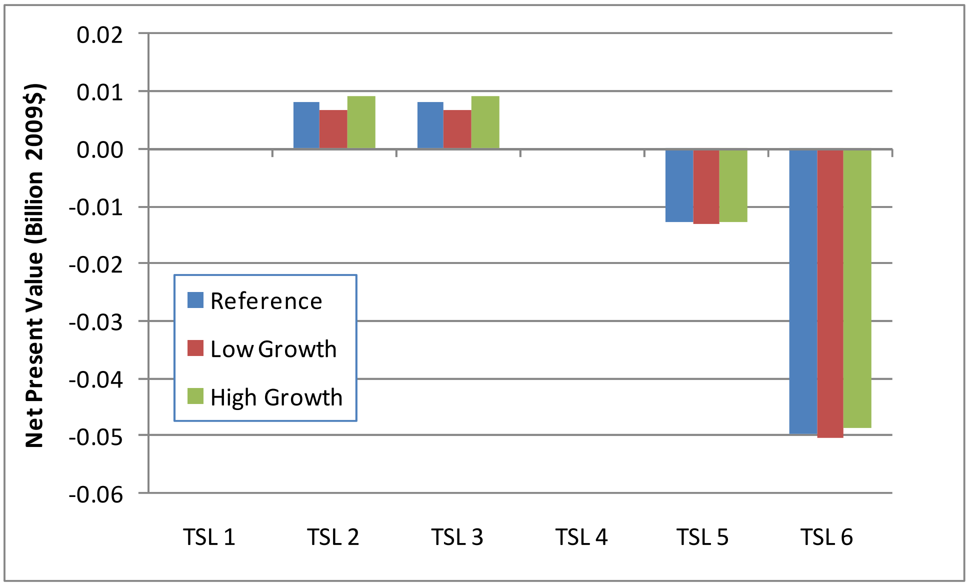

Figure 10-B.5.11 Electric Compact 240V Vent-less Clothes Dryer Energy Price Scenarios (NPV; 7% Discount Rate)

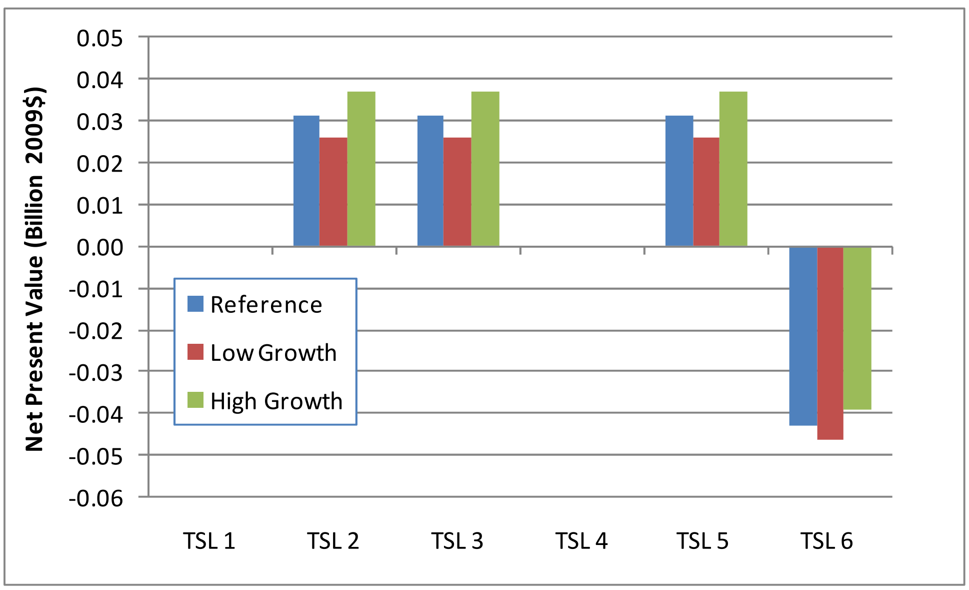

Figure 10-B.5.12 Electric Combination Washer/Dryer Energy Price Scenarios (NPV; 7% Discount Rate)

APPENDIX 10-C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS AND EMISSIONS REDUCTIONS USING ALTERNATIVE LEARNING RATES

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APPENDIX 10-C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS AND EMISSIONS REDUCTIONS USING ALTERNATIVE LEARNING RATES

10-C.1 INTRODUCTION

DOE investigated the impact of different learning rates on the combined net present value (NPV) for the considered TSLs for room air conditioners and clothes dryers. The NPV results presented in chapter 10 are based on learning rates of 38.9% for room air conditioners and 41.6% for clothes dryers, both of which are referred to as the "default" learning rates. DOE considered three learning rate sensitivities: (1) a "high learning" rate; (2) a "low learning" rate; and (3) a "no learning" rate. In addition, for clothes dryers there is a fourth sensitivity: "Clothes Dryers Only".

The "high learning" rates are 41.4% for room air conditioners and 42.9% for clothes dryers. The "low learning' rates are 31.0% for room air conditioners and 33.9% for clothes dryers. The "no learning" rate sensitivity, which is zero percent for all products, assumes constant real prices over the entire forecast period. For clothes dryers, "clothes dryers only" is based on limited set of historical price data specifically for clothes dryers and the learning rate is 52.2%. Refer to appendix 8-J for details on the development of the above learning rates.

The results presented here combine the NPV of the consumer savings, calculated for each TSL using 3 and 7 percent discount rates, with the present value of the potential economic benefits resulting from reduced CO_2 and NO_X emissions. For these results, the economic benefits from reduced CO_2 emissions were calculated using a SCC value of $22.1/metric ton in 2010 (in 2009$) for CO_2, increasing at 3% per year, and a discount rate of 3%. The economic benefits from reduced NO_X emissions were calculated using a value of $2,519/ton (in 2009$), which is the average of the low and high values used in DOE's analysis, and either a 3% or 7% discount rate. See chapter 16 for information regarding the derivation of these values. All results refer to lifetime impacts of products shipped in 2014-2043.

The results presented here are annualized values. DOE used a two-step calculation process to convert the time-series of costs and benefits into annualized values. First, DOE calculated a present value in 2011, the year used for discounting the NPV of total consumer costs and savings, for the time-series of costs and benefits using discount rates of three and seven percent for all costs and benefits except for the value of CO_2 reductions. For the latter, DOE used the discount rate appropriate for each SCC time series. From the present value, DOE then calculated the fixed annual payment over a 30-year period, starting in 2011, that yields the same present value. The fixed annual payment is the annualized value. Although DOE calculated annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined would be a steady stream of payments.

10-C.2 ROOM AIR CONDITIONER NPV RESULTS USING ALTERNATIVE LEARNING RATES

Table 10-C.2.1 Room Air Conditioners: Annualized Present Value of Consumer Impacts (3 Percent Discount Rate) and Annualized Present Value of Monetized Benefits from CO_2 and NO_X Emissions Reductions (3 Percent Discount Rate)

		Learning Rate (LR)			
Trial Standard Level		**Default:** LR_{RoomAC} =38.9%	**Low Sensitivity:** LR_{RoomAC} =31.0%	**High Sensitivity:** LR_{RoomAC} =41.4%	**No Learning:** LR = 0% (constant real prices)
		Billion 2009$			
1	Incr. Installed Cost	0.060	0.064	0.059	0.080
	Operating Cost Savings	0.128	0.128	0.128	0.128
	Value of Emissions Reduction	0.012	0.012	0.012	0.012
	Net Present Value	0.079	0.075	0.081	0.059
2	Incr. Installed Cost	0.059	0.063	0.057	0.078
	Operating Cost Savings	0.125	0.125	0.125	0.125
	Value of Emissions Reduction	0.014	0.014	0.014	0.014
	Net Present Value	0.080	0.076	0.082	0.061
3	Incr. Installed Cost	0.055	0.059	0.054	0.074
	Operating Cost Savings	0.132	0.132	0.132	0.132
	Value of Emissions Reduction	0.015	0.015	0.015	0.015
	Net Present Value	0.092	0.088	0.093	0.072
4	Incr. Installed Cost	0.111	0.118	0.108	0.146
	Operating Cost Savings	0.186	0.186	0.186	0.186
	Value of Emissions Reduction	0.021	0.021	0.021	0.021
	Net Present Value	0.096	0.088	0.098	0.061
5	Incr. Installed Cost	0.215	0.230	0.210	0.284
	Operating Cost Savings	0.289	0.289	0.289	0.289
	Value of Emissions Reduction	0.032	0.032	0.032	0.032
	Net Present Value	0.106	0.091	0.111	0.037
6	Incr. Installed Cost	0.689	0.736	0.674	0.909
	Operating Cost Savings	0.403	0.402	0.403	0.401
	Value of Emissions Reduction	0.045	0.045	0.045	0.045
	Net Present Value	(0.241)	(0.289)	(0.226)	(0.463)

Parentheses indicate negative (-) values.

Table 10-C.2.2 Room Air Conditioners: Annualized Present Value of Consumer Impacts (7 Percent Discount Rate) and Annualized Present Value of Monetized Benefits from CO_2 and NO_X Emissions Reductions (Discount Rate of 3% for CO_2 and 7% for NO_X)

		Learning Rate (LR)			
Trial Standard Level		**Default:** LR_{RoomAC} =38.9%	**Low Sensitivity:** LR_{RoomAC} =31.0%	**High Sensitivity:** LR_{RoomAC} =41.4%	**No Learning:** LR = 0% (constant real prices)
		Billion 2009$			
1	Incr. Installed Cost	0.058	0.062	0.057	0.076
	Operating Cost Savings	0.106	0.106	0.106	0.106
	Value of Emissions Reduction	0.011	0.011	0.011	0.011
	Net Present Value	0.059	0.055	0.060	0.041
2	Incr. Installed Cost	0.057	0.061	0.056	0.074
	Operating Cost Savings	0.103	0.103	0.103	0.103
	Value of Emissions Reduction	0.014	0.014	0.014	0.014
	Net Present Value	0.060	0.057	0.061	0.043
3	Incr. Installed Cost	0.054	0.057	0.052	0.070
	Operating Cost Savings	0.111	0.111	0.111	0.111
	Value of Emissions Reduction	0.015	0.015	0.015	0.015
	Net Present Value	0.072	0.068	0.073	0.056
4	Incr. Installed Cost	0.108	0.114	0.106	0.137
	Operating Cost Savings	0.154	0.154	0.154	0.154
	Value of Emissions Reduction	0.020	0.020	0.020	0.020
	Net Present Value	0.066	0.060	0.069	0.037
5	Incr. Installed Cost	0.209	0.221	0.204	0.267
	Operating Cost Savings	0.235	0.235	0.235	0.235
	Value of Emissions Reduction	0.032	0.032	0.032	0.032
	Net Present Value	0.058	0.045	0.062	(0.000)
6	Incr. Installed Cost	0.681	0.722	0.668	0.869
	Operating Cost Savings	0.323	0.323	0.323	0.322
	Value of Emissions Reduction	0.045	0.045	0.045	0.044
	Net Present Value	(0.313)	(0.355)	(0.300)	(0.502)

Parentheses indicate negative (-) values.

10-C.3 CLOTHES DRYER NPV RESULTS USING ALTERNATIVE LEARNIG RATES

Table 10-C.3.1 Clothes Dryers: Annualized Present Value of Consumer Impacts (3 Percent Discount Rate) and Annualized Present Value of Monetized Benefits from CO_2 and NO_X Emissions Reductions (3 Percent Discount Rate)

		Learning Rate (LR)				
Trial Standard Level		**Default:** LR_{CD} =41.6%	**Low Sensitivity:** LR_{CD} =33.9%	**High Sensitivity:** LR_{CD} =42.9%	**No Learning:** LR = 0% (constant real prices)	**Sensitivity (Clothes Dryers Only):** LR = 52.2%
		Billion 2009$				
1	Incr. Installed Cost	0.000	0.000	0.000	0.000	0.000
	Operating Cost Savings	0.001	0.001	0.001	0.001	0.001
	Value of Emissions Reduction	0.000	0.000	0.000	0.000	0.000
	Net Present Value	0.001	0.001	0.001	0.001	0.001
2	Incr. Installed Cost	0.002	0.002	0.002	0.003	0.002
	Operating Cost Savings	0.034	0.034	0.034	0.034	0.034
	Value of Emissions Reduction	0.004	0.004	0.004	0.004	0.004
	Net Present Value	0.036	0.036	0.036	0.035	0.036
3	Incr. Installed Cost	0.047	0.051	0.046	0.067	0.041
	Operating Cost Savings	0.200	0.200	0.200	0.200	0.200
	Value of Emissions Reduction	0.025	0.025	0.025	0.025	0.025
	Net Present Value	0.178	0.173	0.179	0.158	0.183
4	Incr. Installed Cost	0.055	0.061	0.055	0.079	0.049
	Operating Cost Savings	0.209	0.209	0.209	0.209	0.209
	Value of	0.026	0.026	0.026	0.026	0.026

	Emissions Reduction					
	Net Present Value	0.180	0.175	0.181	0.156	0.186
5	Incr. Installed Cost	0.772	0.849	0.761	1.103	0.683
	Operating Cost Savings	0.783	0.783	0.783	0.783	0.783
	Value of Emissions Reduction	0.099	0.099	0.099	0.099	0.099
	Net Present Value	0.110	0.033	0.121	(0.220)	0.199
6	Incr. Installed Cost	1.767	1.934	1.744	2.483	1.574
	Operating Cost Savings	1.689	1.689	1.689	1.689	1.689
	Value of Emissions Reduction	0.263	0.263	0.263	0.263	0.263
	Net Present Value	0.185	0.018	0.209	(0.531)	0.378

Parentheses indicate negative (-) values.

Table 10-C.3.2 Clothes Dryers: Annualized Present Value of Consumer Impacts (7 Percent Discount Rate) and Annualized Present Value of Monetized Benefits from CO_2 and NO_X Emissions Reductions (Discount Rate of 3% for CO_2 and 7% for NO_X)

		Learning Rate (LR)				
Trial Standard Level		**Default:** LR_{CD} =41.6%	**Low Sensitivity:** LR_{CD} =33.9%	**High Sensitivity:** LR_{CD} =42.9%	**No Learning:** LR = 0% (constant real prices)	**Sensitivity (Clothes Dryers Only):** LR = 52.2%
		Billion 2009$				
1	Incr. Installed Cost	0.000	0.000	0.000	0.000	0.000
	Operating Cost Savings	0.001	0.001	0.001	0.001	0.001
	Value of Emissions Reduction	0.000	0.000	0.000	0.000	0.000
	Net Present Value	0.001	0.001	0.001	0.001	0.001
2	Incr. Installed	0.002	0.002	0.002	0.003	0.002

	Cost					
	Operating Cost Savings	0.022	0.022	0.022	0.022	0.022
	Value of Emissions Reduction	0.004	0.004	0.004	0.004	0.004
	Net Present Value	0.025	0.024	0.025	0.024	0.025
3	Incr. Installed Cost	0.044	0.048	0.044	0.060	0.040
	Operating Cost Savings	0.133	0.133	0.133	0.133	0.133
	Value of Emissions Reduction	0.025	0.025	0.025	0.025	0.025
	Net Present Value	0.114	0.110	0.114	0.098	0.118
4	Incr. Installed Cost	0.052	0.057	0.052	0.071	0.047
	Operating Cost Savings	0.139	0.139	0.139	0.139	0.139
	Value of Emissions Reduction	0.026	0.026	0.026	0.026	0.026
	Net Present Value	0.113	0.108	0.113	0.094	0.118
5	Incr. Installed Cost	0.730	0.794	0.721	0.994	0.659
	Operating Cost Savings	0.521	0.521	0.521	0.521	0.521
	Value of Emissions Reduction	0.098	0.098	0.098	0.098	0.098
	Net Present Value	(0.111)	(0.176)	(0.103)	(0.375)	(0.041)
6	Incr. Installed Cost	1.665	1.805	1.647	2.236	1.513
	Operating Cost Savings	1.124	1.124	1.124	1.124	1.124
	Value of Emissions Reduction	0.259	0.259	0.259	0.259	0.259
	Net Present Value	(0.282)	(0.421)	(0.263)	(0.853)	(0.130)

Parentheses indicate negative (-) values.

APPENDIX 12-A. MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDES

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APPENDIX 12-A MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDES

12-A.1 RESIDENTIAL CLOTHES DRYER MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

April 21, 2010

The Department of Energy (DOE) conducts the manufacturer impact analysis (MIA) as part of the rulemaking process for amended energy conservation standards for clothes dryers. 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 explicitly analyzes the six product classes, with the following baseline efficiencies.[1]

Table 1.1 Baseline Efficiencies for Clothes Dryer Product Classes

Product Class Number	Product Type	Product Class Description	Baseline EF* *(lb/kWh)*	Baseline Standby Power *(W)*	Baseline IEF* *(lb/kWh)*
1	**Vented Dryers**	Electric, Standard (4.4 cubic feet (ft^3) or greater capacity)	3.01	2.0	2.96
2	**Vented Dryers**	Electric, Compact (120 volts (v)) (less than 4.4 ft^3 capacity)	3.13	2.0	3.00
3	**Vented Dryers**	Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	2.90	2.0	2.79
4	**Vented Dryers**	Gas	2.67	2.0	2.63
5	**Vent-less Dryers**	Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	2.37	2.0	2.29
6	**Vent-less Dryers**	Electric, Combination Washer/Dryer	1.95	2.0	1.90

* The baseline Energy Factors (EFs) for vented product classes are the current minimum energy conservation standards for residential clothes dryers measured in pounds (lb) per kilowatt-hour (kWh). Baseline EFs for vent-less product classes are estimated by DOE. Integrated Energy Factor (IEF) is calculated as the clothes dryer test load weight in lb divided by the sum of "active mode" per-cycle energy use and "inactive mode" per-cycle energy use in kWh.

For each of these product classes, DOE is considering integrated efficiency levels (ELs) which also incorporate EF and standby power. DOE is currently considering six ELs for each of the electric vented clothes dryer classes and five ELs for the gas vented and both of the vent-less clothes dryer classes. In responding to this questionnaire, please refer to the ELs in the tables below.

[1] Please see http://www1.eere.energy.gov/buildings/appliance_standards/residential/preliminary_analysis.html for a complete description.

Table 1.2 Clothes Dryer Integrated Efficiency Levels – Vented Product Classes

Level	Efficiency Level Description	Integrated Efficiency Level (IEF) *(lb/kWh)*			
		Electric Standard	**Electric Compact (120V)**	**Electric Compact (240V)**	**Gas**
Baseline	DOE Standard + 2.0 W Standby	2.96	3.00	2.79	2.63
1	Gap Fill + 2.0 W Standby	3.04	3.08	2.86	2.71
2	Gap Fill + 2.0 W Standby	3.10	3.15	2.96	2.80
3	Gap Fill/Maximum Available + 2.0 W Standby	3.33	3.37	3.06	2.97
4	Maximum Available + 1.5 W Standby	3.35	3.41	3.10	2.98
5	Maximum Available + 0.08 W Standby	3.40	3.53	3.19	3.02
6	Heat Pump (Max Tech) + 0.08 W Standby	4.52	4.69	4.34	

Table 1.3 Clothes Dryer Integrated Efficiency Levels – Vent-less Electric Compact (240V)

Level	Efficiency Level Description	Integrated Efficiency Level (IEF) *(lb/kWh)*
		Electric Compact (240 V)
Baseline	Baseline + 2.0 W Standby	2.29
1	Baseline + 1.5 W Standby	2.31
2	Baseline + 0.08 W Standby	2.37
3	Gap Fill + 0.08 W Standby	2.39
4	Gap Fill + 0.08 W Standby	2.59
5	Heat Pump (Max-Tech) + 0.08 W Standby	3.54

Table 1.4 Clothes Dryer Integrated Efficiency Levels – Vent-less Electric Combination Washer/Dryers

Level	Efficiency Level Description	Integrated Efficiency Level (IEF) *(lb/kWh)*
		Electric Combination Washer/Dryer
Baseline	Baseline + 2.0 W Standby	1.90
1	Gap Fill + 2.0 W Standby	2.15
2	Gap Fill + 2.0 W Standby	2.34
3	Gap Fill + 1.5 W Standby	2.36
4	Gap Fill + 0.08 W Standby	2.42
5	Heat Pump (Max-Tech) + 0.08 W Standby	3.31

1 KEY ISSUES

1.1 In general, what are the key issues for your company regarding amended energy conservation standards for residential clothes dryers and this rulemaking?

1.2 Are any of the issues more or less significant for different product classes?

1.3 Do any of the issues become more significant at higher efficiency levels?

1.4 Has DOE effectively incorporated these issues in its analyses? Do have any suggestions for incorporating any of these issues into the into DOE's manufacturing impact model?

2 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

DOE is interested in understanding manufacturer impacts at the plant or profit center level directly pertinent to clothes dryer 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 clothes dryer industry profit center will help DOE understand the probable future of the manufacturing activity with and without amended energy conservation standards.

2.1 Do you have a parent company, and/or any subsidiaries relevant to the clothes dryer industry?

2.2 Do you manufacture any products other than clothes dryers? If so, what other products do you manufacture? What percentage of your total manufacturing revenue corresponds to residential clothes dryers?

2.3 What percentage of your residential clothes dryer manufacturing corresponds to each product class, both in terms of revenue and shipments? Please indicate if you do not manufacture products in any given product class.

Table 2.1 Residential Clothes Dryer Revenue and Shipment Volumes by Product Class

Product Class Number	Product Type	Product Class Description	2009 Revenue	2009 Shipments
1	**Vented Dryers**	Electric, Standard (4.4 ft^3 or greater capacity)		
2	**Vented Dryers**	Electric, Compact (120 v) (less than 4.4 ft^3 capacity)		
3	**Vented Dryers**	Electric, Compact (240 v) (less than 4.4 ft^3 capacity)		
4	**Vented Dryers**	Gas		
5	**Vent-less Dryers**	Electric, Compact (240 v) (less than 4.4 ft^3 capacity)		
6	**Vent-less Dryers**	Electric, Combination Washer/Dryer		

2.4 What is your company's approximate market share in the residential clothes dryer market?

3 ENGINEERING AND LIFE-CYCLE COST ANALYSIS FOLLOW-UP

3.1 Are the incremental manufacturing costs at each efficiency level used in the Engineering Analysis and described in Chapter 5 of the preliminary TSD representative of costs your company incurs at each of these efficiency levels? If not, please provide a quantitative indication of the differences.

3.2 Do you manufacture baseline efficiency residential clothes dryers? If so, what percentage of your baseline clothes dryer shipments for each product class use electromechanical versus electronic controls?

3.3 What design changes do you expect to have to make to your baseline residential clothes dryers to meet the new UL Fire Containment/Burn Resistant Safety Requirement in UL 2158? What would be the manufacturing cost associated with these design changes? Do these costs vary by product class? How would the new UL Fire Containment/Burn Resistant Safety Requirement in UL 2158 affect the incremental manufacturing costs at higher efficiency levels (please provide a quantitative response)?

3.4 How would repair and maintenance costs be impacted by more stringent energy conservation standards? How would the frequency of repair and maintenance be affected? How would the nature of the repair and maintenance work needed change with more stringent energy conservation standards? In particular would repair and maintenance costs be impacted by energy conservation standards that would require heat pump technology?

3.5 For the automatic cycle termination technologies listed below (and any others that you may be aware of that are not listed), what is the manufacturing cost associated with each technology? How much efficiency improvement can be achieved with each of the automatic cycle termination technologies listed (please provide a quantitative indication in your response)?

- Temperature sensors with electromechanical controls
- Moisture sensors (conductivity bars w/ dedicated PCB) + temperature sensors with electromechanical controls
- Moisture sensors (conductivity bars) + temperature sensors/thermistors with electronic controls
- Moisture sensor slip ring + temperature sensors/thermistors with electronic controls

In addition, please comment on DOE’s estimates for electromechanical versus electronic controls and wiring harnesses provided in the table below.

Table 3.1 Control Component Pricing Assumptions

Component Description	Estimated Prices (2009$)[2]	Manufacturer Comment
Electromechanical Control System (Timer, Switches, Face Plate)	$25.68 - $26.33	
Electromechanical Wiring Harness	$7.78 (Gas) $11.16 (Electric)	
Electronic Control System (User Interface, Fascia, Unit Control Board)	$38.60 - $46.88	
Electronic Control System Wiring Harness	$12.30 (Gas) $14.90 (Electric)	

3.6 Would you consider using outside air for the clothes dryer intake as a means to improve efficiency? If so, could you provide an estimate of the efficiency improvement associated with such an approach? Can you please explain what design changes and incremental manufacturing cost would be required to implement such a design option?

3.7 Could you provide an estimate of the efficiency improvement associated with inlet air preheat? A report by Ecos Consulting stated that with an exhaust temperature of about 110°F and a 90% efficient air-to-air counter-flow heat exchanger between the intake and exhaust, preheating of the intake air would save 1.348 kWh of heater energy, or about 40 percent of the energy consumed by the dryer. [3] Would you agree with these estimates? If not, please explain why. Is the estimated heat exchanger efficiency reasonable? If not, what efficiencies can be achieved for air-to-air heat exchangers?

3.8 Can you please comment on the following issues related to the DOE clothes washer test procedure:

3.8.a Test Cloth

How would changing the DOE clothes dryer test procedure test load from a 50/50 cotton/polyester mix to 100-percent cotton affect the measured efficiency of a baseline clothes dryer? Are these any issues with repeatability of active mode efficiency results if a 100-percent cotton load were used instead of the 50/50 cotton polyester mix? How would changing to a 100-percent cotton test load affect the measured efficiency of a clothes dryer equipped with reverse tumble? If there is an efficiency improvement, what would be the incremental manufacturing cost of incorporating reverse tumble?

3.8.b Test Load Size

Standard-Size Dryer Load Size

In comments to the preliminary energy conservation standards rulemaking analyses for residential clothes dryers, AHAM stated that the shipment-weighted residential clothes

2 Estimated prices were updated from $2008 to $2009 using the producer price index for household laundry equipment manufacturing from the Bureau of Labor Statistics (http://www.bls.gov/ppi/).

3 The 40 percent dryer energy savings is calculated based on a unit with an EF of 3.417. It is not clear from the report whether this EF was determined according to the DOE clothes dryer test procedure.

washer drum volume for standard-size products in 2008 was 3.24 cubic feet, which corresponds to an average load size of 8.15 pounds (lb). For units that you manufacture (in particular those units with baseline active mode energy factor (EF)), can you please quantify or provide any test data showing the effects on the measured EF of changing the standard-size clothes dryer test load weight in the DOE clothes dryer test procedure from 7 lb to 8.15 lb? Can you provide any test data showing the repeatability of test results using an 8.15 lb test load?

Compact-Size Dryer Load Size
In comments to the preliminary energy conservation standards rulemaking analyses for residential clothes dryers, AHAM stated that the shipment-weighted residential clothes washer drum volume for compact-size products in 2008 was 1.5 cubic feet, which corresponds to an average load size of 4.70 pounds (lb). For units that you manufacture (in particular those units with baseline active mode energy factor (EF)), can you please quantify or provide any test data showing the effects on the measured EF of changing the compact-size clothes dryer test load weight in the DOE clothes dryer test procedure from 3 lb to 4.70 lb? Can you provide any test data showing the repeatability of test results using an 4.70 lb test load?

Load Size as a Function of Dryer Capacity
Do you have, or are you aware of any, consumer usage data showing the pounds of clothes load dried per dryer cycle relative to the size of the dryer drum for residential clothes dryer use? How would matching the test load size to the drum size, as is done in the DOE clothes washer test procedure, affect the measured efficiency of residential clothes dryers that you manufacture as compared to the existing DOE clothes dryer test procedure (which specifies a 7-lb or 3-lb test load for standard or compact size clothes dryers, respectively?

