CHAPTER 1. INTRODUCTION

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses and results supporting the information presented in the Notice of Proposed Rulemaking (NOPR) for walk-in coolers and walk-in freezers. This NOPR TSD reports on the activities and analysis conducted in support of the NOPR.

1.2 SUMMARY OF NATIONAL BENEFITS

DOE's analyses indicate that the proposed standards would save a significant amount of energy. The lifetime full-fuel cycle energy savings for walk-in coolers and freezers purchased in the 30-year period that begins in the year of compliance with new standards (2017–2046) amount to 5.39 quads.[a]

The cumulative net present value (NPV) of total consumer costs and savings of the proposed standards in 2012$ ranges from $8.6 billion (at a 7-percent discount rate) to $24.3 billion (at a 3-percent discount rate) for walk-in coolers and freezers. This NPV expresses the estimated total value of future operating-cost savings minus the estimated increased product costs for products purchased between 2017–2046, discounted to 2013.

In addition, the proposed standards would have significant environmental benefits. The energy savings would result in cumulative emission reductions of 298 million metric tons (MMt)[b] of carbon dioxide (CO_2), 443.8 thousand tons of nitrogen oxides (NO_X), 379.5 thousand tons of sulfur dioxide (SO_2), and 0.63 tons of mercury (Hg).[c] DOE estimates the net present monetary value of the CO_2 emissions reduction is between $1.88 billion and $27.51 billion at a 3-percent discount rate, expressed in 2012$ and discounted to 2013. DOE also estimates the net present monetary value of the NO_X emissions reduction, expressed in 2012$ and discounted to 2013, is $243.5 million at a 7-percent discount rate and $553.5 million at a 3-percent discount rate.[d]

The benefits and costs of today's proposed standards, for equipment sold in 2017-2046, can also be expressed in terms of annualized values. The annualized monetary values are the sum

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[a] The year 2017was chosen in anticipation of the potential compliance date.

[b] A metric ton is equivalent to 1.1 short tons. Results for NO_X and Hg are presented in short tons.

[c] DOE calculates emissions reductions relative to the most recent version of the Annual Energy Outlook (AEO) Reference case forecast. This forecast accounts for regulatory emissions reductions through 2010, including the Clean Air Interstate Rule (CAIR, 70 FR 25162 (May 12, 2005)), but not the Clean Air Mercury Rule (CAMR, 70 FR 28606 (May 18, 2005)). Subsequent regulations, including the recently finalized transport rule, the Cross-State Air Pollution rule issued on July 6, 2011, do not appear in the forecast at this time. See 76 FR 48208 (Aug. 8, 2011) (publication of the Cross-State Air Pollution final rule).

[d] DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg in its rulemakings.

of (1) the annualized national economic value of the benefits from consumer operation of equipment that meets the proposed standards (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase and installation costs, and (2) the annualized monetary value of the benefits of emission reductions, including CO_2 emission reductions. The value of the CO_2 reductions, otherwise known as the Social Cost of Carbon (SCC), is calculated using a range of values per metric ton of CO_2 developed by a recent interagency process. The derivation of the SCC values is discussed in chapter 16 of the TSD.

Although combining the values of operating savings and CO_2 emission reductions provides a useful perspective, two issues should be considered. First, the national operating savings are domestic U.S. consumer monetary savings that occur as a result of market transactions while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use different time frames for analysis. The national operating cost savings is measured for the lifetime of walk-ins shipped from 2017–2046. The SCC values, on the other hand, reflect the present value of some future climate-related impacts resulting from the emission of one ton of carbon dioxide in each year. These impacts continue well beyond 2100.

Table 1.2.1 shows the annualized values for today's proposed standards. (All monetary values below are expressed in 2012$.) The results under the primary estimate are as follows. Using a 7-percent discount rate for benefits and costs other than CO2 reduction, for which DOE used a 3-percent discount rate along with the SCC series corresponding to a value of $25.9/ton in 2012, the cost of the standards proposed in today's rule is $367 million per year in increased equipment costs, while the annualized benefits are $1.225 billion per year in reduced equipment operating costs, $499 million in CO2 reductions, and $24 million in reduced NO_X emissions. In this case the net benefit amounts to $1.382 billion per year. Using a 3-percent discount rate for all benefits and costs and the SCC series corresponding to a value of $25.7/ton in 2012, the cost of the standards proposed in today's rule is $399 million per year in increased equipment costs, while the benefits are $1.606 billion per year in reduced operating costs, $499 million in CO2 reductions, and $31 million in reduced NO_X emissions. In this case, the net benefit amounts to $1.737 billion per year.

Table 1.2.1 Annualized Benefits and Costs of Proposed Standards for Walk-in Coolers and Walk-in Freezers

	Discount Rate	**Primary Estimate***	**Low Net Benefits Estimate***	**High Net Benefits Estimate***
		(million 2012$/year)		
Benefits				
Operating Cost Savings	7%	1,225	1,188	1,279
	3%	1,606	1,544	1,687
CO_2 Reduction Monetized Value (at $12.9/Metric Ton)**	5%	142	142	142
CO_2 Reduction Monetized Value (at $40.8./Metric Ton)**	3%	499	499	499
CO_2 Reduction Monetized Value (at $62.2/Metric Ton)**	2.50%	739	739	739
CO_2 Reduction Monetized Value (at $117.0/Metric Ton)**	3%	1,534	1,534	1,534
NO_X Reduction Monetized Value (at $2,639/Ton)**	7%	24	24	24
	3%	31	31	31
Total Benefits†	7% plus CO_2 range	1,748	1,712	1,803
	7%	1,249	1,212	1,303
	3%	1,637	1,574	1,718
	3% plus CO_2 range	2,136	2,074	2,217
Costs				
Total Incremental Installed Costs	7%	367	377	357
	3%	399	414	385
Net Benefits				
Total†	7% plus CO_2 range	1,382	1,335	1,446
	7%	883	835	946
	3%	1,238	1,160	1,333
	3% plus CO_2 range	1,737	1,660	1,832

* This table presents the annualized costs and benefits associated with walk-in coolers and freezers shipped in 2017−2046. These results include benefits to consumers which accrue after 2046 from the walk-in coolers and freezers purchased in 2017−2046. Costs incurred by manufacturers, some of which may be incurred in preparation for the rule, are not directly included, but are indirectly included as part of incremental equipment costs. The Primary, Low Benefits, and High Benefits Estimates utilize projections of energy prices from the AEO2012 Reference case, Low Estimate, and High Estimate, respectively. In addition, incremental product costs reflect a medium decline rate for projected product price trends in the Primary Estimate, a low decline rate for projected product price trends using a Low Benefits Estimate, and a high decline rate for projected product price trends using a High Benefits Estimate.

** These values represent global values (in 2012$) of the social cost of CO_2 emissions in 2015 under several scenarios. The values of $12.9, $40.8, and $62.2. per ton are the averages of SCC distributions calculated using 5-percent, 3-percent, and 2.5-percent discount rates, respectively. The value of $117.0 per ton represents the 95th percentile of the SCC distribution calculated using a 3-percent discount rate. For NO_x, an average value ($2,639) of the low ($468) and high ($4,809) values was used.

† Total Monetary Benefits for both the 3 percent and 7 percent cases utilize the central estimate of social cost of NO_x and CO_2 emissions calculated at a 3-percent discount rate (averaged across three Integrated Assessment Models (IAMs)), which is equal to $40.8/ton in 2015 (in 2012$).

1.3 OVERVIEW OF APPLIANCE STANDARDS

Title III of the Energy Policy and Conservation Act (EPCA) of 1975, as amended sets forth a variety of provisions designed to improve energy efficiency. Part B of Title III (42 U.S.C. 6291–6309) provides for the Energy Conservation Program for Consumer Products Other Than Automobiles. The National Energy Conservation Policy Act (NECPA), Pub. L. 95-619, amended EPCA to add Part C[e] of Title III (42 U.S.C. 6311-6317), which established an energy conservation program for certain industrial equipment. Section 312 of the Energy Independence and Security Act of 2007 (EISA 2007) further amended EPCA by adding certain equipment to this energy conservation program, including walk-in coolers and walk-in freezers (collectively "walk-in equipment" or "walk-ins"), the subject of this rulemaking. (42 U.S.C 6311(1), (2), 6313(f) and 6314(a)(9))

EPCA sets forth general prescriptive standards for walk-ins. Walk-ins must have automatic door closers that firmly close all walk-in doors that have been closed to within 1 inch of full closure, for all doors narrower than 3 feet 9 inches and shorter than 7 feet; walk-ins must also have strip doors, spring hinged doors, or other methods of minimizing infiltration when doors are open. Walk-ins must also contain wall, ceiling, and door insulation of at least R-25 for coolers and R-32 for freezers, excluding glazed portions of doors and structural members, and floor insulation of at least R-28 for freezers. Walk-in evaporator fan motors of under 1 horsepower and less than 460 volts must be electronically commutated motors (brushless direct current motors) or three-phase motors, and walk-in condenser fan motors of under 1 horsepower must use permanent split capacitor motors, electronically commutated motors, or three-phase motors. Interior light sources must have an efficacy of 40 lumens per watt or more, including any ballast losses; less-efficacious lights may only be used in conjunction with a timer or device that turns off the lights within 15 minutes of when the walk-in is unoccupied. See 42 U.S.C. 6313(f)(1).

Second, EPCA sets forth new requirements related to electronically commutated motors for use in walk-ins. See 42 U.S.C. 6313(f)(2)). Specifically, in those walk-ins that use an evaporator fan motor with a rating of under 1 horsepower and less than 460 volts, that motor must be an electronically commutated motor unless DOE determined prior to January 1, 2009 that these motors are available from only one manufacturer. (42 U.S.C. 6313(f)(2)(A)) DOE determined by January 1, 2009 that these motors were available from more than one manufacturer; thus, the stated requirements apply. Additionally, EISA provided DOE with the authority to permit the use of other types of motors as evaporative fan motors—if DOE determines that, on average, those other motor types use no more energy in evaporative fan

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[e] Part C has been redesignated as Parts A-1for editorial reasons.

applications than electronically commutated motors. (42 U.S.C. 6313(f)(2)(B)) DOE is unaware of any other motors that would offer performance levels comparable to the electronically commutated motors required by Congress. Accordingly, all evaporator motors rated at under 1 horsepower and under 460 volts must be electronically commutated motors.

Third, EPCA sets forth additional requirements for walk-ins with transparent reach-in doors. Freezer doors must have triple-pane glass with either heat-reflective treated glass or gas fill for doors and windows for freezers. Cooler doors must have either double-pane glass with treated glass and gas fill or triple-pane glass with treated glass or gas fill. (42 U.S.C. 6313(f)(3)(A)-(B)) For walk-ins with transparent reach-in doors, EISA also prescribed specific anti-sweat heater-related requirements: walk-ins without anti-sweat heater controls must have a heater power draw of no more than 7.1 or 3.0 watts per square foot of door opening for freezers and coolers, respectively. Walk-ins with anti-sweat heater controls must either have a heater power draw of no more than 7.1 or 3.0 watts per square foot of door opening for freezers and coolers, respectively, or the anti-sweat heater controls must reduce the energy use of the heater in a quantity corresponding to the relative humidity of the air outside the door or to the condensation on the inner glass pane. See 42 U.S.C. 6313(f)(3)(C)-(D).

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 increase in the initial cost or maintenance expenses;
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 January 2009, DOE published a NOPM and announced the availability of the framework document. 74 FR 411 (January 6, 2009) The framework document, *Walk-In Coolers and Walk-In Freezers Energy Conservation Standard Framework Document*, describes the procedural and analytical approaches DOE anticipated using to evaluate the establishment of amended energy conservation standards for this product. This document is available at: http://www1.eere.energy.gov/buildings/appliance_standards/commercial/wicf_framework_document.html.

Subsequently, DOE held a public meeting on February 4, 2009 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 February 2009 public meeting, interested parties commented about numerous issues relating to each one of the analyses. 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	
Markups for equipment price determination	Environmental assessment	
Life-cycle cost and payback period	Employment impact analysis	
Shipment analysis	Regulatory impact analysis	
National impact analysis		
Preliminary manufacturer impact analysis		

As part of the information gathering and sharing process, DOE organized and held interviews with manufacturers of walk-in coolers and walk-in freezers considered in this rulemaking. DOE selected companies that represented production of all types of products, ranging from small to large manufacturers. 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 of the preliminary TSD) and the preliminary manufacturer impact analysis (chapter 12 of the preliminary TSD).

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.

In April 2010, DOE published the NOPM and availability of the preliminary TSD. 75 FR 17080 (April 15 2010). The preliminary TSD provides technical analyses and results that support the information presented in the preliminary NOPM and the executive summary for walk-in coolers and walk-in freezers. The preliminary TSD also provides a detailed description of all of the analyses discussed in the paragraphs above. The preliminary TSD is available at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0015-0042

Following publication of the NOPM and the preliminary TSD, DOE held a public meeting on May 19, 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 May 28, 2010 to allow interested parties to provide new comments or elaborate on any comments made at the public meeting.

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 this NOPR.

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 this NOPR.

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 the walk-in coolers and freezers rulemaking, provides a history of DOE's actions to date, and outlines the structure of this document.
Chapter 2	Analytical Framework: describes the rulemaking process.
Chapter 3	Market and Technology Assessment: characterizes the market for the considered products and technologies available for increasing product efficiency.
Chapter 4	Screening Analysis: identifies all the design options that improve walk-in cooler and walk-in freezer efficiency, 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 Analyses: 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 from 2016 through 2045 and estimates the future product energy efficiency distributions in the absence and presence of energy conservation standards.
Chapter 11	Life-Cycle Cost Sub-Group Analysis: evaluates impacts on any identifiable groups or customers who may be disproportionately affected by any proposed national energy efficiency standard level.
Chapter 12	Manufacturer Impact Analysis: discusses the effects of standards on the finances and profitability of product manufacturers.
Chapter 13	Employment Impact Analysis: discusses the effects of standards on national employment.
Chapter 14	Utility Impact Analysis: discusses the effects of standards and electric and gas utilities.
Chapter 15	Emissions Analysis: discusses the effects of standards on emissions of carbon dioxide (CO_2), nitrogen oxide (NO_x), and mercury.

Chapter 16	Monetization of Emissions 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 Report: discusses the impact of non-regulatory alternatives to efficiency standards.
Appendix 5A	Engineering Data: Full engineering analysis results for all equipment classes and analysis points.
Appendix 6A	Data for Refrigeration System Wholesalers.
Appendix 6B	Data for General Contractors.
Appendix 7A	Detailed Methodology for Developing the State Weighting Factors.
Appendix 8A	Instructions for using the Life Cycle Cost and Payback Period spreadsheets.
Appendix 8B	Provides details of the Monte Carlo analysis – characterizing uncertainty and variability in the Life Cycle Cost analysis.
Appendix 8C	Discount rate distributions.
Appendix 8D	Estimates of refrigeration systems price trends for walk-in coolers and freezers.
Appendix 8E	Life-cycle cost and payback period results for refrigeration systems with respect to its own baseline (discrete inputs)
Appendix 8F	Distribution of Consumer LCC Impacts for Refrigeration Systems.
Appendix 8G	Distribution of Consumer LCC Impacts for Envelope Components.
Appendix 9A	Instructions for using the Shipment Model spreadsheets.
Appendix 10A	Instructions for using the National Impact Analysis Spreadsheets.
Appendix 10B	Provides detailed National Energy Savings results.
Appendix 10C	Provides detailed Net Present Value results.
Appendix 10D	Description of the Trial Standard Levels Selection Process.
Appendix 10E	National net present value using alternative price forecasts

Appendix 10F	Annualized benefits and costs of considered standard levels
Appendix 12A	Government Regulatory Impact Model Overview
Appendix 16A	Table A1 of “Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866”.

CHAPTER 2. ANALYTICAL FRAMEWORK

TABLE OF CONTENTS

CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Section 6313(f)(4)(A) of 42 United States Code (U.S.C.) requires the U.S. Department of Energy (DOE) to set forth energy conservation standards that achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. For purposes of this rulemaking, DOE also plans to adopt those standards that are likely to result in a significant conservation of energy. See 42 U.S.C. 6295(o)(3)(B). This chapter provides a description of the general analytical framework that DOE uses in developing such standards; in particular, standards for walk-in coolers and walk-in freezers (WICF or walk-ins; "the considered equipment"). The analytical framework is a description of the methodology, 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.

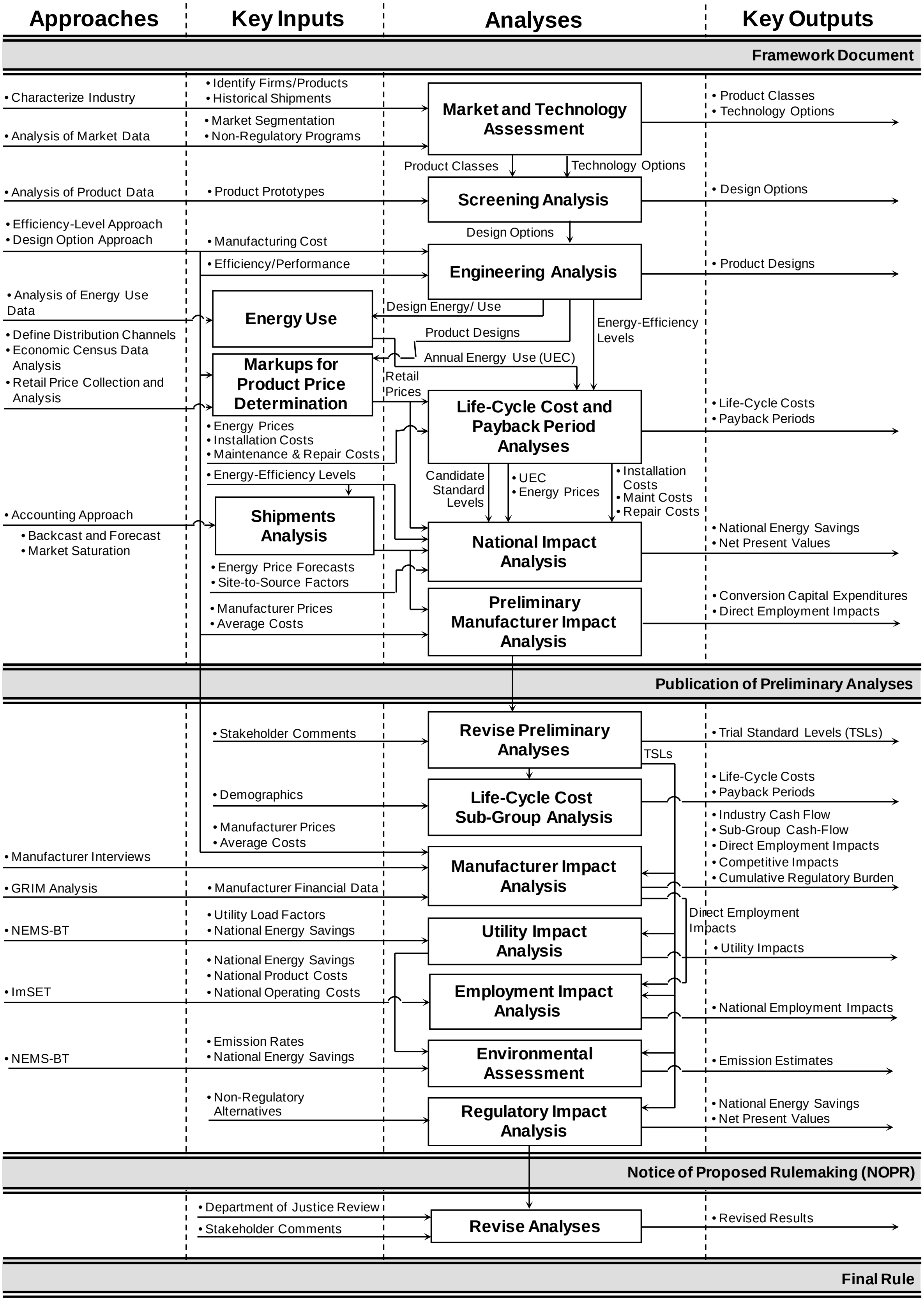

Figure 2.1.1 Flow Diagram of Analyses for the Rulemaking Process

The analyses performed prior to the notice of proposed rulemaking (NOPR) stage as part of the preliminary analyses and described in the preliminary technical support document (TSD) are listed below. These analyses were revised for the NOPR based in part on comments received, and reported in the NOPR TSD.