3.8.c Test Load Preparation

How would changing the test load preparation in the DOE clothes dryer test procedure to specify agitating the test load in water at 60°F ± 5°F affect the measured efficiency as compared to the existing test procedure (which specifies 100°F ± 5°F)? Assuming a 7-lb test load, which would hold about 4.66 lbs of water, the energy required to heat the water from a starting temperature of 60°F to the vaporization temperature would be about 746.6 kiloJoules (kJ) (or 0.2074 kWh), whereas the energy required to heat the water from a starting temperature of 100°F to the vaporization temperature would be about 550.1 kJ (or 0.1528 kWh), resulting in a 0.0546 kWh increase in energy consumption using a starting temperature of 60°F.[4] Would this be an accurate estimate of the additional energy consumed as a result of changing the provisions for the test load preparation?

3.8.d Initial RMC

Shipment-weighted RMC data for residential clothes washers submitted by AHAM for the years 2000 through 2008 shows that the overall shipment-weighted average RMC in

4 Calculated assuming a specific heat of water, c_p, of 4.187 kJ/kg*°C.

2008 was 47 percent. For units that you manufacture (in particular those units with baseline active mode energy factor (EF)), can you please quantify or provide any test data showing the effects on the measured EF of changing the initial RMC in the DOE clothes dryer test procedure from 70 percent to 47 percent? Can you provide any test data showing the repeatability of test results using an initial RMC of 47 percent?

3.8.e Automatic Cycle Termination

For residential dryer models that you manufacture with automatic cycle termination (noting the type of sensor technology used), if the dryer is set to a normal cycle and normal (or medium) dryness level setting and allowed to run until the completion of the cycle, how would the energy consumption compare to that measured according to the existing DOE clothes dryer test procedure? How would the energy consumption and final RMC vary when using “more”, “less”, and “normal” (or medium) dryness level settings with a normal cycle?

4 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 estimated the manufacturer production costs for the six product classes of residential clothes dryers. DOE defines manufacturer production cost as all direct costs associated with manufacturing a product: direct labor, direct materials, and overhead (which includes depreciation). The manufacturer markup is a multiplier applied to manufacturer production cost to cover non-production costs, such as SG&A and R&D, as well as profit. *It does not reflect a “profit margin.”*

The manufacturer production cost 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 1.26 for residential clothes dryers.

4.1 Is the 1.26 baseline markup representative of an average industry markup?

4.2 Please comment on the baseline markups DOE calculated as compared to your company's baseline markups for the clothes dryer product classes.

Table 4.1 Residential Clothes Dryer Baseline Manufacturer Markups by Product Class

Product Class	Product Type	Product Class Description	Estimated Baseline Markup	Manufacturer Comments or Revised Estimates
1	**Vented Dryers**	Electric, Standard (4.4 ft^3 or greater capacity)	1.26	
2	**Vented Dryers**	Electric, Compact (120 v) (less than 4.4 ft^3 capacity)	1.26	
3	**Vented Dryers**	Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	1.26	
4	**Vented Dryers**	Gas	1.26	
5	**Vent-less Dryers**	Electric, Compact (240 v) (less than 4.4 ft^3 capacity)	1.26	
6	**Vent-less Dryers**	Electric, Combination Washer/Dryer	1.26	

4.3 Please explain if profit levels vary by product class or product line. If yes, please indicate why.

4.4 One of the possible scenarios DOE uses to model impacts on industry profitability is the impact of commoditization of premium products. Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding if efficiency is a feature that earns a premium. Within each product class, do markups vary by efficiency level? If yes, please provide information about the markups at higher efficiencies.

4.5 What factors besides efficiency affect the profitability of clothes dryers within a product class?

4.6 Does your markup change with selected design options? Is the markup on incremental costs for more efficient designs different than the markup on the baseline models (as is assumed for retailer markups used in the analyses)?

4.7 Would you expect changes in your estimated profitability following an amended energy conservation standard? If so, please explain why. Can you suggest any scenarios that would model these expected changes?

4.8 In Chapter 6 of the preliminary TSD, DOE estimated that all of the clothes dryers are purchased by consumers from retail outlets. Could you confirm whether the description of the distribution channel for clothes dryer is correct?

5 SHIPMENT PROJECTIONS

An amended energy conservation standard can change overall shipments by altering product attributes, marketing approaches, product availability, and prices. The industry revenue calculations are based on the shipment projections developed in DOE's shipments model. The shipments model includes forecasts for the base case shipments (i.e., total industry shipments absent amended energy conservation standards) and the standards case shipments (i.e., total industry shipments with amended energy conservation standards).

To determine efficiency distributions after the effective date of the standard, DOE used a "roll-up + market shift" scenario for 2014 and subsequent years. DOE assumed that product efficiencies in the base case that did not meet the standard under consideration would roll up to meet the new standard in 2014. DOE further assumed that the ENERGY STAR program would continue to promote efficient appliances after revised standards are introduced in 2014, resulting in a gradual market shift to higher efficiencies after the compliance date of the standard.

5.1 How do you think amended energy conservation standards will impact the sales of more efficient products? For example, would customers continue to buy products that exceed the energy conservation standard level? Would your response change for higher mandated efficiency levels?

5.2 DOE assumed that revised standards that increase purchase price result in reduced demand or shipments (price elasticity effect). DOE assumed an elasticity coefficient of -0.34 for all product classes, meaning a 10% increase in price would result in a 3.4% decrease in shipments. Do you agree with this assumption? How sensitive do you think shipments will be to price changes? Does it vary with product class?

5.3 The preliminary TSD provides shipments and market share by efficiency data until 2006. Could you provide updated data on shipments and market share by efficiency for the last three years? (2007-2009)

6 FINANCIAL PARAMETERS

DOE's contractor has developed a "strawman" model of the residential clothes dryer 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 clothes dryer profit center. This section attempts to understand the financial parameters for clothes dryer manufacturing and how your company's financial situation could differ from the industry aggregate picture.

6.1 In order to accurately collect information about clothes dryer manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Table 6.1 Financial Parameters for Residential Clothes Dryer 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)	33.9	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	7.2	
Working Capital	Current assets less current liabilities (percentage of revenues)	2.9	
Net PPE	Net plant property and equipment (percentage of revenues)	19.9	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	12.5	
R&D	Research and development expenses (percentage of revenues)	2.2	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.4	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	3.5	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	79.4	

6.2 Do any of the financial parameters in Table 6.1 change *based on product class*? Please describe any differences.

6.3 Do any of the financial parameters in Table 6.1 change for a particular *subgroup of manufacturers*? Please describe any differences.

6.4 How would you expect an amended energy conservation standard to impact any of the financial parameters for the industry?

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, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.

DOE asks a number of questions to understand the nature and magnitude of your expected capital and product conversion costs.

7.1 Table 7.1 through Table 7.4 shows the integrated efficiency levels analyzed in the Engineering Analysis for the product categories covered by this rulemaking. The tables also show the design options used in the Engineering Analysis to reach higher efficiencies. Because DOE is using an efficiency level approach for the Engineering Analysis, the design options listed represent one possible path to reach these efficiency levels. If you would apply different design options to reach each active mode efficiency level, please describe those changes in detail.

Please provide estimates for your capital conversion costs by product class and efficiency level in Table 7.1 through Table 7.4. In the description column, DOE is interested in understanding the kinds of changes that would need to be implemented to production lines and production facilities at each efficiency level. Where applicable, please quantify the number and cost of new production equipment, molds, etc. that would be required to implement the specified design changes.

Table 7.1 Expected Capital Conversion Costs for Vented Electric Clothes Dryers

IEF Efficiency Level	Design Options	Total Capital Conversion Costs	Description
1	Switching to Open Cylinder Drum; Dedicated Heater Duct; and Change in Air Flow Patterns		
2	Design options for EL 1 + Inlet Air Pre-Heating; Moisture Sensing; and Variable Airflow		
3	Design options for EL 2 (without Inlet Air Pre-Heating) + Modulating Heat		
4	Design options for EL 3 + Switching Power Supply		
5	Design options for EL 3 + Transformerless Drop-Cap Power Supply with a Conventional Power Supply		
6	Design options for EL 2 (without Change in Air Flow Patterns and Inlet Air Pre-Heating) + Heat Pump System; Electronic Controller, Thermal and Moisture Sensing; Upgraded Airflow System; Booster Heater; and Condensate Removal + Transformerless Drop-Cap Power Supply with a Conventional Power Supply		

Table 7.2 Expected Capital Conversion Costs for Vented Gas Clothes Dryers

IEF Efficiency Level	Design Options	Total Capital Conversion Costs	Description
1	Switching to Open Cylinder Drum; Dedicated Heater Duct; and Change in Air Flow Patterns		
2	Design options for EL 1 + Inlet Air Pre-Heating; Moisture Sensing; and Variable Airflow		
3	Design options for EL 2 (without Inlet Air Pre-Heating) + Modulating Gas Valve and Controls		
4	Design options for EL 3 + Switching Power Supply		
5	Design options for EL 3 + Transformerless Drop-Cap Power Supply with a Conventional Power Supply		

Table 7.3 Expected Capital Conversion Costs for Vent-less Electric Compact (240V) Clothes Dryers

IEF Efficiency Level	Design Options	Total Capital Conversion Costs	Description
1	Switching Power Supply		
2	Transformerless Drop-Cap Power Supply with a Conventional Power Supply		
3	Design Options for EL2 + Switching to Open Cylinder Drum; and Change in Air Flow Patterns		
4	Design options for EL 3 + Modulating Heat; Moisture Sensing; and Variable Airflow		
5	Design options for EL 3, + Heat Pump System; Electronic Controller, Thermal and Moisture Sensing; Upgraded Airflow System; Booster Heater; and Condensate Removal		

Table 7.4 Expected Capital Conversion Costs for Vent-less Combination Washer Dryer

IEF Efficiency Level	Design Options	Total Capital Conversion Costs	Description
1	Automatic Cycle Termination		
2	Design options for EL 1 + Modulating Heat; Moisture Sensing; and Variable Airflow		
3	Design options for EL 2 + Switching Power Supply		
4	Design options for EL 2 + Transformerless Drop-Cap Power Supply with a Conventional Power Supply		
5	Design options for EL 1+ Heat Pump System; Electronic Controller, Thermal and Moisture Sensing; Upgraded Airflow System; Booster Heater; and Condensate Removal + Transformerless Drop-Cap Power Supply with a Conventional Power Supply		

7.2 Would the changes in question 7.1 be similar across all of your production lines and factories for each product class?

7.3 At your manufacturing facilities, would the design options for each efficiency level be difficult to implement? If so, would your company modify the existing facility or develop a new facility?

7.4 Are there certain efficiency levels that would require relatively minor changes to existing products? Are there certain efficiency levels where the capital or product conversion costs significantly increase over the previous efficiency levels? Would your answer change for different product classes? Please describe these changes qualitatively.

7.5 For each of the product categories shown in Table 7.1 through Table 7.4, which efficiency level changes could be made within existing platform designs and which would result in major product redesigns?

7.6 What level of product conversion costs would you expect to incur for each of these design changes for each product class? Please provide your estimates in Table 7.5 through **Error! Reference source not found.** considering such expenses as product development expenses, prototyping, testing, certification, and marketing. In the description column, please describe the assumptions behind the estimates provided.

Table 7.5 Expected Product Conversion Costs for Vented Electric Clothes Dryers

IEF Efficiency Level	Design Options	Total Product Conversion Costs	Description
1	Switching to Open Cylinder Drum; Dedicated Heater Duct; and Change in Air Flow Patterns		
2	Design options for EL 1 + Inlet Air Pre-Heating; Moisture Sensing; and Variable Airflow		
3	Design options for EL 2 (without Inlet Air Pre-Heating) + Modulating Heat		
4	Design options for EL 3 + Switching Power Supply		
5	Design options for EL 3 + Transformerless Drop-Cap Power Supply with a Conventional Power Supply		
6	Design options for EL 2 (without Change in Air Flow Patterns and Inlet Air Pre-Heating) + Heat Pump System; Electronic Controller, Thermal and Moisture Sensing; Upgraded Airflow System; Booster Heater; and Condensate Removal + Transformerless Drop-Cap Power Supply with a Conventional Power Supply		

Table 7.6 Expected Product Conversion Costs for Vented Gas Clothes Dryers

IEF Efficiency Level	Design Options	Total Product Conversion Costs	Description
1	Switching to Open Cylinder Drum; Dedicated Heater Duct; and Change in Air Flow Patterns		
2	Design options for EL 1 + Inlet Air Pre-Heating; Moisture Sensing; and Variable Airflow		
3	Design options for EL 2 (without Inlet Air Pre-Heating) + Modulating Gas Valve and Controls		
4	Design options for EL 3 + Switching Power Supply		
5	Design options for EL 3 + Transformerless Drop-Cap Power Supply with a Conventional Power Supply		

Table 7.7 Expected Product Conversion Costs for Vent-less Electric Compact (240V) Clothes Dryers

IEF Efficiency Level	Design Options	Total Product Conversion Costs	Description
1	Switching Power Supply		
2	Transformerless Drop-Cap Power Supply with a Conventional Power Supply		
3	Design Options for EL2 + Switching to Open Cylinder Drum; and Change in Air Flow Patterns		
4	Design options for EL 3 + Modulating Heat; Moisture Sensing; and Variable Airflow		
5	Design options for EL 3, + Heat Pump System; Electronic Controller, Thermal and Moisture Sensing; Upgraded Airflow System; Booster Heater; and Condensate Removal		

Table 7.8 Expected Product Conversion Costs for Vent-less Combination Washer Dryer

IEF Efficiency Level	Design Options	Total Capital Conversion Costs	Description
1	Automatic Cycle Termination		
2	Design options for EL 1 + Modulating Heat; Moisture Sensing; and Variable Airflow		
3	Design options for EL 2 + Switching Power Supply		
4	Design options for EL 2 + Transformerless Drop-Cap Power Supply with a Conventional Power Supply		
5	Design options for EL 1+ Heat Pump System; Electronic Controller, Thermal and Moisture Sensing; Upgraded Airflow System; Booster Heater; and Condensate Removal + Transformerless Drop-Cap Power Supply with a Conventional Power Supply		

7.7 Please provide additional qualitative information to help DOE understand the types and nature of your investments, including the plant and tooling changes and the product development effort required at different efficiency levels.

8 CUMULATIVE REGULATORY BURDEN

Cumulative regulatory burden refers to the burden that industry faces from overlapping effects of new or revised DOE standards and/or other regulatory actions affecting the same product or industry.

8.1 In the preliminary analysis and in written comments, the UL Safety Regulation 2158 was highlighted as a major concern for manufacturers. Have you had any r&d expenditures related to complying with this regulation? What r&d, product development, and testing expenses will be required to make your residential clothes dryer compliant? Do you expect to incur any capital expenses to make your products comply? Will any of these changes be coordinated with the changes required by this rulemaking?

8.2 Below is a list of the other relevant regulations that could affect manufacturers of residential clothes dryers. Please provide any comments on the listed regulations and provide an estimate for your expected compliance cost.

Table 8.1 Other Regulations Identified by DOE

Regulation	Estimated or Actual Effective Date(s)	Comments	Expected Expense for Compliance
UL Safety Regulation 2158			
Residential Clothes Washer Energy Conservation Standard			
HCFC Phase-Out			

8.3 Are there any other recent or impending regulations that residential clothes dryer manufacturers face (from DOE or otherwise)? If so, please identify the regulation, the corresponding effective dates, and your expected compliance cost.

8.4 Under what circumstances would you be able to coordinate any expenditure related to these other regulations with an amended energy conservation standard?

9 DIRECT EMPLOYMENT IMPACT ASSESSMENT

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in residential clothes dryer manufacturer employment and solicit manufacturer views on how domestic employment patterns might be affected by amended energy conservation standards.

9.1 Where are your residential clothes dryer facilities that produce products for the United States located? What types of products are manufactured at each location? Please provide annual shipment figures for your company's residential clothes dryer manufacturing at each location by product class. Please also provide employment levels at each of these facilities.

Table 9.1 Residential Clothes Dryer Revenue and Shipment Volumes by Product Class

Facility	Location	Product Types Manufactured	Employees	Annual Shipments
Example	*Jackson, TN*	*Vented gas dryers, standard electric vented dryers*	*650*	*300,000 for vented gas; 100,000 for electric vented*
1				
2				
3				
4				
5				

9.2 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.

9.3 Would the workforce skills necessary under amended energy conservation standards require extensive retraining or replacement of employees at your manufacturing facilities?

9.4 Would amended energy conservation standards require extensive retraining of your service/field technicians? If so, could you expand on how your service infrastructure would be impacted in general as a result of amended energy conservation standards?

10 MANUFACTURING CAPACITY AND NON-US SALES

10.1 How would amended energy conservation standards impact your company's manufacturing capacity?

10.2 For any design changes that would require new production equipment, please describe how much downtime would be required. What impact would downtime have on your business? Are there any design changes that could not be implemented before the compliance date of the final rule for certain product classes?

10.3 What percentage of your company's residential clothes dryer **sales** are made within the United States?

10.4 What percentage of your residential clothes dryers are **produced** in the United States?

10.5 What percentage of your U.S. production of residential clothes dryers is exported?

10.6 Are there any foreign companies with North American production facilities?

10.7 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 exiting domestic production facilities outside the U.S.?

11 IMPACT ON COMPETITION

Amended energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that would result from an amended energy conservation standard.

11.1 How would amended energy conservation standards affect your ability to compete in the marketplace? Would the effects on your company be different than others in the industry?

11.2 Would you expect your market share to change if amended energy conservation standards become effective?

11.3 Do any firms hold intellectual property that gives them a competitive advantage following amended energy conservation standards?

11.4 How would industry competition change as a result of amended energy conservation standards?

12 IMPACTS ON SMALL BUSINESS

12.1 The Small Business Administration (SBA) denotes a small business in the residential clothes dryer manufacturing industry as having less than 1,000 total employees, including the parent company and all subsidiaries.[5] By this definition, is your company considered a small business?

12.2 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.

12.3 To your knowledge, are there any **small businesses** for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, why?

12.4 To your knowledge, are there any **niche manufacturers** or **component manufacturers** for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, why?

[5] DOE uses the small business size standards published on August 22, 2008, as amended, by the SBA to determine whether a company is a small business. To be categorized as a small business, a household laundry equipment manufacturer (which includes residential clothes dryer manufacturers) and its affiliates may employ a maximum of 1,000 employees. The 1,000 employee threshold includes all employees in a business's parent company and any other subsidiaries.

12-A.2 ROOM AIR CONDITIONER MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

April 20, 2010

The Department of Energy (DOE) conducts the manufacturer impact analysis (MIA) as part of the rulemaking process for amended energy conservation standards for room air conditioners. 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 explicitly analyzes the four product classes in the table below. DOE is currently considering between three and five efficiency levels (ELs) for each product class that correspond to percentage improvements over the existing standards. In responding to this questionnaire, please refer to the efficiency levels in the table below. DOE explains how it intends to determine the minimum efficiencies for the remaining product classes in the engineering chapter of the technical support document.[6]

Baseline Efficiencies for Analyzed Product Classes

Product Class Number	Product Type	Product Class Description	Baseline EER (Btu/h – W)	Baseline IEER* (Btu/h – W)
1	**Without reverse cycle and with louvered sides**	Less than 6,000 Btu/h	9.70	9.52
3	**Without reverse cycle and with louvered sides**	8,000 Btu/h to 13,999 Btu/h	9.80	9.71
5	**Without reverse cycle and with louvered sides**	20,000 Btu/h or more	8.50	8.47
8	**Without reverse cycle and without louvered sides**	8,000 Btu/h to 13,999 Btu/h	8.50	8.43

Btu/h = British thermal units per hour
* These definitions are based on testing according to the current energy test procedure for EER plus a baseline standby power measurement of 1.4 W to reach the combined IEER measurement. DOE expects to propose revisions to the current room air conditioner test procedure to account for this and other changes.

Efficiency Levels Under Consideration

	IEER (EER)*				
Product Class Number	**EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**
1	10.1 (10.3)	10.6 (10.7)	11.1 (11.2)	11.6 (11.7)	12.0 (12.1)
3	10.3 (10.4)	10.8 (10.9)	11.3 (11.4)	11.5 (11.6)	N/A
5	9.0 (9.0)	9.4 (9.4)	9.8 (9.8)	10.0 (10.0)	N/A
8	8.9 (9.0)	9.3 (9.4)	9.8 (9.9)	N/A	N/A

*EER levels are for reference, efficiency levels are being considered in IEER

[6] Please see http://www1.eere.energy.gov/buildings/appliance_standards/residential/preliminary_analysis.html for a complete description.

1 KEY ISSUES

1.5 In general, what are the key issues for your company regarding amended energy conservation standards for room air conditioners and this rulemaking?

1.6 Are any of the issues more or less significant for different product classes?

1.7 Do any of the issues become more significant at higher efficiency levels, such as Energy Star levels?

1.8 Has DOE effectively incorporated these issues in its analyses? Do you have any suggestions for incorporating these issues into DOE's manufacturing impact model?

2 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

DOE is interested in understanding manufacturer impacts at the plant or profit center level directly pertinent to room air conditioner production. However, the context within which the plant operates and the details of plant production and costs are not always readily available from public sources. Therefore, DOE invites you to provide these details confidentially in your own words to the extent possible and practical. Understanding the organizational setting around the room air conditioner industry profit center will help DOE understand the probable future of the manufacturing activity with and without amended energy conservation standards.

2.1 Do you have a parent company, and/or any subsidiaries relevant to the room air conditioner industry?

2.2 Do you manufacture any products other than room air conditioners? If so, what other products do you manufacture? What percentage of your total manufacturing revenue corresponds to room air conditioners?

2.3 What product classes of room air conditioners do you manufacturer? (See Table 2.1 below for descriptions of certain product classes, and list any additional product classes.)

2.4 What percentage of your room air conditioner manufacturing corresponds to each product class, both in terms of revenue and shipments? Please indicate if you do not manufacturer products in any given product class.

Table 2.1 Room Air Conditioner Revenue and Shipment Volumes by Product Class

Product Class	Product Type	Product Class Description	2009 Revenue	2009 Shipments
1	**Without reverse cycle and with louvered sides**	Less than 6,000 Btu/h		
2	**Without reverse cycle and with louvered sides**	6,000 Btu/h to 7,999 Btu/h		
3	**Without reverse cycle and with louvered sides**	8,000 Btu/h to 13,999 Btu/h		
4	**Without reverse cycle and with louvered sides**	14,000 Btu/h to 19,999 Btu/h		
5	**Without reverse cycle and with louvered sides**	20,000 Btu/h or more		
8	**Without reverse cycle and without louvered sides**	8,000 Btu/h to 13,999 Btu/h		
16	**Casement-Slider**	-		
All Other Product Classes				

2.5 What is your company's approximate market share by product class in the room air conditioners market?

2.6 In Chapter 6 of the preliminary TSD, DOE estimated that all of the room air conditioners are purchased by consumers from retail outlets. Do you agree with this assessment of the distribution channel for room air conditioners?

3 ENGINEERING AND LIFE CYCLE COST ANALYSIS FOLLOW-UP

3.1 For the products directly analyzed for the Engineering Analysis that represent the bulk of room air conditioner sales, can you comment on the progressive use of design options for achieving the successively higher efficiency levels (compared with the design option information presented by efficiency level in Appendix 5D of the preliminary TSD)?

3.2 Are the incremental design option costs used in the Engineering Analysis and described in Chapter 5 of the preliminary TSD representative of costs your company pays for these design options? If not, please provide a quantitative indication of the differences.

3.3 Please comment on the interpolated and extrapolated cost-efficiency curves developed for the product classes not directly analyzed. This process is described in the TSD in Chapter 5, but summarized as follows:

- PC 2 and 4 based on interpolation by capacity based on PC 1, 3, and 5.

- PC 6 and 7 using extrapolation of PC 8 results to lower capacities based on PC 1 and 3 results.
- PC 9 and 10 using extrapolation of PC 8 results to higher capacity based on PC 3 and 5 results for design options not requiring package size increase.
- PC 11 and 13 based on interpolation of PC 1, 3, and 5 results, assuming that presence of the reversing feature, while impacting efficiency, would not have a greater impact on efficiency at higher efficiency levels.
- PC 12 and 14 based on similar interpolation of PC 6 through 10 results.
- PC 15 and 16 based on results for PC3, with limitation to design options such that only modest package size increase is allowed.

3.4 Please comment on the maximum available EER of 12.0. Is this EER the highest EER available using R-410A?

3.5 Please comment on current package sizes for R-410A units and how they compare to package sizes for R-22 units.

3.6 Please comment on the package sizes used to achieve higher efficiency levels in the TSD What data or information can you provide that will support arguments regarding limitations of maximum package growth, including impacts on consumer utility?

Design Description	**Width** *(inches (in))*	**Height** *(in)*	**Depth** *(in)*	**Weight** *(lb)*
Product Class 1				
Baseline	15.5	11.75	12	38.6
First Size Increase	18.5	12.5	14	42.7
Second Size Increase	19.69	13.63	17.72	46.8
Product Class 3, 8,000 Btu/h				
Baseline	18.5	12.5	15.5	49.4
First Size Increase	19.3	15.63	18	55.7
Second Size Increase	22.5	15.63	23.6	63.6
Product Class 3, 12,000 Btu/h				
Baseline	23.63	15	22.25	76.5
First Size Increase	24.63	17.5	22.25	81.2
Second Size Increase	26.38	17.5	26.75	87.6
Product Class 5				
Baseline	26	17.69	28.41	129.2
First Size Increase	27.75	17.94	30.94	136.4
Second Size Increase	29.81	22.38	30.94	156.5

3.7 Please comment on the current efficiency of R-410A rotary compressors. Is the maximum EER of R-410A rotary compressors 10 EER?

3.8 Please comment on the conversion costs of switching from R-22 refrigerant to R-410 refrigerant. Do the costs shown below reflect your company’s total incremental costs?

Product Class	Total Costs Due to Refrigerant Switch
PC 1	$3.92
PC 3 (8,000 Btu/h Capacity)	$5.47
PC 3 (12,000 Btu/h Capacity)	$7.49
PC 5	$13.70
PC 8 (8,000 Btu/h Capacity)	$5.77
PC 8 (12,000 Btu/h Capacity)	$7.95

3.9 Please comment on the efficiency impact of switching to R-410A refrigerant. Is there a 10% drop in overall unit efficiency? How have you addressed this impact (larger units, more efficient components)?

3.10 How would repair and maintenance costs be impacted by more stringent energy conservation standards? How would the frequency of repair and maintenance be affected? How would the nature of the repair and maintenance work needed change with more stringent energy conservation standards?

4 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 estimated the manufacturer production costs for four product classes of room air conditioners. DOE defines manufacturer production cost as all direct costs associated with manufacturing a product: direct labor, direct materials, and overhead (which includes depreciation). The manufacturer markup is a multiplier applied to manufacturer production cost to cover non-production costs, such as SG&A and R&D, as well as profit. It does not reflect a "profit margin."

The manufacturer production cost 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 1.26 for room air conditioners.

4.1 Is the 1.26 baseline markup representative of an average industry markup?

4.2 Please comment on the baseline markups DOE calculated as compared to your company's baseline markups for the room air conditioner product classes.

Table 4.1 Room Air Conditioner Baseline Manufacturer Markups by Product Class

Product Class	Product Type	Product Class Description	Baseline Markup	Manufacturer Comments or Revised Estimates
1	**Without reverse cycle and with louvered sides**	Less than 6,000 Btu/h	1.26	
3	**Without reverse cycle and with louvered sides**	8,000 Btu/h to 13,999 Btu/h	1.26	
5	**Without reverse cycle and with louvered sides**	20,000 Btu/h or more	1.26	
8	**Without reverse cycle and without louvered sides**	8,000 Btu/h to 13,999 Btu/h	1.26	

4.3 Please explain if profit levels vary by product class or product line. If yes, please indicate why.

4.4 Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding how margins currently change with efficiency. Within each product class, do markups vary by efficiency level? If yes, please provide information about the markups at higher efficiencies, such as Energy Star.

4.5 What factors besides efficiency affect the profitability of room air conditioners within a product class?

4.6 Does your markup change with selected design options? Is the markup on incremental costs for more efficient designs different than the markup on the baseline models (as is assumed for retailer markups used in the analyses)?

4.7 Would you expect changes in your estimated profitability following an amended energy conservation standard? If so, please explain why. Can you suggest any scenarios that would model these expected changes?

5 SHIPMENT PROJECTIONS

An amended energy conservation standard can change overall shipments by altering product attributes, marketing approaches, product availability, and prices. The industry revenue calculations are based on the shipment projections developed in DOE's shipments model. The shipments model includes forecasts for the base case shipments (i.e., total industry shipments absent amended energy conservation standards) and the standards case shipments (i.e., total industry shipments with amended energy conservation standards).

To determine efficiency distributions after the effective date of the standard, DOE used a "roll-up" scenario for 2014 and subsequent years. DOE assumed that product efficiencies in the base case that did not meet the standard under consideration would roll up to meet the new standard in 2014.

5.1 How do you think amended energy conservation standards will impact the sales of more efficient products? For example, would customers continue to buy products that exceed the energy conservation standard level? What would occur to the split of sales of Energy Star vs. non-Energy Star units? Would your response change for higher mandated efficiency levels?

5.2 DOE assumed that revised standards that increase purchase price result in reduced demand or shipments (price elasticity effect). DOE assumed an elasticity coefficient of -0.34, meaning a 10% increase in price would result in a 3.4% decrease in shipments. Do you agree with this assumption? How sensitive do you think shipments will be to price changes? Does it vary with product class?

5.3 The preliminary TSD provides shipments and market share by efficiency data until 2007. Could you provide updated data on shipments and market share by efficiency for 2008 and 2009?

6 FINANCIAL PARAMETERS

DOE's contractor has developed a "strawman" model of the room air conditioners 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 room air conditioners profit center. This section attempts to understand the financial parameters for room air conditioner manufacturing and how your company's financial situation could differ from the industry aggregate picture.

6.1 In order to accurately collect information about room air conditioner manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Table 6.1 Financial Parameters for Room Air Conditioner Manufacturers

GRIM Input	Definition	Industry Estimated Value	Your Actual (If Significantly Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	33.9	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	7.2	
Working Capital	Current assets less current liabilities (percentage of revenues)	2.9	
Net PPE	Net plant property and equipment (percentage of revenues)	19.9	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	12.5	
R&D	Research and development expenses (percentage of revenues)	2.2	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.4	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	3.5	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	79.4	

6.2 Do any of the financial parameters in Table 6.1 change *based on product class*? Please describe any differences.

6.3 Do any of the financial parameters in Table 6.1 change for a particular *subgroup of manufacturers*? Please describe any differences.

6.4 How would you expect an amended energy conservation standard to impact any of the financial parameters for the industry?

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 a 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 to research, product development, testing, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.*

Table 7.1 shows the design options used to research higher efficiencies for the major product categories covered by this rulemaking. DOE asks a number of questions to understand the nature and magnitude of your expected capital and product conversion costs. Please refer to Table 7.1 when considering your response to the following questions.

Table 7.1 Design Options Used to Improve Efficiency for each Analyzed Product Class

Product Class Number	Design Options
1	Add subcooler, increase evaporator circuits, increase evaporator width, increase chassis size, stand-by reduction, increase heat exchanger tube ODs, increase PSC efficiency, DC brushless motor
3	Increase evaporator width, increase evaporator tube OD, add subcooler, increase chassis size, stand-by reduction, increase PSC efficiency, DC brushless motor
5	Add subcooler, increase chassis size, standby increase, increase PSC efficiency, scroll compressor, DC brushless motor
8	Increase evaporator width, add subcooler, increase condenser width with coil bend, standby increase, increase PSC efficiency, increase evaporator tube OD, increase condenser tube OD, DC brushless motor

7.1 At your manufacturing facilities, would these design options be difficult to implement? If so, would your company modify the existing facility or develop a new facility?

7.2 Are there certain design options that would require relatively minor changes to existing products? Are there certain efficiency levels where the capital or product conversion costs significantly increase over the previous efficiency levels? Would your answer change for different product classes? Please describe these changes qualitatively.

7.3 For each of the product classes shown in Table 7.1, which design options could be made within existing platform designs and which would result in major product redesigns?

7.4 Please provide estimates for your capital conversion costs by product class in Table 7.2 through Table 7.5 below. In the description column, DOE is interested in understanding the kinds of changes that would need to be implemented to production lines and production facilities at each efficiency level. Where applicable, please quantify the number and cost of new production equipment, molds, foaming fixtures, etc. that would be required to implement the specified design changes.

Table 7.2 Expected Capital Conversion Costs for Product Class 1

Efficiency Level (IEER)	Pathway of Design Options You Would Take	Total Capital Conversion Costs	Description of Expected Capital Requirements
EL 1 (10.1)			
EL 2 (10.6)			
EL 3 (11.1)			
EL 4 (11.6)			
EL 5 (12.0)			

Table 7.3 Expected Capital Conversion Costs for Product Class 3

Efficiency Level (IEER)	Pathway of Design Options You Would Take	Total Capital Conversion Costs	Description of Expected Capital Requirements
EL 1 (10.3)			
EL 2 (10.8)			
EL 3 (11.3)			
EL 4 (11.5)			

Table 7.4 Expected Capital Conversion Costs for Product Class 5

Efficiency Level (IEER)	Pathway of Design Options You Would Take	Total Capital Conversion Costs	Description of Expected Capital Requirements
EL 1 (9.0)			
EL 2 (9.4)			
EL 3 (9.8)			
EL 4 (10.0)			

Table 7.5 Expected Capital Conversion Costs for Product Class 8

Efficiency Level (IEER)	Pathway of Design Options You Would Take	Total Capital Conversion Costs	Description of Expected Capital Requirements
EL 1 (8.9)			
EL 2 (9.3)			
EL 3 (9.8)			

7.5 Would the changes in 7.4 be similar across all of your production lines and factories for each product class?

7.6 What level of product development and other product conversion costs would you expect to incur for each of these design changes for each product class? Please provide your estimates in Table 7.6 through Table 7.9 below considering such expenses as product development expenses, prototyping, testing, certification, and marketing. In the description column, please describe the assumptions behind the estimates provided.

Table 7.6 Expected Product Conversion Costs for Product Class 1

Efficiency Level (IEER)	Pathway of Design Options You Would Take	Total Product Conversion Costs	Description of Expected Development Requirements
EL 1 (10.1)			
EL 2 (10.6)			
EL 3 (11.1)			
EL 4 (11.6)			
EL 5 (12.0)			

Table 7.7 Expected Product Conversion Costs for Product Class 3

Efficiency Level (IEER)	Pathway of Design Options You Would Take	Total Product Conversion Costs	Description of Expected Development Requirements
EL 1 (10.3)			
EL 2 (10.8)			
EL 3 (11.3)			
EL 4 (11.5)			

Table 7.8 Expected Product Conversion Costs for Product Class 5

Efficiency Level (IEER)	Pathway of Design Options You Would Take	Total Product Conversion Costs	Description of Expected Development Requirements
EL 1 (9.0)			
EL 2 (9.4)			
EL 3 (9.8)			
EL 4 (10.0)			

Table 7.9 Expected Product Conversion Costs for Product Class 8

Efficiency Level (IEER)	Pathway of Design Options You Would Take	Total Product Conversion Costs	Description of Expected Development Requirements
EL 1 (8.9)			
EL 2 (9.3)			
EL 3 (9.8)			

7.7 Please provide additional qualitative information to help DOE understand the types and nature of your investments, including the plant and tooling changes and the product development effort required at different efficiency levels.

8 CUMULATIVE REGULATORY BURDEN

Cumulative regulatory burden refers to the burden that industry faces from overlapping effects of new or revised DOE standards and/or other regulatory actions affecting the same product or industry.

8.1 Below is a list of regulations that could affect manufacturers of room air conditioners. Please provide any comments on the listed regulations and provide an estimate for your expected compliance cost.

Table 8.1 Other Regulations Identified by DOE

Regulation	Estimated or Actual Effective Date(s)	Expected Expense for Compliance	Comments
DOE's Energy Conservation Standards for Other Products and Equipment			
International Energy-Efficiency Standards			
EPA Phase-Out of HCFC-22	2010		

8.2 Are there any other recent or impending regulations that room air conditioner manufacturers face (from DOE or otherwise)? If so, please identify the regulation, the corresponding effective dates, and your expected compliance cost.

8.3 Under what circumstances would you be able to coordinate any expenditure related to these other regulations with an amended energy conservation standard?

8.4 DOE research has not identified any production tax credits for manufacturers of room air conditioners. Do you know of any current or future tax credits or other benefits available to your company for manufacturing more efficient room air conditioners? If so, please describe.

9 DIRECT EMPLOYMENT IMPACT ASSESSMENT

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in room air conditioner employment and solicit manufacturer views on how domestic employment patterns might be affected by amended energy conservation standards.

9.1 Where are your room air conditioner facilities that produce products for the United States located? What types of products are manufactured at each location? Please provide annual shipment figures for your company's room air conditioner manufacturing at each location by product class. Please also provide employment levels at each of these facilities.

9.2 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.

9.3 Would the workforce skills necessary under amended energy conservation standards require extensive retraining or replacement of employees at your manufacturing facilities?

9.4 Would amended energy conservation standards require extensive retraining of your service/field technicians? If so, could you expand on how your service infrastructure would be impacted in general as a result of amended energy conservation standards?

10 MANUFACTURING CAPACITY AND NON-US SALES

10.1 How would amended energy conservation standards impact your company's manufacturing capacity?

10.2 For any design changes that would require new production equipment, please describe how much downtime would be required. What impact would downtime have on your business? Are there any design changes that could not be implemented before the compliance date of the final rule for certain product classes?

10.3 What percentage of your company's room air conditioner **sales** are made within the United States?

10.4 What percentage of your room air conditioner sales are **produced** in the United States?

10.5 What percentage of your U.S. production of room air conditioners is exported?

10.6 Are there any foreign companies with North American production facilities?

10.7 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 exiting domestic production facilities outside the U.S.?

11 IMPACT ON COMPETITION

Amended energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that would result from an amended energy conservation standard.

11.1 How would amended energy conservation standards affect your ability to compete in the marketplace? Would the effects on your company be different than others in the industry?

11.2 Would you expect your market share to change if amended energy conservation standards become effective?

11.3 Do any firms hold intellectual property that gives them a competitive advantage following amended energy conservation standards?

11.4 How would industry competition change as a result of amended energy conservation standards?

12 IMPACTS ON SMALL BUSINESS

12.1 The Small Business Administration (SBA) denotes a small business in the room air conditioner manufacturing industry as having less than 750 total employees, including the parent company and all subsidiaries.[7] By this definition, is your company considered a small business?

12.2 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.

12.3 To your knowledge, are there any **small businesses** for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, why?

12.4 To your knowledge, are there any **niche manufacturers** or **component manufacturers** for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, why?

[7] DOE uses the small business size standards published on August 22, 2008, as amended, by the SBA to determine whether a company is a small business. To be categorized as a small business, an air conditioning and warm air heating equipment manufacturer or a commercial and industrial refrigeration equipment manufacturer and its affiliates may employ a maximum of 750 employees. The 750 employee threshold includes all employees in a business's parent company and any other subsidiaries.

APPENDIX 12-B. GOVERNMENT REGULATORY IMPACT MODEL (GRIM) OVERVIEW

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APPENDIX 12-B. GOVERNMENT REGULATORY IMPACT MODEL (GRIM) OVERVIEW

12-B.1 INTRODUCTION AND PURPOSE

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards and other regulations on manufacturers. The basic mode of analysis is to estimate the change in the value of the industry or manufacturers(s) following a regulation or a series of regulations. The model structure also allows an analysis of multiple products with regulations taking effect over a period of time, and of multiple regulations on the same products.

Industry net present value is defined, for the purpose of this analysis, as the discounted sum of industry free cash flows plus a discounted terminal value. The model calculates the actual cash flows by year and then determines the present value of those cash flows both without an energy conservation standard (*i.e.*, the base case) and under different trial standard levels (TSLs) (*i.e.*, the standards case).

Output from the model consists of summary financial metrics, graphs of major variables, and, when appropriate, access to the complete cash flow calculation.

12-B.2 MODEL DESCRIPTION

The basic structure of the GRIM is a standard annual cash flow analysis that uses manufacturer selling prices, manufacturing costs, a shipments forecast, and financial parameters as inputs and accepts a set of regulatory conditions as changes in costs and investments. The cash flow analysis is separated into two major blocks: income and cash flow. The income calculation determines net operating profit after taxes. The cash flow calculation converts net operating profit after taxes into an annual cash flow by including investment and non-cash items. Below are definitions of listed items on the printout of the output sheet of the GRIM.

(1) ***Unit Sales:*** Total annual shipments for the industry were obtained from the National Impact Analysis Spreadsheet;

(2) ***Revenues:*** Annual revenues - computed by multiplying products' unit prices at each efficiency level by the appropriate manufacturer markup;

(3) ***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;

(4) ***Material:*** The portion of COGS that includes materials;

(5) ***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;

(6) ***Depreciation:*** The portion of overhead that includes an allowance for the total amount of fixed assets used to produce that one unit. Annual depreciation computed as a percentage of ***COGS.*** While included in overhead, the depreciation is shown as a separate line item;

(7) ***Stranded Assets:*** In the year the standard becomes effective, a one time write-off of stranded assets is accounted for;

(8) ***Standard SG&A:*** Selling, general, and administrative costs are computed as a percentage of ***Revenues (2)***;

(9) ***R&D:*** GRIM separately accounts for ordinary research and development (R&D) as a percentage of ***Revenues (2)***;

(10) ***Product Conversion Costs:*** Product conversion costs are one-time investments in research, development, testing, marketing, and other costs focused on making products designs comply with the new energy conservation standard. The GRIM allocates these costs over the period between the standard's announcement and compliance dates;

(11) ***Earnings Before Interest and Taxes (EBIT):*** Includes profits before deductions for interest paid and taxes;

(12) ***EBIT as a Percentage of Sales (EBIT/Revenues):*** GRIM calculates EBIT as a percentage of sales to compare with the industry's average reported in financial statements;

(13) ***Taxes:*** Taxes on ***EBIT (11)*** are calculated by multiplying the tax rate contained in Major Assumptions by ***EBIT (11)***.

(14) ***Net Operating Profits After Taxes (NOPAT):*** Computed by subtracting ***Cost of Goods Sold ((3) to (6))***, ***SG&A (8)***, ***R&D (9)***, ***Product Conversion Costs (10)***, and ***Taxes (13)*** from ***Revenues (2)***.

(15) ***NOPAT repeated***: NOPAT is repeated in the Statement of Cash Flows;

(16) ***Depreciation repeated***: Depreciation and Stranded Assets are added back in the Statement of Cash Flows because they are non-cash expenses;

(17) ***Change in Working Capital***: Change in cash tied up in accounts receivable, inventory, and other cash investments necessary to support operations is calculated by multiplying working capital (as a percentage of revenues) by the change in annual revenues.

(18) ***Cash Flow From Operations***: Calculated by taking ***NOPAT (15)***, adding back non-cash items such as a ***Depreciation (16)***, and subtracting the ***Change in Working Capital (17)***;

(19) ***Ordinary Capital Expenditures:*** Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of ***Revenues (2)***;

(20) ***Capital Conversion Costs:*** Capital conversion costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new product designs can be fabricated and assembled under the new regulation; The GRIM allocates these costs over the period between the standard's announcement and compliance dates;

(21) ***Capital Investment:*** Total investments in property, plant, and equipment are computed by adding ***Ordinary Capital Expenditures (19)*** and ***Capital Conversion Costs (20)***;

(22) ***Free Cash Flow:*** Annual cash flow from operations and investments; computed by subtracting ***Capital Investment (21)*** from ***Cash Flow from Operations (18)***;

(23) ***Terminal Value:*** Estimate of the continuing value of the industry after the analysis period. Computed by growing the Free Cash Flow at the beginning of 2045 at a constant rate in perpetuity;

(24) ***Present Value Factor:*** Factor used to calculate an estimate of the present value of an amount to be received in the future;

(25) ***Discounted Cash Flow: Free Cash Flows (22)*** multiplied by the ***Present Value Factor (24)***. For the end of 2043, the discounted cash flow includes the discounted ***Terminal Value (23)***; and

(26) ***Industry Value thru the end of 2043:*** The sum of ***Discounted Cash Flows (25)***.

12-B.3 DETAILED CASH FLOW EXAMPLE

STANDARD CASE SCENARIO			2009	2010	Base Year 2011	2012	2013	Standard Year 2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Industry Income Statement																		
Unit Sales			5.784	6.095	6.489	9.669	9.507	8.281	7.978	8.049	8.092	8.082	8.032	7.994	7.966	7.943	7.916	7.886
Revenues			1,488.636	1,568.587	1,669.967	2,488.493	2,446.781	2,954.606	2,846.633	2,871.803	2,887.256	2,883.672	2,865.784	2,852.448	2,842.966	2,834.950	2,825.675	2,815.208
Cost of Sales																		
	Labor	11.2%	166.243	175.172	186.493	277.902	273.244	251.418	242.229	244.374	245.685	245.375	243.850	242.699	241.871	241.170	240.363	239.455
	Material	53.7%	799.267	842.194	896.626	1,336.103	1,313.708	1,735.577	1,672.153	1,686.930	1,696.011	1,693.913	1,683.408	1,675.603	1,670.073	1,665.401	1,659.988	1,653.874
	Overhead	8.5%	126.344	133.130	141.734	211.204	207.664	172.541	166.239	167.711	168.616	168.408	167.364	166.572	165.999	165.511	164.949	164.319
	Depreciation	3.4%	48.869	51.493	54.821	81.692	80.322	96.655	93.123	93.946	94.452	94.335	93.750	93.314	93.003	92.741	92.437	92.095
	Shipping		40.734	42.921	45.695	68.093	66.951	88.734	85.490	86.248	86.709	86.598	86.060	85.660	85.376	85.138	84.862	84.550
	Stranded Assets		$ -	$ -	$ -	$ -	$ -	$ 16.1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Selling, General and Administrative																		
	Standard SG&A		$ 186.8	$ 196.8	$ 209.5	$ 312.2	$ 307.0	$ 370.7	$ 357.1	$ 360.3	$ 362.2	$ 361.8	$ 359.5	$ 357.9	$ 356.7	$ 355.7	$ 354.5	$ 353.2
	R&D	2.2%	$ 32.7	$ 34.5	$ 36.7	$ 54.7	$ 53.8	$ 65.0	$ 62.6	$ 63.2	$ 63.5	$ 63.4	$ 63.0	$ 62.8	$ 62.5	$ 62.4	$ 62.2	$ 61.9
	Product Conversion Costs		$ -	$ -	$ 28.7	$ 40.1	$ 45.9	$ 2.3	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Earnings Before Interest and Taxes (EBIT)		5.7%	$ 87.7	$ 92.4	$ 69.7	$ 106.4	$ 98.2	$ 155.6	$ 167.6	$ 169.1	$ 170.0	$ 169.8	$ 168.8	$ 168.0	$ 167.4	$ 166.9	$ 166.4	$ 165.8
EBIT/Revenues			5.9%	5.9%	4.2%	4.3%	4.0%	5.3%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%
Taxes			$ 29.7	$ 31.3	$ 23.6	$ 36.1	$ 33.3	$ 52.7	$ 56.8	$ 57.3	$ 57.6	$ 57.6	$ 57.2	$ 56.9	$ 56.8	$ 56.6	$ 56.4	$ 56.2
Net Operating Profit after Taxes (NOPAT)			$ 57.9	$ 61.1	$ 46.1	$ 70.3	$ 64.9	$ 102.8	$ 110.8	$ 111.8	$ 112.4	$ 112.2	$ 111.6	$ 111.0	$ 110.7	$ 110.3	$ 110.0	$ 109.6
Cash Flow Statement																		
	NOPAT		$ 57.9	$ 61.1	$ 46.1	$ 70.3	$ 64.9	$ 102.8	$ 110.8	$ 111.8	$ 112.4	$ 112.2	$ 111.6	$ 111.0	$ 110.7	$ 110.3	$ 110.0	$ 109.6
	Depreciation		$ 48.9	$ 51.5	$ 54.8	$ 81.7	$ 80.3	$ 112.7	$ 93.1	$ 93.9	$ 94.5	$ 94.3	$ 93.7	$ 93.3	$ 93.0	$ 92.7	$ 92.4	$ 92.1
	Change in Working Capital		$ -	$ -	$ (2.9)	$ (23.7)	$ 1.2	$ (14.7)	$ 3.1	$ (0.7)	$ (0.4)	$ 0.1	$ 0.5	$ 0.4	$ 0.3	$ 0.2	$ 0.3	$ 0.3
Cash Flows from Operations			$ 106.8	$ 112.6	$ 97.9	$ 128.3	$ 146.5	$ 200.8	$ 207.1	$ 205.0	$ 206.4	$ 206.7	$ 205.8	$ 204.7	$ 203.9	$ 203.3	$ 202.7	$ 202.0
	Ordinary Capital Expenditures	3.5%	$ (52.1)	$ (54.9)	$ (58.4)	$ (87.1)	$ (85.6)	$ (103.4)	$ (99.6)	$ (100.5)	$ (101.1)	$ (100.9)	$ (100.3)	$ (99.8)	$ (99.5)	$ (99.2)	$ (98.9)	$ (98.5)
	Capital Conversion Costs		$ -	$ -	$ (48.4)	$ (67.7)	$ (77.4)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Capital Investments			$ (52.1)	$ (54.9)	$ (106.8)	$ (154.8)	$ (163.0)	$ (103.4)	$ (99.6)	$ (100.5)	$ (101.1)	$ (100.9)	$ (100.3)	$ (99.8)	$ (99.5)	$ (99.2)	$ (98.9)	$ (98.5)
Free Cash Flow			$ 54.7	$ 57.6	$ (8.9)	$ (26.5)	$ (16.6)	$ 97.4	$ 107.43	$ 104.5	$ 105.3	$ 105.8	$ 105.5	$ 104.9	$ 104.4	$ 104.1	$ 103.8	$ 103.4
Terminal Value			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor			1.149	1.072	1.000	0.933	0.870	0.812	0.757	0.706	0.659	0.615	0.573	0.535	0.499	0.465	0.434	0.405
Discounted Cash Flow			$ 62.87	$ 61.80	$ (8.87)	$ (24.73)	$ (14.40)	$ 79.09	$ 81.35	$ 73.81	$ 69.41	$ 65.00	$ 60.50	$ 56.11	$ 52.11	$ 48.45	$ 45.07	$ 41.90
Industry Value thru	2043	$ 1,201.41																
Net PPE			$ 296.2	$ 312.1	$ 332.3	$ 405.4	$ 488.1	$ 478.8	$ 485.3	$ 491.9	$ 498.5	$ 505.1	$ 511.6	$ 518.1	$ 524.6	$ 531.1	$ 537.6	$ 544.0
Net PPE as % of Sales			19.9%	19.9%	19.9%	16.3%	19.9%	16.2%	17.0%	17.1%	17.3%	17.5%	17.9%	18.2%	18.5%	18.7%	19.0%	19.3%
Net Working Capital			$ 43.2	$ 45.5	$ 48.4	$ 72.2	$ 71.0	$ 85.7	$ 82.6	$ 83.3	$ 83.7	$ 83.6	$ 83.1	$ 82.7	$ 82.4	$ 82.2	$ 81.9	$ 81.6
Return on Invested Capital (ROIC)			17.07%	17.07%	12.10%	14.73%	11.61%	18.22%	19.51%	19.44%	19.30%	19.07%	18.76%	18.48%	18.23%	17.99%	17.75%	17.51%
Weighted Average Cost of Capital (WACC)			7.20%	7.20%	7.20%	7.20%	7.20%	7.20%	7.20%	7.20%	7.20%	7.20%	7.20%	7.20%	7.20%	7.20%	7.20%	7.20%
Return on Sales (EBIT/Sales)			5.89%	5.89%	4.17%	4.28%	4.01%	5.27%	5.89%	5.89%	5.89%	5.89%	5.89%	5.89%	5.89%	5.89%	5.89%	5.89%

APPENDIX 15-A. EMISSIONS FACTORS FOR FUEL COMBUSTION FROM NATURAL GAS, LPG, AND OIL-FIRED RESIDENTIAL APPLIANCES

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APPENDIX 15-A. EMISSIONS FACTORS FOR FUEL COMBUSTION FROM NATURAL GAS, LPG, AND OIL-FIRED RESIDENTIAL APPLIANCES

15-A.1 OVERVIEW

The modified version of the National Energy Modeling System (NEMS) used for the appliance energy-efficiency standards analysis, called NEMS-BT, comprehensively considers a wide range of aspects of energy use. However, this model does not consider household emissions from the combustion of natural gas, residential heating fuel oil #2 (i.e., high-sulfur distillate fuel oil), and LPG. Because an efficiency standard could result in changes to household emissions, the Department has performed some elementary research to determine appropriate emissions factors for CO_2, NO_x, and SO_2 for each of the fuel types consumed by household appliances. This work focuses on emissions rates from the use of furnace and boilers and is used to calculate emissions savings for proposed appliance efficiency standards. Emissions factors for furnaces are presented over small-scale boilers whenever both are available.

This analysis attempts to verify that the emissions factors from the U.S. Environmental Protection Agency (EPA) for CO_2, NO_x, and SO_2 from natural gas, fuel oil #2, and LPG combustion are representative of the U.S.[1] The EPA cautions against the use of these emissions factors as representative of actual emissions. Rather, they are to be used, and are used here, as general approximations of national average emissions factors in order to calculate emissions savings that result from proposed appliance standards. This analysis compares the EPA's emissions factors with those from other sources and with regional regulations.

Table 15-A.1.1 summarizes the emissions factor estimates for the three fuels of interest. The values presented here are based on the EPA's assessment of combustion emissions (with the exception of SO_2 from LPG, see discussion below). These emissions estimates represent an approximate emissions factor for the U.S. as a whole. They are used, together with estimated energy savings, to calculate end-use site emissions savings. The emissions factors discussed in this analysis are represented as mass (g or kg) of the specific emission of interest per gigajoule (GJ) of energy input to the furnace and boiler.[*]

Table 15-A.1.1 Estimated National Average Emissions Factors for Household Fuel Combustion of Natural Gas, Fuel Oil #2, and LPG

	CO_2 (kg/GJ)	NO_x (g/GJ)	SO_2 (g/GJ)
Natural Gas	50.6	40	0
Fuel Oil #2	68.6	55	218
LPG	58.7	66	7

[*] 0.454 kg = 1 lb; 1.055 GJ = 1 MBtu

There are significant differences in state regulations, making it difficult to generalize about localized emissions. For residential fuel oil combustion, stricter state standards exist in the northeastern United States and southern California than elsewhere. State and local agencies like southern California's South Coast Air Quality Management District (SCAQMD)[2], the New Jersey Department of Environmental Protection, and the New York Department of Environmental Conservation have established regulations for residential fuel combustion emissions. These regulations, however, are local to individual counties and do not apply to all regions in the Northeast or even all of California.