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

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

- An engineering analysis to develop cost-efficiency relationships that show the manufacturer's cost of achieving increased efficiency.

- An energy use analysis to determine the annual energy use in the field of the considered equipment as a function of efficiency level.

- An LCC and payback period (PBP) analysis to calculate, at the consumer level, the relationship between savings in operating costs compared to any increase in the installed cost for equipment at higher efficiency levels.

- A shipments analysis to forecast equipment shipments, which then are used to calculate the national impacts of standards and future manufacturer cash flows.

- A national impact analysis (NIA) to assess the impacts at the national level of potential energy conservation standards for each of the considered equipment, as measured by the net present value (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, such as impacts on capital conversion expenditures, marketing costs, shipments, and research and development costs.

In this NOPR, 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 NOPR:

- An LCC subgroup analysis to evaluate variations in consumer characteristics that might cause a standard to affect particular consumer subpopulations, such as small restaurants, 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 *Rulemaking Framework for Walk-in Coolers and Walk-in Freezers* (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 January 6, 2009. 74 FR 711. DOE presented the analytical approach to interested parties during a public meeting held on February 4, 2009. The framework document is available at http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0015-0008.

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 April 5, 2010 (75 FR 17080), addressing key comments received from interested parties. DOE subsequently held a public meeting on May 19, 2010, to present the preliminary analysis and to seek public comment. The preliminary TSD is available at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0015-0042.

In response to comments it receives after publishing the NOPR, DOE may revise some of its analyses before publishing the Final Rule.

2.2 MARKET AND TECHNOLOGY ASSESSMENT

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

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 equipment concerned. This activity assesses the industry and equipment, both quantitatively and qualitatively, based on publicly available information. As such, for the considered equipment, DOE addressed the following: (1) manufacturer market share and characteristics; (2) existing regulatory and non-regulatory equipment efficiency improvement initiatives; and (3) trends in equipment 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 equipment in the United States. Industry publications, 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 equipment through consultation with manufacturers of components and systems, and from trade publications and technical papers. Since many options for improving equipment efficiency are available in existing units, equipment 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 equipment 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 equipment 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 TSD) establishes the relationship between the manufacturing production cost and the efficiency for each class of walk-in cooler and walk-in freezer equipment. This relationship serves as the basis for cost/benefit calculations in terms of individual consumers, manufacturers, and the nation. Chapter 5 discusses the equipment classes DOE analyzed, the representative baseline units, the incremental efficiency levels, the methodology DOE used to develop the manufacturing production costs, the cost-efficiency curves, and the impact of efficiency improvements on the considered equipment.

In the engineering analysis, DOE evaluates a range of equipment efficiency levels and their associated manufacturing costs. The purpose of the analysis is to estimate the incremental MPCs for a unit that would result from increasing efficiency levels above the level of the baseline model in each equipment 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 equipment being analyzed.

In the framework document, DOE considered using the design-option approach for walk-in cooler and walk-in freezer equipment, combined with the cost-assessment approach to develop a cost for each efficiency level. This approach involved physically disassembling commercially available equipment, consulting with outside experts, reviewing publicly available cost and performance information, and modeling equipment cost. DOE continues to use this approach in the NOPR. Chapter 5 of this TSD describes the methodology and results of the design option approach and cost-assessment 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 equipment (baseline markups) and for more efficient equipment (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 equipment is 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 equipment passes 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 equipment use in commercial applications. The analysis uses information on use of actual equipment in the field to estimate the energy that would be used by new equipment 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 equipment that would meet possible energy efficiency standards, the analysis produces a distribution of results for a variety of building types and uses covering a range of climate locations in order to represent the diversity of use, and performance, of walk-in coolers and walk-in freezers.

2.7 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

New or amended energy conservation standards affect equipment' operating expenses—usually decreasing them—and consumer prices for the equipment—usually increasing them. DOE analyzes the effect of new or amended standards on consumers by evaluating changes in the LCC of owning and operating the equipment. 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 equipment 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 equipment typically increases while operating cost typically decreases in response to new standards, there is a time in the life of equipment 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 equipment. The length of time required for equipment 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 2.6, DOE developed samples of individual commercial enterprises that use walk-in cooler and walk-in freezer equipment. By developing such samples, DOE was able to perform the LCC and PBP calculations for the businesses to account for the variability in energy consumption and electricity price associated with actual users of the considered equipment. DOE identified several other input values for estimating the LCC, including electricity prices, discount rates, equipment location, equipment lifetime and also equipment oversizing (applicable for the refrigeration systems only). DOE characterized all the input variables with appropriate probability distributions.

DOE developed discount rates specifically for commercial customers. Because walk-ins are used in commercial applications, DOE developed commercial discount rates for those commercial subsectors that purchase walk-ins. DOE developed discount rates from estimates of the interest rate, or finance cost, applied to purchases of commercial equipment. Following accepted principles of financial theory, the finance cost of raising funds to purchase such equipment can be interpreted as: (1) the financial cost of any debt incurred to purchase equipment, principally interest charges on debt; or (2) the opportunity cost of any equity used to purchase equipment.

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 equipment. Units 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 equipment 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 the considered equipment. In DOE’s shipments model, shipments of equipment are driven by new construction, stock replacements, and other types of purchases.

The shipments models take an accounting approach, tracking market shares of each equipment class and the vintage of units in the existing stock. Stock accounting uses equipment shipments as inputs to estimate the age distribution of in-service equipment stocks for all years. The age distribution of in-service equipment 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 equipment 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 equipment, 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 equipment 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 equipment 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 equipment that perform at levels below a prospective standard are moved, or rolled-up, to the minimum performance level allowed under the standard. Equipment 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 the equipment analyzed are: (1) annual energy consumption per unit; (2) shipments; (3) equipment stock; (4) national energy consumption; and (5) site-to-source conversion factors. DOE calculated the national energy consumption by multiplying the number of units, or stock, of the equipment (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 equipment 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 the equipment. 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 equipment bought in the standards case usually costs more than equipment 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 equipment 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 SUB-GROUP 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 equipment. 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 the subgroup of small restaurant owners.

2.11 MANUFACTURER IMPACT ANALYSIS

The MIA assesses the impacts of new energy conservation standards on manufacturers of the considered equipment. Potential impacts include financial effects, both quantitative and qualitative, that might lead to changes in the manufacturing practices for these equipment. 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 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 equipment, 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 new or 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 walk-in coolers and walk-in freezers 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 ($_{CO2}$), nitrogen oxides (NO_x), and mercury (Hg). The environmental assessment also considers impacts on $_{SO2}$ emissions and discusses particulate matter (PM) emissions. The following sections 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.

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 $_{CO2}$ 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 2012 were $12.9, $40.8, $62.2, and $117 per metric ton in 2012 dollars. 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 2070. 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 NOx 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 $468 to $4,809 per ton in 2012$). 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 equipment 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 equipment energy use, consumer utility, and LCC. DOE based its assessment on the actual impacts of any such initiatives to date, but also considered information presented regarding the impacts that any existing initiative might have in the future.

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This document details the market and technology assessment that the U.S. Department of Energy (DOE) has conducted in support of its energy conservation standards rulemaking for walk-in coolers and walk-in freezers (WICF or walk-ins).

This chapter consists of two major sections: the market assessment and the technology assessment. The goal of the market assessment is to develop a qualitative and quantitative characterization of the WICF market. This assessment characterizes the market structure based on publicly available information as well as data supplied by manufacturers and other interested parties. Issues include manufacturer characteristics and market shares, existing regulatory and non-regulatory efficiency improvement programs, equipment classes, and trends in market and equipment characteristics. The goal of the technology assessment is to develop a preliminary list of technology options or measures that manufacturers can use to improve the efficiency of walk-in coolers and walk-in freezers.

3.1.1 Walk-in Cooler and Walk-in Freezer Definitions

The Energy Policy and Conservation Act (EPCA) defines “walk-in cooler” and “walk-in freezer” as an enclosed storage space refrigerated to temperatures, respectively, above, and at or below 32 °F that can be walked into, and has a total chilled storage area of less than 3,000 ft^2. The definition excludes products designed and marketed exclusively for medical, scientific, or research purposes. (42 U.S.C. 6311(20))

EPCA defines walk-in equipment, in part, as meaning a space that is “refrigerated,” and as having a “chilled storage area.” (42 U.S.C. 6311(20)) In the WICF test procedure final rule, DOE established a definition of the term “refrigerated” within the statutory definition to refer to equipment at or below 55 °F. 75 FR 21580, 33631.

Walk-ins that meet the definition may be located indoors or outdoors. They may be used exclusively for storage, but they may also have transparent doors or panels for the purpose of displaying stored items. Examples of items that may be stored in walk-ins include, but are not limited to, food, beverages, and flowers.

In this notice of proposed rulemaking (NOPR), DOE is proposing to set standards for a walk-in cooler or freezer’s constituent components: the panels, doors (both display doors and non-display doors—that is, doors that are not display doors), and refrigeration system. In the test procedure, DOE defined panel, door, display door, and refrigeration system as follows:

> *Panel* means a construction component that is not a door and is used to construct the envelope of the walk-in, i.e., elements that separate the interior refrigerated environment of the walk-in from the exterior.
>
> *Door* means an assembly installed in an opening on an interior or exterior wall that is used to allow access or close off the opening and that is movable in a

> sliding, pivoting, hinged, or revolving manner of movement. For walk-in coolers and walk-in freezers, a door includes the door panel, glass, framing materials, door plug, mullion, and any other elements that form the door or part of its connection to the wall.
>
> *Display door* means a door designed for product movement, display, or both, rather than the passage of persons.
>
> *Refrigeration system* means the mechanism (including all controls and other components integral to the system's operation) used to create the refrigerated environment in the interior of a walk-in cooler or freezer, consisting of:
>
> (1) A packaged dedicated system where the unit cooler and condensing unit are integrated into a single piece of equipment; or
> (2) A split dedicated system with separate unit cooler and condensing unit sections; or
> (3) A unit cooler that is connected to a multiplex condensing system.

76 FR 33631 (June 9, 2011).

In this NOPR, DOE proposes to amend the definition of display door and to add definitions of passage door and freight door. The proposed amendment would define a display door as a door that is composed of 50 percent or more glass or other transparent material. This amendment is intended to classify all doors that are mostly composed of glass as display doors—in particular, doors that are also used for the passage of people—because the utility and construction of such doors more closely resemble that of a display door.

DOE's proposed definition of passage door is intended to differentiate passage doors from freight doors and display doors. DOE's proposal defines passage door as a door that is less than 3 feet 9 inches wide and 7 feet tall and that is not a display door. Such doors are intended primarily for the passage of people. The size restriction is meant to be consistent with EPCA's requirement to have automatic door closers on all doors that are not wider than 3 feet 9 inches or taller than 7 feet. Likewise, DOE proposes to define freight door as a door that is not a passage door or a display door and that is equal to or larger than 3 feet 9 inches wide or 7 feet tall. Such doors are usually intended for large machines, such as forklifts, to pass through carrying freight.

DOE's definitions of display door, passage door, and freight door are meant to be categorically exhaustive and mutually exclusive. That is, they should cover all doors used in the walk-in market, but there should be no ambiguity over whether a given door is a display door, a passage door, or a freight door. The three types of doors represent different types of equipment or equipment classes for which DOE is proposing different energy conservation standards. Therefore, it is important that all doors are covered by the standards and that it is clear which standards apply to a given door.

3.1.2 Proposed Equipment Classes

In general, DOE identifies a class of covered equipment by the type of energy used, capacity, and performance-related features that affect consumer utility or efficiency. Different energy conservation standards may apply to different equipment classes. For this NOPR, DOE is proposing different equipment classes for panels, doors, and refrigeration systems.

3.1.2.1 Panel and Door Equipment Classes

In the preliminary analysis, DOE proposed to created separate equipment classes for display (D) and non-display (ND) walk-ins (that is, walk-ins with and without glass). However, for this NOPR, DOE has proposed to set individual standards for the main components that make up a walk-in envelope. In the walk-in test procedure final rule, DOE identified these components as panels, display doors, and non-display doors. 76 FR 21580, 21582 (April 15, 2011).

DOE analyzed two equipment classes for panels: non-floor panels (also known as structural panels) and freezer floor panels. Non-floor panels and freezer floor panels serve two different utilities, and therefore warrant separate standards. Freezer floor panels may have to support the load of small machines like hand carts and pallet jacks on their horizontal face, and often require more structural support to bear the load. Also, a freezer floor panel is rated with its external face exposed to a lower temperature, 55 °F, in contrast with a non-floor panel, which is rated at an external temperature of 75 °F. Non-floor panels, which include ceiling and wall panels, are generally oriented vertically and require fewer structural members than floor panels.

In this NOPR, DOE proposes to define display doors as distinct from non-display doors. Non-display doors and display doors are considered to be different products because these two types of doors serve separate utilities. Display doors are typically used to display products or objects located inside the walk-in, and therefore are composed mainly of glass or other transparent material. Non-display doors—that is, doors that are not display doors—function as passage and freight doors and are mainly used to allow people and products to be moved into and out of the walk-in. Since non-display doors do not need to be transparent, these doors are typically composed of highly insulative materials. Insulation used in doors must be at least R-25 for coolers and R-32 for freezers as required by EPCA. (42 U.S.C. 6313(f)(1)(C))

Non-display doors are further separated into passage and freight door classes, defined above. Different classes are warranted for these types of equipment because differences in their size and design could affect their energy consumption. In particular, freight doors are larger and may require more structural members for support.

DOE also proposes separate classes for coolers (C) and freezers (F) for structural panels, floor panels, display doors, passage doors, and freight doors. Coolers and freezers have different insulation requirements under EPCA. Like display and non-display products, cooler and freezer components have distinct design requirements; for example, freezer doors must have heater wire to prevent the door from freezing closed. Coolers and freezers also have different rating conditions under DOE’s test procedure. 76 FR at 33632.

Outdoor panels and doors were not considered as a separate product class because there are limited design options that would reduce energy consumption for outdoor components and not indoor components, and vice versa, so there would be little if any added benefit to proposing separate classes for indoor and outdoor panels and doors. Manufacturers typically sell indoor units as outdoor units by including roofing or other weatherization systems to prevent rain from entering panel-to-panel interfaces. In addition, the WICF test procedure does not have different rating conditions for indoor and outdoor walk-in envelope components.

DOE proposes the following equipment classes, shown in Table 3.1.1, Table 3.1.2, and Table 3.1.3 for panels, display doors, and non-display doors, respectively. A lettering system simplifies discussion of equipment classes. The lettering designation, or "class code," for a particular equipment class consists of the lettering abbreviations for the equipment type and operating temperature, separated by periods. For each class, DOE analyzed multiple analysis points corresponding to representative units of different sizes. These analysis points are described in chapter 5 of the technical support document (TSD).

Table 3.1.1 Equipment Classes for Panels

Type	Temperature	Class Code
Structural Panel	Medium	SP.M
	Low	SP.L
Floor Panel	Low	FP.L

Table 3.1.2 Equipment Classes for Display Doors

Type	Temperature	Class Code
Display Door	Medium	DD.M
	Low	DD.L

Table 3.1.3 Equipment Classes for Non-display Doors

Type	Temperature	Class Code
Passage Door	Medium	PD.M
	Low	PD.L
Freight Door	Medium	FD.M
	Low	FD.L

3.1.2.2 Refrigeration System Equipment Classes

Refrigeration systems of walk-in coolers and walk-in freezers can be divided into various equipment classes categorized by key physical characteristics that affect the efficiency of the equipment: the operating temperature, the location of the walk-in (*i.e.*, indoors or outdoors) and the type of condensing unit (*i.e.*, whether the system has a dedicated condensing unit or is connected to a multiplex system).

The condensing unit type has a significant impact on utility and energy use. DOE proposes to create two classes of equipment associated with the condensing unit type: dedicated condensing (DC) systems and multiplex condensing (MC) systems. In a dedicated condensing system, there is only one condensing unit (consisting of one or more compressors and condensers) that serves a single walk-in. In a multiplex condensing system, the unit cooler inside the walk-in envelope is connected via a refrigerant line to a system consisting of several condensers and compressors in parallel; the set of condensers and compressors serves both the walk-in and the other equipment, which may include other walk-ins or other types of refrigeration equipment such as reach-ins. Walk-in units that are connected to a large supermarket compressor rack fall into this category. Multiplex condensing equipment is typically more efficient than dedicated condensing equipment because it uses compressors of varying capacities and cycles them on and off as needed to avoid excess capacity in operation. Compressor racks and condensers of multiplex systems are outside the scope of this rulemaking. In the test procedure, a nominal efficiency is assumed for the multiplex condensing system when rating the unit cooler.

For dedicated condensing refrigeration systems only, the location of the condensing unit, indoors or outdoors, affects the characteristics with regard to energy consumption. Indoor units tend to operate at a consistent ambient temperature, while outdoor units typically experience varying temperatures throughout the year. The test procedure accounts for this variation by requiring outdoor condensing units to be tested at three ambient temperatures: 95 °F, 59 °F, and 35 °F. This gives credit for certain energy-saving technologies that may allow the compressor to use less energy at lower ambient temperatures. Therefore, DOE proposes to create separate classes for refrigeration equipment with indoor (I) and outdoor (O) condensing units.

The operating temperature for walk-ins determines whether the equipment is a cooler (medium or high operating temperature) or a freezer (low operating temperature). Because different types of merchandise require different temperatures (*e.g.*, chilled or frozen), operating temperature is a necessary class distinction. Furthermore, EPCA specifically divides walk-in equipment into coolers (above 32 °F) and freezers (at or below 32 °F). (42 U.S.C. 6311(20)(A)) The larger temperature differences and thermodynamic behavior of refrigerants means that equipment with lower operating temperatures generally runs less efficiently than equipment with higher operating temperatures. Thus, DOE proposes to create separate classes for refrigeration equipment that is medium-temperature (M), operating above 32 °F; and low-temperature (L), operating at or below 32 °F.

Finally, for dedicated refrigeration systems only, DOE is dividing equipment into classes based on capacity or size. In the preliminary analysis, DOE did not consider different equipment classes based on refrigeration equipment size, but in the NOPR analysis, DOE analyzed a broader range of equipment and observed that small-sized equipment may have difficulty meeting an efficiency standard that is based on an analysis of large equipment. This is primarily due to a lack of availability of more efficient compressors and compressor types (*e.g.*, scroll compressors) at lower capacities. Therefore, DOE proposes different classes for high- and low-capacity equipment. These capacity points were chosen primarily based on compressor performance data. DOE observed that compressor efficiency tends to decrease at capacities lower than approximately 9,000 Btu/h (see section 3.2.6 for compressor performance data). The compressor is the primary driver of refrigeration system energy use, but WICF refrigeration system manufacturers generally do not have control over the characteristics of compressors available on the market and do not have sufficient purchasing power to significantly affect the compressors offered by suppliers. Therefore, DOE proposes to consider different classes for equipment with a rated gross capacity lower than 9,000 Btu/h and equipment with a rated gross capacity greater than or equal to 9,000 Btu/h.