15-A.2 EMISSIONS FACTORS BY FUEL TYPE

15-A.2.1 All Fuels: Carbon Dioxide

NEMS-BT tracks CO_2 well, but factors are included here for completeness. The CO_2 estimates in Table 15-A.1.1 are based on EPA's assessment of CO_2 combustion from natural gas, fuel oil #2, and LPG use. Other sources of information include the U.S. DOE's Energy Information Administration (EIA), Oregon State EPA, and the Gas Research Institute (GRI). All agree to within ± 2.0 percent of EPA's assessed estimate of CO_2 emissions. EPA's CO_2 emissions factors for natural gas, fuel oil #2, and LPG combustion are therefore a reasonable evaluation of nationally averaged CO_2 emissions rates.

Carbon monoxide (CO) can be formed by incomplete carbon oxidization, causing a severe health hazard. Carbon monoxide emissions only result from poorly functioning appliances, and since NEMS-BT assumes that all appliances are functioning properly, it is consistent to assume that these emissions will not change.

15-A.3 NATURAL GAS

15-A.3.1 Oxides of Nitrogen

Emissions of NO_x that result from the combustion of natural gas from appliances are also covered by regulations in some jurisdictions. The EPA's estimated NO_x emissions factor of 40 g/GJ from gas-fired furnaces is roughly equivalent to the regulation set by the state of New York. The SCAQMD limits NO_x emissions to 40 g/GW from gas-fired residential furnaces, equivalent to EPA's AP-42 estimate. The San Luis Obispo Air Pollution Control District also mandates the same NO_x limit from furnaces. The SCAQMD also provided performance test results from numerous commercially available residential gas furnaces. In general, the emissions rates ranged from 35-40 g/GJ NO_x with some higher efficiency units emitting between 26-35 g/GJ NO_x. New Jersey's state regulation mandates no more than 43 g/GJ NO_x emissions from natural gas combustion in small boilers and furnaces. The absence of regulations in other states suggests that most have emissions rates comparable to the EPA's estimated value.

15-A.3.2 Sulfur Dioxide

SO_2 emissions from natural gas combustion are assumed to be zero.

15-A.4 FUEL OIL #2

15-A.4.1 Oxides of Nitrogen

NO_x formation in combustion processes is significantly more complex than the formation of SO_2 or CO_2. NO_x can result from oxidization of N_2 in the fuel, but the larger source is N_2 in the combustion intake. This process is sensitive to combustion chemistry, and therefore, quite variable. It also implies that appliance design can lower NO_x emissions. An added difficulty is that the potential hazard of residential NO_x emissions is hard to quantify. NO_x is both an acid precipitation and ozone (O_3) precursor, but because residential appliances are a relatively small and dispersed (i.e., hard to monitor) source, these emissions tend to play a small role in NO_x control strategies. The O_3 hazards of NO_x emissions are highly variable both spatially and over time, as weather conditions favor or disfavor O_3 formation. One would, therefore, expect NO_x emissions rules to vary significantly across jurisdictions.

The value estimated by EPA of 55 g of NO_x/GJ is for residential oil-fired furnaces. Additional research into specific state regulations reveals good matches with EPA's emissions factor: New Hampshire limits NO_x emissions to 60 g/GJ for non-utility boilers and New York and New Jersey regulations cap emissions at 52 g of NO_x/GJ. These state limits confirm that EPA's estimate can serve as a reasonable national average.

15-A.4.2 Sulfur Dioxide

Emissions of SO_2 are a direct function of the sulfur content of the fuel. Assuming complete combustion of sulfur to SO_2 makes it easy to assess and compare emissions across data sources. Individual state and county regulations limiting the amount of sulfur in residential fuel oil, however, reveal substantial variability in SO_2 emissions factors from EPA's estimate of 218g of SO_2/GJ of fuel energy content for both residential furnaces and boilers. This is roughly equivalent to 0.5 percent sulfur content by weight using an emissions factor for fuel oil #2 of 43,950 g/GJ weight per unit energy content. A straight multiplication of the fuel energy content and the percentage of sulfur content in the fuel provide the emissions factor.

In the state of New York, SO_2 emissions limits range from 88-659 g/GJ depending on the county. In New Hampshire, the emissions rate of SO_2 from high-sulfur distillate fuel oil combustion cannot exceed 176 g/GJ. In Maine and Michigan, the regulations are higher than EPA's assessment, limiting SO_2 emissions from fuel oil to 500 g of SO_2/GJ of heat input. Such broad ranges and varying limits in certain regions are a strong argument for using EPA's averaged national value over a regionally weighted average incorporating the various state and county regulations.

Comparing the sulfur content of fuel oil from different refineries also demonstrates regional variability. Most sources were obtained through online websites detailing product specifications. Mobil Corporation's residential heating fuel oil (#2 high-sulfur) for most states contains a maximum 0.5% sulfur by mass (219 g of SO_2/GJ of heat input), which is very close to EPA's emissions factor. Mobil also markets fuel with lower sulfur content to some regions in the Northeast. For example, Mobil's lowest sulfur content residential heating fuel oil contains 0.2 percent sulfur by weight (88 g/GJ), as required in New York City, Philadelphia, parts of Delaware, and most of New Jersey. Other regional regulations adhered to by Mobil are 132 g/GJ for most of Pennsylvania and parts of New Jersey, a limit of 127 g of SO_2/GJ of heat input for the state of Illinois, and an SO_2 emissions factor of 145 g/GJ in Massachusetts. The sulfur contents of distillate fuel oil from Chevron, Phillips 66, and the American Society for Testing and Materials (ASTM) exactly match EPA's estimate, substantiating the use of the latter for the analysis. Considerable variation does exist among counties and states, especially in the Northeast. Nonetheless, EPA provides a reasonable estimate of emissions from residential oil-fired furnaces and boilers that are representative of the national average.

15-A.5 LPG

15-A.5.1 Oxides of Nitrogen

EPA estimates emissions for only propane and butane, fuels within the LPG family of gases. In the United States, the composition of LPG is typically 90 percent propane (C_3H_8) by liquid volume, 5 percent propylene (C_3H_6), and 2.5 percent butane (C_4H_{10}).[3, 4] This analysis uses EPA's propane emissions estimate to verify its comparability with LPG combustion or determines a more suitable estimate from other sources that best represents LPG emissions rates.

EPA estimates an emissions factor of 66 g of NO_x/GJ of energy input from propane-fired furnaces and boilers, which is slightly higher than the natural gas estimate. The University of New Hampshire's Energy Office estimates an emissions factor of 43 g/GJ from LPG combustion for the state of New Hampshire. In contrast, the state of New Jersey's EPA establishes an 86 g/GJ emissions factor. Both sources, therefore, support EPA's national assessment of NO_x emissions from residential propane combustion.

15-A.5.2 Sulfur Dioxide

The sulfur content of LPG is very low[5], although a few regulations exist in certain parts of the country. EPA's SO_2 emissions estimate is derived from the sulfur content of the propane fuel. With 90% of LPG comprised of propane, the EPA's propane emissions factor is a reasonable value for LPG emissions rates. Under the New Hampshire Department of Environmental Services (DES) regulation, the maximum sulfur content allowable is 13.3 g/GJ of SO_2 from LPG combustion. The San Diego County Air Pollution Control District enforces a stricter limit of only 8.8 g of SO_2/GJ of energy input using EPA's recommended value. Both the ASTM and Santa Barbara County Air Pollution Control District specify a sulfur standard of 0.0185 percent sulfur by weight, which approximates an emissions factor of 4.0 g of SO_2/GJ of energy input. This calculation is based on an LPG weight per unit energy of 21,756 g/GJ. Even lower, Nett Technologies Inc. estimates a 0.012 percent sulfur content by mass LPG average for the United States as well as Canada, which is approximately 2.6 g of SO_2/GJ of heat input.

The wide range of emissions factors for SO_2 makes it difficult to determine a representative estimate for the emissions factor and the very small net effect of any energy-efficiency standard argue against making a significant research effort. The obtained estimates range in magnitude from approximately 4 to 13 g/GJ of energy input. The statistical average or arithmetic mean of these four estimates is 7.2 g/GJ, the value provided in Table 15-A.1.1. The averaged emissions factor estimate of 7.2 g/GJ energy input is reasonable to explain three of the five sources presented and suitably accounts for the average among the two extreme estimates. Table 15-A.1.1 therefore adequately represents national SO_2 emissions from residential LPG combustion.

15-A.6 SUMMARY

This investigation of emissions factors from natural gas-, fuel oil-, and LPG-fired residential furnaces and boilers indicates that using the values estimated by EPA's AP-42 is a robust and credible basis for analysis with NES output. This analysis indicates that regulations at the state and county level, especially in the northeastern region of the United States, are generally not good estimators of the national average set forth by the EPA AP-42 report. This is especially true for SO_2 emissions factors from fuel oil combustion where individual state and county regulations are highly variable. Thus, although it is worthwhile examining regional legislation to support the national average, this analysis demonstrates the complexity that would be required to establish a weighted regional calculation for each emission. The EPA's own lack of data on the sulfur content of LPG made it difficult to derive a nationally representative emissions factor for the country as a whole. External sources were therefore incorporated in the Table 15-A.1.1 estimate for SO_2 emissions from LPG combustion.

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APPENDIX 16-A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

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16-A.1 EXECUTIVE SUMMARY

Under Executive Order 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the "social cost of carbon" (SCC) estimates presented here is to allow agencies to incorporate the social benefits of reducing carbon dioxide (CO_2) emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

This document presents a summary of the interagency process that developed these SCC estimates. Technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

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[a] Prepared by Interagency Working Group on Social Cost of Carbon, United States Government.
With participation by:
Council of Economic Advisers
Council on Environmental Quality
Department of Agriculture
Department of Commerce
Department of Energy
Department of Transportation
Environmental Protection Agency
National Economic Council
Office of Energy and Climate Change
Office of Management and Budget
Office of Science and Technology Policy
Department of the Treasury

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution.

Table 16-A.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

16-A.2 MONETIZING CARBON DIOXIDE EMISSIONS

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. We report estimates of the SCC in dollars per metric ton of carbon dioxide throughout this document.[b]

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

[b] In this document, we present all values of the SCC as the cost per metric ton of CO_2 emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of CO_2 and the mass of carbon is 3.67 (the molecular weight of CO_2 divided by the molecular weight of carbon = 44/12 = 3.67).

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Under Executive Order 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. Most federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the benefits from reduced (or costs from increased) emissions in any future year can be estimated by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions; we do not attempt to answer that question here.

An interagency group convened on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key inputs and assumptions in order to generate SCC estimates. Agencies that actively participated in the interagency process include the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury. This process was convened by the Council of Economic Advisers and the Office of Management and Budget, with active participation and regular input from the Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions that are grounded in the existing literature. In this way, key uncertainties and model differences can more transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are \$5, \$21, \$35, and \$65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socioeconomic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95^{th} percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of CO_2 in 2015 and \$26 per ton of CO_2 in 2020. See section 16-A.5 for the full range of annual SCC estimates from 2010 to 2050.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, we have set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, we will continue to explore the issues raised in this document and consider public comments as part of the ongoing interagency process.

16-A.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.

16-A.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.

16-A.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-

[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).

reviewed literature and used in the IPCC assessment. Each model is given equal weight in the SCC values developed through this process, bearing in mind their different limitations (discussed below).

These models are useful because they combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework. At the same time, they gain this advantage at the expense of a more detailed representation of the underlying climatic and economic systems. DICE, PAGE, and FUND all take stylized, reduced-form approaches (see NRC 2009 for a more detailed discussion; see Nordhaus 2008 on the possible advantages of this approach). Other IAMs may better reflect the complexity of the science in their modeling frameworks but do not link physical impacts to economic damages. There is currently a limited amount of research linking climate impacts to economic damages, which makes this exercise even more difficult. Underlying the three IAMs selected for this exercise are a number of simplifying assumptions and judgments reflecting the various modelers' best attempts to synthesize the available scientific and economic research characterizing these relationships.

The three IAMs translate emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. The emissions projections used in the models are based on specified socioeconomic (GDP and population) pathways. These emissions are translated into concentrations using the carbon cycle built into each model, and concentrations are translated into warming based on each model's simplified representation of the climate and a key parameter, climate sensitivity. Each model uses a different approach to translate warming into damages. Finally, transforming the stream of economic damages over time into a single value requires judgments about how to discount them.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. In PAGE, for example, the consumption-equivalent damages in each period are calculated as a fraction of GDP, depending on the temperature in that period relative to the pre-industrial average temperature in each region. In FUND, damages in each period also depend on the rate of temperature change from the prior period. In DICE, temperature affects both consumption and investment. We describe each model in greater detail here. In a later section, we discuss key gaps in how the models account for various scientific and 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 Figures 16A.4.1 and 16A.4.2, using the modeler’s default scenarios and mean input assumptions. There are significant differences between the three models both at lower (figure 16A.4.2) and higher (figure 16A.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).

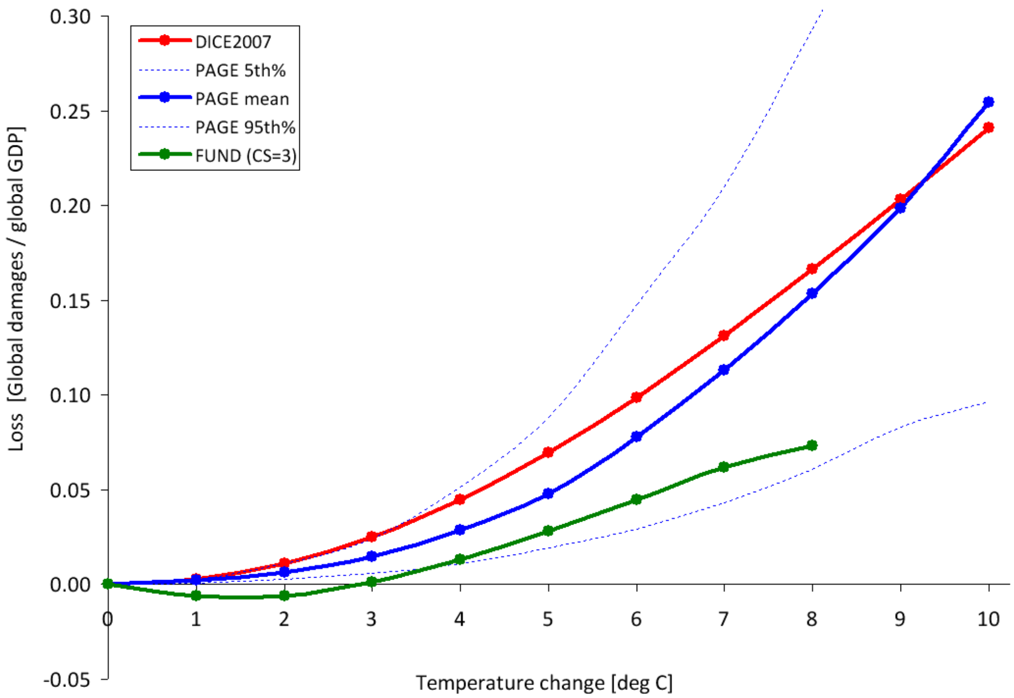

Figure 16-A.4.1 Annual Consumption Loss as a Fraction of Global GDP in 2100 Due to an Increase in Annual Global Temperature in the DICE, FUND, and PAGE models[f]

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

[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.

committed to exploring how these (and other) models can be modified to incorporate more accurate estimates of damages.

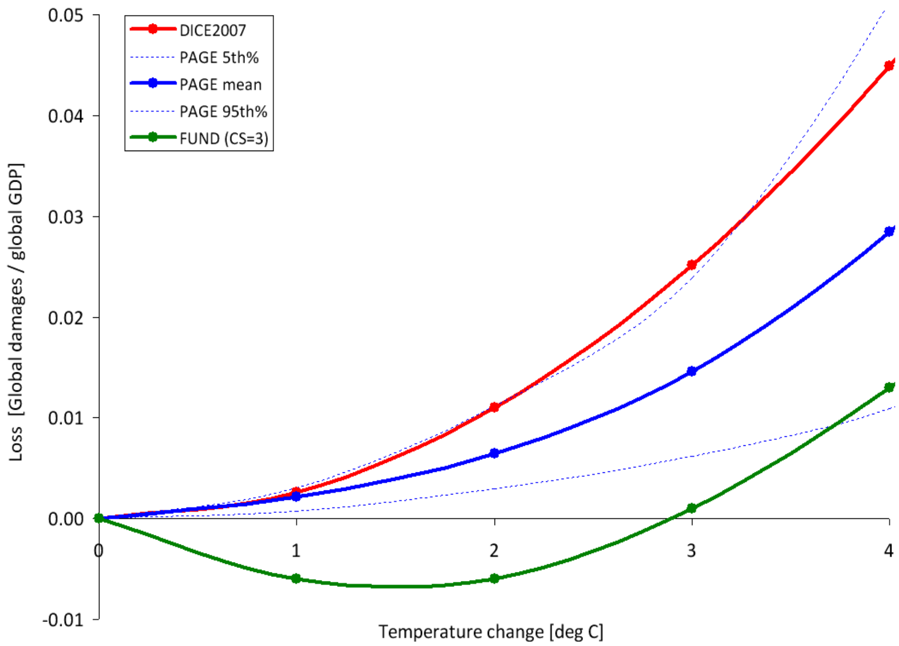

Figure 16-A.4.2 Annual Consumption Loss for Lower Temperature Changes in DICE, FUND, and PAGE

16-A.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

[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.

United States. Consequently, to address the global nature of the problem, the SCC must incorporate the full (global) damages caused by GHG emissions. Second, climate change presents a problem that the United States alone cannot solve. Even if the United States were to reduce its greenhouse gas emissions to zero, that step would be far from enough to avoid substantial climate change. Other countries would also need to take action to reduce emissions if significant changes in the global climate are to be avoided. Emphasizing the need for a global solution to a global problem, the United States has been actively involved in seeking international agreements to reduce emissions and in encouraging other nations, including emerging major economies, to take significant steps to reduce emissions. When these considerations are taken as a whole, the interagency group concluded that a global measure of the benefits from reducing U.S. emissions is preferable.

When quantifying the damages associated with a change in emissions, a number of analysts (e.g., Anthoff, et al. 2009a) employ "equity weighting" to aggregate changes in consumption across regions. This weighting takes into account the relative reductions in wealth in different regions of the world. A per-capita loss of $500 in GDP, for instance, is weighted more heavily in a country with a per-capita GDP of $2,000 than in one with a per-capita GDP of $40,000. The main argument for this approach is that a loss of $500 in a poor country causes a greater reduction in utility or welfare than does the same loss in a wealthy nation. Notwithstanding the theoretical claims on behalf of equity weighting, the interagency group concluded that this approach would not be appropriate for estimating a SCC value used in domestic regulatory analysis.[h] For this reason, the group concluded that using the global (rather than domestic) value, without equity weighting, is the appropriate approach.

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

[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*.

approximate, provisional, and highly speculative. There is no a priori reason why domestic benefits should be a constant fraction of net global damages over time. Further, FUND does not account for how damages in other regions could affect the United States (e.g., global migration, economic and political destabilization). If more accurate methods for calculating the domestic SCC become available, the Federal government will examine these to determine whether to update its approach.

16-A.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.

16-A.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.

[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).

The most authoritative statement about equilibrium climate sensitivity appears in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC):

> *Basing our assessment on a combination of several independent lines of evidence…including observed climate change and the strength of known feedbacks simulated in [global climate models], we conclude that the global mean equilibrium warming for doubling CO_2, or 'equilibrium climate sensitivity', is likely to lie in the range 2 °C to 4.5 °C, with a most likely value of about 3 °C. Equilibrium climate sensitivity is very likely larger than 1.5 °C.* [k]
>
> *For fundamental physical reasons as well as data limitations, values substantially higher than 4.5 °C still cannot be excluded, but agreement with observations and proxy data is generally worse for those high values than for values in the 2 °C to 4.5 °C range.* (Meehl et al., 2007, p 799)

After consulting with several lead authors of this chapter of the IPCC report, the interagency workgroup selected four candidate probability distributions and calibrated them to be consistent with the above statement: Roe and Baker (2007), log-normal, gamma, and Weibull. Table 16A.4.1 included below gives summary statistics for the four calibrated distributions.

Table 16-A.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:

[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.

(1) a median equal to 3°C, to reflect the judgment of “a most likely value of about 3 °C”;[1]
(2) two-thirds probability that the equilibrium climate sensitivity lies between 2 and 4.5 °C; and
(3) zero probability that it is less than 0°C or greater than 10°C (see Hegerl et al. 2006, p. 721).

We selected the calibrated Roe and Baker distribution from the four candidates for two reasons. First, the Roe and Baker distribution is the only one of the four that is based on a theoretical understanding of the response of the climate system to increased greenhouse gas concentrations (Roe and Baker 2007, Roe 2008). In contrast, the other three distributions are mathematical functions that are arbitrarily chosen based on simplicity, convenience, and general shape. The Roe and Baker distribution results from three assumptions about climate response: (1) absent feedback effects, the equilibrium climate sensitivity is equal to 1.2 °C; (2) feedback factors are proportional to the change in surface temperature; and (3) uncertainties in feedback factors are normally distributed. There is widespread agreement on the first point and the second and third points are common assumptions.

Second, the calibrated Roe and Baker distribution better reflects the IPCC judgment that “values substantially higher than 4.5°C still cannot be excluded.” Although the IPCC made no quantitative judgment, the 95th percentile of the calibrated Roe & Baker distribution (7.1 °C) is much closer to the mean and the median (7.2 °C) of the 95th percentiles of 21 previous studies summarized by Newbold and Daigneault (2009). It is also closer to the mean (7.5 °C) and median (7.9 °C) of the nine truncated distributions examined by the IPCC (Hegerl, et al., 2006) than are the 95th percentiles of the three other calibrated distributions (5.2-6.0 °C).

Finally, we note the IPCC judgment that the equilibrium climate sensitivity “is very likely larger than 1.5°C.” Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5°C is almost 99 percent, is not inconsistent with the IPCC definition of “very likely” as “greater than 90 percent probability,” it reflects a greater degree of certainty about very low values of ECS than was expressed by the IPCC.

[1] Strictly speaking, “most likely” refers to the mode of a distribution rather than the median, but common usage would allow the mode, median, or mean to serve as candidates for the central or “most likely” value and the IPCC report is not specific on this point. For the distributions we considered, the median was between the mode and the mean. For the Roe and Baker distribution, setting the median equal to 3°C, rather than the mode or mean, gave a 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.

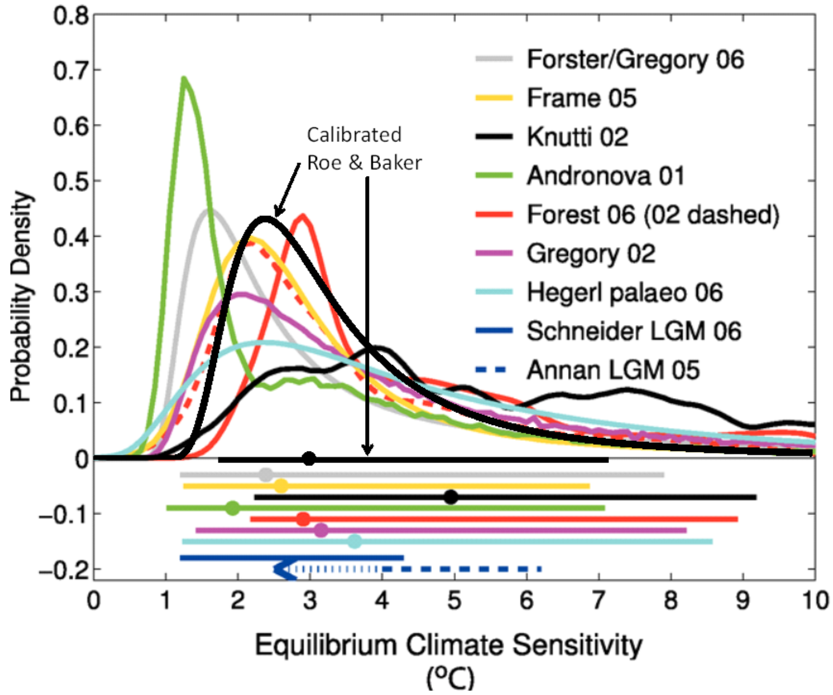

Figure 16-A.4.3 Estimates of the Probability Density Function for Equilibrium Climate Sensitivity (°C)

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 16A.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]

16-A.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 16A.4.2 below). Four of these represent potential business-as-usual (BAU) growth in population, wealth, and emissions and are associated with CO_2 (only) concentrations ranging from 612 to 889 ppm in 2100. One represents an emissions pathway that achieves stabilization at 550 ppm CO_2e (i.e., CO_2-only concentrations of 425 – 484 ppm or a radiative forcing of 3.7 W/m^2) in 2100, a lower-than-BAU trajectory.[n] Out of the 10 models included in the EMF-22 exercise, we selected the trajectories used by MiniCAM, MESSAGE, IMAGE, and the optimistic scenario from MERGE. For the BAU pathways, we used the GDP, population, and emission trajectories from each of these four models. For the 550 ppm CO_2e scenario, we averaged the GDP, population, and emission trajectories implied by these same four models.

[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 16-A.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.

[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.

16-A.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

[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.

temperatures, as represented in each of the three IAMs. Then we discount the stream of future damages to its present value in the year when the additional unit of emissions was released using the selected discount rate, which is intended to reflect society's marginal rate of substitution between consumption in different time periods.

For rules with both intra- and intergenerational effects, agencies traditionally employ constant discount rates of both 3 percent and 7 percent in accordance with OMB Circular A-4. As Circular A-4 acknowledges, however, the choice of discount rate for intergenerational problems raises distinctive problems and presents considerable challenges. After reviewing those challenges, Circular A-4 states, “If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent.” For the specific purpose of developing the SCC, we adapt and revise that approach here.

Arrow et al. (1996) outlined two main approaches to determine the discount rate for climate change analysis, which they labeled “descriptive” and “prescriptive.” The descriptive approach reflects a positive (non-normative) perspective based on observations of people’s actual choices—e.g., savings versus consumption decisions over time, and allocations of savings among more and less risky investments. Advocates of this approach generally call for inferring the discount rate from market rates of return “because of a lack of justification for choosing a social welfare function that is any different than what decision makers [individuals] actually use” (Arrow et al. 1996).

One theoretical foundation for the cost-benefit analyses in which the social cost of carbon will be used—the Kaldor-Hicks potential-compensation test—also suggests that market rates should be used to discount future benefits and costs, because it is the market interest rate that would govern the returns potentially set aside today to compensate future individuals for climate damages that they bear (e.g., Just et al. 2004). As some have noted, the word “potentially” is an important qualification; there is no assurance that such returns will actually be set aside to provide compensation, and the very idea of compensation is difficult to define in the intergenerational context. On the other hand, societies provide compensation to future generations through investments in human capital and the resulting increase in knowledge, as well as infrastructure and other physical capital.

The prescriptive approach specifies a social welfare function that formalizes the normative judgments that the decision-maker wants explicitly to incorporate into the policy evaluation—e.g., how inter-personal comparisons of utility should be made, and how the welfare of future generations should be weighed against that of the present generation. Ramsey (1928), for example, has argued that it is “ethically indefensible” to apply a positive pure rate of time preference to discount values across generations, and many agree with this view.

Other concerns also motivate making adjustments to descriptive discount rates. In particular, it has been noted that the preferences of future generations with regard to consumption versus environmental amenities may not be the same as those today, making the current market rate on consumption an inappropriate metric by which to discount future climate-related damages. Others argue that the discount rate should be below market rates to correct for market distortions and uncertainties or inefficiencies in intergenerational transfers of wealth, which in the Kaldor-Hicks logic are presumed to compensate future generations for damage (a potentially controversial assumption, as noted above) (Arrow et al. 1996, Weitzman 1999).