Using appropriate combinations of condensing unit types, location, and temperature, DOE proposes a total of 10 equipment classes for walk-in cooler and walk-in freezer refrigeration systems, shown in Table 3.1.4. A lettering system simplifies discussion of equipment classes. The lettering designation for a particular equipment class consists of the lettering abbreviations for the condenser type, equipment operating temperature, and condenser location (where applicable), separated by periods. For each class, DOE analyzed multiple analysis points corresponding to representative units of different sizes. These analysis points are described in chapter 5 of the TSD.

Table 3.1.4 Equipment Classes for Refrigeration Equipment

Condensing Type	**Operating Temperature**	**Condenser Location**	**Refrigeration Capacity *Btu/h***	**Class Code**
Dedicated	Medium	Indoor	< 9,000	DC.M.I, < 9,000
			≥ 9,000	DC.M.I, ≥ 9,000
		Outdoor	< 9,000	DC.M.O, < 9,000
			≥ 9,000	DC.M.O, ≥ 9,000
	Low	Indoor	< 9,000	DC.L.I, < 9,000
			≥ 9,000	DC.L.O, ≥ 9,000
		Outdoor	< 9,000	DC.L.O, < 9,000
			≥ 9,000	DC.L.O, ≥ 9,000
Multiplex	-	Medium	-	MC.M
	-	Low	-	MC.L

3.2 MARKET ASSESSMENT

This section addresses the scope of the rulemaking, identifies potential equipment classes, and estimates national shipments of walk-in cooler and walk-in freezer equipment and the market shares of WICF equipment manufacturers. This section also addresses typical equipment lifetimes and market performance data, and discusses regulatory and non-regulatory programs that apply to walk-in coolers and walk-in freezers.

3.2.1 Manufacturers and Market Segments

DOE identified 52 manufacturers of walk-in panels (listed in Table 3.2.1), of which 42 are considered to be small businesses. DOE identified 59 door manufacturers for walk-ins. However, 52 of the 59 door manufacturers produce panels as their primary business and are considered in the category of panel manufacturers. Of the remaining seven door manufacturers, DOE identified three manufacturers of walk-in non-display doors (listed in Table 3.2.2), all three of which are considered small businesses; and four manufacturers of display doors (listed in Table 3.2.3), two of which are considered small businesses. DOE identified nine walk-in refrigeration system manufacturers (listed in Table 3.2.4) and considers two of them to be small businesses.

Table 3.2.1 Manufacturers of Panels

*Advance Energy Technologies, Inc.	*Custom Cooler, Inc.	*North Star Refrigerator Co., Inc.
*Advanced Refrigeration Technology	*Dade Engineering Corporation DBA Daeco	*Penn Refrigeration Service Co.
*Aircooler Corporation	*Duracold Refrigeration Manufacturing Company	*Polar King International, Inc.
*Airdyne Refrigeration (ARI Industries)	Harford Duracool, LLC (Manitowoc)	*Refrigeration Gaskets of Texas, Inc.
*American Cooler Technologies	Hill Phoenix	*Refrigerator Manufacturers, Inc.
*American Insulated Panel Co.	*Howard-McCray	*Rudy's Commercial Refrigeration
*American Panel Corporation	Hussmann Corporation (Ingersoll-Rand)	*Snowman Cooler LLC
*American Walk-In Coolers	*Imperial Walk-in Coolers	*Southeast Cooler Corporation
*Amerikooler, Inc.	*International Cold Storage (Rainey Road LLC)	*SRC Refrigeration
*Arctic Industries, Inc.	Kolpak (Manitowoc)	*Storflex Fixture Corporation
*Artic Temp Inc.	Kool Star (Standex International Corporation)	*Superior Commercial Coolers, Inc.
*Bally Refrigerated Boxes, Inc.	Kysor Panel Systems (Manitowoc)	*T.O. DeVilbiss Manufacturing Co.*
*Bush Refrigeration	Leer Limited Partnership (Dexter Apache Holdings, Inc.)	*Tafco/T.M.P. Company, Inc. (Tafco)
Carroll Coolers Inc. (Dexter Apache Holdings, Inc.)	*Louisville Cooler Manufacturing Company	*Thermo-Kool/Mid-South Ind, Inc.
*Chrysler & Koppin Company	Master-Bilt Products (Standex International Corporation)	*U.S. Cooler Company, Inc. (Craig Industries)
*Commercial Cooling (PAR Engineering, Inc.)	*Mr. Winter/Isopanel	*W.A. Brown, Inc. (Imperial Walk-in Coolers)
*Cool Solutions Panel Manufacturing LLC	Nor-Lake, Inc. (Standex International Corporation)	*Worldwide Refrigeration
*Crown Tonka Walk-ins/ThermalRite (Rainey Road LLC)		

*Small business manufacturer

Table 3.2.2 Manufacturers of Non-Display Doors

*Chase Doors	*Frank Door Company	*Jamison Doors

*Small business manufacturer

Table 3.2.3 Manufacturers of Display Doors

Anthony	Gemtron (Schott)	*Styleline
*Commercial Display Systems, LLC		

*Small business manufacturer

Table 3.2.4 Manufacturers of Walk-in Refrigeration Systems

*Century Refrigeration (RAE Corporation)	Kolpak (Manitowoc)	Master-Bilt Products (Standex International Corporation)
Heat Transfer Products Group DBA Russell (Monomoy Capital Partners, L.P. and Starboard Capital Partners, LLC)	Krack (Ingersoll Rand)	*Peerless of America, Inc.
Heatcraft Refrigeration Products, LLC (Lennox International)	Manitowoc	Trenton Refrigeration Products (National Refrigeration and Air Conditioning Products Inc.)

*Small business manufacturer

As illustrated in these tables, the walk-in market is characterized by many small companies and a few large companies. In general, the large companies tend to be part of public corporations while the small companies tend toward private ownership. The total walk-in market, including panels, doors, and/or refrigeration equipment, is valued at roughly $1.8 billion in annual revenue. No single company controls the market, although several large companies combined represent roughly half of the annual revenue. This diversity reflects the wide range of end-users that make up the customer base: larger manufacturers tend to serve chain and brand name stores in the grocery, supermarket, and convenience store markets, while smaller manufacturers may be preferred by regional non-chain convenience and grocery stores, and restaurants.

DOE estimated that the panel manufacturers have combined total annual revenues of approximately $760 million. DOE is aware that there may be additional small manufacturers of panels not listed in any of the tables above or in publicly available documents or websites. DOE estimated that the non-display door and display door manufacturers have combined total annual revenues of approximately $280 million and that the refrigeration industry has annual revenues of approximately $840 million.

DOE also identified several manufacturers of more than one type of component—for instance, panels and refrigeration. DOE found that the market was dominated by the large companies: Ingersoll Rand (subsidiary brands are Hussman and Krack), Standex International Corporation (subsidiary brands are Master-Bilt, Nor-Lake, and Kool Star), and Manitowoc (subsidiary brands are Harford Duracool, Kysor Panel, and Kolpak). These large companies tended to break out food service equipment in their public revenues reports, but this could include types of equipment other than walk-ins, such as commercial refrigerated display cases, reach-ins, and refrigerated beverage vending machines. Walk-in-specific revenues were embedded in these data within the public revenue reports, but were not broken out specifically.

3.2.1.1 Small Businesses

DOE recognizes that small businesses could be particularly impacted by the promulgation of energy conservation standards for walk-ins. The Small Business Administration (SBA) lists small business size standards for industries as they are described in the North American Industry Classification System (NAICS). The size standard for an industry is the largest that a for-profit concern can be in that industry and still qualify as a small business for Federal Government programs. These size standards are generally expressed in terms of the average annual receipts or the average employment of a firm. In the preliminary analysis, DOE matched walk-in coolers and walk-in freezers to NAICS code 333415, “Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing,” which has a size standard of 750 employees. Manufacturers classified as small businesses according to this NAICS code are indicated in Table 3.2.1 through Table 3.2.4 with an asterisk (*).

DOE realizes that small business manufacturers of panels and doors tend to be much smaller than the 750-employee size standard. For instance, DOE found that more than half of small walk-in manufacturers have 100 or fewer employees. DOE studied the potential impacts on small businesses in detail during the manufacturer impact analysis. See chapter 12 of the TSD for details.

3.2.1.2 Industry Consolidation

The consolidation of major manufacturers through mergers and acquisitions is an industry trend. In some cases consolidation serves to expand vertical reach, such as the acquisition of a panel manufacturer by a refrigeration manufacturer, while in other cases consolidation creates companies with a more dominant market share in a similar manufacturing process. For example:

- In 1995, commercial refrigeration manufacturer Manitowoc acquired walk-in manufacturer Kolpak.
- In 2000, Hill PHOENIX (Dover Corporation) acquired National Cooler Corporation, a manufacturer of walk-in coolers and walk-in freezers. This company was re-named Hill Phoenix Walk-Ins.
- In 2000, refrigeration and envelope manufacturer Hussmann was acquired by Ingersoll Rand.
- In 2003, Standex International Corporation acquired Nor-Lake, which manufactures walk-in envelopes. In 2005, the company acquired Kool Star, a refrigeration manufacturer for walk-in end uses. Standex International also owns Master-Bilt, a major refrigeration and envelope manufacturer.
- In 2008, Manitowoc bought Enodis, PLC. Enodis owned another envelope manufacturer, Kysor Panel Systems.
- In 2009, Rainey Road, LLC, owner of CrownTonka Walk-ins/ThermalRite, purchased another envelope manufacturer, International Cold Storage, from Carrier Commercial Refrigeration, Inc. (Carrier Corporation).
- In 2010, Carrier Corporation sold its Heat Transfer Products Group (HTPG), including Russell Refrigeration, to Monomoy Capital Partners, L.P. and Starboard Capital Partners, LLC.

3.2.2 Existing Standards from Regulatory and Voluntary Programs

The prescriptive standards for walk-ins set out in EPCA and any standards established by DOE during the WICF rulemaking process preempt state standards established for the same equipment. Exceptions include any state standards established for equipment not regulated by the

Federal Government and State standards that exceed those established by the Federal Government.

3.2.2.1 U.S. State Regulatory Programs

Several states had established efficiency standards for walk-ins prior to 2009. These standards were preempted by the Federal energy standards in EPCA when the provisions of EPCA took effect January 1, 2009. DOE is not aware of any subsequently established state standards that are more stringent than the standards in EPCA.

3.2.2.2 U.S. Voluntary Programs

DOE is not aware of any voluntary or incentive programs targeting walk-in coolers and walk-in freezers.

3.2.2.3 International Programs

Several international organizations have implemented energy efficiency standards for various types of commercial equipment:

- The Natural Resources Canada (NRCan) Office of Energy Efficiency (OEE) sets efficiency standards for residential products and commercial equipment.
- The National Appliance and Equipment Energy Efficiency Committee (NAEEEC) establishes energy performance standards for a variety of technologies manufactured and sold in Australia and New Zealand.
- The European Union's ECO-Design Standards program currently regulates 14 groups of residential products and commercial equipment, and the organization plans to extend the program to other products in the long term.
- Japan's Top Runner program sets Target Product Standards for vehicles, residential appliances, and commercial equipment.

None of these international programs have established standards for walk-in coolers and walk-in freezers, but may do so in the future.

3.2.3 Shipments

Table 3.2.5 shows the forward-looking trend in values of WICF shipments beginning in 1993, as estimated by the Freedonia Group in a 2008 report.

Table 3.2.5 Value of Shipments of Walk-In Coolers and Freezers (in millions)

Years	**1993**	**1998**	**2003**	**2008**	**2013**
Walk-In Cooler/Freezer Shipments	$390	$680	$620	$800	$1,000

Source: The Freedonia Group, Inc. (2008)

The walk-in industry lacks aggregated data on historical shipments of walk-ins. In the preliminary analysis, DOE estimated the installed base of walk-ins for 1997, 2002, and 2007 using Commercial Buildings Energy Consumption Survey and U.S. Census data. For the preliminary analysis, DOE estimated year-to-year shipments by assuming equal shipments for each year during each 5-year interval. During interviews, manufacturers made qualitative comments on the shipment trends DOE presented. They noted that historical shipments were not consistent from year to year but depended largely on the state of the economy. In particular, shipments peaked around 2007–2008, but declined dramatically in subsequent years. They also predicted that unfavorable economic conditions would lead to purchase of replacement parts rather than entire walk-ins.

Table 3.2.6 summarizes DOE's new estimates of historical shipments of envelope and refrigeration equipment. Due to uncertainty regarding year-to-year shipments, DOE presents aggregate shipments for the 5-year intervals between 1997, 2002, and 2007, the years for which it can estimate the installed base. The shipments estimates are based on building growth and replacement of equipment. For this NOPR analysis, DOE has updated its estimated replacement rate of WICF equipment and distributions of equipment classes. Refrigeration system shipments exceed envelope shipments because the shorter equipment lifetime of refrigeration systems means they need more frequent replacements.

Table 3.2.6 Estimated Shipments of Envelopes and Refrigeration Systems

	Shipments 1998–2002	**Shipments 2003–2007**
Envelope		
Coolers	452,571	450,575
Freezers	193,959	193,104
TOTAL	646,531	643,679
Refrigeration Systems		
Multiplex	241,396	240,797
Dedicated	563,257	561,860
TOTAL	804,653	802,658

For the NOPR, DOE is analyzing the panels and doors of envelopes separately. Also, manufacturers indicated that panel shipments are typically measured in square feet, not by individual panels. Table 3.2.7 shows DOE's estimates of historical panel shipments, in millions of square feet of panel shipped. Table 3.2.8 shows DOE's estimates of historical door shipments, in thousands of doors shipped.

Table 3.2.7 Estimated Shipments of Panels

	Shipments 1998–2002 *million square feet*	**Shipments 2003–2007** *million square feet*
Non-Floor Panels		
Coolers	416	415
Freezers	125	125
Floor Panels		
Coolers	8.54	8.50
Freezers	27.5	27.3

Table 3.2.8 Estimated Shipments of Doors

	Shipments 1998–2002 *thousand doors*	**Shipments 2003–2007** *thousand doors*
Passage Doors		
Coolers	651	648
Freezers	275	274
Freight Doors		
Coolers	18.9	18.9
Freezers	15.1	15.0
Display Doors		
Coolers	1270	1260
Freezers	77.4	77.0

3.2.4 Industry Cost Structure

As discussed in section 3.2.1, DOE found that WICF manufacturing can be classified as a subset under NAICS code 333415, “Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing.”

DOE is unaware of any publicly available industry-wide cost data specific to only manufacturers of walk in coolers and walk in freezers. Therefore, DOE used the data for the Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing Industry as a broader industry proxy for the WICF industry, which, in combination with information gained in interviews, inform DOE’s analysis of the industry cost structure. These data, shown in Table 3.2.9, are taken from the U.S. Census Bureau’s Annual Survey of Manufacturers, Statistics for Industry Groups and Industries. DOE presents the WICF employment levels and earnings from 2004 to 2009. The statistics approximately illustrate an overall 18 percent decrease in production workers and 13 percent decrease in overall number of employees from 2004 to 2009.

Table 3.2.9 Employment and Earnings for the Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing Industry

Year	Production Workers	All Employees	Annual Payroll *$000s*
2004	73,559	99,669	3,707,969
2005	76,011	102,354	3,942,808
2006	74,909	98,097	4,019,813
2007	73,993	100,284	3,975,785
2008	70,787	96,610	4,020,656
2009	60,041	86,454	3,666,278

Source: U.S. Census Bureau. *Annual Survey of Manufacturers, 2004-2009*

Table 3.2.10 presents the costs of materials and industry payroll as a percentage of shipment value from 2004 to 2009. The cost of materials as a percentage of shipment value steadily increased from 2004 to 2007, and then dipped in 2008. The cost of payroll for production workers and the cost of total payroll have declined by 11.6 percent and 4.3 percent, respectively.

Table 3.2.10 Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing Industry Material and Payroll Costs

Year	Cost of Materials *percent of shipment value*	Cost of Payroll for Production Workers *percent of shipment value*	Cost of Total Payroll *percent of shipment value*
2004	51.81	8.99	14.57
2005	53.78	8.52	13.78
2006	53.17	8.87	13.80
2007	55.52	8.12	13.29
2008	54.56	8.10	13.46
2009	55.05	7.95	13.94

Source: U.S. Census Bureau. *Annual Survey of Manufacturers, 2004-2009*

3.2.5 Equipment Lifetimes

3.2.5.1 Refrigeration

DOE reviewed available literature and consulted with experts on walk-in refrigeration equipment to establish typical equipment lifetimes. The literature and individuals consulted estimated a wide range of typical equipment lifetimes, as shown in Table 3.2.11.

A 2008 report by The Freedonia Group suggests that custom-made walk-in refrigeration units are typically used by the food production/distribution sectors.[1] As these units are not seen by consumers but are made for durability, efficiency, and dependability, there is little attention paid to aesthetics in design. U.S. tax depreciation schedules (which allow depreciation over a 5-year period for retail fixtures, including walk-in refrigerators and walk-in freezers)[2] may be one driver for regular replacement of walk-in refrigeration equipment in the United States.

Table 3.2.11 Lifetime of Refrigeration Equipment

Lifetime ***years***	**Reference**
7-15	Mark Ellis & Associates,[3]
15	Foster-Miller (2001)[4]
15-20	U.S. Environmental Protection Agency (EPA) (2001)[5]
15	Arthur D. Little (ADL) (2002)[6]
7-10	Intergovernmental Panel on Climate Change (IPCC) 2001[7]

Some literature suggested longer lifetimes of up to 20 years or more for walk-in refrigeration equipment. Many of the studies cited here are related to examination of environmental impacts of refrigerant emissions and therefore may not always clearly distinguish between the lifetime of the case and the lifetime of the compressor racks.[8] However, consultation with experts in the field suggested that smaller, independently owned grocery stores were more likely to keep equipment longer than larger chain stores.

3.2.5.2 Panels and Doors

Unlike motorized or electrical equipment, a walk-in panel or door may not have a clear point of failure. In some instances, panel and/or door failure may be obvious, such as in the cases of a severe puncture or freeze-thaw distortion of panel shape. However, it is more common that envelope components fail from an insulation perspective long before they exhibit any visual forms or signs of failure. Even if the panel or door appears structurally intact, its ability to insulate effectively may have been diminished substantially by diffusion, water absorption, or wear and tear.

Owing to this visual ambiguity, and the wide variety of material properties and environmental conditions that may impact the walk-in, walk-in panel and door lifetimes may have a wide range. Panel and door lifetimes across a variety of sources cited a range of 12–25 years that was first referenced in the widely referenced commercial refrigeration equipment industry report by Arthur D. Little, Inc. (1996). Anecdotal evidence suggests that some walk-in panels and doors remain operational for years longer.

In addition, since there is possibly a large discrepancy between when a panel or door fails and when it is replaced, all following analysis for panels and doors is based on estimated replacement rates.

3.2.5.3 Used or Refurbished Equipment

Several industry experts suggested there is a significant used/refurbished equipment market. However, the size of the used market relative to the new market was not determined. Those consulted generally agreed that the salvage value of used equipment was very low compared to the initial purchase price. This is due to both cosmetic concerns and the custom nature of much of the equipment. Additionally, the difficulty in collecting used equipment of the same “look” for planned display case line-ups was cited as another reason for the low price of used equipment. A survey in the Pacific Northwest reported that for small, independent grocery stores (<20,000 ft^2) and for independently owned convenience stores, the fraction of owners who would consider purchase of refurbished equipment was 25 and 16 percent, respectively. For larger, regional chains, this fraction was approximately 11 percent. None of the large grocery chains surveyed had plans to purchase refurbished equipment.