Further, a legitimate concern about both descriptive and prescriptive approaches is that they tend to obscure important heterogeneity in the population. The utility function that underlies the prescriptive approach assumes a representative agent with perfect foresight and no credit constraints. This is an artificial rendering of the real world that misses many of the frictions that characterize individuals' lives and indeed the available descriptive evidence supports this. For instance, many individuals smooth consumption by borrowing with credit cards that have relatively high rates. Some are unable to access traditional credit markets and rely on payday lending operations or other high-cost forms of smoothing consumption. Whether one puts greater weight on the prescriptive or descriptive approach, the high interest rates that credit-constrained individuals accept suggest that some account should be given to the discount rates revealed by their behavior.

We draw on both approaches but rely primarily on the descriptive approach to inform the choice of discount rate. With recognition of its limitations, we find this approach to be the most defensible and transparent given its consistency with the standard contemporary theoretical foundations of benefit-cost analysis and with the approach required by OMB's existing guidance. The logic of this framework also suggests that market rates should be used for discounting future consumption-equivalent damages. Regardless of the theoretical approach used to derive the appropriate discount rate(s), we note the inherent conceptual and practical difficulties of adequately capturing consumption trade-offs over many decades or even centuries. While relying primarily on the descriptive approach in selecting specific discount rates, the interagency group has been keenly aware of the deeply normative dimensions of both the debate over discounting in the intergenerational context and the consequences of selecting one discount rate over another.

Historically Observed Interest Rates

In a market with no distortions, the return to savings would equal the private return on investment, and the market rate of interest would be the appropriate choice for the social discount rate. In the real world risk, taxes, and other market imperfections drive a wedge between the risk-free rate of return on capital and the consumption rate of interest. Thus, the literature recognizes two conceptual discount concepts—the consumption rate of interest and the opportunity cost of capital.

According to OMB's Circular A-4, it is appropriate to use the rate of return on capital when a regulation is expected to displace or alter the use of capital in the private sector. In this case, OMB recommends Agencies use a discount rate of 7 percent. When regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services—a lower discount rate of 3 percent is appropriate to reflect how private individuals trade-off current and future consumption.

The interagency group examined the economics literature and concluded that the consumption rate of interest is the correct concept to use in evaluating the benefits and costs of a marginal change in carbon emissions (see Lind 1990, Arrow et al 1996, and Arrow 2000). The consumption rate of interest also is appropriate when the impacts of a regulation are measured in consumption (-equivalent) units, as is done in the three integrated assessment models used for estimating the SCC.

Individuals use a variety of savings instruments that vary with risk level, time horizon, and tax characteristics. The standard analytic framework used to develop intuition about the discount rate typically assumes a representative agent with perfect foresight and no credit constraints. The risk-free rate is appropriate for discounting certain future benefits or costs, but the benefits calculated by IAMs are uncertain. To use the risk-free rate to discount uncertain benefits, these benefits first must be transformed into "certainty equivalents," that is the maximum certain amount that we would exchange for the uncertain amount. However, the calculation of the certainty-equivalent requires first estimating the correlation between the benefits of the policy and baseline consumption.

If the IAM projections of future impacts represent expected values (not certainty-equivalent values), then the appropriate discount rate generally does not equal the risk-free rate. If the benefits of the policy tend to be high in those states of the world in which consumption is low, then the certainty-equivalent benefits will be higher than the expected benefits (and vice versa). Since many (though not necessarily all) of the important impacts of climate change will flow through market sectors such as agriculture and energy, and since willingness to pay for environmental protections typically increases with income, we might expect a positive (though not necessarily perfect) correlation between the net benefits from climate policies and market returns. This line of reasoning suggests that the proper discount rate would exceed the riskless rate. Alternatively, a negative correlation between the returns to climate policies and market returns would imply that a discount rate below the riskless rate is appropriate.

This discussion suggests that both the post-tax riskless and risky rates can be used to capture individuals' consumption-equivalent interest rate. As a measure of the post-tax riskless rate, we calculate the average real return from Treasury notes over the longest time period available (those from Newell and Pizer 2003) and adjust for Federal taxes (the average marginal rate from tax years 2003 through 2006 is around 27 percent).[r] This calculation produces a real interest rate of about 2.7 percent, which is roughly consistent with Circular A-4's 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

[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.

market returns can be obtained by adjusting pre-tax rates of household returns to risky investments (approximately 7 percent) for taxes, which yields a real rate of roughly 5 percent.[t]

The Ramsey Equation

Ramsey discounting also provides a useful framework to inform the choice of a discount rate. Under this approach, the analyst applies either positive or normative judgments in selecting values for the key parameters of the Ramsey equation: η (coefficient of relative risk aversion or elasticity of the marginal utility of consumption) and ρ (pure rate of time preference).[u] These are then combined with g (growth rate of per-capita consumption) to equal the interest rate at which future monetized damages are discounted: $\rho + \eta \cdot g$.[v] In the simplest version of the Ramsey model, with an optimizing representative agent with perfect foresight, what we are calling the "Ramsey discount rate," $\rho + \eta g$, 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, since η equal to 1 suggests savings rates that do not conform to observed behavior.

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[t] Cambell et al (2001) estimates that the annual real return from stocks for 1900-1995 was about 7 percent. The annual real rate of return for the S&P 500 from 1950 – 2008 was about 6.8 percent. In the absence of a better way to population-weight the tax rates, we use the middle of the 20 – 40 percent range to derive a post-tax interest rate (Kotlikoff and Rapson 2006).

[u] The parameter ρ measures the *pure rate of time preference*: people's behavior reveals a preference for an increase in utility today versus the future. Consequently, it is standard to place a lower weight on utility in the future. The parameter η captures *diminishing marginal utility*: consumption in the future is likely to be higher than consumption today, so diminishing marginal utility of consumption implies that the same monetary damage will cause a smaller reduction of utility for wealthier individuals, either in the future or in current generations. If $\eta = 0$, then a one dollar increase in income is equally valuable regardless of level of income; if $\eta = 1$, then a one percent increase in income is equally valuable no matter the level of income; and if $\eta > 1$, then a one percent increase in income is less valuable to wealthier individuals.

[v] In this case, g could be taken from the selected EMF socioeconomic scenarios or alternative assumptions about the rate of consumption growth.

[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 $\rho = 1.07$.

- 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-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

[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.)

uncertainty in the discount rate (e.g., the rate follows a random walk), then it will result in an effective (or certainty-equivalent) discount rate that declines over time. Consequently, lower discount rates tend to dominate over the very long term (see Weitzman 1998, 1999, 2001; Newell and Pizer 2003; Groom et al. 2006; Gollier 2008; Summers and Zeckhauser 2008; and Gollier and Weitzman 2009).

The proper way to model discount rate uncertainty remains an active area of research. Newell and Pizer (2003) employ a model of how long-term interest rates change over time to forecast future discount rates. Their model incorporates some of the basic features of how interest rates move over time, and its parameters are estimated based on historical observations of long-term rates. Subsequent work on this topic, most notably Groom et al. (2006), uses more general models of interest rate dynamics to allow for better forecasts. Specifically, the volatility of interest rates depends on whether rates are currently low or high and the variation in the level of persistence over time.

While Newell and Pizer (2003) and Groom et al (2006) attempt formally to model uncertainty in the discount rate, others argue for a declining scale of discount rates applied over time (e.g., Weitzman 2001, and the UK's "Green Book" for regulatory analysis). This approach uses a higher discount rate initially, but applies a graduated scale of lower discount rates further out in time.[y] A key question that has emerged with regard to both of these approaches is the trade-off between potential time inconsistency and giving greater weight to far future outcomes (see the EPA Science Advisory Board's recent comments on this topic as part of its review of their *Guidelines for Economic Analysis*).[z]

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

[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.

mentioned, the consumption rate of interest is the correct discounting concept to use when future damages from elevated temperatures are estimated in consumption-equivalent units. Further, 3 percent roughly corresponds to the after-tax riskless interest rate. The upper value of 5 percent is included to represent the possibility that climate damages are positively correlated with market returns. Additionally, this discount rate may be justified by the high interest rates that many consumers use to smooth consumption across periods.

The low value, 2.5 percent, is included to incorporate the concern that interest rates are highly uncertain over time. It represents the average certainty-equivalent rate using the mean-reverting and random walk approaches from Newell and Pizer (2003) starting at a discount rate of 3 percent. Using this approach, the certainty equivalent is about 2.2 percent using the random walk model and 2.8 percent using the mean reverting approach.[aa] Without giving preference to a particular model, the average of the two rates is 2.5 percent. Further, a rate below the riskless rate would be justified if climate investments are negatively correlated with the overall market rate of return. Use of this lower value also responds to certain judgments using the prescriptive or normative approach and to ethical objections that have been raised about rates of 3 percent or higher.

16-A.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.

[aa] Calculations done by Pizer et al. using the original simulation program from Newell and Pizer (2003).

a. In PAGE, the consumption-equivalent damages in each period are calculated as a fraction of the EMF GDP forecast, depending on the temperature in that period relative to the pre-industrial average temperature in each region.
b. In FUND, damages in each period depend on both the level and the rate of temperature change in that period.
c. In DICE, temperature affects both consumption and investment, so we first adjust the EMF GDP paths as follows: Using the Cobb-Douglas production function with the DICE2007 parameters, we extract the path of exogenous technical change implied by the EMF GDP and population paths, then we recalculate the baseline GDP path taking into account climate damages resulting from the baseline emissions path.

3. Add an additional unit of carbon emissions in year *t.* (The exact unit varies by model.)

4. Recalculate the temperature effects and damages expected in all years beyond *t* resulting from this adjusted path of emissions, as in step 2.

5. Subtract the damages computed in step 2 from those in step 4 in each year. (DICE is run in 10-year time steps, FUND in annual time steps, while the time steps in PAGE vary.)

6. Discount the resulting path of marginal damages back to the year of emissions using the agreed upon fixed discount rates.

7. Calculate the SCC as the net present value of the discounted path of damages computed in step 6, divided by the unit of carbon emissions used to shock the models in step 3.

8. Multiply by 12/44 to convert from dollars per ton of carbon to dollars per ton of CO_2 (2007 dollars) in DICE and FUND. (All calculations are done in tons of CO_2 in PAGE).

The steps above were repeated in each model for multiple future years to cover the time horizons anticipated for upcoming rulemaking analysis. To maintain consistency across the three IAMs, climate damages are calculated as lost consumption in each future year.

It is important to note that each of the three models has a different default end year. The default time horizon is 2200 for PAGE, 2595 for DICE, and 3000 for the latest version of FUND. This is an issue for the multi-model approach because differences in SCC estimates may arise simply due to the model time horizon. Many consider 2200 too short a time horizon because it could miss a significant fraction of damages under certain assumptions about the growth of marginal damages and discounting, so each model is run here through 2300. This step required a small adjustment in the PAGE model only. This step also required assumptions about GDP, population, and greenhouse gas emission trajectories after 2100, the last year for which these data are available from the EMF-22 models. (A more detailed discussion of these assumptions is included in the Annex.)

This exercise produces 45 separate distributions of the SCC for a given year, the product of 3 models, 3 discount rates, and 5 socioeconomic scenarios. This is clearly too many separate distributions for consideration in a regulatory impact analysis.

To produce a range of plausible estimates that still reflects the uncertainty in the estimation exercise, the distributions from each of the models and scenarios are equally weighed and combined to produce three separate probability distributions for SCC in a given year, one for each assumed discount rate. These distributions are then used to define a range of point estimates for the global SCC. In this way, no IAM or socioeconomic scenario is given greater weight than another. Because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context, we present SCCs based on the average values across models and socioeconomic scenarios for each discount rate.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC across models and socioeconomic and emissions scenarios at the 2.5, 3, and 5 percent discount rates. The fourth value is included to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. (The full set of distributions by model and scenario combination is included in the Annex.) As noted above, the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range.

As previously discussed, low probability, high impact events are incorporated into the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high-temperature outcomes, which in turn lead to higher projections of damages. Although FUND does not include catastrophic damages (in contrast to the other two models), its probabilistic treatment of the equilibrium climate sensitivity parameter will directly affect the non-catastrophic damages that are a function of the rate of temperature change.

In Table 16A.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 16-A.5.1 Disaggregated Social Cost of CO_2 Values by Model, Socioeconomic Trajectory, and Discount Rate for 2010 (in 2007 dollars)

Model	*Discount rate:* *Scenario*	**5%** Avg	**3%** Avg	**2.5%** Avg	**3%** 95th
DICE	IMAGE	10.8	35.8	54.2	70.8
	MERGE	7.5	22.0	31.6	42.1
	Message	9.8	29.8	43.5	58.6
	MiniCAM	8.6	28.8	44.4	57.9
	550 Average	8.2	24.9	37.4	50.8
PAGE	IMAGE	8.3	39.5	65.5	142.4
	MERGE	5.2	22.3	34.6	82.4
	Message	7.2	30.3	49.2	115.6
	MiniCAM	6.4	31.8	54.7	115.4
	550 Average	5.5	25.4	42.9	104.7
FUND	IMAGE	-1.3	8.2	19.3	39.7
	MERGE	-0.3	8.0	14.8	41.3
	Message	-1.9	3.6	8.8	32.1
	MiniCAM	-0.6	10.2	22.2	42.6
	550 Average	-2.7	-0.2	3.0	19.4

These results are not surprising when compared to the estimates in the literature for the latest versions of each model. For example, adjusting the values from the literature that were used to develop interim SCC values to 2007 dollars for the year 2010 (assuming, as we did for the interim process, that SCC grows at 3 percent per year), FUND yields SCC estimates at or near zero for a 5 percent discount rate and around $9 per ton for a 3 percent discount rate. There are far fewer estimates using the latest versions of DICE and PAGE in the literature: Using similar adjustments to generate 2010 estimates, we calculate a SCC from DICE (based on Nordhaus 2008) of around $9 per ton for a 5 percent discount rate, and a SCC from PAGE (based on Hope 2006, 2008) close to $8 per ton for a 4 percent discount rate. Note that these comparisons are only approximate since the literature generally relies on Ramsey discounting, while we have assumed constant discount rates.[bb]

[bb] Nordhaus (2008) runs DICE2007 with $\rho = 1.5$ and $\eta = 2$. The default approach in PAGE2002 (version 1.4epm) treats ρ and η as random parameters, specified using a triangular distribution such that the min, mode, and max = 0.1, 1, and 2 for ρ, and 0.5, 1, and 2 for η, respectively. The FUND default value for η is 1, and Tol generates SCC estimates for values of ρ = 0, 1, and 3 in many recent papers (e.g. Anthoff et al. 2009). The path of per-capita consumption growth, g, varies over time but is treated deterministically in two of the three models. In DICE, g is

The SCC estimates from FUND are sensitive to differences in emissions paths but relatively insensitive to differences in GDP paths across scenarios, while the reverse is true for DICE and PAGE. This likely occurs because of several structural differences among the models. Specifically in DICE and PAGE, the fraction of economic output lost due to climate damages increases with the level of temperature alone, whereas in FUND the fractional loss also increases with the rate of temperature change. Furthermore, in FUND increases in income over time decrease vulnerability to climate change (a form of adaptation), whereas this does not occur in DICE and PAGE. These structural differences among the models make FUND more sensitive to the path of emissions and less sensitive to GDP compared to DICE and PAGE.

Figure 16A.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.

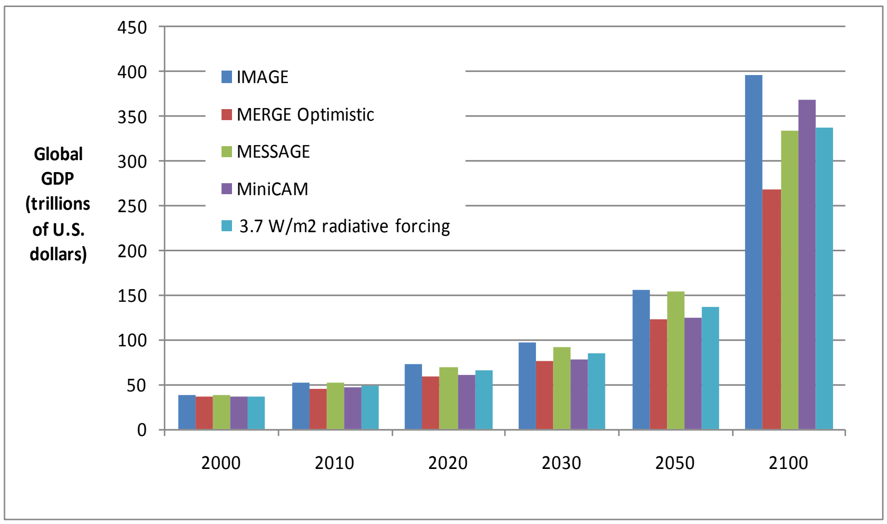

Figure 16-A.5.1 Level of Global GDP across EMF Scenarios

Table 16A.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 16-A.5.2 Social Cost of CO_2, 2010 – 2050 (in 2007 dollars)

Discount Year	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that this approach allows us to estimate the growth rate of the SCC directly using DICE, PAGE, and FUND rather than assuming a constant annual growth rate as was done for the interim estimates (using 3 percent). This helps to ensure that the estimates are internally consistent with other modeling assumptions. Table 16A.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 16-A.5.3 Changes in the Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Growth Rate (%)	**5%** Avg	**3%** Avg	**2.5%** Avg	**3.0%** 95th
2010-2020	3.6%	2.1%	1.7%	2.2%
2020-2030	3.7%	2.2%	1.8%	2.2%
2030-2040	2.7%	1.8%	1.6%	1.8%
2040-2050	2.1%	1.4%	1.1%	1.3%

While the SCC estimate grows over time, the future monetized value of emissions reductions in each year (the SCC in year *t* multiplied by the change in emissions in year *t*) must be discounted to the present to determine its total net present value for use in regulatory analysis. Damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency—i.e., future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate. For example, climate damages in the year 2020 that are calculated using a SCC based on a 5 percent discount rate also should be discounted back to the analysis year using a 5 percent discount rate.[cc]

16-A.6 LIMITATIONS OF THE ANALYSIS

As noted, any estimate of the SCC must be taken as provisional and subject to further refinement (and possibly significant change) in accordance with evolving scientific, economic, and ethical understandings. During the course of our modeling, it became apparent that there are several areas in particular need of additional exploration and research. These caveats, and additional observations in the following section, are necessary to consider when interpreting and applying the SCC estimates.

Incomplete treatment of non-catastrophic damages. The impacts of climate change are expected to be widespread, diverse, and heterogeneous. In addition, the exact magnitude of these impacts is uncertain because of the inherent complexity of climate processes, the economic behavior of current and future populations, and our inability to accurately forecast technological change and adaptation. Current IAMs do not assign value to all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature (some of which are discussed above) because of lack of precise information on the nature of damages and because the science incorporated into these models understandably lags behind the most recent research. Our ability to quantify and monetize impacts will undoubtedly improve with time. But it is also likely that even in future applications, a number of potentially significant damage categories will remain non-monetized. (Ocean acidification is one example of a potentially large damage from CO_2 emissions not quantified by any of the three models. Species and wildlife loss is another example that is exceedingly difficult to monetize.)

Incomplete treatment of potential catastrophic damages. There has been considerable recent discussion of the risk of catastrophic impacts and how best to account for extreme scenarios, such as the collapse of the Atlantic Meridional Overturning Circulation or the West Antarctic Ice Sheet, or large releases of methane from melting permafrost and warming oceans. Weitzman (2009) suggests that catastrophic damages are extremely large—so large, in fact, that the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. However, Nordhaus (2009) concluded that the conditions under which Weitzman's results hold “are limited and do not apply to a wide range of potential uncertain scenarios."

Using a simplified IAM, Newbold and Daigneault (2009) confirmed the potential for large catastrophe risk premiums but also showed that the aggregate benefit estimates can be highly sensitive to the shapes of both the climate sensitivity distribution and the damage function at high temperature changes. Pindyck (2009) also used a simplified IAM to examine high-

[cc] However, it is possible that other benefits or costs of proposed regulations unrelated to CO_2 emissions will be discounted at rates that differ from those used to develop the SCC estimates.

impact, low-probability risks, using a right-skewed gamma distribution for climate sensitivity as well as an uncertain damage coefficient, but in most cases found only a modest risk premium. Given this difference in opinion, further research in this area is needed before its practical significance can be fully understood and a reasonable approach developed to account for such risks in regulatory analysis. (The next section discusses the scientific evidence on catastrophic impacts in greater detail.)

Uncertainty in extrapolation of damages to high temperatures: The damage functions in these IAMs are typically calibrated by estimating damages at moderate temperature increases (e.g., DICE was calibrated at 2.5 °C) and extrapolated to far higher temperatures by assuming that damages increase as some power of the temperature change. Hence, estimated damages are far more uncertain under more extreme climate change scenarios.

Incomplete treatment of adaptation and technological change: Each of the three integrated assessment models used here assumes a certain degree of low- or no-cost adaptation. For instance, Tol assumes a great deal of adaptation in FUND, including widespread reliance on air conditioning; so much so, that the largest single benefit category in FUND is the reduced electricity costs from not having to run air conditioning as intensively (NRC 2009).

Climate change also will increase returns on investment to develop technologies that allow individuals to cope with adverse climate conditions, and IAMs to do not adequately account for this directed technological change.[dd] For example, scientists may develop crops that are better able to withstand higher and more variable temperatures. Although DICE and FUND have both calibrated their agricultural sectors under the assumption that farmers will change land use practices in response to climate change (Mastrandrea, 2009), they do not take into account technological changes that lower the cost of this adaptation over time. On the other hand, the calibrations do not account for increases in climate variability, pests, or diseases, which could make adaptation more difficult than assumed by the IAMs for a given temperature change. Hence, models do not adequately account for potential adaptation or technical change that might alter the emissions pathway and resulting damages. In this respect, it is difficult to determine whether the incomplete treatment of adaptation and technological change in these IAMs understate or overstate the likely damages.

Risk aversion: A key question unanswered during this interagency process is what to assume about relative risk aversion with regard to high-impact outcomes. These calculations do not take into account the possibility that individuals may have a higher willingness to pay to reduce the likelihood of low-probability, high-impact damages than they do to reduce the likelihood of higher-probability, but lower-impact, damages with the same expected cost. (The inclusion of the 95th percentile estimate in the final set of SCC values was largely motivated by this concern.) If individuals do show such a higher willingness to pay, a further question is whether that fact should be taken into account for regulatory policy. Even if individuals are not 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.

16-A.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 16A.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 16A.4.1), so the high-end output from PAGE potentially offers the best insight into the SCC if the world were to experience catastrophic climate change. For instance, at the 95th percentile and a 3 percent discount rate, the SCC estimated by PAGE across the five socioeconomic and emission trajectories of $113 per ton of CO_2 is almost double the value estimated by DICE, $58 per ton in 2010. We cannot evaluate how well the three models account for catastrophic or non-catastrophic impacts, but this estimate highlights the sensitivity of SCC values in the tails of the distribution to the assumptions made about catastrophic impacts.

Table 16-A.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.

16-A.8 CONCLUSION

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are \$5, \$21, \$35, and \$65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socioeconomic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of CO_2 in 2015 and \$26 per ton of CO_2 in 2020.

We noted a number of limitations to this analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking climate impacts to economic damages makes this modeling exercise even more difficult. It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling.

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16-A.9 ANNEX

Table 16-A.9.1 Annual SCC Values: 2010–2050 (in 2007 dollars)

Discount Rate Year	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	4.7	21.4	35.1	64.9
2011	4.9	21.9	35.7	66.5
2012	5.1	22.4	36.4	68.1
2013	5.3	22.8	37.0	69.6
2014	5.5	23.3	37.7	71.2
2015	5.7	23.8	38.4	72.8
2016	5.9	24.3	39.0	74.4
2017	6.1	24.8	39.7	76.0
2018	6.3	25.3	40.4	77.5
2019	6.5	25.8	41.0	79.1
2020	6.8	26.3	41.7	80.7
2021	7.1	27.0	42.5	82.6
2022	7.4	27.6	43.4	84.6
2023	7.7	28.3	44.2	86.5
2024	7.9	28.9	45.0	88.4
2025	8.2	29.6	45.9	90.4
2026	8.5	30.2	46.7	92.3
2027	8.8	30.9	47.5	94.2
2028	9.1	31.5	48.4	96.2
2029	9.4	32.1	49.2	98.1
2030	9.7	32.8	50.0	100.0
2031	10.0	33.4	50.9	102.0
2032	10.3	34.1	51.7	103.9
2033	10.6	34.7	52.5	105.8
2034	10.9	35.4	53.4	107.8
2035	11.2	36.0	54.2	109.7
2036	11.5	36.7	55.0	111.6
2037	11.8	37.3	55.9	113.6
2038	12.1	37.9	56.7	115.5
2039	12.4	38.6	57.5	117.4
2040	12.7	39.2	58.4	119.3
2041	13.0	39.8	59.0	121.0
2042	13.3	40.4	59.7	122.7
2043	13.6	40.9	60.4	124.4
2044	13.9	41.5	61.0	126.1
2045	14.2	42.1	61.7	127.8
2046	14.5	42.6	62.4	129.4
2047	14.8	43.2	63.0	131.1
2048	15.1	43.8	63.7	132.8
2049	15.4	44.4	64.4	134.5
2050	15.7	44.9	65.0	136.2

This Annex provides additional technical information about the non-CO_2 emission projections used in the modeling and the method for extrapolating emissions forecasts through 2300 and shows the full distribution of 2010 SCC estimates by model and scenario combination.

16-A.9.1 Other (non-CO2) gases

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane (CH_4), nitrous oxide (N_2O), fluorinated gases, and net land use CO_2 emissions to 2100. These assumptions are used in all three IAMs while retaining each model's default radiative forcings (RF) due to other factors (e.g., aerosols and other gases). Specifically, to obtain the RF associated with the non-CO_2 EMF emissions only, we calculated the RF associated with the EMF atmospheric CO_2 concentrations and subtracted them from the EMF total RF.[ee] This approach respects the EMF scenarios as much as possible and at the same time takes account of those components not included in the EMF projections. Since each model treats non-CO_2 gases differently (e.g., DICE lumps all other gases into one composite exogenous input), this approach was applied slightly differently in each of the models.

FUND: Rather than relying on RF for these gases, the actual emissions from each scenario were used in FUND. The model default trajectories for CH_4, N_20, SF_6, and the CO_2 emissions from land were replaced with the EMF values.

PAGE: PAGE models CO_2, CH_4, sulfur hexafluoride (SF_6), and aerosols and contains an "excess forcing" vector that includes the RF for everything else. To include the EMF values, we removed the default CH_4 and SF_6 factors[ff], decomposed the excess forcing vector, and constructed a new excess forcing vector that includes the EMF RF for CH_4, N_20, and fluorinated gases, as well as the model default values for aerosols and other factors. Net land use CO_2 emissions were added to the fossil and industrial CO_2 emissions pathway.

DICE: DICE presents the greatest challenge because all forcing due to factors other than industrial CO_2 emissions is embedded in an exogenous non-CO_2 RF vector. To decompose this exogenous forcing path into EMF non-CO_2 gases and other gases, we relied on the references in DICE2007 to the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) and the discussion of aerosol forecasts in the IPCC's Third Assessment Report (TAR) and in AR4, as explained below. In DICE2007, Nordhaus assumes that exogenous forcing from all non-CO_2 sources is -0.06 W/m^2 in 2005, as reported in AR4, and increases linearly to 0.3 W/m^2 in 2105, based on GISS projections, and then stays constant after that time.