3.2.6 Market Performance Data

NRCan provides estimates of the installed number, sales, and energy consumption of WICF equipment on an annual basis, summarized in Table 3.2.12.

Table 3.2.12 Summary of Walk-in Cooler and Freezer Data Compiled by NRCan[9]

Equipment Type	**Total Installed**	**Annual Sales (New or replacement)**	**Annual Energy Consumption *kWh***
Refrigerator (15 m^2)	-	-	16,200
Freezer (15 m^2)	-	-	21,400
Refrigerator-Freezer (31 m^2)	-	-	30,200
Total	96,000	3,300	-

DOE was unable to find a source that compiled WICF data in the United States. Because there has not been a test procedure in place in this industry, there is no established industry-wide metric for performance of walk-in panels, doors, and refrigeration systems as they relate to energy consumption. Manufacturers' specification sheets typically provide only information relevant to the end user or contractor. Refrigeration specification sheets typically include refrigeration capacity, physical dimensions, electrical characteristics, and a description of standard and optional features. Panel and door specification sheets typically include physical dimensions, characteristics of any electrical components, and sometimes R-value in the case of panels and non-display doors.

Although DOE could not find any quantitative industry-wide performance data, DOE has researched the industry and presents its findings below pertaining to equipment performance.

Panels

The majority of panels are made of 4-inch-thick foam. They are also available in 5-inch and 6-inch thicknesses, but these sizes are not used frequently. They are more difficult to manufacture because the increased thickness increases the curing time of the foam (for foam-in-place polyurethane (PU)) and are more difficult to handle, increasing the labor time for the manufacturer. Also, customers do not prefer thicker panels because they take up space that could otherwise be used to store or market products.

Most panels are made of foam-in-place PU. Of the panel manufacturers identified, approximately 75 percent manufacture PU panels, with the remainder manufacturing either extruded polystyrene (XPS) panels or both types of panels. However, all the manufacturers DOE identified who make XPS panels are small businesses. Therefore, DOE estimates that the overall percentage of PU panels on the market is higher than 75 percent and could be as high as 90 percent.

When first manufactured, PU has an R-value of approximately 7 per inch, and XPS has an R-value of approximately 8 per inch. Over time, the R-value of PU decreases to approximately R-6.8 per inch and the R-value of XPS decreases to approximately R-5.8 per inch. DOE expects that this would be accounted for in the test for long-term thermal resistance, which contributes to the measurement of the panel's U-factor. DOE does not have any industry data on current panel U-factor ranges.

Non-Display Doors

Most passage doors are made by panel manufacturers who supply the door to the customer along with the set of panels that make up a walk-in. Almost all passage doors are made of foam-in-place PU and tend to be the same thickness as the walk-in they are intended to be used with, to meet the EPCA standards and for cosmetic purposes. Many passage doors incorporate a small window (approximately 1 to 2.5 ft^2).

Freight doors are often manufactured by a specialty manufacturer. They tend to be the minimum thickness necessary to meet the EPCA standards, to avoid additional weight. Freight doors may open horizontally or vertically, and may be manual or powered.

Display Doors

Display doors are almost exclusively manufactured by manufacturers who specialize in display doors because they are difficult and expensive to manufacture. Most display doors only have the energy saving features necessary to comply with the EPCA standards, but all manufacturers of display doors market one or more lines of high-efficiency doors. DOE estimates that high-efficiency doors could comprise a small portion of the market.

Refrigeration

Three major refrigeration manufacturers include at least one energy-saving feature not already required by EPCA in at least some of their standard equipment, and all refrigeration manufacturers DOE identified have optional energy-saving features. DOE assumed that of refrigeration systems sold, 75 percent were at baseline and 25 percent had, on average, an efficiency equivalent to level 1 in DOE's engineering analysis (for more details on the engineering analysis, see chapter 5 of the TSD).

The most significant sub-component of a refrigeration system in terms of energy use is its compressor, and many compressor manufacturers publish the energy efficiency ratio (EER) of their compressors. EER is the ratio of the compressor's cooling capacity (ability to remove heat) in Btu/h to the power input in watts. DOE surveyed compressors of the sizes and types that would normally be used in WICF refrigeration systems. Below, DOE presents data on compressor EER at rating conditions consistent with those in the refrigeration system test procedure. Figure 3.2.1 contains data for medium-temperature systems over the whole range of analyzed sizes, while Figure 3.2.2 shows a more detailed view of medium-temperature compressors in a smaller size range. Figure 3.2.3 and Figure 3.2.4 show the same data for low-temperature compressors.

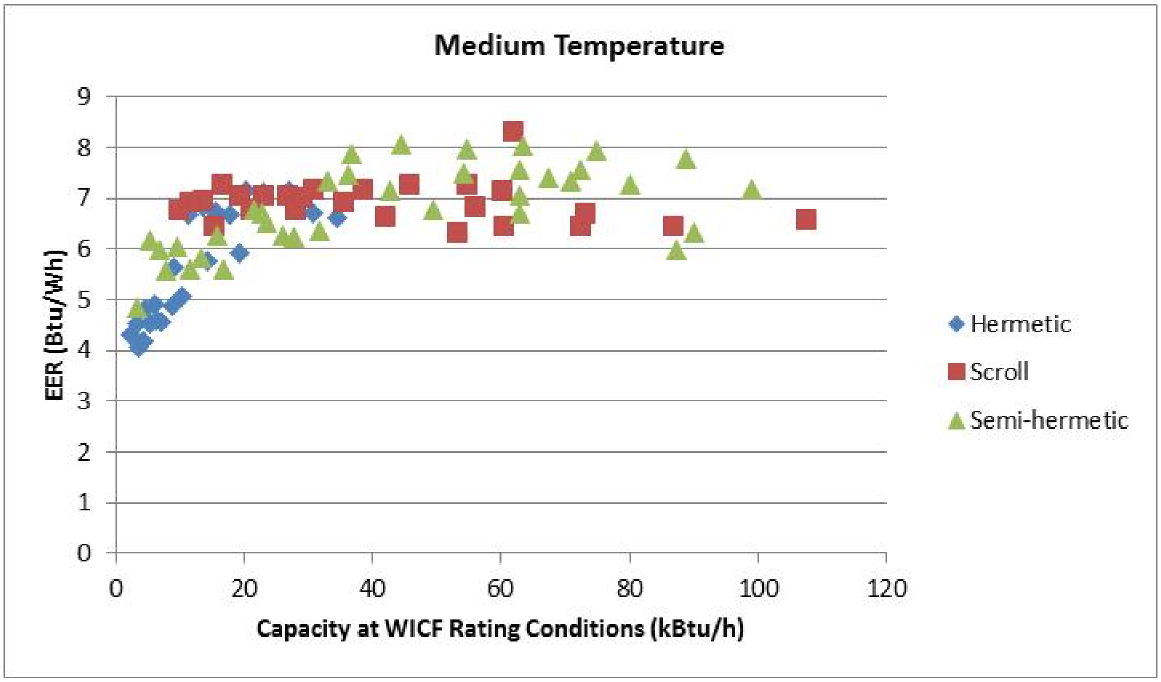

Figure 3.2.1 All Medium-Temperature WICF Compressors

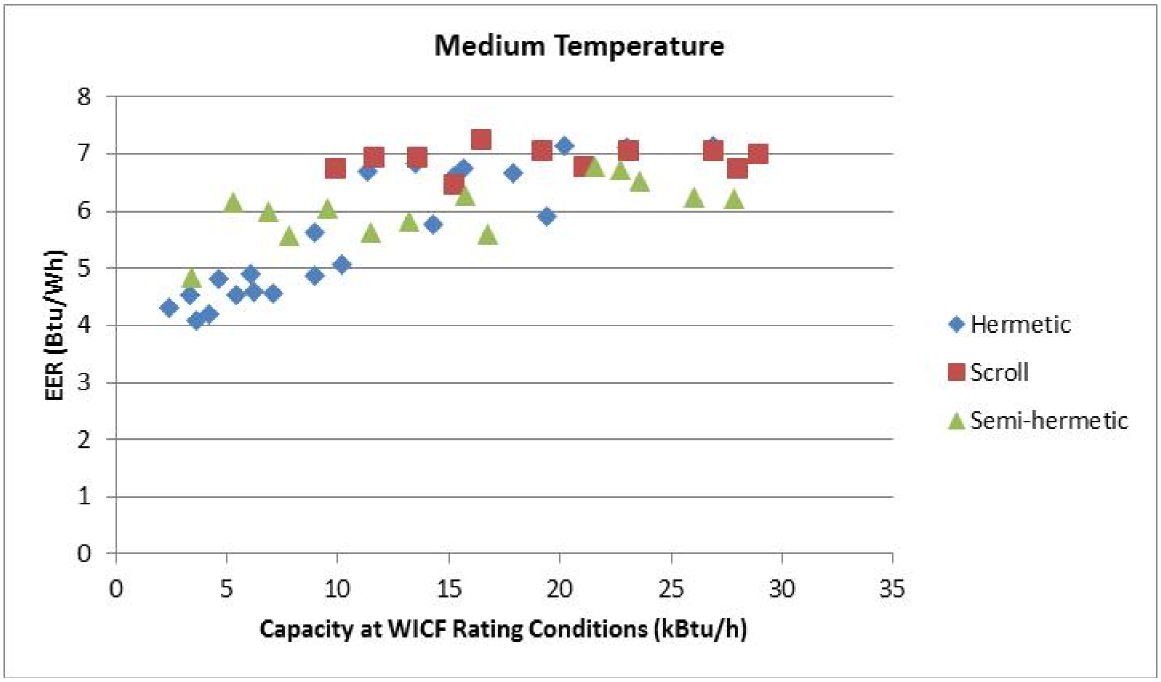

Figure 3.2.2 Small-Size Medium-Temperature WICF Compressors

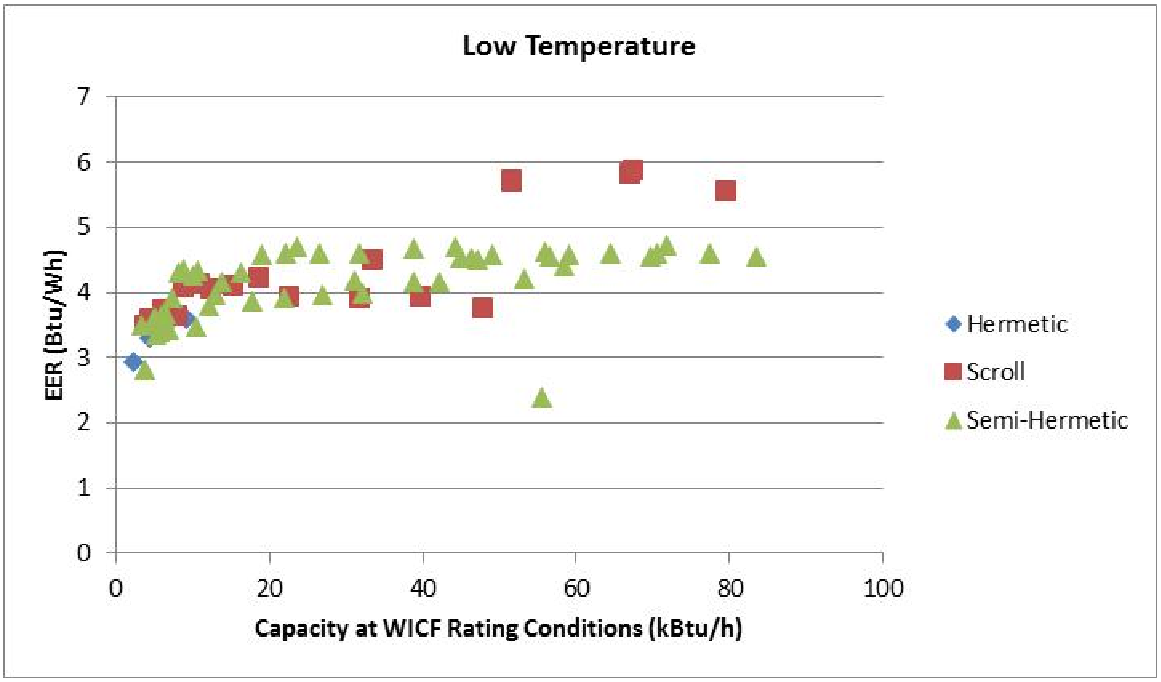

Figure 3.2.3 All Low-Temperature WICF Compressors

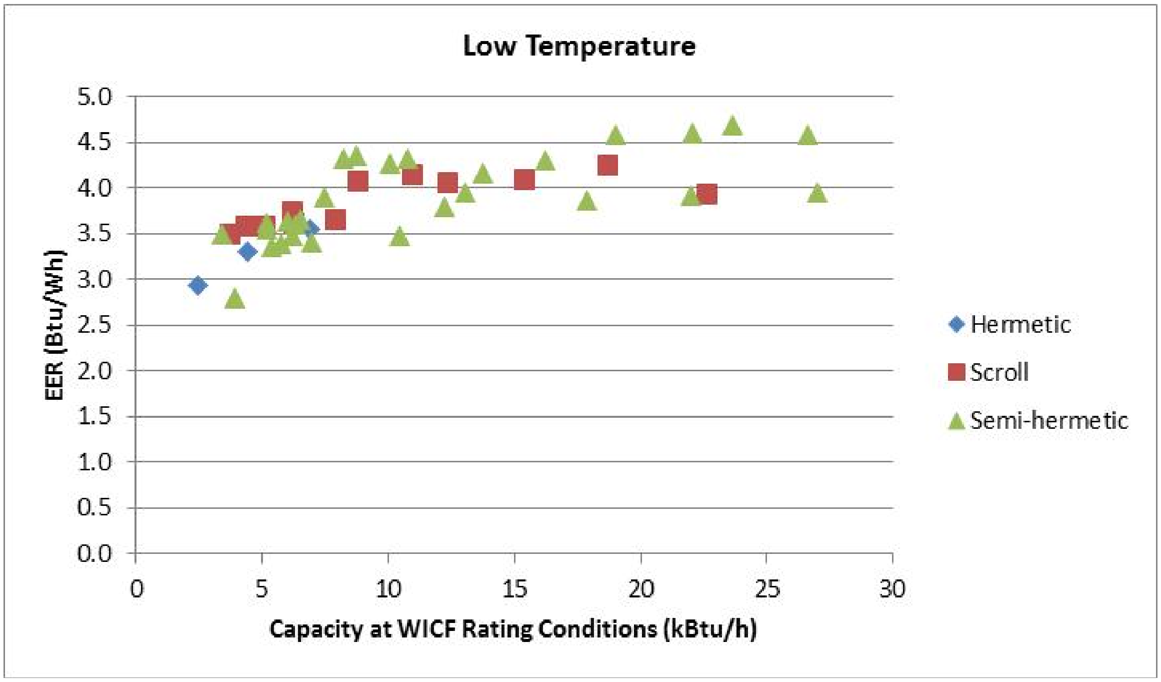

Figure 3.2.4 Small-Size Low-Temperature WICF Compressors

3.2.7 Key Stakeholders

The following table lists key stakeholders who have provided comments on the rulemaking to date.

Table 3.2.13 List of Interested Parties

Commenter(s)	Abbreviated Designation	Affiliation	Comment Number(s) in Docket
Kason Industries, Inc.	Kason	Component Supplier	0009.1, 0019.1
Craig Industries, Inc. and US Cooler Company	Craig Industries	Manufacturer	0011.1, 0025.1, 0038.1, 0064.1, 0071.1
AFM Corporation	AFM	Manufacturer	0012.1
Eliason Corporation	Eliason	Manufacturer	0013.1, 0022.1
The Northwest Energy Efficiency Alliance and the Northeast Power Coordinating Council	NEEA and NPCC	Utility Representative	0021.1, 0059.1
Bally Refrigerated Boxes, Inc.	Bally	Manufacturer	0023.1
Appliance Standards Awareness Project	ASAP	Energy Efficiency Advocate	0024.1
CrownTonka Walk-ins	CrownTonka	Manufacturer	0026.1, 0057.1
Earthjustice	Earthjustice	Energy Efficiency Advocate	0027.1, 0047.1
Edison Electric Institute	EEI	Energy Efficiency Advocate	0028.1
Foam Supplies, Inc.	FSI	Material Supplier	0029.1
Hired Hand Technologies	Hired Hand	Manufacturer	0030.1, 0050.1
Heating, Air-conditioning & Refrigeration Distributors International	HARDI	Trade Association	0031.1
Kysor Panel Systems	Kysor	Manufacturer	0032.1, 0054.1
Nor-Lake, Incorporated	Nor-Lake	Manufacturer	0049.1
Owens Corning Foam Insulation, LLC	Owens Corning	Material Supplier	0034.1
Southern California Edison and Technology Test Centers	SCE	Utility	0035.1
Air-Conditioning, Heating, and Refrigeration Institute	AHRI	Trade Association	0036.1, 0055.1
American Panel Corporation	American Panel	Manufacturer	0039.1, 0048.1
Master-Bilt Products, Inc.	Master-Bilt	Manufacturer	0033.1, 0046.1
Zero-Zone, Inc.	Zero-Zone	Manufacturer	0051.1
American Chemistry Council Center for the Polyurethanes Industry	CPI	Material Supplier	0052.1
Hussmann and Ingersoll Rand	Ingersoll Rand	Manufacturer	0053.1
Manitowoc Ice	Manitowoc	Manufacturer	0056.1
Heatcraft Refrigeration Products LLC	Heatcraft	Manufacturer	0058.1, 0069.1
Southern California Edison, San Diego Gas & Electric, Pacific Gas & Electric Company, Sacramento Municipal Utility District	Joint Utilities	Utility Group	0061.1
American Chemistry Council	ACC	Material Supplier	0062.1
Craig Industries, Inc. and U.S. Cooler Company	Craig Industries	Manufacturer	0064.1
AmeriKooler, Inc.	AmeriKooler	Manufacturer	0065.1
Hill Phoenix Walk-Ins	Hill Phoenix	Manufacturer	0066.1
NanoPore Insulation, LLC	NanoPore	Material Supplier	0067.1
Carpenter Co. Chemical Systems Division	Carpenter	Material Supplier	0068.1
American Council for an Energy Efficient Economy, Appliance Standards Awareness Project, Alliance to Save Energy, Natural Resources Defense Council, Northwest Energy Efficiency Alliance	Joint Advocates	Energy Efficiency Advocates	0070.1

3.2.7.1 Trade Associations

There is no single, unifying trade organization representing manufacturers of walk-in coolers and walk-in freezers or their components. Rather, the industry is segmented by equipment type and end use. Several refrigeration system manufacturers are represented by a single association. Also, some walk-in manufacturers belong to a trade association that represents manufacturers of foodservice equipment. No association represents manufacturers of panels and doors specifically, although several organizations represent manufacturers of different types of foam used in WICF panels and non-display doors.

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) is one of the trade associations representing WICF manufacturers. AHRI primarily represents refrigeration manufacturers, although some of these companies also make the panels and doors used in walk-in coolers and walk-in freezers. Manufacturers of panels, doors, and refrigeration systems with membership in AHRI include:

Associate Members:

- Anthony
- Imperial Manufacturing

Full Members:

- Bally Refrigerated Boxes, Inc.
- Carrier Corporation
- Craig Industries (U.S. Cooler Corp.)
- Heatcraft Refrigeration Products, LLC
- Hill PHOENIX
- Hussmann Corporation
- KeepRite Refrigeration (Canadian)
- Lennox International, Inc.
- Manitowoc
- Master-Bilt
- Tecumseh

As an organization, AHRI is subdivided into divisions that represent various parts of the refrigeration market. One of these is the Commercial Refrigerator Manufacturers Division (CRMD). Originally founded in 1933 as a separate trade association, CRMD was established within AHRI with the purpose of developing and implementing a certification program for commercial refrigerators, commercial freezers, and commercial refrigerator-freezers. Technical activities of CRMD include:

- harmonization of international equipment standards;
- development of industry performance standards for commercial refrigeration equipment;
- updating of industry guidelines for retail store fixture installation, design, energy conservation, electronic case controls, and specifications for equipment installation;

- maintaining liaison with refrigerant suppliers and government agencies on environmentally acceptable chlorofluorocarbon (CFC) alternatives; and
- providing input to government agencies concerning regulations affecting the industry.

The North American Association of Food Equipment Manufacturers (NAFEM) represents manufacturers of foodservice equipment. Several WICF manufacturers who sell equipment to the foodservice industry belong to NAFEM, including:

- American Panel Corporation
- Amerikooler, Inc.
- Arctic Industries, Inc.
- Bally Refrigerated Boxes, Inc.
- Chrysler & Koppin Company
- Heatcraft Refrigeration Products, LLC
- Howard-McCray
- Imperial Manufacturing
- International Cold Storage
- Kolpak Walk-ins
- Kool Star
- Leer, Inc.
- Manitowoc Foodservice
- Master-Bilt Products
- Nor-Lake, Inc.
- Polar King International, Inc.
- Standex International
- Tafco – TMP Company
- Tecumseh Products Company
- ThermalRite
- Thermo-Kool/Mid-South Industries Inc.
- U.S. Cooler Company
- W.A. Brown, Inc.

Panel and door manufacturers have no single organization serving in an umbrella role. Reflecting the diversity of products available, several trade associations represent manufacturers of specific foam types within the WICF industry.

- Polyurethane Manufacturers Association (PMA, www.pmahome.org) composed of numerous suppliers, distributors, and contractors of polyurethane foam insulation.
- Extruded Polystyrene Foam Association (XPSA, www.xpsa.com) composed of Dow Chemical, Owens Corning, and Pactiv, the main manufacturers of extruded polystyrene foam insulation.
- Spray Polyurethane Foam Alliance (SPFA, www.sprayfoam.org) composed of contractors, chemical manufacturers, and distributors of spray polyurethane foam insulation. Chemical manufacturers include BASF Polyurethane Foam Enterprises LLC, Gaco Western, Honeywell, Huntsman Polyurethanes.

- Polyisocyanurate Insulation Manufacturers Association (PIMA, www.polyiso.org) composed of manufacturers, suppliers, and brand relabelers associated with the polyisocyanurate foam insulation industry. Arkema, Inc. is a member.

3.3 TECHNOLOGY ASSESSMENT

The function of the technology assessment is to develop a preliminary list of technologies that could potentially be used to reduce the energy consumption of walk-in coolers and walk-in freezers and their components, as well as to highlight the developments within those technology categories and their applicability to these product classes. Walk-ins present a wide variety of design options that could lead to energy savings if implemented in production models.

The components of a walk-in cooler covered by this rulemaking are the panels, doors, and the mechanical refrigeration system. Each of these presents specific energy use or heat transmission issues that can be addressed through new technologies. Within the refrigeration system, some energy loss is due to inefficiencies in the components, including the compressor, motors, and fan blades; while some is due to system inefficiencies, including refrigerant pressures and temperatures. Advanced designs can lead to both direct energy savings and a reduction of waste heat discharged into the refrigerated space, which must be removed. The panels and doors present another group of energy loss pathways, including the conduction of external heat through insulated walls and electricity consuming devices such as lights and anti-sweat heaters.

Certain types or classes of WICF components may also exhibit further means through which energy loss occurs. For example, walk-in refrigeration systems located outdoors are exposed to increased fluctuations in temperature that affect the operation of the condenser, and display doors exhibit pronounced energy losses due to conduction through the glass, as well as the presence of anti-sweat heating devices. The following assessment provides descriptions of technologies and designs that apply to panels, doors, and refrigeration, or classes thereof.

3.3.1 Technologies and Designs Relevant to Whole Walk-Ins

3.3.1.1 Non-Penetrative Internal Racks and Shelving

Many manufacturers have noted that end users and customers will install interior shelving units and racks in the walk-ins using penetrative fasteners such as nails and screws. These compromise the inner skin and insulation of the envelope, resulting in reduced insulating capacity and possibly air leakage. The use of freestanding racks and shelving units by end users could be a simple and effective method for reducing losses.

3.3.1.2 Humidity Sensors

The humidity of the exterior ambient air can influence the performance of the mechanical refrigeration system. As air with a higher humidity has a higher specific heat, more energy is required to cool the air on a day with high humidity. Sensors installed in the system could provide real-time information about the outside humidity, which would allow the end user to make more informed decisions about such matters as when to load and unload product. Such intelligently managed use would reduce infiltration losses due to prolonged door opening on days exhibiting adverse operating conditions.

3.3.1.3 Fiber Optic Natural Lighting

During daytime business hours, instead of using electrically powered lighting systems, roof mounted collectors can be used to direct sunlight into fiber optic cables that transmit the light to where it is needed in a walk-in. This would save energy by preventing electricity use from lighting at these times.

3.3.1.4 Energy Storage Systems

Thermal energy storage systems could be used to stabilize cooling demand on the refrigeration system, allow the system to operate only during optimal environmental conditions, and shift electrical demand to off-peak hours to achieve cost savings. For example, the refrigeration equipment could cool a large mass during the night when outdoor temperatures are lowest and electricity prices are cheapest. During the daytime or periods of peak demand, this stored energy could then be utilized. Energy storage would allow for systems to be designed for more-efficient steady-state operation rather than being oversized for “worst-case” weather or product loading scenarios.

3.3.1.5 Refrigeration System Override

During periods of high traffic, such as when a shipment of product is received and must be transferred into the walk-in, the door to the cooler or freezer may be repeatedly opened or simply left open for a long period of time. With traditional systems, the thermostat engages the compressor and fans during such periods. However, such operation wastes a large amount of electricity, as the attempt on behalf of the system to cool the interior space is lost via the open door. A better alternative is to simply override the thermostat, turning off the refrigeration system completely during high-traffic periods and reengaging it after the tasks have been performed. Such a simple control would prevent the cooling system from continuously running at maximum capacity in an attempt to bring the inside temperature down to the desired value while continuously ejecting cold air to the surrounding environment. The result would be an immediate and sizeable energy savings.

3.3.1.6 Automatic Evaporator Fan Shut-Off

Typically, evaporator fans run at all times to circulate cool air in the walk-in. This design option consists of a control that would automatically shut off evaporator fans whenever the walk-in door is opened. The result would be that less chilled air would be blown out into the walk-in’s surroundings, meaning that less energy would be needed to restore the temperature in the interior space following a door opening.

3.3.2 Technologies and Designs Relevant to Panels and Non-Display Doors Only

3.3.2.1 Insulation Thickness and Material

Most walk-in envelopes are constructed from panels known as structurally insulated panels, which are composed of a sandwich of metal skins encapsulating an insulating material. A similar methodology is used for non-display walk-in doors. Most walk-ins currently manufactured and installed use traditional foam materials as insulation for the panels and non-display doors. Their main purpose is to reduce heat transfer from the external environment to the internal conditioned space of the walk-in.

Improvements to the insulating capacity of the envelope could be achieved through a number of methods. The most basic of these would be increased insulation thickness using existing foam insulating materials. Another option would be the incorporation of insulating materials that have higher thermal resistance per inch thickness. One such technology is the vacuum insulated panel, which consists of an outer air-tight membrane surrounding a core material. The inner core is evacuated to remove air from the material. This greatly reduces heat conduction on a per inch basis compared to foam materials. Other options include the incorporation of aerogels, a low-density and low heat conducting material.

3.3.2.2 Framing Materials

The insulation found in walk-in panels and non-display doors is typically framed by wood to provide structural support and ease the foaming process for foam-in-place polyurethane manufacturers. The thermal resistance of wood is much lower than that of foam-in-place polyurethane or polystyrene, common insulation materials. Improving the material used to frame a walk-in panel or eliminating the framing material would improve the overall thermal resistance of the walk-in panel or non-display door.

3.3.2.3 Air and Water Infiltration Sensors

Infiltration of water and/or water vapor into the envelope insulating material may significantly reduce the insulating capacity of the affected regions because the thermal conductivity of water and ice is higher than that of insulation. This sort of infiltration may result from specific incidents, such as punctures or damage, or may be a steady-state process occurring over a long period of time. A water condensate or vapor sensor implanted within the insulating material would allow for early detection of damage to the insulating material. This would prevent continued operation with a damaged unit and would provide notification of the need for repairs. As a result, the energy that would have been wasted during sustained operation of a damaged unit would be conserved. In addition, pressure or flow sensors may be used to directly measure walk-in air exchange rates, providing end users with data on historical air exchange patterns so they can monitor real-time performance.

3.3.2.4 Heat Flux Sensors

As mentioned earlier, damage to the envelope of the walk-in can occur for many reasons, including penetrative fasteners used to attach shelves or racks and/or long-term degradation of insulation due to gas diffusion or water infiltration. Heat flux sensors are available, which use a simple hot plate method to provide real-time information regarding the insulating properties of a wall on which they are mounted. This non-destructive, R-value monitoring would provide manufacturers with useful data of walk-in performance as installed in the field and allow end users to monitor performance of the insulation over time to avoid energy losses incurred due to a drop in insulation R-value.

3.3.3 Technologies and Designs Relevant to Display and Non-Display Doors Only

3.3.3.1 Door Gaskets

All walk-in doors use seals to prevent air exchange with the surroundings when the door is closed. These seals typically consist of rubber gaskets that are compressed when the door latch is closed, or magnetic, vinyl-coated systems used display glass doors. Improvements in these systems and the seal materials could result in less air leakage, reducing energy loss due to air infiltration.

3.3.3.2 Anti-Sweat Heater/Freezer Wire Controls

The external surface of a glass display door may experience temperatures below the dew point of the ambient air. In this situation, condensation can form on the surface of the door, reducing visibility of the product and also possibly leading to ice buildup or pools of condensate forming at the base of the glass door. This phenomenon is known as “sweating.” Anti-sweat heaters are generally used to ensure that the external glass temperature is above the dew point of the ambient air, which prevents sweating.

Generally, electric heater wire, in contact with the door perimeter, is energized to continuously heat the glass. However, anti-sweat heat may only be required during particularly humid environmental conditions or walk-in temperatures. Control devices are available that sense external humidity and temperature, and regulate anti-sweat heater wire use on demand. These systems significantly reduce the required daily electrical demand.

Non-display freezer doors also use a heater wire to prevent the door from freezing shut. The heater wire may also use a control device to regulate use on demand.

3.3.3.3 Display and Window Glass System Insulation Performance

Heat transfer losses through display doors may represent 30 to 40 percent of walk-in energy consumption. While current regulation prescribes minimum standards for number of panes, gas fill, and low emissivity coatings, there is significant opportunity for improvement. In addition, windows used in non-display doors also contribute to energy consumption, but on a much lower percentage basis.

Improvements to reduce heat transfer performance could include the use of additional panes of glass and expanded use of inert gas-filled panes using argon, krypton, or xenon. Treating the window glass with advanced low emissivity coatings and increasing the number of coated surfaces could also reduce losses due to radiation heat transfer. The result of these improvements would include both direct energy savings due to reduced anti-sweat heater demand and an indirect reduction in energy consumption through reduced conduction losses.

3.3.3.4 Non-Electric Anti-Sweat Systems

While conventional anti-sweat heaters operate using separately powered electric resistance heater wire, any heat source capable of bringing the door surfaces to a temperature above dewpoint could also serve this purpose. It may be possible to use the waste heat generated by the mechanical refrigeration system to provide the required glass door heating. In these non-electric systems, a heat transfer fluid could be used to absorb heat from the refrigeration system and reject heat to the glass doors. Using waste heat that is readily available may eliminate a major source of electrical energy consumption in display units.

3.3.3.5 No Anti-Sweat Systems

Another option for addressing the issue of sweating is the use of static systems that prevent the phenomenon. These include multi-pane glass doors, which have greater insulating properties, preventing the exterior temperature from becoming low enough for sweating to occur. Another option may be advanced hydrophobic materials that prevent condensate from attaching or lingering on the glass surface and therefore prevent the formation of water droplets that may obscure a customer's view of a product.

3.3.4 Technologies and Designs Relevant to Panels Only

3.3.4.1 Panel Interface Systems

Panel interface systems include the methods and materials designed to seal the panel-to-panel interfaces, panel-to-floor interfaces, and other interfaces present. Use of improved materials, geometries, and manufacturing techniques could further reduce infiltration and improve the overall insulating capacity of the envelope, resulting in less energy input required by the refrigeration system.

3.3.5 Technologies and Designs Relevant to Display Doors Only

3.3.5.1 High-Efficiency Lighting

New advanced lights such as light emitting diodes (LEDs) and organic light emitting diodes (OLEDs) offer significant increases in efficacy compared to standard fluorescent systems. Namely, the electricity consumption and waste heat generated are far lower for the same light output. Nearly every major display door manufacturer offers LED lighting as design option. LED bulbs that fit in Edison type fixtures are also widely available.

3.3.5.2 Occupancy Sensors

One major source of energy consumption associated with a walk-in display door is the operation of lighting when it is not needed, primarily due to lights being left on when the unit is unused. Occupancy sensors ensure operation of the lighting only when an individual is viewing products in a display type walk-in. When motion has not been detected for a set period of time, the lights are turned off. This would reduce waste due to lights being left on unnecessarily. Moreover, the sensors could also be used to notify personnel of periods when the door is ajar;

that is, if the door is open and no one has been inside the space for a period of time. This would save energy due to loss of refrigerated air from the interior space.

3.3.5.3 Automatic Insulation Deployment Systems

In many businesses, such as convenience and grocery stores with limited hours of operation, display doors are not used during non-business hours. In such applications, automatic insulation deployment systems could be put in place to lower a layer of insulation over the interior or exterior surface of the glass doors during non-business hours, thus increasing the thermal resistance of the door and, correspondingly, the net insulating capacity of the entire envelope. This would greatly reduce conduction losses and save energy.

3.3.6 Technologies and Designs Relevant to Non-Display Doors Only

3.3.6.1 Automatic Door Opening and Closing Systems

Doors left open accidentally by employees can be a major cause of heat transfer to the envelope due to air infiltration. To avoid the frequency and duration of accidental and intentional door opening, especially while products are being loaded into the walk-in, the use of automatic door opening and closing mechanisms can reduce air infiltration. By sensing approaching personnel and through the use of powered door openers, the door can be quickly opened and closed at a rate that both ensures safe movement through the doorway and minimizes the duration of the door opening event. Instead of the door being propped while the walk-in is being loaded, the door would only be opened for the short period that a person or forklift needs to pass through the doorway.

3.3.6.2 Air Curtains

Air curtains consist of fans mounted horizontally or vertically that direct a stream of air across a door opening. When the door is opened, the air current is activated, blowing air perpendicular to direction of air movement into and out of the walk-in. This air barrier greatly reduces unwanted exchange of air while the door is open.

Two types of air curtains exist: recirculating and non-recirculating. Non-recirculating units are the most common, as these simply use air from the interior space to form the moving stream. The air then impinges upon the floor and the stream splits. If properly positioned, the systems are very effective at reducing air infiltration. In recirculating units, the stream of air is captured through a floor grate and run through the blower again. Manufacturers claim that recirculating units are even more effective than non- recirculating systems. Air curtains are not standard on most walk-ins, but have been widely available for quite some time and are often installed by end users as an accessory.

3.3.6.3 Strip Curtains

Strip curtains are barriers composed of vertically-oriented strips of plastic, usually clear PVC, which can be suspended in the doorway opening of a walk-in. When undisturbed, the curtain forms a barrier that limits movement of the cooled air out into the environment, yet allows for easy and unobstructed passage through the doorway. These are commonly installed by end users to save energy. Generally, strip curtains are used in larger units that experience heavy traffic, such as constant movement of goods using forklifts. However, their proficiency in preventing the loss of chilled air from the inside of the refrigerated space makes them a candidate for use in walk-ins of all sizes and uses.

3.3.6.4 Vestibule Entryways

The implementation of vestibule or air-lock doors would greatly reduce the losses that result from opening the doors for entry. This type of entry system is typically used in larger building entrances to prevent heat loss due to door opening air infiltration. The doors open and close sequentially during entry and exit, never allowing direct air exchange. Instead, only a small amount of air would move with the user into the small space between the two doors. This would significantly reduce the increase in interior temperature that occurs each time the door is opened, as well as the corresponding amount of energy required to cool that space back down to the desired set point.

3.3.6.5 Revolving Doors

Another provision for the reduction of losses due to air infiltration from door opening would be the use of revolving doors. Like vestibule entries, revolving door systems are commonly used for the entryways of large buildings. Similarly, they prevent direct exchange of air and reduce the rate of infiltration compared to a standard door.

3.3.7 Technologies and Designs Relevant to All Refrigeration Equipment Classes

3.3.7.1 Evaporator and Condenser Fan Blades

Conventional fans have sheet metal blades mounted to a central hub, and are generally not optimized for the specific application in which they will be used. Instead, they are designed for mass production and scalability to minimize production cost and waste. Optimization of fan design for specific applications could significantly reduce input energy needed to perform the work. Higher efficiency fan blades can move more air at a given rotational speed compared to traditional fan blades. This means that a smaller motor can be used, or the existing motor can be run at a lower speed, resulting in direct energy savings.

3.3.7.2 Improved Condenser and Evaporator Coils

The effectiveness of the refrigeration system in moving heat from the temperature-controlled space to the ambient environment is constrained by the ability of the evaporator and condenser coils to transfer heat. Coils are generally constructed of copper and aluminum, with these materials being chosen for their favorable heat transfer characteristics. Enhancements to both the refrigerant side (inside) and air side (outside) of the coils can improve their heat transfer characteristics, requiring less compressor power and fan energy to achieve the same system capacity. Improvements to the refrigerant side of the coil can include increased tubing passes as well as changes in the geometric profile of the tubing itself. Air-side improvements consist of decreasing the spacing between the fins, thus increasing the number of fins per unit coil length, as well as changes in the fin patterns. Increased overall coil size also improves heat transfer.

3.3.7.3 Evaporator Fan Control

In traditionally operated systems, evaporator fans run at all times, whether or not the compressor is running. This could result in an overuse of electrical power. Evaporator fan controls save energy by allowing the evaporator fans to run at variable speed or to modulate on and off during periods when the compressor is off.

3.3.8 Technologies and Designs Relevant to Dedicated Condensing Refrigeration Systems Only

3.3.8.1 Ambient Sub-Cooling

This design option is applicable for outdoor systems with dedicated condensing units only. This process uses an oversized condenser or sub-cooling heat exchanger to further cool the condensed refrigerant using ambient air, effectively improving the heat transfer capability of the condenser as a whole. Ambient sub-cooling is particularly effective when implemented on systems operating in cool regions, where the temperature of the ambient air may be substantially lower than the temperature of the refrigerant just after it is condensed.

The result is a decrease in coolant enthalpy at the exit of the condenser and a corresponding increase in evaporator capacity, so a lower mass flow rate of compressed refrigerant, and thus less compressor power, is needed.