According to AR4, the RF in 2005 from CH_4, N_20, and halocarbons (approximately similar to the F-gases in the EMF-22 scenarios) was 0.48 + 0.16 + 0.34 = 0.98 W/m^2 and RF from total aerosols was -1.2 W/m^2. Thus, the -.06 W/m^2 non-CO_2 forcing in DICE can be

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[ee] Note EMF did not provide CO_2 concentrations for the IMAGE reference scenario. Thus, for this scenario, we fed the fossil, industrial, and land CO_2 emissions into MAGICC (considered a "neutral arbiter" model, which is tuned to emulate the major global climate models) and the resulting CO_2 concentrations were used. Note also that MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (i.e., we add up the land use emissions from the other three models and divide by 4).

[ff] Both the model default CH_4 emissions and the initial atmospheric CH_4 is set to zero to avoid double counting the effect of past CH_4 emissions.

decomposed into: 0.98 W/m^2 due to the EMF non-CO_2 gases, -1.2 W/m^2 due to aerosols, and the remainder, 0.16 W/m^2, due to other residual forcing.

For subsequent years, we calculated the DICE default RF from aerosols and other non-CO_2 gases based on the following two assumptions:

(1) RF from aerosols declines linearly from 2005 to 2100 at the rate projected by the TAR and then stays constant thereafter; and
(2) With respect to RF from non-CO_2 gases not included in the EMF-22 scenarios, the share of non-aerosol RF matches the share implicit in the AR4 summary statistics cited above and remains constant over time.

Assumption (1) means that the RF from aerosols in 2100 equals 66 percent of that in 2000, which is the fraction of the TAR projection of total RF from aerosols (including sulfates, black carbon, and organic carbon) in 2100 vs. 2000 under the A1B SRES emissions scenario. Since the SRES marker scenarios were not updated for the AR4, the TAR provides the most recent IPCC projection of aerosol forcing. We rely on the A1B projection from the TAR because it provides one of the lower aerosol forecasts among the SRES marker scenarios and is more consistent with the AR4 discussion of the post-SRES literature on aerosols:

> *Aerosols have a net cooling effect and the representation of aerosol and aerosol precursor emissions, including sulfur dioxide, black carbon and organic carbon, has improved in the post-SRES scenarios. Generally, these emissions are projected to be lower than reported in SRES. {WGIII 3.2, TS.3, SPM}.*[gg]

Assuming a simple linear decline in aerosols from 2000 to 2100 also is more consistent with the recent literature on these emissions. For example, the figure below shows that the sulfur dioxide emissions peak over the short term of some SRES scenarios above the upper bound estimates of the more recent scenarios.[hh] Recent scenarios project sulfur emissions to peak earlier and at lower levels compared to the SRES in part because of new information about present and planned sulfur legislation in some developing countries, such as India and China.[ii] The lower-bound projections of the recent literature have also shifted downward slightly compared to the SRES scenario (IPCC 2007).

[gg] AR4 Synthesis Report, p. 44, http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

[hh] See Smith, S.J., R. Andres, E. Conception, and J. Lurz, 2004: Historical sulfur dioxide emissions, 1850-2000: methods and results. Joint Global Research Institute, College Park, 14 pp.

[ii] See Carmichael, G., D. Streets, G. Calori, M. Amann, M. Jacobson, J. Hansen, and H. Ueda, 2002: Changing trends in sulphur emissions in Asia: implications for acid deposition, air pollution, and climate. Environmental Science and Technology, 36(22):4707- 4713; Streets, D., K. Jiang, X. Hu, J. Sinton, X.-Q. Zhang, D. Xu, M. Jacobson, and J. Hansen, 2001: Recent reductions in China's greenhouse gas emissions. Science, 294(5548): 1835-1837.

With these assumptions, the DICE aerosol forcing changes from -1.2 in 2005 to -0.792 in 2105 W/m^2; forcing due to other non-CO_2 gases not included in the EMF scenarios declines from 0.160 to 0.153 W/m^2.

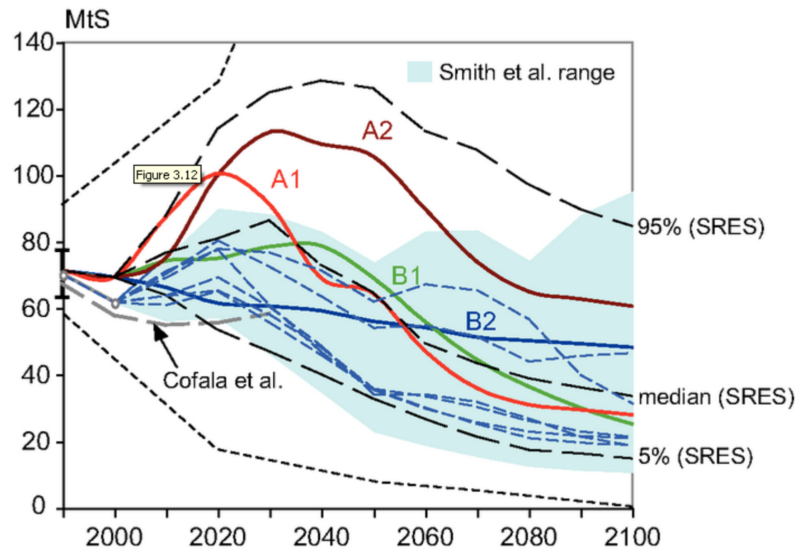

Figure 16-A.9.2 Sulfur Dioxide Emission Scenarios

Notes: Thick colored lines depict the four SRES marker scenarios and black dashed lines show the median, 5th, and 95th percentile of the frequency distribution for the full ensemble of 40 SRES scenarios. The blue area (and the thin dashed lines in blue) illustrates individual scenarios and the range of Smith et al. (2004). Dotted lines indicate the minimum and maximum of SO_2 emissions scenarios developed pre-SRES.
Source: IPCC (2007), AR4 WGIII 3.2, http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch3-ens3-2-2-4.html.

Although other approaches to decomposing the DICE exogenous forcing vector are possible, initial sensitivity analysis suggests that the differences among reasonable alternative approaches are likely to be minor. For example, adjusting the TAR aerosol projection above to assume that aerosols will be maintained at 2000 levels through 2100 reduces average SCC values (for 2010) by approximately 3 percent (or less than $2); assuming all aerosols are phased out by 2100 increases average 2010 SCC values by 6-7 percent (or $0.50-$3)–depending on the discount rate. These differences increase slightly for SCC values in later years but are still well within 10 percent of each other as far out as 2050.

Finally, as in PAGE, the EMF net land use CO_2 emissions are added to the fossil and industrial CO_2 emissions pathway.

16-A.9.2 Extrapolating Emissions Projections to 2300

To run each model through 2300 requires assumptions about GDP, population, greenhouse gas emissions, and radiative forcing trajectories after 2100, the last year for which these projections are available from the EMF-22 models. These inputs were extrapolated from 2100 to 2300 as follows:

1. Population growth rate declines linearly, reaching zero in the year 2200.
2. GDP/per capita growth rate declines linearly, reaching zero in the year 2300.
3. The decline in the fossil and industrial carbon intensity (CO_2/GDP) growth rate over 2090-2100 is maintained from 2100 through 2300.
4. Net land use CO_2 emissions decline linearly, reaching zero in the year 2200.
5. Non-CO_2 radiative forcing remains constant after 2100.

Long run stabilization of GDP per capita was viewed as a more realistic simplifying assumption than a linear or exponential extrapolation of the pre-2100 economic growth rate of each EMF scenario. This is based on the idea that increasing scarcity of natural resources and the degradation of environmental sinks available for assimilating pollution from economic production activities may eventually overtake the rate of technological progress. Thus, the overall rate of economic growth may slow over the very long run. The interagency group also considered allowing an exponential decline in the growth rate of GDP per capita. However, since this would require an additional assumption about how close to zero the growth rate would get by 2300, the group opted for the simpler and more transparent linear extrapolation to zero by 2300.

The population growth rate is also assumed to decline linearly, reaching zero by 2200. This assumption is reasonably consistent with the United Nations long run population forecast, which estimates global population to be fairly stable after 2150 in the medium scenario (UN 2004).[jj] The resulting range of EMF population trajectories (figure below) also encompass the UN medium scenario forecasts through 2300—global population of 8.5 billion by 2200, and 9 billion by 2300.

Maintaining the decline in the 2090-2100 carbon intensity growth rate (i.e., CO_2 per dollar of GDP) through 2300 assumes that technological improvements and innovations in the areas of energy efficiency and other carbon reducing technologies (possibly including currently unavailable methods) will continue to proceed at roughly the same pace that is projected to occur towards the end of the forecast period for each EMF scenario. This assumption implies that total cumulative emissions in 2300 will be between 5,000 and 12,000 GtC, which is within the range of the total potential global carbon stock estimated in the literature.

Net land use CO_2 emissions are expected to stabilize in the long run, so in the absence of any post 2100 projections, the group assumed a linear decline to zero by 2200. Given no a priori reasons for assuming a long run increase or decline in non-CO_2 radiative forcing, it is assumed to remain at the 2100 levels for each EMF scenario through 2300.

[jj] United Nations. 2004. *World Population to 2300*. http://www.un.org/esa/population/publications/longrange2/worldpop2300final.pdf

Figures below show the paths of global population, GDP, fossil and industrial CO_2 emissions, net land CO_2 emissions, non-CO_2 radiative forcing, and CO_2 intensity (fossil and industrial CO_2 emissions/GDP) resulting from these assumptions.

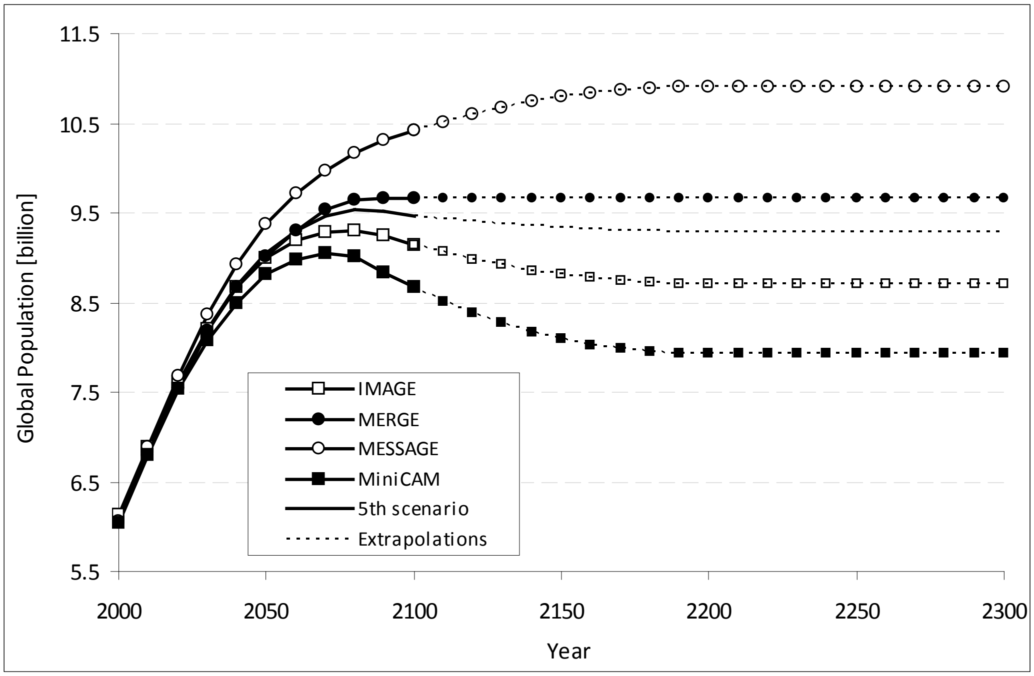

Figure 16-A.9.3 Global Population, 2000-2300 (Post-2100 extrapolations assume the population growth rate changes linearly to reach a zero growth rate by 2200.)

Note: In the fifth scenario, 2000-2100 population is equal to the average of the population under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

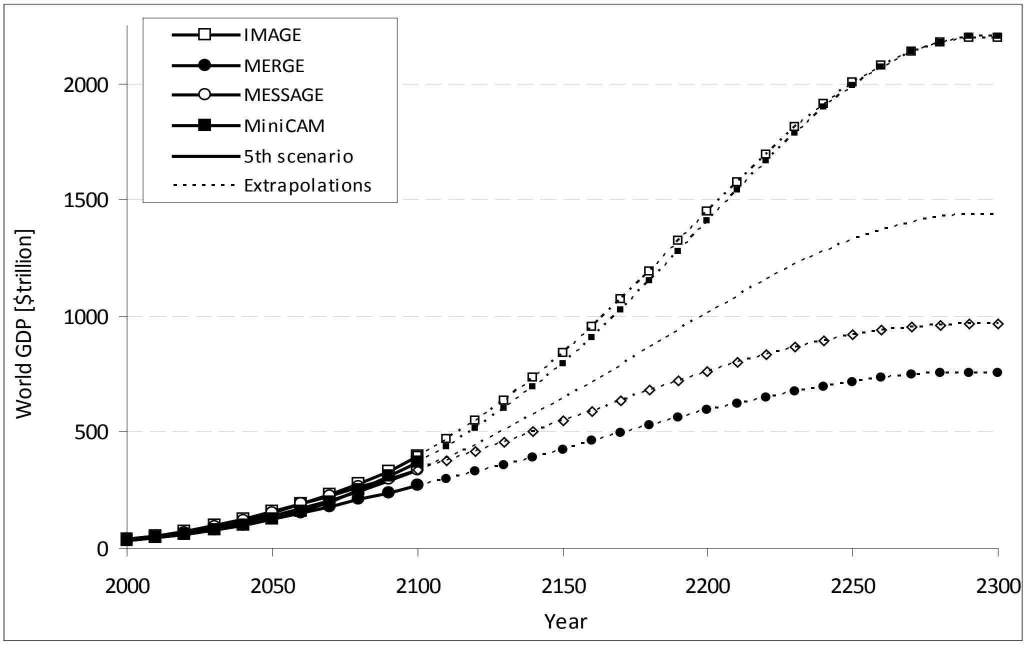

Figure 16-A.9.4 World GDP, 2000-2300 (Post-2100 extrapolations assume GDP per capita growth declines linearly, reaching zero in the year 2300)

Note: In the fifth scenario, 2000-2100 GDP is equal to the average of the GDP under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

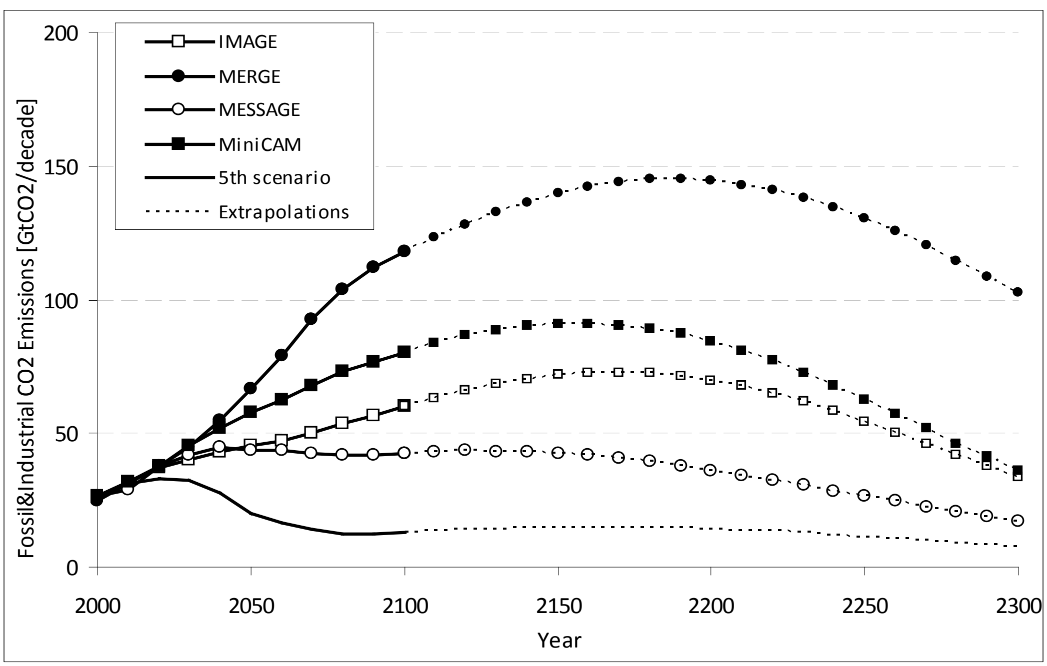

Figure 16-A.9.5 Global Fossil and Industrial CO_2 Emissions, 2000-2300 (Post-2100 extrapolations assume growth rate of CO_2 intensity (CO_2/GDP) over 2090-2100 is maintained through 2300)

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

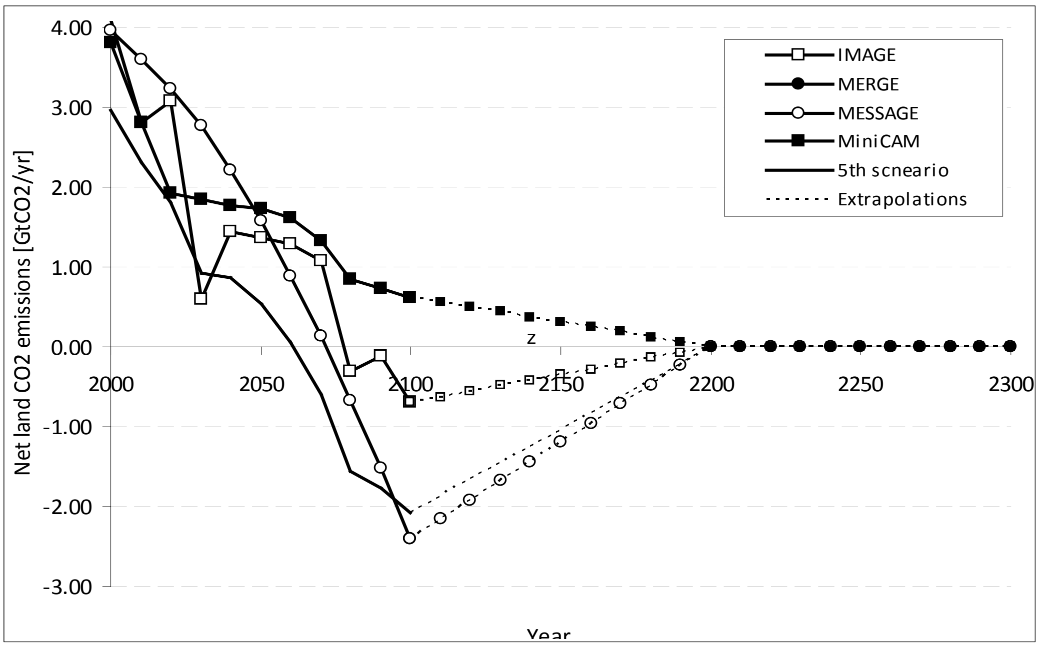

Figure 16-A.9.6 Global Net Land Use CO_2 Emissions, 2000-2300 (Post-2100 extrapolations assume emissions decline linearly, reaching zero in the year 2200)[kk]

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

[kk] MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (i.e., we add up the land use emissions from the other three models and divide by 4).

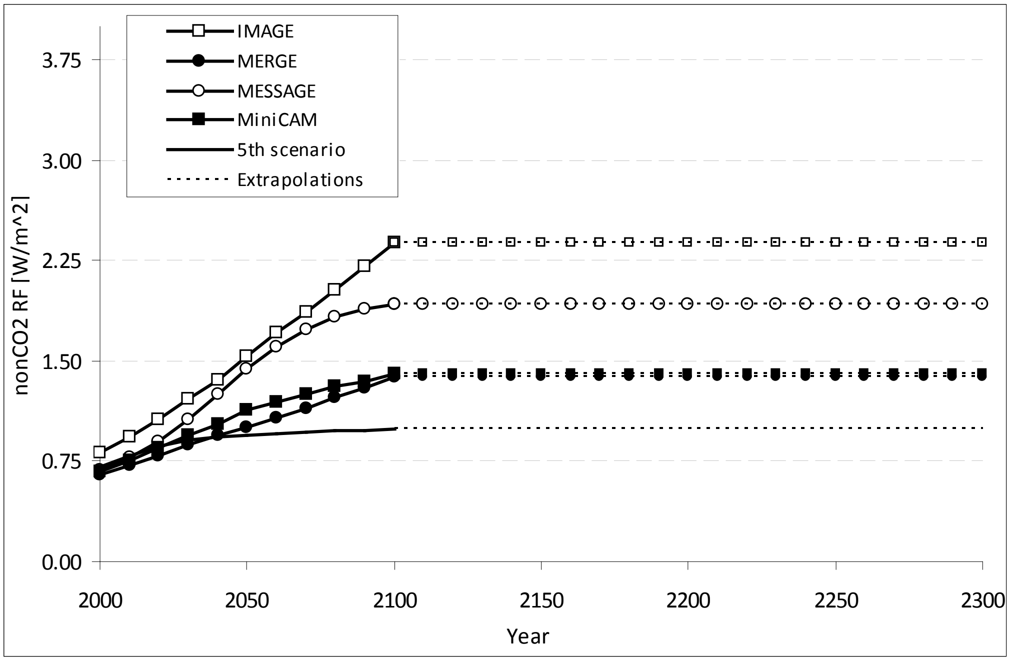

Figure 16-A.9.7 Global Non-CO_2 Radiative Forcing, 2000-2300 (Post-2100 extrapolations assume constant non-CO_2 radiative forcing after 2100)

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

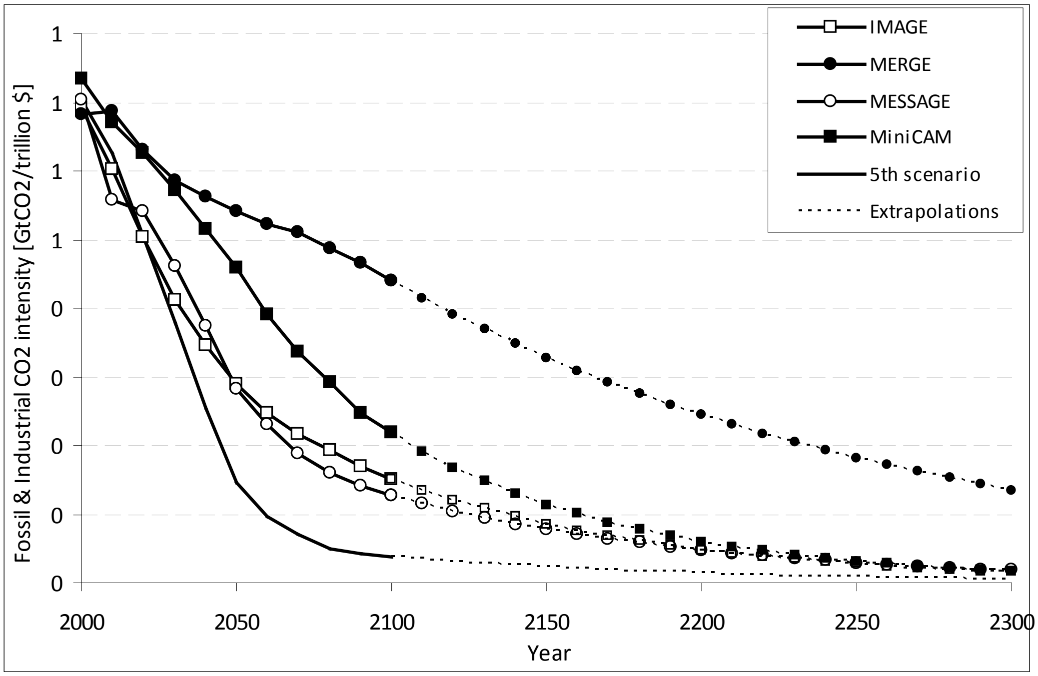

Figure 16-A.9.8 Global CO_2 Intensity (fossil & industrial CO_2 emissions/GDP), 2000-2300 (Post-2100 extrapolations assume decline in CO_2/GDP growth rate over 2090-2100 is maintained through 2300)

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

Table 16-A.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 16-A.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 16-A.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

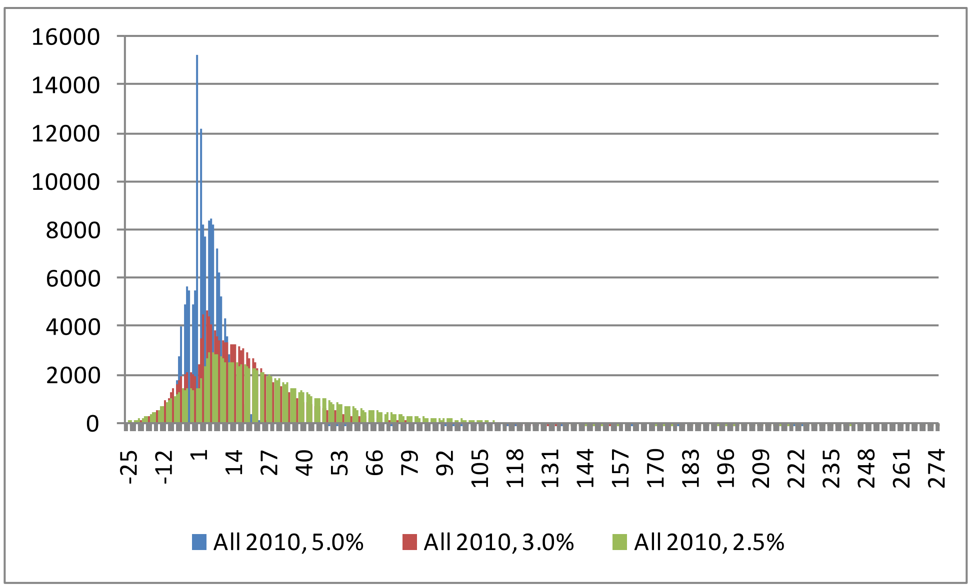

Figure 16-A.9.9 Histogram of Global SCC Estimates in 2010 (2007$/ton CO_2), by discount rate

* 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 16-A.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 17-A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

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APPENDIX 17-A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

17-A.1 INTRODUCTION

This appendix contains sections discussing the following topics:

- NIA-RIA Integrated Models
- XENERGY penetration curves used to analyze consumer rebates, including:
    - Background material,
    - DOE’s adjustment of these curves for this analysis, and
    - DOE’s new method for interpolating the curves
- Detailed tables of rebates offered for the considered products
- Background material on Federal and state tax credits for appliances

17-A.2 NIA-RIA INTEGRATED MODEL

For this analysis, DOE developed an integrated NIA-RIA[a] model approach that built on the NIA models discussed in Chapter 10 and documented in Appendix 10-A.The resulting NIA-RIA models, one for clothes dryers and one for room air conditioners, featured both the NIA analysis inputs and results and the RIA inputs with capability to generate results for each of the RIA policies. A separate module produced summaries of inputs for the rebate policy, generated their penetration curves (discussed in section 17-A.3.3 below), reported shipment and market share increase data by product class, and produced summary tables for the national energy savings and net present value results reported in chapter 17, sections 17.4 and 17.5. This module also generated tables of market share increases for each policy reported in section 17-A.4 of this Appendix.

[a] NIA = national impact analysis; RIA = regulatory impact analysis

17-A.3 CONSUMER REBATE POLICY MARKET PENETRATION CURVES

This section first discusses the theoretical basis for the market penetration curves that DOE used to analyze the Consumer Rebates policy. Next it discusses the adjustments it made to the maximum penetration rates. It then presents the method it developed to create interpolated penetration curves for each specific product class and efficiency level in the analysis. Examples of the resulting curves for the most common clothes dryer and room air-conditioner product classes are in chapter 17, section 17.3.2.1. The curves for the product classes in the remaining product classes are in section 17-A.3.4 below.