3.3.8.2 Higher-Efficiency Fan Motors

Two separate sets of fan motors service the evaporator and condenser of the walk-in, respectively. They facilitate heat transfer by moving air across the heat exchangers, in order to move heat transfer heat to and from the refrigerant. Current regulations require that all evaporator fan motors must be either 3-phase or electrically commutated motors (ECM), and that all condenser fan motors must be ECMs, permanent split capacitor motors, or 3-phase. This eliminates the usage of an older and less sophisticated motor type, the shaded-pole motor. Aside from motor type alone, other design options can be implemented into the motors to reduce internal friction and improve operating capacity. The result is that less electrical energy input is required to generate the same amount of output shaft work, and less waste heat is discharged due to friction, reducing electricity consumption directly. In the case of evaporator fan motors, more efficient motors reduce the system heat load, thereby reducing the indirect energy consumption of the refrigeration system in removing that load.

3.3.8.3 Higher-Efficiency Compressors

The compressor is the single component that uses the most power out of all those comprising the refrigeration system, making it a likely and appropriate target for improvement. Even a small percentage increase in compressor efficiency would result in very large energy savings over the life of the product. Currently, several types of compressors are in use for walk-in refrigeration systems. Smaller systems use hermetic reciprocating compressors, while larger units utilize semi-hermetic compressors. Additionally, scroll compressors are now being used across a range of capacities due to their higher efficiency at certain operating temperatures. Moreover, multiple capacity compressors present an opportunity for energy savings as well.

These systems can take many forms, including single compressors with multiple stages or variable operating speeds as well as coupled sets of compressors that engage as necessitated by the load on the envelope. These technologies allow for the compressor operating time and power to more closely match the heat load, improving performance and decreasing energy consumption.

3.3.8.4 Liquid Suction Heat Exchanger

This option is applicable for dedicated condensing units only. In many systems, compressor performance is decreased due to low temperature of a liquid-vapor refrigerant mixture at the suction point—that is, the compressor entrance. This also reduces the life of the compressor due to wear and tear. The liquid suction heat exchanger subsystem transfers heat from the liquid refrigerant exiting the condenser to the suction gas, thus sub-cooling the condensed liquid while heating the suction gas. The subsystem minimizes liquid refrigerant entering the compressor, thus improving the performance, and as a side effect sub-cools the liquid at the condenser exit, thus improving the capacity of the evaporator as described in section 3.3.8.1.

3.3.9 Technologies and Designs Relevant to Low-Temperature Refrigeration Systems Only

3.3.9.1 Defrost Controls

Management of frost buildup on coils is essential in ensuring continued efficient operation of the unit. Formerly, defrosting systems were run on regular intervals using a simple timer. However, this system has two possible negative consequences in that the defroster may run too often, wasting energy, or not often enough, decreasing system performance. Current systems continue to initiate defrost cycles periodically using a timer, but allow for control of the termination of defrost using a thermometer; when the coils reach a specified temperature—indicating that all ice has melted—the defroster is turned off.

More efficient systems may use sensors to determine that a defrost cycle is needed. The data collected can consist of either the temperature drop across the coil or detection of the physical thickness of frost buildup using photocells. The first of these two methods is based on the idea that decreased airflow across the coil is a result of frost buildup, meaning that the temperature differential of the air across the coil will increase. However, there are issues in that external factors aside from frost buildup on the coil that may be the reason for decreased airflow or a higher temperature differential. The second method is more accurate but requires more sophisticated sensors. Even more advanced defrost controls may involve adaptive algorithms that analyze past behavior of the system and attempt to predict when defrost is needed. Defrost controls tend to save energy because the system only undergoes defrost when necessary. By reducing the number of defrosts, the energy used to heat the coil during defrost is saved.

3.3.9.2 Hot Gas Defrost

Typical low temperature refrigeration systems have electrically powered heating rods attached to the coil. When a defrost is needed, the rods heat up and transfer heat to the coil, which melts the ice. Hot gas defrost involves the recirculation of hot gas discharged from the compressor to warm the evaporator during a defrost. Compared to other defrosting methods, namely electric defrost, energy consumption is much less as the heat comes from an existing by-product of the refrigeration process. However, sophisticated controls are required, along with complex pipe routing, for the system to be effective. A more serious consequence of using this defrosting system is cracking and leaking resulting from thermal stresses induced upon the coolant piping due to alternate exposure to high- and low-temperature refrigerant.

3.3.10 Technologies and Designs Relevant to Outdoor Refrigeration Systems Only

3.3.10.1 Floating Head Pressure

Traditionally, the pressure at which the compressor discharges, known as the head pressure, is kept at a constantly fixed setting in order to enable operation over a variety of environmental temperatures in outdoor units. Generally, this is fixed at a high value to ensure that enough refrigerant can flow through the system, which also protects the evaporative condenser against freezing and maintains the necessary pressure difference across the expansion valve.

However, modern technology, in the form of more sophisticated expansion valves, allows for the use of floating head pressure schemes, in which the refrigerant flow is dynamically controlled over a broad range of external temperatures. In this case, condensing temperatures down to the minimum operating temperature of the compressor can be used, much lower than the temperatures of 90 or 95 °F necessary for a fixed-head pressure system. In this case, the evaporative condenser is in constant or near-constant operation, rather than simply turning on and off as needed. This has the potential to generate a significant net energy reduction through a decrease in compressor energy use, and also can reduce the wear induced upon moving parts due to continual starting and stopping.

3.3.10.2 Condenser Fan Control

At high temperatures, condenser fans typically run at full speed when the compressor is on, and are off when the compressor is off. However, at lower ambient temperatures, less airflow is necessary to reject the heat produced by the coil, so condenser fans typically cycle on and off to maintain the necessary heat transfer. Condenser fan controls allow the evaporator fans to run at variable speed, saving energy through the fan power law, which states that motor speed reduction causes a corresponding reduction in power cubed.

3.3.10.3 Economizer Cooling

Economizer cooling consists of directly venting outside air into the interior of the walk-in when the outside air is as cold as or colder than the interior of the walk-in. This relieves load on the refrigeration system when pull-down load is necessary.

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CHAPTER 4. SCREENING ANALYSIS

TABLE OF CONTENTS

CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter addresses the screening analysis that the U.S. Department of Energy (DOE) conducted in support of the ongoing energy conservation standards rulemakings for walk-in coolers and walk-in freezers (WICF or walk-ins). In the market and technology assessment (chapter 3 of the technical support document (TSD)), DOE presented an initial list of technologies that can reduce the energy consumption of walk-ins. The goal of the screening analysis is to screen out technologies that will not be considered further in the rulemaking analyses. Some of the technologies considered in chapter 3 can reduce annual energy consumption under real world conditions, but may not increase the efficiency as measured under the DOE test procedure. DOE removed from consideration those technologies that do not decrease measured energy consumption. DOE evaluated the remaining technologies using the screening criteria set forth in the Energy Policy and Conservation Act (EPCA). (42 U.S.C. 6311–6317)

Section 325(o) of EPCA establishes criteria for prescribing new or amended standards that are designed to achieve the maximum improvement in energy efficiency. Further, EPCA directs the Secretary of Energy to determine whether a standard is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A), as directed by 42 U.S.C. 6316(a)(1)–(3)) EPCA also establishes guidelines for determining whether a standard is economically justified. (42 U.S.C. 6295(o)(2)(B)) In view of the EPCA requirements for determining whether a standard is technologically feasible and economically justified, appendix A to subpart C of Title 10, Code of Federal Regulations, Part 430 (10 CFR Part 430), "Procedures, Interpretations, and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products" (the Process Rule), sets forth procedures to guide DOE in its consideration and promulgation of new or revised efficiency standards. These procedures elaborate on the statutory criteria provided in 42 U.S.C. 6295(o) and, in part, eliminate problematic technologies early in the process of prescribing or amending an energy efficiency standard. In particular, sections 4(b)(4) and 5(b) of the Process Rule provide guidance to DOE for making a determination whether to eliminate from consideration any technology that presents unacceptable problems with respect to the following criteria:

Technological feasibility. Technologies incorporated in commercial equipment or in working prototypes will be considered technologically feasible.

Practicability to manufacture, install, and service. If mass production of a technology in commercial equipment and reliable installation and servicing of the technology could 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 be considered practicable to manufacture, install, and service.

Adverse impacts on equipment utility or equipment availability. If DOE determines that a technology has a significant adverse impact on the utility of the equipment to significant subgroups of consumers, or will result in the unavailability of any covered equipment type with performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as equipment generally available in the United States at the time, it will not be considered further.

Adverse impacts on health or safety. If DOE determines that a technology will have significant adverse impacts on health or safety, it will not be considered further.

In sum, if DOE determines that a particular technology or combination of technologies fails to meet one or more of the four criteria, it will be screened out. Section 4.3 documents the reasons for eliminating any technology.

4.2 TECHNOLOGIES THAT DO NOT AFFECT RATED ENERGY CONSUMPTION

As stated above, technologies that do not decrease measured energy consumption are not considered beneficial in the context of this rulemaking. Therefore, DOE removed the following technologies from consideration.

4.2.1 Non-Penetrative Internal Racks and Shelving

Many manufacturers have noted that often end users will install interior shelving units and racks in the walk-ins using penetrative fasteners such as nails and screws. These, by nature, compromise the inner metal skin and insulation of the envelope resulting in reduced insulating capacity and possibly air leakage. However, the test procedure used to measure the daily energy performance of a walk-in does not account for any energy savings related to this equipment. Furthermore, since manufacturers have little control over behavior of end users and most shelving systems are now designed to be free-standing, this issue may have less of an impact on the design of equipment. Consequently, DOE did not consider non-penetrative racks and shelving in the engineering analysis.

4.2.2 Air and Water Infiltration Sensors

Infiltration of water and/or water vapor into the envelope insulating material may significantly reduce the insulating capacity of the affected regions due to the thermal conductivity properties of water. This sort of infiltration may result from specific incidents, such as punctures or damage or a steady-state process occurring over a long period of time. A water condensate or vapor sensor, implanted within the insulating material, would allow for early detection of damage to the insulating material. However, while the data may be useful for end users and manufacturers, the technology does not directly result in a reduction in energy consumption. Consequently, DOE did not consider air and water sensors in the engineering analysis.

4.2.3 Infiltration-Reducing Devices

In the preliminary analysis, DOE considered several technologies and designs to reduce infiltration of air into the walk-in. However, following DOE's decision to develop component-based test procedures and standards, DOE is not proposing to account for the energy consumption of walk-ins due to infiltration loads. Therefore, DOE excluded the following infiltration-reducing technologies and designs from its analysis: door gaskets, panel interface systems, automatic door opening and closing systems, air curtains, strip curtains, vestibule entryways, and revolving doors, all of which are discussed in chapter 3 of the TSD.

4.2.4 Humidity Sensors

Humidity of the air is another factor which can influence the performance of the mechanical refrigeration system. Because more humid air has a higher enthalpy, it requires more energy to cool the air on a day with high humidity. Sensors installed in the system could provide real-time information regarding the outside humidity, which would allow for more informed decisions regarding topics such as the loading and unloading of product at certain times. However, these sensors (unless they are used for anti-sweat heater control) do not provide a means of directly reducing energy consumption. Consequently, DOE did not consider humidity sensors in the engineering analysis.

4.2.5 Heat Flux Sensors

Heat flux sensors use a simple hot plate method to provide real-time information regarding the insulating properties of a wall on which they are mounted. DOE did not consider heat flux sensors in the engineering analysis because they do not provide a means of directly reducing energy consumption.

4.2.6 Automatic Evaporator Fan Shut-Off

This control would automatically shut off evaporator fans whenever the walk-in door is opened. The result would be that less chilled air would be blown out into the surroundings, meaning that less energy would be needed to restore the interior space temperature following a door opening. However, the proposed DOE test procedure contains no provision for calculating energy savings that would occur with such a system because the envelope (including doors) and the refrigeration system are tested separately. Consequently, DOE did not consider automatic evaporator fan shut-off in the engineering analysis.

4.2.7 Liquid Suction Heat Exchanger

This subsystem minimizes the likelihood of a liquid-vapor mixture entering the compressor by using the refrigerant exiting the condenser to superheat the refrigerant exiting the evaporator, sub-cooling the refrigerant exiting the condenser in the process. This can effectively increase the performance and life of the compressor and may save energy under certain circumstances due to the sub-cooled liquid entering the evaporator. However, for higher efficiency systems, the overall effect of the liquid suction heat exchanger is reduced to minimal or no energy savings. DOE found that other techniques to improve energy efficiency were less expensive than liquid suction heat exchangers, but implementing these techniques reduced or eliminated the energy-saving effect of the liquid suction heat exchanger. Hence, DOE did not consider it as part of the engineering analysis.[1]

4.2.8 Refrigeration System Override

A refrigeration system override would consist of an option to manually shut off the mechanical refrigeration system for select periods of time, such as during the loading and unloading of product. At these times, high traffic results in many door openings, or the door being left open altogether. In a conventional system, the refrigeration system continues to operate in an attempt to bring the temperature down to the desired value. An override would prevent this, meaning that less energy would be used during these periods. However, the DOE test procedure for walk-ins has no provision for the testing of walk-ins equipped with such systems, and thus there would be no reduction in energy consumption as tested. Consequently, DOE did not consider refrigeration system override in the engineering analysis.

4.2.9 Economizer Cooling

Economizer cooling consists of directly venting outside air into the interior of the walk-in when the outside air is as cold as or colder than the interior of the walk-in. This technique relieves the load on the refrigeration system when a pull-down load (i.e., a load due to items brought into the walk-in at a higher temperature than the operating temperature and must then be cooled to the operating temperature) is necessary. However, the test procedure does not include a method for accounting for economizer cooling, as it does not specify conditions for air that would be vented into the walk-in, nor does it provide a method for measuring the energy use of the economizer. Therefore, any benefits from including an economizer on a WICF would not be captured by the test procedure.

4.3 SCREENED-OUT TECHNOLOGIES

This section addresses the technologies that DOE screened out because they did not meet the requirements of sections 4(a) and 5(b) of the Process Rule. DOE considered the following four factors: (1) technological feasibility; (2) practicability to manufacture, install, and service; (3) adverse impacts on equipment utility to consumers; and (4) adverse impacts on health or safety. The technologies that were screened out are fiber optic lighting, energy storage systems, non-electric anti-sweat systems, automatic insulation deployment systems, insulation thicker than 6 inches, higher efficiency evaporator fan motors, 3-phase motors, and improved evaporator coils.

4.3.1 Fiber Optic Natural Lighting

Fiber optic lighting systems are often used in the building industry. However, in this analysis, DOE has not encountered any such systems either in prototype or manufactured and sold for walk-in applications. As a result, DOE screened out fiber optic natural lighting on the grounds of technological infeasibility.

4.3.2 Energy Storage Systems

One proposed technology included the incorporation of thermal storage media that could be cooled during the overnight hours and then used to lessen the refrigeration load during the peak daytime operating period. However, in this analysis, DOE has not encountered any such systems either in prototype or manufactured and sold for walk-in applications. As a result, DOE screened out energy storage systems on the grounds of technological infeasibility.

4.3.3 Non-Electric Anti-Sweat Systems

While it is technically possible to perform door heating with non-electric primary energy resources, DOE has not encountered any such systems either in prototype or manufactured and sold for walk-in applications. As a result, DOE screened out non-electric anti-sweat systems on the grounds of technological infeasibility.

4.3.4 Automatic Insulation Deployment Systems

A system that enhances the insulation of glass display doors during non-business hours would significantly reduce energy consumption without impacting utility of the walk-in. However, in this analysis, DOE has not encountered any such systems either in prototype or manufactured and sold for walk-in applications. As a result, DOE screened out automatic insulation deployment systems on the grounds of technological infeasibility.

4.3.5 Insulation Thicker than 6 Inches

Increasing the thickness of the panel and non-display door insulation reduces energy consumption by preventing heat from being conducted into the walk-in. DOE considered design options that would increase the insulation up to a reasonable thickness, which it believes is 6 inches. Beyond 6 inches of thickness, panels and doors become extremely heavy and unwieldy. Panels and non-display doors that use foam-in-place insulation would take an excessive amount of time to cure. The thicker components also take up space that the consumer would otherwise use to store product. Thus, DOE screened out insulation thicker than 6 inches because it is not practicable to manufacture and install, and has adverse impacts on consumer utility.

4.3.6 Higher Efficiency Evaporator Fan Motors

The provisions of the Energy Independence and Security Act (EISA) mandate that WICF evaporator fans be equipped with electronically commutated motors (ECMs). In this analysis, DOE has not encountered any electric motor technologies that perform more efficiently than the ECMs already required for this application, either in prototype or manufactured and sold for walk-in applications. As a result, DOE has screened out the possibility of using higher efficiency evaporator fan motors on the grounds of technological infeasibility.

4.3.7 3-Phase Motors

3-phase motors can save energy over single-phase motors; however, use of 3-phase motors requires 3-phase power. Not all businesses that use walk-ins are equipped with 3-phase power, and therefore must use single-phase equipment. DOE screened out this design option on the grounds of utility.

4.3.1 Improved Evaporator Coils

The effectiveness of the refrigeration system in moving heat from the temperature-controlled space to the ambient environment is constrained by the ability of the evaporator and condenser coils to transfer heat. Improvements to the refrigerant side (evaporator) of the coil can include increased tubing passes as well as changes in the geometric profile of the tubing itself. Increasing the size of this coil showed effects on the humidity inside the walk-in and the energy savings. For systems where the high energy savings were observed, due to the higher temperature difference, the humidity inside the walk-in was calculated to exceed allowable limits, thus being eligible for screening out on the basis of adverse impacts on utility to the consumer because many items stored in walk-ins have specific humidity requirements. In addition, in cases where humidity levels are under allowable limits, the energy savings are minimal. Hence, DOE screened out improved evaporator coil as a design option.

4.4 REMAINING TECHNOLOGIES

After eliminating those technologies that do not decrease energy consumption as measured by the test procedure, and do not meet the requirements of sections 4(a) and 5(b) of the Process Rule, DOE is considering the following technologies.

4.4.1 Panel and Door Design Options

- Increased insulation thickness up to 6 inches
- Improved insulation material (hybrid insulation)
- Improved panel and non-display door framing material
- Electronic lighting ballasts and high-efficiency lighting
- Occupancy sensors
- Display and window glass system insulation performance
- Anti-sweat heater controls
- No anti-sweat systems

4.4.2 Refrigeration Design Options

- Higher efficiency compressors
- Improved condenser coil
- Higher efficiency condenser fan motors
- Improved condenser and evaporator fan blades
- Ambient sub-cooling
- Evaporator and condenser fan control
- Defrost control
- Hot gas defrost
- Head pressure control

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CHAPTER 5. ENGINEERING ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 5. ENGINEERING ANALYSIS

5.1 INTRODUCTION

The engineering analysis establishes the relationship between manufacturer selling price (MSP) and energy consumption for the walk-in cooler and freezer (WICF or walk-ins) components covered in this rulemaking. The cost-energy consumption relationship serves as the basis for the cost/benefit calculations for individual customers, manufacturers, and the Nation. In determining this relationship, the U.S. Department of Energy (DOE) estimates the increase in manufacturer production cost (MPC) associated with technological changes that reduce the energy consumption of baseline models, and then converts each MPC to MSP by applying a multiplier to determine the manufacturer markup and factoring in shipping cost.

The primary inputs to the engineering analysis are market baseline information and data for each equipment class addressed in the market and technology assessment (chapter 3 of the technical support document (TSD)) and technology options from the screening analysis (chapter 4 of the TSD). Additional inputs include cost and energy consumption data that DOE estimated using a cost model and an energy model, respectively. The primary output of the engineering analysis is a set of cost-energy consumption curves and a manufacturer markup multiplier used to convert MPC to MSP. In the subsequent markups analysis (chapter 6 of the TSD), DOE determines customer prices by applying distribution markups, sales tax, and contractor markups. After applying these markups, the data serve as inputs to the energy use analysis (chapter 7 of the TSD) and the life cycle cost and payback period analyses (chapter 8 of the TSD).

In this chapter, DOE discusses representative baseline units, methodology used to develop MPC, markups to MSP, sensitivity to material prices, methodology used to estimate energy consumption, cost-energy consumption curves, normalization of energy consumption metrics, and design options.

5.2 METHODOLOGY OVERVIEW

This section describes the analytical methodology used in the engineering analysis. In this rulemaking, DOE is adopting a design-option approach, which calculates the incremental costs of adding specific design options to a baseline model. As discussed in chapter 3 of the TSD, DOE is considering the panels, non-display doors, display doors, and refrigeration system separately. Consequently, DOE developed separate engineering curves for these components. Furthermore, for each equipment class of the covered components, DOE analyzed different size equipment to assess how energy use varies with size. A baseline unit was specified for each equipment class based on equipment offerings currently on the market.

For each equipment class and size of component, DOE estimated the manufacturing cost in 2012$ using a cost model and the energy consumption using an energy model. DOE combined the cost analyses and energy consumption analyses to obtain a relationship between cost and energy consumption; that is, the increase in cost associated with each design option that reduces energy consumption. DOE expressed the data in plots of cost versus energy consumption for each equipment class and size of each component. These plots are presented in appendix 5A.

5.3 EQUIPMENT CLASSES AND EQUIPMENT SIZES ANALYZED

DOE proposes to set separate standards for the primary components that make up walk-in coolers and freezers, which are the refrigeration unit, panels, display doors, and non-display doors. Each of these components was categorized into equipment classes, as discussed in chapter 3. Of these initial equipment classes, DOE proposes to analyze and set standards for equipment classes that have significant market share, are simple enough to model accurately, and can be significantly improved beyond the prescriptive standards already set by the Energy Policy and Conservation Act (EPCA).

5.3.1 Equipment Classes and Units Analyzed

5.3.1.1 Panels

In chapter 3 of the TSD, DOE described three main equipment classes for panels: floor panels, structural panels, and display panels. Each equipment class can be further divided into medium and low temperature applications.

DOE proposes not to regulate display panels and cooler floor panels in this rulemaking. Based on interviews with manufacturers, DOE found that display panels, typically found in beer coolers, make up a small percentage of the panel market share. DOE also recognizes that EPCA set forth prescriptive requirements for display panels, and further improvements to display panels will not result in significant energy savings without incurring disproportionate costs. 42 U.S.C. 6313(a)

DOE has excluded walk-in cooler floor panels from the analysis because of their complex nature. Establishing a performance standard for walk-in cooler floors would be unduly burdensome on the walk-in cooler floor manufacturer. Through manufacturer interviews and market research, DOE determined that, unlike walk-in freezers, the majority of walk-in coolers are made with concrete floors and not with insulated floor panels. The entity that installs the cooler floor is considered the floor's manufacturer and is responsible for testing and complying with a walk-in cooler floor standard. The onus of complying falls on manufacturers that do not specialize in constructing walk-in coolers, and the burden would be expensive and difficult for the manufacturer. Therefore, DOE finds that a standard for walk-in cooler floor panels is not warranted.

Equipment classes analyzed in this rulemaking include cooler and freezer structural panels and freezer floor panels. These classes of panels make up the majority of panels found in the walk-in cooler and freezer market. Within each class, DOE analyzed three different sizes to determine how size may affect the performance characteristics. Table 5.3.1 lists the panel classes and sizes DOE analyzed in the engineering analysis.

Table 5.3.1 Analysis Points: Panels

Equipment Family	Temperature	Class Code	Size	Dimensions *height x length, ft*	Thickness of Additional Structural Layer *In*
Structural Panels	Medium	SP.M	Small	8 x 1.5	-
			Medium	8 x 4	-
			Large	9 x 5.5	-
	Low	SP.L	Small	8 x 1.5	-
			Medium	8 x 4	-
			Large	9 x 5.5	-
Floor Panels	Low	FP.L	Small	8 x 2	0.5
			Medium	8 x 4	0.5
			Large	9 x 6	0.5

5.3.1.2 Non-Display Doors

In chapter 3 of the TSD, DOE identified two classes of non-display doors: passage doors and freight doors. Each equipment class can be further divided into medium and low temperature applications. For each class, DOE analyzed three sizes of equipment. Table 5.3.2 lists the non-display door classes and sizes DOE analyzed in the engineering analysis.

Table 5.3.2 Analysis Points: Non-Display Doors

Equipment Family	Temperature	Class Code	Size	Dimensions *height x length, ft*	Window Area *ft^2*
Passage Doors	Medium	PD.M	Small	6.5 x 2.5	2.25
			Medium	7 x 3	2.25
			Large	7.5 x 4	2.25
	Low	PD.L	Small	6.5 x 2.5	2.25
			Medium	7 x 3	2.25
			Large	7.5 x 4	2.25
Freight Doors	Medium	FD.M	Small	8 x 5	2.25
			Medium	9 x 7	4
			Large	12 x 7	4
	Low	FD.L	Small	8 x 5	2.25
			Medium	9 x 7	4
			Large	12 x 7	4

5.3.1.3 Display Doors

Display doors are divided into medium and low temperature classes. DOE analyzed three sizes for each display door class. Table 5.3.3 lists the display door classes and sizes DOE analyzed in the engineering analysis.

Table 5.3.3 Analysis Points: Display Doors

Equipment Family	Temperature	Class Code	Size	Dimensions *height x length, ft*	Light Bulb Length *ft*
Display Doors	Medium	DD.M	Small	5.25 x 2.25	5
			Medium	6.25 x 2.5	5
			Large	7 x 3	6
	Low	DD.L	Small	5.25 x 2.2.5	5
			Medium	6.25 x 2.5	5
			Large	7 x 3	6

5.3.1.4 Refrigeration System

DOE identified 10 equipment classes for the refrigeration system in chapter 3. Classes are differentiated by condensing type (dedicated condensing or multiplex condensing) and operating temperature (medium or low). Dedicated condensing systems are further divided into classes by location of the condensing unit (indoor or outdoor) and size (small and large). For dedicated condensing classes, DOE analyzed units with different compressor types; and for multiplex condensing classes, DOE also analyzed units with different fin spacing and different numbers of fans. Within each class, DOE also analyzed one or more sizes. DOE chose these various analysis points within each class in order to account for these factors—compressor type, fin spacing, etc.—in the engineering analysis. Table 5.3.4 and Table 5.3.5 list the refrigeration system classes and sizes DOE analyzed for dedicated condensing systems and multiplex condensing systems, respectively.

Table 5.3.4 Analysis Points: Dedicated Condensing Refrigeration Systems

Condensing Type	Temperature	Condenser Location	Size *Btu/h*	Class Code	Compressor Type	Capacity *Btu/h*	Analysis Point Code
Dedicated Condensing	Medium	Indoor	<9,000	DC.M.I-<9,000	Hermetic	6,000	DC.M.I.HER.006
					Semihermetic	6,000	DC.M.I.SEM.006
			≥9,000	DC.M.I-≥9,000	Hermetic	18,000	DC.M.I.HER.018
					Scroll	18,000	DC.M.I.SCR.018
					Semihermetic	18,000	DC.M.I.SEM.018
					Scroll	54,000	DC.M.I.SCR.054
					Semihermetic	54,000	DC.M.I.SEM.054
					Scroll	96,000	DC.M.I.SCR.096
					Semihermetic	96,000	DC.M.I.SEM.096
	Low		<9,000	DC.L.I-<9,000	Hermetic	6,000	DC.L.I.HER.006
					Scroll	6,000	DC.L.I.SCR.006
					Semihermetic	6,000	DC.L.I.SEM.006
			≥9,000	DC.L.I-≥9,000	Hermetic	9,000	DC.L.I.HER.009
					Scroll	9,000	DC.L.I.SCR.009
					Semihermetic	9,000	DC.L.I.SEM.009
					Scroll	54,000	DC.L.I.SCR.054
					Semihermetic	54,000	DC.L.I.SEM.054
	Medium	Outdoor	<9,000	DC.M.O-<9,000	Hermetic	6,000	DC.M.O.HER.006
					Semihermetic	6,000	DC.M.O.SEM.006
			≥9,000	DC.M.O-≥9,000	Hermetic	18,000	DC.M.O.HER.018
					Scroll	18,000	DC.M.O.SCR.018
					Semihermetic	18,000	DC.M.O.SEM.018
					Scroll	54,000	DC.M.O.SCR.054
					Semihermetic	54,000	DC.M.O.SEM.054
					Scroll	96,000	DC.M.O.SCR.096
					Semihermetic	96,000	DC.M.O.SEM.096
	Low		<9,000	DC.L.O-<9,000	Hermetic	6,000	DC.L.O.HER.006
					Scroll	6,000	DC.L.O.SCR.006
					Semihermetic	6,000	DC.L.O.SEM.006
			≥9,000	DC.L.O-≥9,000	Hermetic	9,000	DC.L.O.HER.009
					Scroll	9,000	DC.L.O.SCR.009
					Semihermetic	9,000	DC.L.O.SEM.009
					Scroll	54,000	DC.L.O.SCR.054
					Semihermetic	54,000	DC.L.O.SEM.054
					Semihermetic	72,000	DC.L.O.SEM.072

Table 5.3.5 Analysis Points: Multiplex Condensing Refrigeration Systems

Condensing Type	Temperature	Class Code	Number of Fins per Inch	Capacity *Btu/h*	Number of Fans	Analysis Point Code
Multiplex Condensing	Medium	MC.M	6	4,000	1	MC.M.N.006.004.1
			6	9,000	2	MC.M.N.006.009.2
			6	24,000	6	MC.M.N.006.024.6
			4	4,000	1	MC.M.N.004.004.1
			4	9,000	2	MC.M.N.004.009.2
	Low	MC.L	6	4,000	1	MC.L.N.006.004.1
			6	9,000	2	MC.L.N.006.009.2
			6	18,000	2	MC.L.N.006.018.2
			4	4,000	1	MC.L.N.004.004.1
			4	9,000	2	MC.L.N.004.009.2
			4	18,000	2	MC.L.N.004.018.2
			4	40,000	2	MC.L.N.004.040.2

5.4 COST MODEL

Manufacturer practices and industry cost structures play an important role in estimating the cost of covered equipment. Depending on conditions in the marketplace regarding capital, labor, and other factors, a manufacturer will choose different approaches to manufacturing equipment, ranging from outsourcing all production to being completely vertically integrated. DOE attempts to capture a representative view of industry economic and manufacturing conditions in the engineering analysis. DOE's method for estimating costs includes gathering data through equipment disassembly, site visits, and catalogue research; and using computer modeling to estimate material costs, labor costs, and facility costs associated with the analyzed equipment. This computer modeling takes the form of a spreadsheet in Microsoft Excel called the cost model: a detailed, component-focused, activity-based tool for estimating the manufacturing cost of a product.

DOE used the cost model to develop core MPC costs (that is, the cost of components without including design options). The core MPC costs were then incorporated into the engineering analysis model where they were combined with additional costs associated with each design option. The engineering analysis model received inputs in the form of the fundamental component costs and the prices for design options implemented at and above the baseline, such as baseline and improved glass doors and higher-efficiency lighting. These two sets of data (core costs and design option costs) were used to build up total system costs for each representative unit at each design option level modeled.

5.4.1 Cost Model Data

DOE gathered data for the cost model by disassembling representative walk-in components and recording the material types and quantities and the manufacturing processes used to assemble each component. The process of disassembling equipment is called a "physical teardown." DOE was not able to conduct a physical teardown on a sample of every equipment class due to the size and complexity of walk-in equipment. DOE supplemented its physical teardowns by conducting "virtual teardowns"—that is, by visiting multiple manufacturing facilities to observe variability in manufacturing techniques, noting materials, purchased parts, and labor used. Additionally, DOE conducted interviews with manufacturers to ensure the accuracy of the WICF model's methodology and pricing. When appropriate, a third method, called a catalogue teardown, was used to supplement the already-gathered data. A catalogue teardown is based on published manufacturer product literature and component data. Typically, it uses a similar product that was torn down as a starting point, and then accounts for differences in construction, purchased parts, etc. A catalog teardown serves the purpose of greatly expanding the number of units and capacity ranges under consideration without the significant expense attached to purchasing a very wide range of equipment. DOE entered all data gathered through teardowns into a bill of materials (BOM) for each unit analyzed.

5.4.2 Cost Model Structure and Process

This section describes the process by which the cost model converts the physical information in each product's BOM into manufacturing cost estimates. The cost model is based on production activities and divides factory costs into materials, labor, depreciation, and overhead. The material costs include both raw materials and purchased part costs. The labor costs include fabrication, assembly, and indirect and overhead (burdened) labor rates. The depreciation costs include manufacturing equipment depreciation, tooling depreciation, and building depreciation. The overhead costs include indirect process costs, utilities, equipment and building maintenance, and rework. DOE lists the cost inputs of these categories in Table 5.4.1.

Table 5.4.1 Cost Model Categories and Descriptions

Major Category	Sub-Category	Description
Material Costs	Direct	Raw materials (*e.g.*, coils of sheet metal) and purchased parts (*e.g.*, fan motors, compressors)
	Indirect	Material used during manufacturing (*e.g.*, welding rods, die oil, release media)
Manufacturing Labor	Assembly	Part/unit assembly on manufacturing line
	Fabrication	Conversion of raw material into parts ready for assembly
	Indirect	Fraction of overall labor not associated directly with product manufacturing (*e.g.*, forklift drivers, quality control)
	Supervisory	Fraction of indirect labor that is paid a higher wage
Depreciation	Equipment, Conveyor, Building	Straight line depreciation over expected life
	Tooling	Cost is allocated on a per-use basis or obsolescence, whichever is shorter
Other Overhead	Utilities	A fixed fraction of all material costs meant to cover electricity and other utility costs
	Maintenance	Based on installed equipment and tooling investment
	Property Tax and Insurance	A fixed fraction based on total unit costs

To determine material costs, DOE followed one of two different paths, depending on whether a subassembly was purchased (out-sourced) or produced in-house. For purchased parts, DOE gathered price quotations from major suppliers at different production volumes. For parts produced in-house, DOE reconstructed manufacturing processes for each part using modeling software based on internal expertise. For example, for a refrigeration system metal cover, DOE deduced the time required for setup, handling, changeover, and punching holes, as well as the number of holes and hits.

For this particular industry, DOE noted that manufacturers generally assembled panel systems with a mix of raw materials (*i.e.*, converted sheet metal, foam, etc.) and purchased parts (*i.e.*, fasteners, door hardware, cut-to-length seals, etc.). Refrigeration systems were generally purchased either as complete assemblies or modified in-house using purchased parts. For the raw materials being converted to ready-to-assemble parts, DOE estimated manufacturing process parameters (manufacturing equipment use and time for each item, the required initial material quantity, scrap, etc.) to determine the value of each component.

Using this process, DOE was able to assign manufacturing labor time, equipment utilization, and other important factors to each subassembly in each of the units considered for this analysis. The last step was to convert the information into dollar values. To perform this task, DOE collected information on such factors as labor rates, tooling depreciation, and costs of purchased raw materials. DOE assumed values for these parameters using internal expertise and confidential information available to its contractors. Figure 5.4.1 provides an illustration of the cost model methodology.

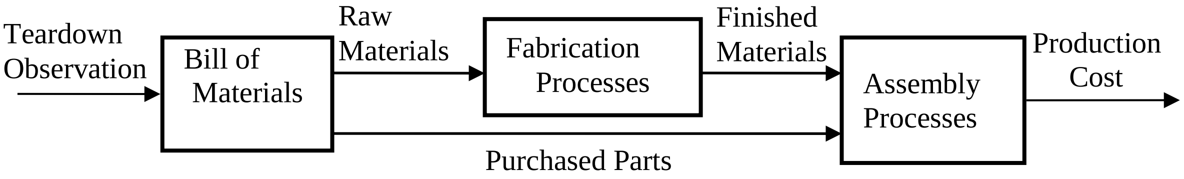

Figure 5.4.1 Cost Model Methodology

In sum, DOE assigned costs of labor, materials, and overhead to each part, whether purchased or produced in-house. DOE then aggregated single-part costs into major assemblies (*e.g.*, for dedicated refrigeration systems this would include packaging, condensing unit, electrical box, condenser coil, condenser fan assembly, compressor sled assembly, unit cooler, unit cooler coil, and unit cooler fan assembly) and summarized these costs in a spreadsheet. All parameters related to manufacture and assembly were then aggregated to determine facility requirements at various manufacturing scales. The final cost obtained by the cost model for each component is the MPC, representing the total cost to the manufacturer of producing the component.

5.4.3 Cost Model Assumptions

Assumptions about manufacturer practices and cost structure play an important role in estimating the MPC of the products. DOE based assumptions about the sourcing of parts and in-house fabrication on industry experience, information in trade publications, and discussions with manufacturers. 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. The following sections describe the cost model assumptions related to material prices, purchased parts and factory parameters.

5.4.3.1 Material Prices

DOE determined the cost of raw materials by using prices for copper, steel, and aluminum from the American Metals Market.[1] DOE noted that there have been drastic fluctuations in metal prices over the last few years. To account for these large fluctuations, DOE used prices of metals that reflect a 5-year average of the Bureau of Labor Statistics Producer Price Indices (PPIs) spanning 2007 to 2012.[2] DOE used the PPIs for steel mill products and copper rolling, drawing, and extruding, and adjusted to 2012$ using the gross domestic product implicit price deflator.[3] For non-metal materials, such as plastics, DOE used the most current material prices it could obtain as opposed to a 5-year average.

5.4.3.2 Fabricated Parts and Purchased Parts

DOE characterized parts based on whether manufacturers fabricated them in-house or purchased them from outside suppliers. For fabricated parts, DOE estimated the price of intermediate materials (*e.g.*, tube, sheet metal) and the cost of forming them into finished parts. DOE estimated initial raw material dimensions to account for scrap. For scrap materials that are recyclable, DOE assigned a scrap credit that is a fraction of the base material cost (*i.e.*, high-cost rifled copper tubing is recycled on the basis of the scrap value for plain copper). Non-recyclable materials incur a disposal cost for all scrap. For purchased parts, DOE estimated the purchase price for original equipment manufacturers based on discussions with the manufacturers and industry expertise. Whenever possible, DOE obtained price quotes directly from suppliers of the units being analyzed. DOE assumed that the components in Table 5.4.2 were purchased from outside suppliers.

Table 5.4.2 Purchased WICF Components

Assembly	Purchased Sub-Assemblies
Refrigeration System	Compressor
	Condenser Fan Blade
	Condenser Fan Motor
	Condenser Coil
	Filter/Dryer
	Hi/Low Pressure Switch
	Accumulator
	Valves
	Evaporator Fan Blade
	Evaporator Fan Motor
	Evaporator Coil
	Defrost Heater Rods
	TXV/EEV/Orifice
	Plastic Parts
	Control Boards
	Capacitors, Transformers, Contactors, etc.
	Oil Separator
	Receiver
Non-Display Door	Hinges
	Door Closing Mechanism
	Latch Assembly
	Gasketing
	Door Sweep
	Camlocks
	Temperature Gauge
	Heater Wire (for freezers only)
	Heater Accessories (for freezers only)
	Hinges
	Window Glass Pack (if applicable)
	Kick Plate (if applicable)
Display Door	Light Fixtures
	Camlocks
	Seal
	Hinges
	Panes of Glass
	Heater Wire
Panel	Gaskets
	Insulation (for board stock only)
	Caulking (for panel-to-floor interface)
	Sealant

As previously stated, variability in the costs of purchased parts can account for large changes in the overall MPC values calculated. Purchased part costs can vary significantly based on the quantities desired and the component suppliers chosen. The purchased part prices used in this study were typical values based on estimated production volume and other factors. However, variability in these prices would exist in reality on a case-by-case basis.