17-A.3.1 Introduction

XENERGY, Inc.[b], developed a re-parameterized, mixed-source information diffusion model to estimate market impacts induced by financial incentives for purchasing energy efficient appliances.[1] The basic premise of the mixed-source model is that information diffusion drives the adoption of technology.

Extensive economic literature describes the diffusion of new products as technologies evolve. Some research focuses primarily on developing analytical models of diffusion patterns applicable to individual consumers or to technologies from competing firms.[2, 3, 4] One study records researchers' attempts to investigate the factors that drive diffusion processes.[5] Because a new product generally has its own distinct characteristics, few studies have been able conclusively to conclusively develop a universally applicable model. Some key findings, however, generally are accepted in academia and industry.

One accepted finding is that, regardless of their economic benefits and technological merits, new technologies are unlikely to be adopted by all potential users. For many products, a ceiling must be placed on the adoption rate. A second conclusion is that not all adopters purchase new products at the same time: some act quickly after a new product is introduced; others wait for the product to mature. Third, diffusion processes can be characterized approximately by asymmetric S-curves that depict three stages of diffusion: starting, accelerating, and decreasing (as the adoption ceiling is approached).

A so-called epidemic model of diffusion is used widely in marketing and social studies. The epidemic model assumes that (1) all consumers place identical value on the benefits of a new product, and (2) the cost of a new product is constant or declines monotonically over time. What induces a consumer to purchase a new product is information about the availability and benefits of the product. In other words, information diffusion drives consumers' adoption of a new product.[3] The model incorporates information diffusion from both internal sources (spread by word of mouth from early adopters to prospective adopters) and external sources (the "announcement effect" produced by government agencies, institutions, or commercial

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[b] XENERGY is now owned by KEMA, Inc. (www.kema.com)

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 17-A.3.1). 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 17-A.3.1).

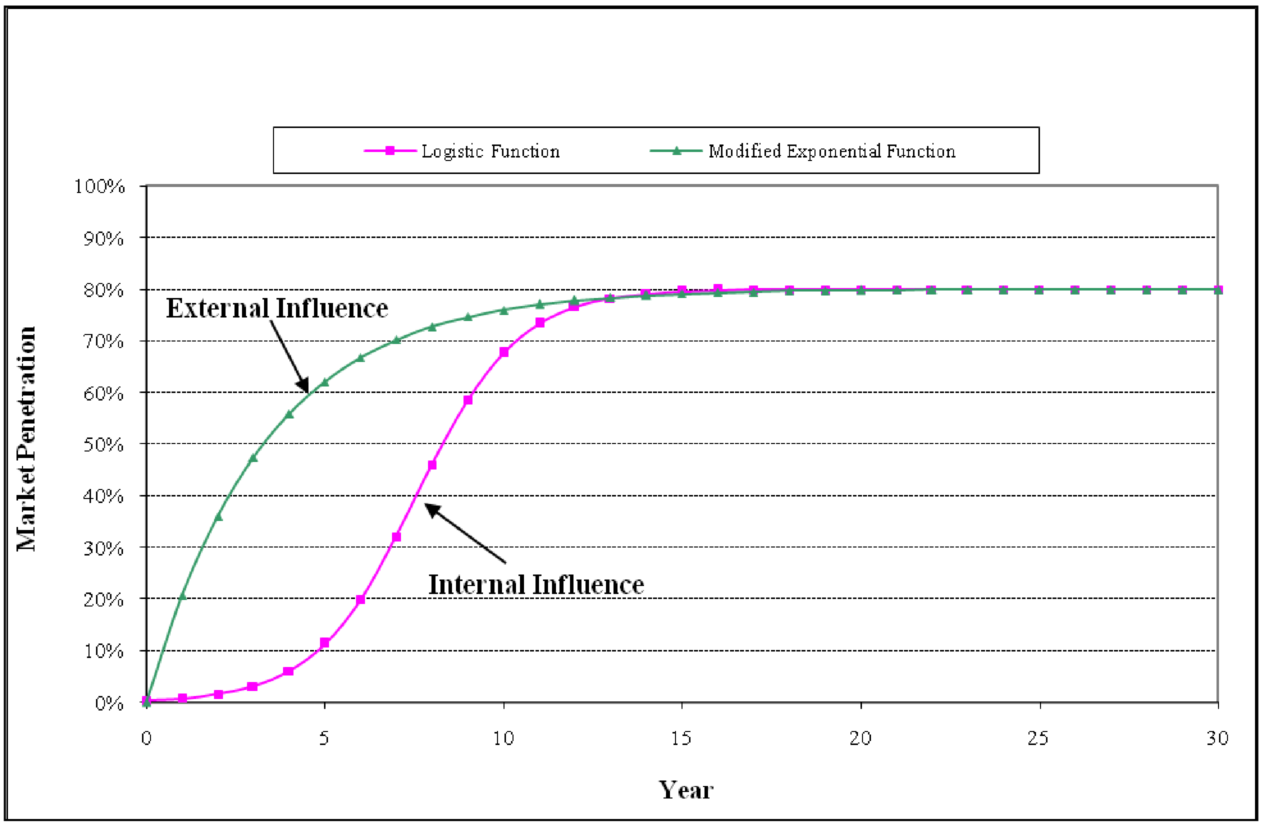

Figure 17-A.3.1 S-Curves Showing Effects of External and Internal Sources on Adoption of New Technologies

17-A.3.2 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.

17-A.3.3 Interpolation of Penetration Curves

As discussed above, the XENERGY penetration (implementation) curves followed a functional form to estimate the market implementation rate caused by energy efficiency measures such as consumer rebates.[c] The XENERGY report presents five reference market implementation curves that vary according to the level of market barriers to technology penetration.[1] Such curves have been used by DOE in the Regulatory Impact Analyses for rulemakings for appliance energy efficiency standards to estimate market share increases in response to rebate programs.[d] They provide a framework for evaluating technology penetration, yet require matching the studied market to the curve that best represents it. This approximate matching can introduce some inaccuracy to the analysis.

This section presents an alternative approach to such evaluation: a method to estimate market implementation rates more accurately by performing interpolations of the reference curves. The following describes the market implementation rate function and the reference curves, the method to calibrate the function to a given market, and the limitations of the method.

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[c] The RIA chapter refers to these curves as *penetration curves*. This section, in references to the original source, uses the term *implementation curve*.

[d] DOE has also used this method to estimate market share increases resulting from consumer tax credit and manufacturer tax credit programs, since the effects of tax credits on markets can be considered proportional to the rebate impacts.

17-A.3.3.1 Market Implementation Rate Function and Curves

The XENERGY curves employ the following functional form to estimate the percentage of the informed market[e] that will accept each energy-efficiency measure based on the participant's benefit/cost ratio:

$$\mathrm{imp(bc)} = \frac{\mathrm{max}}{\left(1 + \mathrm{e}^{-\ln\left(\frac{\mathrm{bc}}{4}\right)}\right) \cdot \left(1 + \mathrm{e}^{-\mathrm{fit} \cdot \ln(\mathrm{mid} \cdot \mathrm{bc})}\right)} \qquad [1]$$

where:

imp implementation rate
bc benefit/cost ratio
max maximum annual acceptance rate for the technology
mid inflection point of the curve
fit parameter that determines the general shape (slope) of the curve.

In recent efficiency standards rulemakings, DOE has been adopting a slightly different functional form of Equation [1], where the constant value 1/4 is replaced by a parameter *r*. By introducing this parameter in Equation [1] and rewriting it without the exponential and logarithmic operators, the market implementation rate of rebate programs can be evaluated using the following equation:

$$imp(bc) = \frac{max}{\left(1 + \frac{1}{r \cdot bc}\right) \cdot \left(1 + (mid \cdot bc)^{-fit}\right)} \qquad [2]$$

In XENERGY's report, Equation [1] is used to generate five primary (reference) curves. These curves produce initial theoretical results that are calibrated to actual measure implementation results associated with the first year of major utility energy efficiency programs. Different curves, generated using distinct values of the parameters *max*, *mid*, *fit* and *r*, reflect different levels of market barriers for different efficiency measures.

DOE has been using similar curves in the appliance efficiency standards rulemaking. The curves characterize market implementation rates for five reference levels of market barriers: *No Barriers*, *Low Barriers*, *Moderate Barriers*, *High Barriers,* and *Extremely High Barriers*. Figure 17-A.3.2 presents the five reference curves.

[e] The *informed market* refers to the portion of the market aware and informed about the energy efficiency measure.

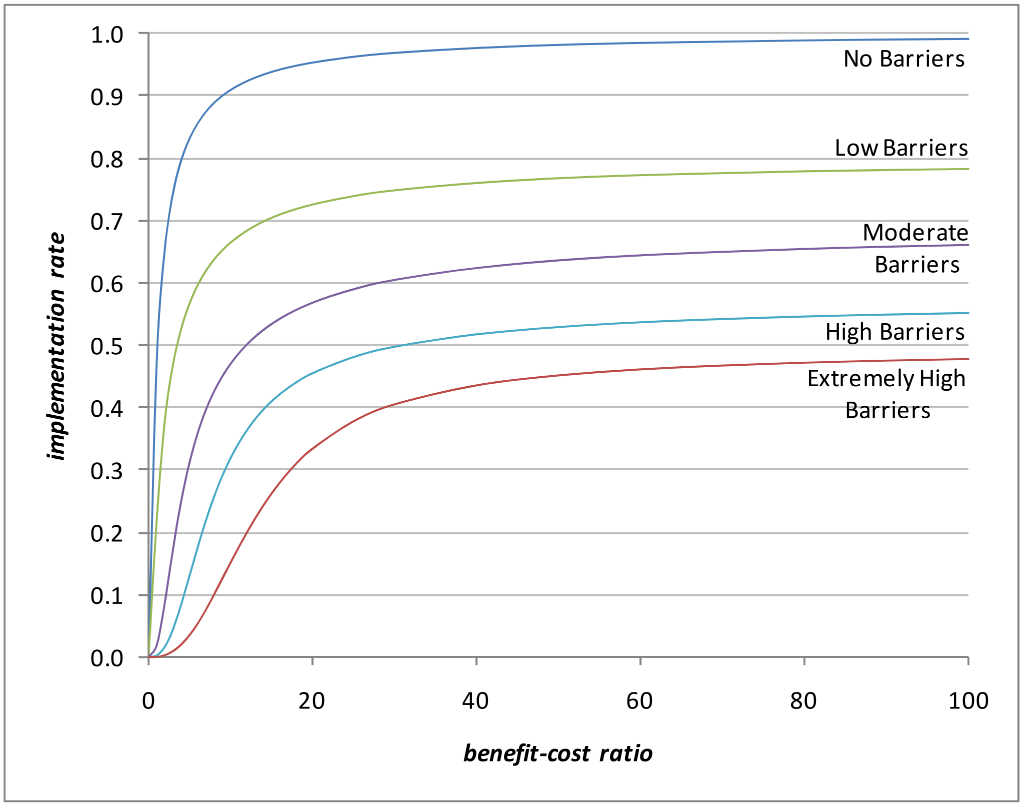

Figure 17-A.3.2 Market Implementation Curves for Five Market Barriers Reference Levels

The reference curves build on the following functional form:

$$imp(b_d, bc) = \frac{max_d(b_d)}{(1 + r_d(b_d) \cdot bc) \cdot (1 + (mid_d(b_d) \cdot bc)^{-fit_d(b_d)})} \qquad [3]$$

where:

b_d = [barrier type]

and $max_d(b_d)$, $mid_d(b_d)$, $fit_d(b_d)$ and $r_d(b_d)$ are as shown in Table 17-A.3.1. The four parameters are also presented in Figure 17-A.3.3 as discrete-value functions.

Table 17-A.3.1 Parameter Values for Reference Curves

	Market Barriers Level				
	No Barriers	*Low Barriers*	*Moderate Barriers*	*High Barriers*	*Extremely High Barriers*
max_d	1.0	0.8	0.7[f]	0.6[g]	0.5
mid_d	10	2	0.3	0.1	0.04
fit_d	1	1.7	1.7	1.7	1.7
r_d	1	0.5	0.25	0.25	0.25

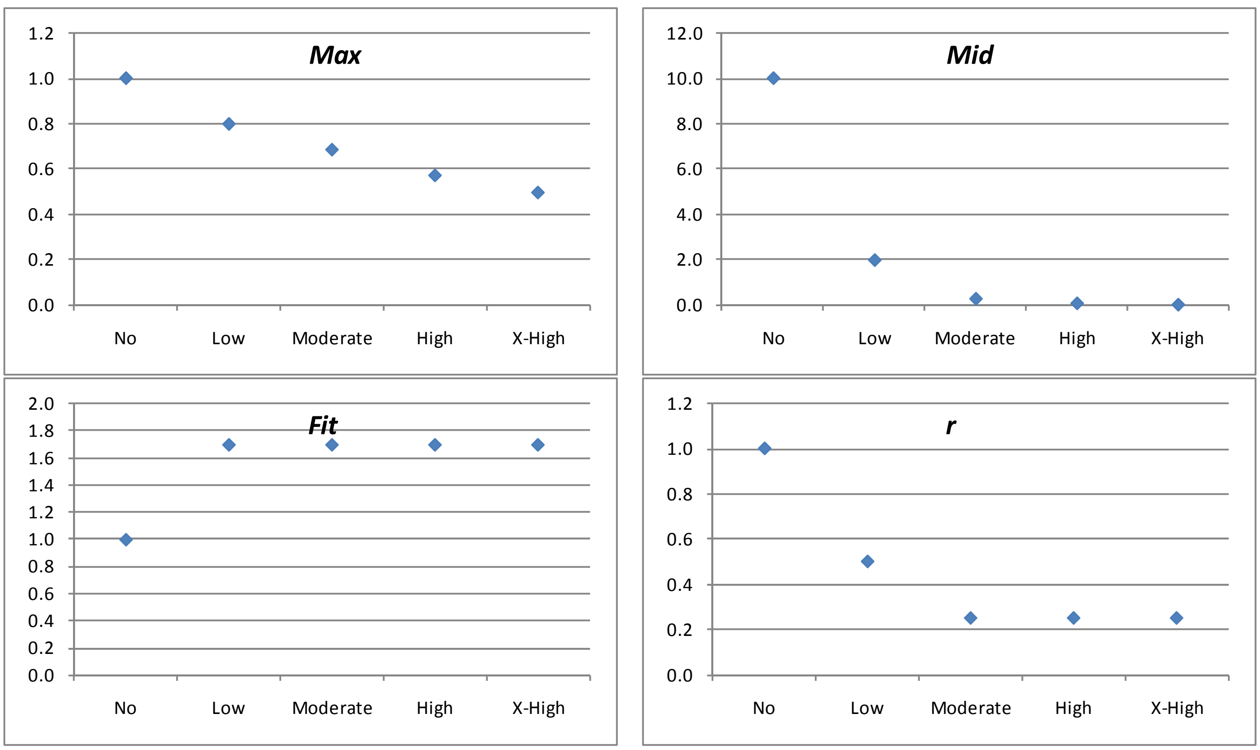

Figure 17-A.3.3 Discrete-value Functions of Parameters Driving Implementation Curve Shape

To estimate the barrier level of a given market, in the past DOE sought the reference curve that most closely represented the pair (base case market share, benefit/cost ratio) of the

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[f] DOE adopted these parameters for the Refrigeration Products RIA, as discussed in section 17-A.3.2, after consultation with the implementation curve authors. For the RIAs for the rulemakings for Cooking Products and Commercial Clothes Washers the *max* value adopted for the *moderate barriers* and *high barriers* market barrier levels was 0.5. RIAs developed during prior rulemakings for Furnaces and Boilers, Commercial Unitary Air Conditioners and Heat Pumps, and Distribution Transformers used a *max* value of 0.8 for all but the *no barriers* curve, based on the original penetration curve values from XENERGY's report.

technology corresponding to the mandatory standard's chosen efficiency level. It then estimated the effect of a rebate program on the technology market penetration using that curve. For this estimation, DOE calculated the increase in market share that an increase in the benefit/cost ratio – driven by a rebate program – would produce. It then assumed that the relative increase in market share calculated from the reference curve was a *proxy* to the effects of a rebate program on the studied market.

17-A.3.3.2 Calibrating the Market Implementation Rate Function

The procedure previously described lacks accuracy when the studied market penetration point based on the actual benefit/cost ratio does not lie close to one of the reference curves. This section presents an interpolation approach to eliminate such inaccuracy. The interpolation process provides intermediate, continuous values for the four parameters (*max*, *mid*, *fit* and *r*) driving the market implementation curves. These intermediate values are obtained after linear interpolation of their corresponding reference values.

The four parameters (*max*, *mid*, *fit* and *r*) were previously defined as discrete-value functions ($max_d(b_d)$, $mid_d(b_d)$, $fit_d(b_d)$ and $r_d(b_d)$) of the market barriers level (Table 17-A.3.1, Figure 17-A.3.2). To facilitate the interpolation, it is necessary to transform the four discrete-value functions into continuous functions, the latter being thus capable of associating each of the four parameters to a real number denoting the market barrier level ($b_c \in \mathbf{R}$). A numeric, continuous scale for the market barriers level is proposed, ranging from 0 to 5 ($b_c \in [0,5]$). The correspondence between the discrete-values of market barrier levels and b_c are shown in Table 17-A.3.2.

Based on the continuous-value market barriers level, the parameters *max*, *mid*, *fit* and *r* are interpolated using the following functions:

$$max_c(b_c) = \propto_{max}(b_c) \cdot b_c + \beta_{max}(b_c) \qquad [4]$$

$$mid_c(b_c) = \propto_{mid}(b_c) \cdot b_c + \beta_{mid}(b_c) \qquad [5]$$

$$fit_c(b_c) = \propto_{fit}(b_c) \cdot b_c + \beta_{fit}(b_c) \qquad [6]$$

$$r_c(b_c) = \propto_{r}(b_c) \cdot b_c + \beta_{r}(b_c) \qquad [7]$$

where $\propto_x(b_c)$ and $\beta_x(b_c)$ are shown in Table 17-A.3.3.

The continuous-value functions defined for *max*, *mid*, *fit* and *r*, as expressed by Equations [4]-[7], are then substituted in Equation [3], leading to the following functional form for the market implementation rate of rebate programs:

$$imp(b_c, bc) = \frac{max_c(b_c)}{(1 + r_c(b_c) \cdot bc) \cdot (1 + (mid_c(b_c) \cdot bc)^{-fit_c(b_c)})} \qquad [8]$$

Table 17-A.3.2 Correspondence between Discrete and Continuous Values of Market Barrier Levels

	Market Barriers Level				
	No Barriers	*Low Barriers*	*Moderate Barriers*	*High Barriers*	*Extremely High Barriers*
b_c	0.0	1.0	2.5	4.0	5.0

Table 17-A.3.3 Coefficients of Continuous-value Functions of *max*, *mid*, *fit* and *r*

	Market Barriers Level Intervals			
	No-Low Barriers $b \in [0,1]$	*Low-Moderate Barriers* $b \in [1,2.5]$	*Moderate-High Barriers* $b \in [2.5,4]$	*High-Extremely High Barriers* $b \in [4,5]$
Max				
$\propto_{max}(b_c)$	-0.200	-0.075	-0.075	-0.075
$\beta_{max}(b_c)$	1.000	0.875	0.875	0.875
Mid				
$\propto_{mid}(b_c)$	-8.000	-1.133	-0.133	-0.060
$\beta_{mid}(b_c)$	10.000	3.133	0.633	0.340
Fit				
$\propto_{fit}(b_c)$	0.700	0.000	0.000	0.000
$\beta_{fit}(b_c)$	1.000	1.700	1.700	1.700
R				
$\propto_{r}(b_c)$	-0.500	-0.167	0.000	0.000
$\beta_{r}(b_c)$	1.000	0.667	0.250	0.250

Figure 17-A.3.4 presents the four continuous-value functions.

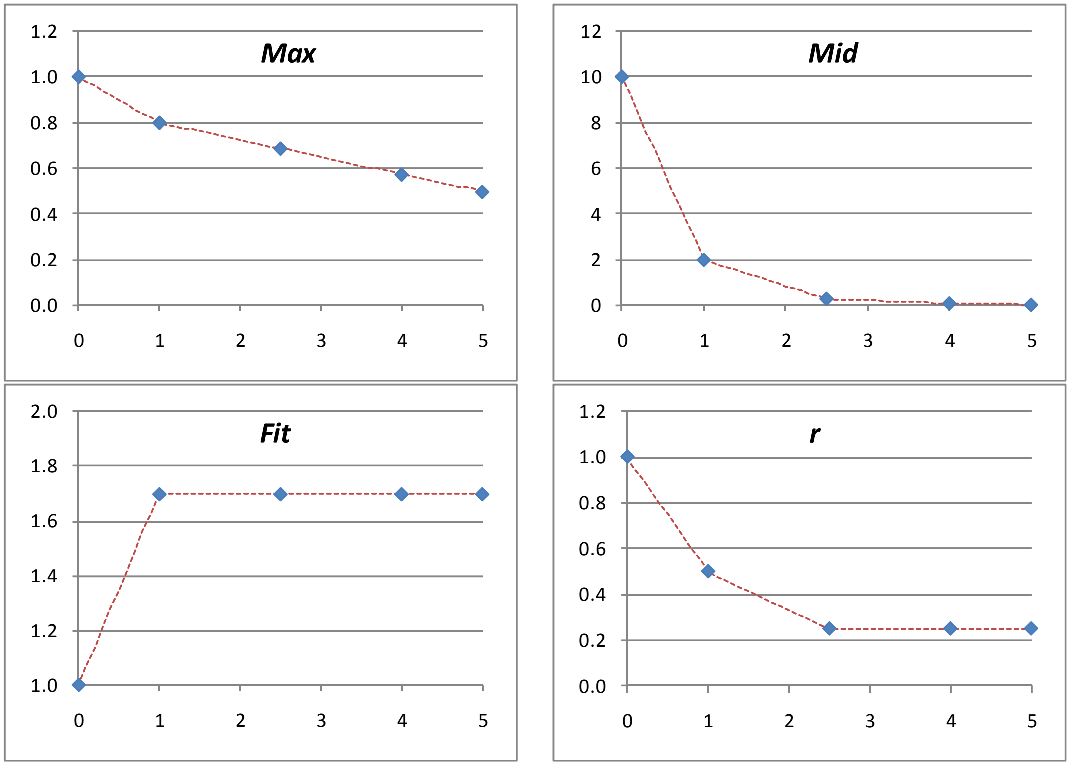

Figure 17-A.3.4 Continuous-value Functions of Parameters Driving Implementation Curve Shape

Hence, estimating the market effects of a rebate program relies on finding the interpolated implementation curve that best represents the studied market. In other words, it involves finding b_c such that the pair $(imp(b_c, bc), bc)$ equals the pair (base case market share, benefit/cost ratio) of the technology corresponding to the mandatory standard's efficiency level. Once the appropriate value of b_c is found (e.g. $b_c = \mathrm{b}_\mathrm{c}^*$), the market penetration of the technology under a rebate program can be calculated by the following equation:

$$imp(\mathrm{b}_\mathrm{c}^*, \mathrm{bc}^*) = \frac{max_c(\mathrm{b}_\mathrm{c}^*)}{(1 + r_c(\mathrm{b}_\mathrm{c}^*) \cdot \mathrm{bc}^*) \cdot (1 + (mid_c(\mathrm{b}_\mathrm{c}^*) \cdot \mathrm{bc}^*)^{-fit_c(\mathrm{b}_\mathrm{c}^*)})} \qquad [9]$$

where:

b_c^* market barriers level corresponding to the studied market
bc^* benefit/cost ratio with rebate.

17-A.3.3.3 Limits to the Interpolation Approach

The approach presented above increases the accuracy of the estimate of the market implementation rate resulting from a rebate program. Consequently, it improves the analysis of the market effects of rebate programs. However, whereas it is feasible to develop interpolated implementation curves between the reference ones, there is no empirical support to extrapolate them beyond the *No Barriers* and the *Extremely High Barriers* curves. In fact, the theoretical boundaries for the market barriers level would be:

(a) Zero Barriers (b_0): With the assumption of the rational consumer, a tiny increase in the benefit/cost ratio of a technology with that ratio greater than 1 would be sufficient to make the technology widely adopted.[g] This would result in the following implementation rate function:

$$imp(b_0, bc) = \begin{cases} 0, & bc < 1 \\ 1, & bc > 1 \end{cases}$$

(b) Infinite Barriers (b_∞): In this case, even an extremely high benefit/cost ratio would not be sufficient to cause the market to adopt a technology. This would result in the following implementation rate function:

$$imp(b_\infty, bc) = 0, \forall bc$$

However, notwithstanding the existence of such theoretical boundaries, the analysis of market implementation rates in cases of markets where the base case market share is either higher than the market share in the *No Barriers* curve (for the corresponding benefit/cost ratio), or lower than the one in the *Extremely High Barriers* curve (idem), should follow the former analysis approach (as described at the end of section 17-A.3.3.2). It should rely, respectively, on the *No Barriers* or the *Extremely High Barriers* curves to estimate a relative market increase due to the rebate program.

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[g] When the benefit/cost ratio is 1 the participant is indifferent to adopting the technology or not, and the implementation rate, in this case, would be undetermined.

17-A.4 MARKET SHARE ANNUAL INCREASES BY POLICY

This section presents the annual increases in market shares for clothes dryers and room air conditioners due to the non-regulatory policies. DOE used these market share increases as inputs to the NIA-RIA spreadsheet models.

17-A.4.1 Market Share Increases for Residential Clothes Dryers

For the consumer rebate, consumer tax credit, and manufacturer tax credit policies, Table 17-A.4.1 shows the annual increases in market shares for vented electric standard and vented gas clothes dryers meeting target efficiency levels.

Table 17-A.4.1 Annual Increases in Market Shares Attributable to Consumer Rebates, Consumer Tax Credits, and Manufacturer Tax Credits Policies for Clothes Dryers

Year	Consumer Rebates		Consumer Tax Credits		Manufacturer Tax Credits	
	Vented Electric Standard %	Vented Gas %	Vented Electric Standard %	Vented Gas %	Vented Electric Standard %	Vented Gas %
2014	50.7	50.9	30.4	30.5	15.2	15.3
2015	50.7	50.9	30.4	30.5	15.2	15.3
2016	50.7	50.9	30.4	30.5	15.2	15.3
2017	50.7	50.9	30.4	30.5	15.2	15.3
2018	50.7	50.9	30.4	30.5	15.2	15.3
2019	50.7	50.9	30.4	30.5	15.2	15.3
2020	50.7	50.9	30.4	30.5	15.2	15.3
2021	50.7	50.9	30.4	30.5	15.2	15.3
2022	50.7	50.9	30.4	30.5	15.2	15.3
2023	50.7	50.9	30.4	30.5	15.2	15.3
2024	50.7	50.9	30.4	30.5	15.2	15.3
2025	50.7	50.9	30.4	30.5	15.2	15.3
2026	50.7	50.9	30.4	30.5	15.2	15.3
2027	50.7	50.9	30.4	30.5	15.2	15.3
2028	50.7	50.9	30.4	30.5	15.2	15.3
2029	50.7	50.9	30.4	30.5	15.2	15.3
2030	50.7	50.9	30.4	30.5	15.2	15.3
2031	50.7	50.9	30.4	30.5	15.2	15.3
2032	50.7	50.9	30.4	30.5	15.2	15.3
2033	50.7	50.9	30.4	30.5	15.2	15.3
2034	50.7	50.9	30.4	30.5	15.2	15.3
2035	50.7	50.9	30.4	30.5	15.2	15.3
2036	50.7	50.9	30.4	30.5	15.2	15.3
2037	50.7	50.9	30.4	30.5	15.2	15.3
2038	50.7	50.9	30.4	30.5	15.2	15.3
2039	50.7	50.9	30.4	30.5	15.2	15.3
2040	50.7	50.9	30.4	30.5	15.2	15.3
2041	50.7	50.9	30.4	30.5	15.2	15.3
2042	50.7	50.9	30.4	30.5	15.2	15.3
2043	50.7	50.9	30.4	30.5	15.2	15.3

For the voluntary efficiency targets, early replacement, and bulk government purchases policies, Table 17-A.4.2 shows the annual increases in market shares for electric standard and vented gas clothes dryers meeting target efficiency levels.

Table 17-A.4.2 Annual Increases in Market Shares Attributable to Voluntary Energy Efficiency Targets, Early Replacement, and Bulk Government Purchases Policies for Clothes Dryers

Year	Voluntary Energy Efficiency Targets		Early Replacement		Bulk Government Purchases	
	Vented Electric Standard %	Vented Gas %	Vented Electric Standard %	Vented Gas %	Vented Electric Standard %	Vented Gas %
2014	0.0	0.0	2.4	1.9	0.0	0.0
2015	0.5	0.5	2.3	1.9	0.0	0.0
2016	5.0	5.0	2.3	1.9	0.0	0.0
2017	8.0	8.0	2.3	1.9	0.1	0.1
2018	8.8	8.8	2.3	1.9	0.1	0.1
2019	9.8	9.8	2.3	1.8	0.1	0.1
2020	9.8	9.8	2.1	1.7	0.1	0.1
2021	9.8	9.8	2.0	1.6	0.1	0.1
2022	9.9	9.9	1.9	1.5	0.1	0.1
2023	9.9	9.9	1.7	1.4	0.2	0.1
2024	9.9	9.9	1.6	1.2	0.2	0.1
2025	9.9	9.9	1.4	1.1	0.2	0.1
2026	10.0	10.0	1.3	1.0	0.2	0.1
2027	10.0	10.0	1.2	0.9	0.2	0.1
2028	10.0	10.0	1.0	0.8	0.2	0.1
2029	10.0	10.0	0.9	0.7	0.2	0.1
2030	10.2	10.2	0.8	0.7	0.2	0.1
2031	10.4	10.4	0.7	0.6	0.2	0.1
2032	10.6	10.6	0.6	0.5	0.2	0.1
2033	10.8	10.8	0.6	0.4	0.2	0.1
2034	11.0	11.0	0.5	0.4	0.2	0.1
2035	11.2	11.2	0.4	0.3	0.2	0.1
2036	11.4	11.4	0.4	0.3	0.2	0.1
2037	11.6	11.6	0.3	0.3	0.2	0.1
2038	11.8	11.8	0.3	0.2	0.2	0.1
2039	12.0	12.0	0.2	0.2	0.2	0.1
2040	12.2	12.2	0.2	0.2	0.2	0.1
2041	12.4	12.4	0.2	0.1	0.2	0.1
2042	12.6	12.6	0.2	0.1	0.2	0.1
2043	12.8	12.8	0.1	0.1	0.2	0.1

17-A.4.2 Market Share Increases for Room Air Conditioners

For the consumer rebate, consumer tax credit, and manufacturer tax credit policies, Table 17-A.4.3 shows the annual increases in market shares for room air conditioners meeting target efficiency levels.

Table 17-A.4.3 Annual Increases in Market Shares Attributable to Consumer Rebates, Consumer Tax Credits, and Manufacturer Tax Credits Policies for Room Air Conditioners

Year	Consumer Rebates		Consumer Tax Credits		Manufacturer Tax Credits	
	Vented Electric Standard %	Vented Gas %	Vented Electric Standard %	Vented Gas %	Vented Electric Standard %	Vented Gas %
2014	1.4	1.2	0.8	0.7	0.4	0.4
2015	1.4	1.2	0.8	0.7	0.4	0.4
2016	1.4	1.2	0.8	0.7	0.4	0.4
2017	1.4	1.2	0.8	0.7	0.4	0.4
2018	1.4	1.2	0.8	0.7	0.4	0.4
2019	1.4	1.2	0.8	0.7	0.4	0.4
2020	1.4	1.2	0.8	0.7	0.4	0.4
2021	1.4	1.2	0.8	0.7	0.4	0.4
2022	1.4	1.2	0.8	0.7	0.4	0.4
2023	1.4	1.2	0.8	0.7	0.4	0.4
2024	1.4	1.2	0.8	0.7	0.4	0.4
2025	1.4	1.2	0.8	0.7	0.4	0.4
2026	1.4	1.2	0.8	0.7	0.4	0.4
2027	1.4	1.2	0.8	0.7	0.4	0.4
2028	1.4	1.2	0.8	0.7	0.4	0.4
2029	1.4	1.2	0.8	0.7	0.4	0.4
2030	1.4	1.2	0.8	0.7	0.4	0.4
2031	1.4	1.2	0.8	0.7	0.4	0.4
2032	1.4	1.2	0.8	0.7	0.4	0.4
2033	1.4	1.2	0.8	0.7	0.4	0.4
2034	1.4	1.2	0.8	0.7	0.4	0.4
2035	1.4	1.2	0.8	0.7	0.4	0.4
2036	1.4	1.2	0.8	0.7	0.4	0.4
2037	1.4	1.2	0.8	0.7	0.4	0.4
2038	1.4	1.2	0.8	0.7	0.4	0.4
2039	1.4	1.2	0.8	0.7	0.4	0.4
2040	1.4	1.2	0.8	0.7	0.4	0.4
2041	1.4	1.2	0.8	0.7	0.4	0.4
2042	1.4	1.2	0.8	0.7	0.4	0.4
2043	1.4	1.2	0.8	0.7	0.4	0.4

For the voluntary efficiency targets, early replacement, and bulk government purchases policies, Table 17-A.4.4 shows the annual increases in market shares for room air conditioners meeting target efficiency levels.

Table 17-A.4.4 Annual Increases in Market Shares Attributable to Voluntary Energy Efficiency Targets, Early Replacement, and Bulk Government Purchases Policies for Room Air Conditioners

Year	Voluntary Energy Efficiency Targets		Early Replacement		Bulk Government Purchases	
	Vented Electric Standard %	Vented Gas %	Vented Electric Standard %	Vented Gas %	Vented Electric Standard %	Vented Gas %
2014	12.6	12.6	3.0	2.9	0.0	0.0
2015	12.8	12.8	3.3	3.2	0.1	0.1
2016	13.0	13.0	3.4	3.3	0.1	0.1
2017	13.2	13.2	2.9	2.8	0.2	0.2
2018	13.4	13.4	2.6	2.5	0.2	0.2
2019	13.6	13.6	2.3	2.2	0.3	0.3
2020	13.8	13.8	2.0	1.9	0.3	0.3
2021	14.0	14.0	1.7	1.7	0.3	0.3
2022	14.2	14.2	1.5	1.5	0.4	0.4
2023	14.4	14.4	1.3	1.3	0.4	0.4
2024	14.6	14.6	1.2	1.1	0.4	0.4
2025	14.8	14.8	1.0	1.0	0.4	0.4
2026	15.0	15.0	0.9	0.9	0.4	0.4
2027	15.3	15.3	0.8	0.8	0.4	0.4
2028	15.5	15.5	0.7	0.7	0.4	0.4
2029	15.7	15.7	0.6	0.6	0.4	0.4
2030	16.0	16.0	0.5	0.4	0.4	0.4
2031	16.0	16.0	0.4	0.3	0.4	0.4
2032	16.0	16.0	0.4	0.2	0.4	0.4
2033	16.0	16.0	0.3	0.1	0.4	0.4
2034	16.0	16.0	0.3	0.1	0.4	0.4
2035	16.0	16.0	0.2	0.0	0.4	0.4
2036	16.0	16.0	0.2	0.0	0.4	0.4
2037	16.0	16.0	0.1	0.0	0.4	0.4
2038	16.0	16.0	0.1	0.0	0.4	0.4
2039	16.0	16.0	0.1	0.0	0.4	0.4
2040	16.0	16.0	0.1	0.0	0.4	0.4
2041	16.0	16.0	0.0	0.0	0.4	0.4
2042	16.0	16.0	0.0	0.0	0.4	0.4
2043	16.0	16.0	0.0	0.0	0.4	0.4

17-A.5 UTILITY REBATE PROGRAMS

This section presents information on rebate programs in effect nationwide for clothes dryers and room air conditioners. The tables organize the data for the rebates offered for these products.

17-A.5.1 Rebate Programs for Residential Clothes Dryers

DOE found 16 organizations, comprising electric utilities and municipal and regional agencies, that have rebate programs for gas clothes dryers. The organizations offer 16 rebates for models that meet various efficiency criteria. Table 17-A.5.1 provides the organizations' names, states, rebate amounts, whether the rebate applies to standard-size or compact units, efficiency levels, and program websites. If there is more than one entry for an organization, that organization offers different rebate amounts depending on efficiency level. The average rebate amounts for gas clothes dryers, given in 2009$ at the end of the table, are simple averages of the individual amounts (rather than being population-weighted).

For electric clothes dryers, DOE found four rebate programs offered by three organizations. For electric combination washer-dryers, DOE found only one rebate program. Tables 17-A.5.2 and 17-A.5.3 show the rebate programs for the electric clothes dryer product classes.

Table 17-A.5.1 Rebates for Gas Clothes Dryers

Utility	State	Rebate Amount 2009$	Website
Alabama Gas Corporation	AL	100	http://www.alagasco.com/Residential/Rebates-and-Offers/Natural-Gas-Dryer-Offer-583.html
Southwest Gas Corp.	AZ	30	http://www.conservationrebates.com/programs/swg/SWG_AZ_Res.aspx
City of Lompoc Utilities	CA	100	http://www.cityoflompoc.com/utilities/conservation/
Black Hills Energy	CO	30	http://www.blackhillsenergy.com/services/programs/builders-heateff-co.php#appliance
Florida Public Utilities	FL	100	http://www.fpuc.com/Conservation/rebate/rebate_gas_rebates.asp
Gainesville Regional Utilities	FL	75	http://www.gru.com/YourHome/Conservation/Energy/Rebates/rangeDryer.jsp
Florida City Gas, Central FL Gas, TECO Peoples Gas	FL	100	http://www.floridacitygas.com/UseNaturalGas/RebatesandPromotions.aspx
Florida City Gas, Central FL Gas, TECO Peoples Gas	FL	100	http://www.getgasfl.com/rebates/TECO.aspx
Town of Smyrna	GA	50	http://www.townofsmyrna.org/utilities/pdf/Natural-Gas-System%20-Rebates.pdf
Sycamore Gas	IN	100	http://www.sycamoregas.com/Documents/SG-Rebate-Letter-Form.pdf
Sycamore Gas	IN	200	http://www.sycamoregas.com/Documents/SG-Rebate-Letter-Form.pdf
Lawrenceburg Gas	IN	100	http://www.lawrenceburggasco.com/Documents/59.pdf
Lawrenceburg Gas	IN	200	http://www.lawrenceburggasco.com/Documents/59.pdf
Southwest Gas Corporation	NV	30	http://www.conservationrebates.com/programs/swg/SWG_NV_Res.aspx
CPS Energy	TX	100	http://www.cpsenergy.com/Residential/Rebates/Natural_Gas_Rebates/index.asp
Questar Gas	UT	30	http://www.thermwise.com/home/ApplianceRebates.html
Burlington Electric Company	VT	100	https://www.burlingtonelectric.com/page.php?pid=54&name=owner_occupied_homes
Average (2009$)		**$90.88**	

Table 17-A.5.2 Rebates for Electric Clothes Dryers

Utility	State	Rebate Amount 2009$	Website
Morgan County REA	CO	50	http://www.mcrea.org/miscellaneous/pdf/APPLIANCE.pdf
Muscatine Power and Water	IA	25	http://www.mpw.org/residential_rebates.aspx
Allegheny Power	MD	25	http://www.nxtbook.com/nxtbooks/garrisonhughes/empowermaryland2010/#/6
Allegheny Power	PA	25	http://www.alleghenypower.com/EngConserv/PA/WattWatchers/RebateCD.asp
Average (2009$)		**$31.25**	

Table 17-A.5.3 Rebates for Electric Combination Washer-Dryers

Utility	State	Rebate Amount 2009$	Website
Morgan County REA	CO	100	http://www.mcrea.org/miscellaneous/pdf/APPLIANCE.pdf
Average (2009$)		**$100.00**	

17-A.5.2 Rebate Programs for Room Air Conditioners

DOE found 61 organizations, comprising electric utilities and municipal and regional agencies that offered 62 rebate programs for room air conditioners. The organizations offer rebates for units that meet a range of efficiency criteria. Table 17-A.4.4 lists the organizations' names, states, rebate amounts, efficiency levels, and program websites. If there is more than one entry for an organization, that organization offers different rebates based on efficiency level. The average rebate amounts, given in 2009$ at the end of the table, are simple averages of the individual amounts (rather than being population-weighted). The table also shows the adjusted rebate amount for room air conditioners, as discussed in chapter 17, section 17.3.2.2.

Table 17-A.5.4 Rebates for Room Air Conditioners

Utility or Agency	State	Rebate Amount 2009$	Efficiency Level	Website
LADWP	CA	50	E*	http://www.ladwp.com/ladwp/cms/ladwp000478.jsp
PG&E	CA	50	E*	http://www.pge.com/myhome/saveenergymoney/rebates/appliance/clothes/index.shtml
SCE	CA	50	E*	http://www.sce.com/residential/rebates-savings/appliance/fridge-freezer-recycling.htm
SDG&E	CA	50	E*	http://www.sdge.com/residential/centralFurnace.shtml
Anaheim Public Utilities	CA	50	E*	http://www.anaheim.net/utilities/adv_svc_prog/nrg_star/flyer.pdf
Burbank Water & Power	CA	75	E*	http://www.burbankwaterandpower.com/download/Home-Rewards-Rebate-Form-Web.p
Burbank Water & Power	CA	50	E*	http://www.burbankwaterandpower.com/download/Home-Rewards-Rebate-Form-Web.p
Glendale Water and Power	CA	50	E*	http://www.glendalewaterandpower.com/save_money/residential/sh_energy_saving_reba
Glendale Water and Power	CA	60	E*	http://www.glendalewaterandpower.com/save_money/residential/sh_energy_saving_reba
IID Energy	CA	50	E*	http://www.iid.com/Media/rewards_instruct_residential10_Eng.pdf
Modesto Irrigation District	CA	50	E*	http://www.mid.org/rebates/pkts/homeAppliance.pdf
Pacific Power	CA	30	E*	http://www.homeenergysavings.net/Downloads/CA_ApplianceForm2010a.pdf
Riverside Public Utilities	CA	50	E*	http://www.riversideca.gov/utilities/resi-energystar.asp
Silicon Valley Power	CA	50	E*	http://www.siliconvalleypower.com/pdf/res_rebates_09.pdf
Turlock Irrigation District	CA	50	E*	http://www.tid.org/stellentdmz/groups/public/documents/tidweb_content/tidweb_energy_
Groton Utilities	CT	60	E*	http://www.grotonutilities.com/files/conservation_forms/Appliance_Rebate.pdf
Norwich Public Utilities	CT	50	E*	http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CT54F&re=0&ee=1
Gainesville Regional Utilities	FL	150	E*	http://www.gru.com/YourHome/Conservation/Energy/Rebates/her_conditioner.jsp
Sawnee EMC	GA	25	E*	http://www.sawnee.com/Energy/incentives.aspx
Access Energy Coop	IA	50	E*	http://www.accessenergycoop.com/Content/Residential/Rebates.aspx
Linn County REC	IA	25	E*	http://www.linncountyrec.com/cgi-script/csarticles/uploads/334/Energy%20Star%20App
MidAmerican Energy	IA	25	E*	http://www.midamericanenergy.com/ee/include/pdf/ia_res_equip_brochure.pdf
MidAmerican Energy	IA	25	E*	http://www.midamericanenergy.com/ee/include/pdf/ia_res_equip_brochure.pdf
MidAmerican Energy	IA	25	E*	http://www.midamericanenergy.com/ee/include/pdf/ia_res_equip_brochure.pdf
MidAmerican Energy	IA	25	E*	http://www.midamericanenergy.com/ee/include/pdf/ia_res_equip_brochure.pdf
Muscatine Power and Water	IA	25	E*	http://www.mpw.org/residential_rebates.aspx
Ameren Illinois Utilities	IL	35	E*	http://www.actonenergy.com/portals/0/forms/REBATE-FORM-AC.PDF
Munihelps	MA	25		http://www.munihelps.org/2010%20rebate%20forms/MailinformAshburnham.pdf

Utility or Agency	State	Rebate Amount 2009$	Effic	Website
Belmont Municipal Light Department	MA	25		http://www.town.belmont.ma.us/public_documents/BelmontMA_LightNews/Announcer
Belmont Municipal Light Department	MA	75		http://www.town.belmont.ma.us/public_documents/BelmontMA_LightNews/Announcer
Concord Municipal Light Plant	MA	50	E*	http://www.concordma.gov/Pages/ConcordMA_LightPlant/appliance
Mansfield Municipal Electric	MA	50	E*	http://www.mansfieldelectric.com/consumerforms/Appliance-Rebate-App.pdf
Marblehead Light Department	MA	50		http://www.marbleheadelectric.com/9-6_Rebate_guide_for_MMLD.pdf
Reading Municipal Light	MA	25		http://www.rmld.com/Pages/rmldma_residential/rebate.pdf
Shrewsbury Electric & Cable Operations	MA	25		http://www.shrewsbury-ma.gov/egov/docs/1263402562_742065.pdf
Wakefield Municipal Gas & Light Department	MA	50	E*	http://www.wakefield.ma.us/Public_Documents/WakefieldMA_MGLD/WMGLDRebate
Allegheny Power	MD	25	E*	http://www.nxtbook.com/nxtbooks/garrisonhughes/empowermaryland2010/#/4
Baltimore Gas & Electric Company	MD	50	E*	http://conservation.bgesmartenergy.com/residential/lighting-appliances/appliance-rebates
Delmarva Power	MD	50	E*	http://www.delmarva.com/energy/conservation/appliance/default.aspx
PEPCO	MD	25	E*	http://homeenergysavings.pepco.com/dc/appliance-rebate
Alexandria Light and Power	MN	15		http://www.alputilities.com/forms/Energy%20Star%20Rebate%20Brochure%202010.pd
Anoka Municipal Utility	MN	25	E*	http://www.ci.anoka.mn.us/index.asp?Type=B_BASIC&SEC={03DDAD7B-EC66-4214
Austin Utilities	MN	25	E*	http://www.austinutilities.com/pages/residential_conserve_incentives.asp
City of North St. Paul Electric Utility	MN	30	E*	http://www.ci.north-saint-paul.mn.us/index.asp?Type=B_BASIC&SEC={F5C1E5FE-1A
Shakopee Public Utilities	MN	25	E*	http://www.shakopeeutilities.com/Residential_Rebate_Packet.pdf
Stearns Electric	MN	35	E*	https://www.stearnselectric.org/energystarres.htm
Co-Mo Electric Cooperative	MO	50	E*	http://www.co-mo.coop/documents/HomeApplianceRebateApp_000.pdf
Intercounty Electric Cooperative	MO	50	E*	http://www.ieca.coop/PROGRAMS/REBATES/tabid/116/Default.aspx
White River Valley Electric Cooperative	MO	50	E*	http://whiteriver.org/RebateProgram.html
Nebraska Public Power District	NE	30	E*	http://www.nppd.com/EnergyWise/ac_application.pdf
New Hampshire Electric Coop	NH	20	E*	http://www.nhec.com/residential_energystar_appliances.php
Northern Utilities	NH	20	E*	http://services.unitil.com/nh/energy_efficiency.asp?t=204
PSNH	NH	20	E*	http://www.psnh.com/Residential/Efficiency/Appliance.asp
Unitil	NH	20	E*	http://services.unitil.com/nh/energy_efficiency.asp?t=204
Verdigris Valley Electric Cooperative	OK	50	E*	http://www.vvec.com/products_services/rebate_program.php
Allegheny Power	PA	25	E*	http://www.alleghenypower.com/EngConserv/PA/WattWatchers/RebateAC.asp
PPL Electric Utilities	PA	25	E*	http://www.rebate-zone.com/ppl/pdf/PEJ.pdf
National Grid	RI	20	E*	https://www.powerofaction.com/rireaircleaner/

Utility or Agency	State	Rebate Amount 2009$	Effic	Website
Austin Energy	TX	50	E*	http://www.austinenergy.com/Energy%20Efficiency/Programs/Rebates/Residential/Air%
Austin Energy	TX	50	E*	http://www.austinenergy.com/Energy%20Efficiency/Programs/Rebates/Residential/Air%
CPS Energy	TX	50	E*	http://www.cpsenergy.com/Residential/Rebates/Air_Conditioner_Rebates/index.asp
CPS Energy	TX	100	E*	http://www.cpsenergy.com/Residential/Rebates/Air_Conditioner_Rebates/index.asp
Garland Power	TX	50	E*	http://www.garlandpower-light.org/pdfs/2009-2010%20Window%20Unit%20Applicatio
Garland Power	TX	100	E*	http://www.garlandpower-light.org/pdfs/2009-2010%20Window%20Unit%20Applicatio
Guadalupe Valley Electric Cooperative	TX	100	E*	http://www.gvec.org/safety_con/Home%20Improvement.pdf
Rocky Mountain Power	UT	30	E*	http://www.homeenergysavings.net/Downloads/UT_ApplianceForm2010.pdf
Pacific Power	WA	30	E*	http://www.homeenergysavings.net/Downloads/WA_ApplianceForm2010.pdf
Barron Electric Cooperative	WI	25	E*	http://www.barronelectric.com/Appliance%20&%20Lighting%20Program.pdf
Eau Claire Energy Cooperative	WI	25	E*	http://www.ecec.com/programs/incentives
Average (2009$)		**$ 42.83**		
Adjusted Average (2009$)		**$ 64.88**		

E* = ENERGY STAR

17-A.6 FEDERAL AND STATE TAX CREDITS

This section summarizes the Federal and State tax credits available to consumers who purchase energy efficient appliances. This section also describes tax credits available to manufacturers who produce certain energy efficient appliances.

17-A.6.1 Federal Tax Credits for Consumers of Residential Appliances

EPACT 2005 included Federal tax credits for consumers who installed efficient air conditioners or heat pumps; gas or oil furnaces are; furnace fans; and/or gas, oil, or electric heat pump water heaters in new or existing homes.[7,8] 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).[9] These tax credits did not apply to consumers who purchased energy efficient clothes dryers or room air conditioners.

Although this tax credit did not include efficient clothes dryers or room air conditioners, 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.*[10] It also estimated the percentage of taxpayers with entries under Form 5695's Line 3, *Residential energy property costs*, which included (3a) *energy-efficient building property (including water heaters)*, (3b) *qualified natural gas, propane, or oil furnace or hot water boiler*, and (3c) *advanced main air circulating fan used in a natural gas, propane, or oil furnace*. While none of these three items corresponds to clothes dryers or room air conditioners, DOE reasoned that the percentage of taxpayers with at least one entry under Line 3 could serve as a rough indication of the potential of taxpayer participation in a Federal tax credit program for an efficient appliance during the initial program years. It found that of all residential taxpayers filing tax returns in 2006 and 2007, 2.1 percent each year claimed at least one credit under Line 3. 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.[11,12,13] 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, section 17.3.3, 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. 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.

17-A.6.2 Federal Tax Credits for Manufacturers

EPACT 2005 provided Federal Energy Efficient Appliance Credits to manufacturers that produced high-efficiency refrigerators, clothes washers, and dishwashers in 2006 and 2007.[14] The Emergency Economic Stabilization Act of 2008[15] amended the credits and extended them through 2010. Manufacturers receive the credits for increasing their production of qualifying appliances relative to a two-year rolling baseline. Each manufacturer is limited to a certain amount for all credits. Manufacturers were eligible for Energy Efficient Appliance Credits for qualifying models of residential refrigerators, residential and commercial clothes washers, and residential dishwashers. The credits were available for models produced in 2008, 2009, and 2010. The credit amounts and criteria applied to manufacturers who produce these appliances. The credit amounts were for each unit manufactured; however, the maximum credit that a manufacturer could receive for qualifying equipment was $75 million for 2008–2010, with the exception that the most efficient refrigerator (30 percent) models were not subject to the cap.[16]

17-A.6.3 State Tax Credits

The States of Oregon and Montana have offered consumer tax credits for efficient appliances for several years, and the States of Indiana, Kentucky and Michigan began offering such credits in 2009. The Oregon Department of Energy (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 refrigerators and clothes washers.) Montana's Department of Revenue does not disaggregate participation data by appliance, although DOE reviewed Montana's overall participation trend that were congruent with its analysis of Oregon's clothes washer tax credits. DOE was unable to obtain state tax credit data from Indiana, Kentucky or Michigan.

Oregon's Residential Energy Tax Credit (RETC) was created in 1977. After the Oregon legislature expanded the RETC program in 1997 to include residential refrigerators, clothes washers, and dishwashers, participation in the program increased significantly. For standard-sized refrigerators the program offers two levels of rebates for units between 12 and 30 $ft.^3$ The required efficiency levels are 20 percent above Federal standard (ENERGY STAR) and 30 percent above Federal standard (CEE Tier 3). The program subsequently added credits for high-efficiency heat pump systems, air conditioners, and water heaters (2001); furnaces and boilers (2002); and duct/air sealing, fuel cells, heat recovery, and renewable energy equipment. For heating, ventilating, and air conditioning equipment; residential appliances; and water heaters, the credit is $0.40 per kilowatt saved in the first year, or 25 percent of the net purchase price, whichever is less. The credit limit for energy efficient appliances and heating and cooling systems is $1,000 per calendar year; excess credit may be carried forward for 5 years.[17]

Montana has had an Energy Conservation Tax Credit for residential measures since 1998.[18] The tax credit covers various residential energy and water efficient products, including ENERGY STAR heating/cooling equipment, water heaters, low-flow showerheads and faucets, and light fixtures and controls. In 2002 the 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.

Beginning in 2009 Indiana offered a tax credit to individuals and small businesses for costs associated with purchasing ENERGY STAR-qualified central air conditioners, room air conditioners, furnaces, programmable thermostats, and water heaters. The credit may be claimed against state income tax, insurance premium tax, or financial institutions tax. The amount of the credit is 20 percent of the expenditure for qualified heating and cooling equipment, to a maximum of $100 per taxable year. The credit applies to expenditures made in 2009 and 2010; there is no carryover.[19,20]

Beginning in 2009 Kentucky offered a 30 percent state income tax credit for taxpayers who install certain energy efficiency measures in their principal residence or residential rental property. The qualifying products include water heaters, heat pumps, central air conditioners, and advanced main air circulating fans. A product must meet the same energy efficiency guidelines as specified for the Federal tax credit for that residential product. The tax credit may not exceed $250. The credit, which applies to products purchased in taxable years 2009–2015, may be carried forward for 1 year.[21,22]

Beginning in 2009, certain Michigan low-income taxpayers became eligible for a tax credit for the purchase and installation of qualifying energy efficient home improvements. The definition of qualifying home improvements is limited to the following categories: insulation, water heaters, furnaces, windows, refrigerators, clothes washers, and dishwashers. All equipment must meet the EPA Energy Star efficiency criteria. The amount of the credit is 10% of the installed cost of each improvement, up to $75 for single filers and $150 for joint filers. A taxpayer may not make more than one claim under each equipment category during a single tax year. The credit only applies to equipment purchased in 2009 - 2011. If the amount of the credit exceeds a taxpayer's tax liability for a given year, the balance is refunded.[23,24]

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