Due to the great diversity of manufacturing scale in the WICF industry, DOE estimates that the purchased parts costs in particular could vary significantly by manufacturer. Some parts like heat exchanger coils, control systems, and foam insulation may be produced in-house by some manufacturers and purchased by others, changing likely overall system costs and investment requirements.

DOE also made several assumptions regarding the purchase costs of control systems, including defrost control, fan motor control, and floating head pressure control. In surveying manufacturers and suppliers, DOE determined that the cost of these components varies widely among manufacturers and suppliers. Often, several of these functions are packaged together into a single control system. Most manufacturers and suppliers apply a significant markup to these control systems—both single-function and multi-function—that can be many times that of the components used to make them; this markup accounts for the labor and, more importantly, the expertise of the maker of these parts. The costs used in the engineering model reflect the price DOE estimated that a manufacturer in the walk-in industry would pay to purchase the controls from a supplier. DOE recognizes that a walk-in manufacturer who makes these components in-house would not see the same cost, yet would be able to charge a premium to the purchaser.

5.4.3.3 Factory Parameters

Certain factory parameters, such as fabrication rates, labor rates, and wages, also affect the cost of each unit produced. DOE factory parameter assumptions were based on internal expertise and manufacturer feedback. Table 5.4.3 and Table 5.4.4 list the factory parameter assumptions used in the cost model. These assumptions are generalized to represent typical production and are not intended to model a specific factory.

Table 5.4.3 Factory Parameter Assumptions, Refrigeration Equipment

Parameter	**Estimate**
Nameplate Production Capacity (units/year)	15,000
Actual Annual Production Volume (units/year)	12,000
Work Days Per Year (days)	250
Fabrication Shifts Per Day (shifts)	2.5
Assembly Shifts Per Day (shifts)	2
Fabrication Labor Wages ($/hr)	16
Assembly Labor Wages ($/hr)	16
Burdened Fabrication Labor Wage ($/hr)	24
Burdened Assembly Labor Wage ($/hr)	24
Fabrication Worker Hours Per Year	4,500
Assembly Worker Hours Per Year	3,600
Supervisor Span (workers/supervisor)	25
Supervisor Wage Premium (over fabrication and assembly wage)	30%
Fringe Benefits Ratio	50%
Indirect to Direct Labor Ratio	33%
Length of Shift (hr)	8
Worker Downtime	10%
Units Per Day	48
Average Equipment Installation Cost (% of purchase price)	10%
Average Scrap Credit (relative to base material cost)	30%
Non-recyclable Trash Cost ($/lb)	0.01
Building Cost ($/ft^2)	178
Building Life (in years)	25

Table 5.4.4 Factory Parameter Assumptions for Panels, Display Doors, and Non-Display Doors

Parameter	Estimate
Name-plate Production Capacity (complete walk-ins/year)	15,000
Actual Annual Production Volume (complete walk-ins/year)	12,000
Work Days Per Year (days)	250
Fabrication Shifts Per Day (shifts)	2.5
Assembly Shifts Per Day (shifts)	2
Fabrication Labor Wages ($/hr)	16
Assembly Labor Wages ($/hr)	16
Burdened Fabrication Labor Wage ($/hr)	24
Burdened Assembly Labor Wage ($/hr)	24
Fabrication Worker Hours Per Year	4,500
Assembly Worker Hours Per Year	3,600
Supervisor Span (workers/supervisor)	25
Supervisor Wage Premium (over fabrication and assembly wage)	30%
Fringe Benefits Ratio	50%
Indirect to Direct Labor Ratio	33%
Length of Shift (hr)	8
Worker Downtime	10%
Panels, Display Door, and Non-Display Doors Per Day	48
Average Equipment Installation Cost (% of purchase price)	10%
Average Scrap Credit (relative to base material cost)	30%
Non-recyclable Trash Cost ($/lb)	0.01
Building Cost ($/ft^2)	170
Building Life (in years)	25

5.4.4 Manufacturer Selling Price Estimates

The MSP is the price of the equipment when it is sold by the manufacturer to the first party in the distribution chain. It includes all direct and indirect production costs, other costs such as research and development, and the manufacturer's profit. The components of MSP are shown in greater detail in Figure 5.4.2. The cost of freight from the manufacturer to the first party in the distribution chain is captured in the non-production cost under "other costs."

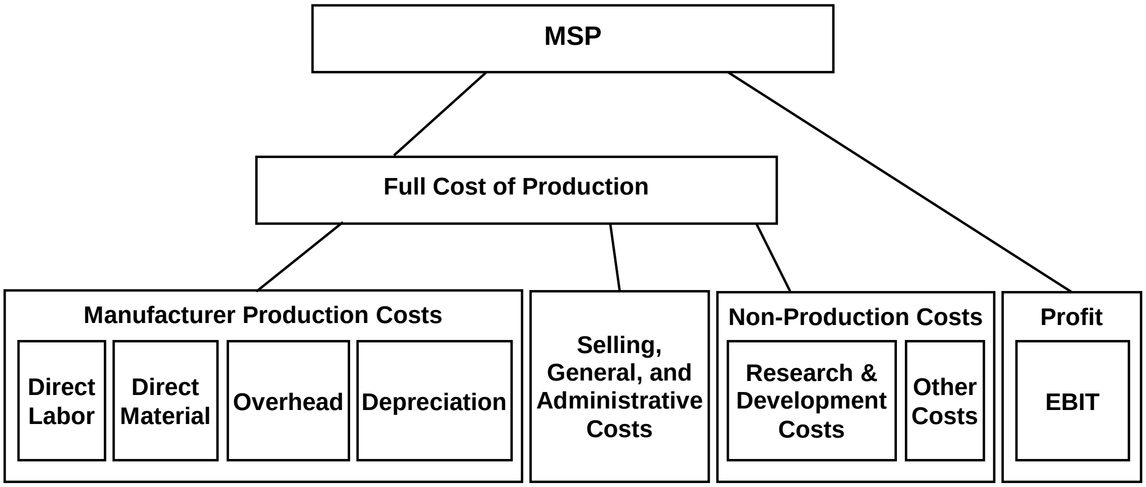

Figure 5.4.2 Components of Manufacturer Selling Price

The MSP is expressed as the product of the MPC and the manufacturer markup, added to the outbound shipping cost, as shown in the following equation:

$$MSP = MPC \times markup + shipping$$

Eq. 5.1

The markup and shipping cost are described in the following subsections.

5.4.4.1 Manufacturer Markup

DOE determined a manufacturer markup for each component and applied this markup to the MPC to arrive at the MSP for each equipment class. Wholesaler, distributor, and other markups are determined in the markups analysis (see chapter 6 of the TSD).

The component markups are not intended to represent the exact markup on any specific model or piece of equipment, or for any particular manufacturer. The cost of specific models—or cost to an individual manufacturer to produce walk-in cooler or freezer equipment—will vary depending on the equipment's precise design and features, actual manufacturing processes, the equipment mix in the factory, and other production factors. There are also considerable differences in the levels of vertical integration that affect cost structure and hence the cost of equipment. Companies with a large market share and/or revenue base tend to be more vertically integrated than lower-volume competitors. These factors could affect the markups for specific equipment. Therefore, DOE's estimated markups represent a market-share-weighted average value for the industry. DOE developed the following estimates for markups for each component.

Table 5.4.5 Manufacturer Markups

Panels	1.32
Display Doors	1.62
Non-Display Doors	1.5
Refrigeration Systems	1.35

For more details on how the manufacturer markups were calculated, see chapter 12 of the TSD.

5.4.4.2 Shipping Costs

For this rulemaking, incoming and outgoing freight were accounted for since they have a significant impact on production and shipping costs due to the large physical volume of WICF panels. Most manufacturers, when ordering component equipment for installation in their particular manufactured product, do not pay for shipping costs. Additionally, most panel, display door, and non-display door manufacturers use less than truck load freight to ship their respective components. Manufacturers typically do not mark up shipments for profit, and instead include the cost of shipping as part of the price quote. DOE estimated freight costs by researching shipping rates and by interviewing manufacturers of the covered equipment. The freight cost for panels and non-display doors was based on the thickness of the insulation and is described in detail in section 5.5.5.1. The total shipping cost per display door was calculated as the sum of the fuel cost and base shipping cost. Table 5.4.6 lists the average fuel cost per square foot of display door surface area and average base shipping cost per square foot of display door surface area.

Table 5.4.6 Display Door Shipping Costs

Fuel Cost ($/ft^2)	0.21
Base Shipping Cost ($/ft^2)	0.87

5.4.5 Panel, Display Door, and Non-Display Door Design Option Costs

As previously mentioned, design option costs were developed independently of costs for the fundament component cost. These costs were procured through a combination of manufacturer estimates, wholesalers' prices, list prices, and other sources. These data included the pricing information for components, including glass doors, lighting, anti-sweat heater controls, and lighting sensors. Data provided by industry through interviews were aggregated across all manufacturers and, where relevant, combined with cost data obtained from other sources to provide a general estimate of the prices paid by industry for baseline and higher efficiency components for each design option.

5.4.5.1 Light-Emitting Diode Price Forecasting

In an effort to capture the anticipated cost reduction in LED fixtures in the analyses for this rulemaking, DOE incorporated price projections from its Solid State Lighting program into its MPC values for the primary equipment classes. The price projections for LED case lighting were developed from projections developed for the DOE's Solid State Lighting Program's 2012 report, *Energy Savings Potential of Solid-State Lighting in General Illumination Applications 2010 to 2030* ("the energy savings report"). DOE analyzed the models used in the Solid State Lighting program work and determined that the LED luminaire projection would serve as an appropriate proxy for a cost projection to apply to display doors LEDs.

The price projections presented in the Solid State Lighting program's energy savings report are based on the DOE's 2011 Solid State Lighting R&D Multi-Year Program Plan (MYPP). The MYPP is developed based on input from manufacturers, researchers, and other industry experts. This input is collected by the DOE at annual roundtable meetings and conferences. The projections are based on expectations that depend on the continued investment into solid-state lighting by the DOE.

DOE incorporated the price projection trends from the energy savings report into its engineering analysis by using the data to develop a curve of decreasing LED prices normalized to a base year. That base year corresponded to the year when LED price data was collected from catalogs, manufacturer interviews, and other sources for the NOPR analyses of this rulemaking. DOE started with this LED cost data specific to walk-in display doors and then applied the anticipated trend from the energy savings report to forecast the projected cost of LED fixtures for this equipment at the time of required compliance with the proposed rule (2017). These 2017 cost figures were incorporated into the engineering analysis in 2012$ as the LED design option cost.

5.4.6 Downstream Analyses

The MSPs derived in the engineering analysis are inputs to the life-cycle cost analysis (LCC) and the manufacturer impact analysis (MIA). In the LCC, the MSPs are necessary to calculate the total installed cost of each unit. In the MIA, DOE constructs a number of scenarios that analyze how different pricing schemes impact manufacturers financially. Hence, both the MSP and the direct production cost components of MSP are important drivers of results in the MIA. In chapters 8 and 12 of the TSD, respectively, DOE discusses how the engineering analysis results are used for those sections in greater detail.

5.5 ENERGY MODEL

The energy model is the second of the two key analytical models used in the engineering analysis. The purpose of the model is to analyze advanced technologies and designs that manufacturers could use to meet energy conservation standards. Manufacturers must use the test procedure to rate their equipment when certifying compliance with energy conservation standards. Therefore, the energy model attempts to find the rated performance of the equipment as it would be determined by the test procedure, using the same calculations and rating conditions. The model is not designed to capture performance under any conditions other than the rating conditions and does not analyze any technologies that would not help manufacturers improve the rated performance of their equipment. Other technologies have also been excluded from the analysis on the basis of DOE’s four screening criteria, explained in chapter 4 of the TSD.

Although termed the “energy model” for conciseness, this model calculates expected equipment ratings in terms of the metric on which the standards for each component are based: U-factor of panels, energy consumption of display and non-display doors, and annual walk-in energy factor (AWEF) of refrigeration systems. DOE developed the energy model as a Microsoft Excel spreadsheet.

For a given equipment class, the model estimates performance of baseline equipment and levels of performance above the baseline corresponding to design options that are added to the baseline equipment. For the baseline level, DOE calculated a corresponding MPC using the cost model (described in section 5.4). For each level above the baseline, DOE used the cost increases of the various design options to recalculate the MPC.

The final output of the energy model is a cost-efficiency curve for each analysis point in each equipment class, for each component analyzed. A cost-efficiency curve plots the added cost versus improved performance for each design option added to baseline equipment. Each design option is added to the baseline in order of efficacy—that is, the greatest improvement in performance for the least cost, because DOE expects that to meet an energy standard, manufacturers will implement options that will give them the greatest improvement in performance for the lowest cost to manufacture. DOE emphasizes that manufacturers are not required to use the options it identified, and may not necessarily implement options in the order that DOE predicted; manufacturers may use any design or combination of designs to meet the energy conservation standards. The energy model is simply a tool that DOE has developed to predict performance improvements of certain design options or combinations thereof.

As an example, Figure 5.5.1 shows the cost-efficiency curve for the small cooler display door analysis point (see section 5.3.1 for a list of all analysis points for each class). The baseline is the point with the highest energy consumption at the lowest cost. The slope of the line between each subsequent point represents the decrease in energy consumption and the increase in cost associated with adding that design option to the equipment represented by the previous point. In other words, the design options are added cumulatively. Design options are added in order of increasing slope; *i.e.*, decreasing efficacy (less energy saved per dollar). The point with the lowest energy consumption and the highest cost represents the maximum energy savings that can be achieved for this unit using the available design options: that is, the "max-tech" level.

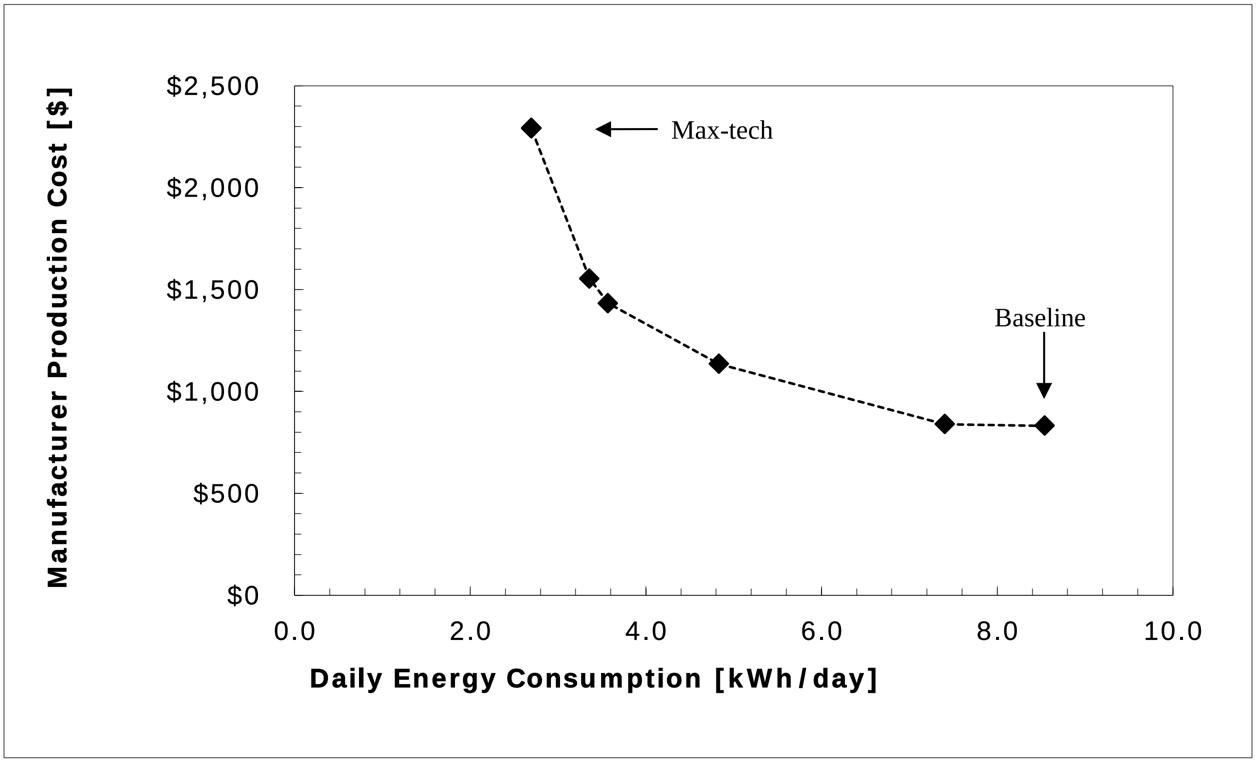

Figure 5.5.1 Cost-Efficiency Curve for Small Cooler Display Door

The following sections describe the overall structure of the energy model, baseline characteristics of the covered equipment, design options that can be added to baseline equipment to improve performance, and all assumptions DOE made in implementing the energy model.

5.5.1 Model Structure: Panels

Figure 5.5.2 shows the structure of the energy consumption model used in the panel engineering analysis. The panel model calculates the long-term U-factor, which represents the conductivity of heat through the panel.

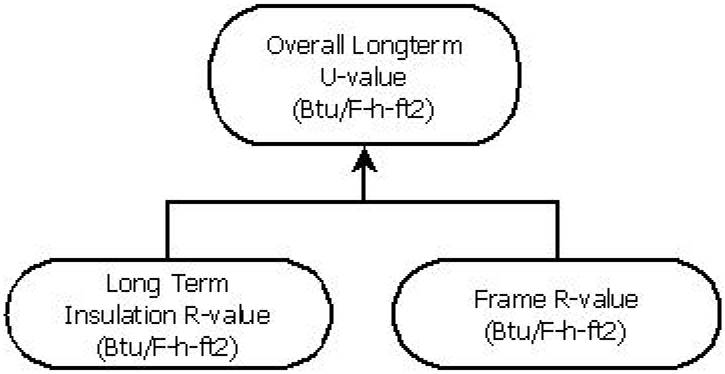

Figure 5.5.2 Overview of Panel Engineering Analysis Calculations

A panel's overall long-term U-factor is determined by the long-term thermal resistance of the foam area and the thermal resistance of the frame area. DOE obtained data from a confidential source on the long-term thermal resistance of foam and estimated the thermal resistance of the framing material from market research. From thermodynamic principles, it was determined that heat flows through the foam and framing materials in parallel, so DOE used this method to calculate the overall U-factor of a walk-in panel. The overall thermal transmittance, R, of materials with parallel heat transfer is the found using equation 5.2, where R_i and R_f represent the area weighted thermal resistance of the insulation material and framing material, respectively. The overall U-factor is calculated as the inverse of the overall thermal resistance.

$$U = \frac{1}{R} = \frac{1}{R_i} + \frac{1}{R_f}$$

Eq. 5.2

Where:

U = the overall thermal transmittance,
R= the overall thermal resistance,
R_i = the area weighted thermal resistance of the insulation, and
R_f = the area weighted thermal resistance of the framing material.

5.5.2 Model Structure: Doors

Figure 5.5.3 and Figure 5.5.4 show the structure of the energy consumption model used in the display door and non-display door engineering analysis, respectively. The display door and non-display door models calculate energy consumption through two major pathways: heat load and electrical energy consumption, which are further broken out by the underlying components or physical characteristics. The following subsections describe the heat load and electrical energy consumption calculations in detail. DOE also explains its method for converting heat load into energy consumption using an assumed value for refrigeration efficiency.

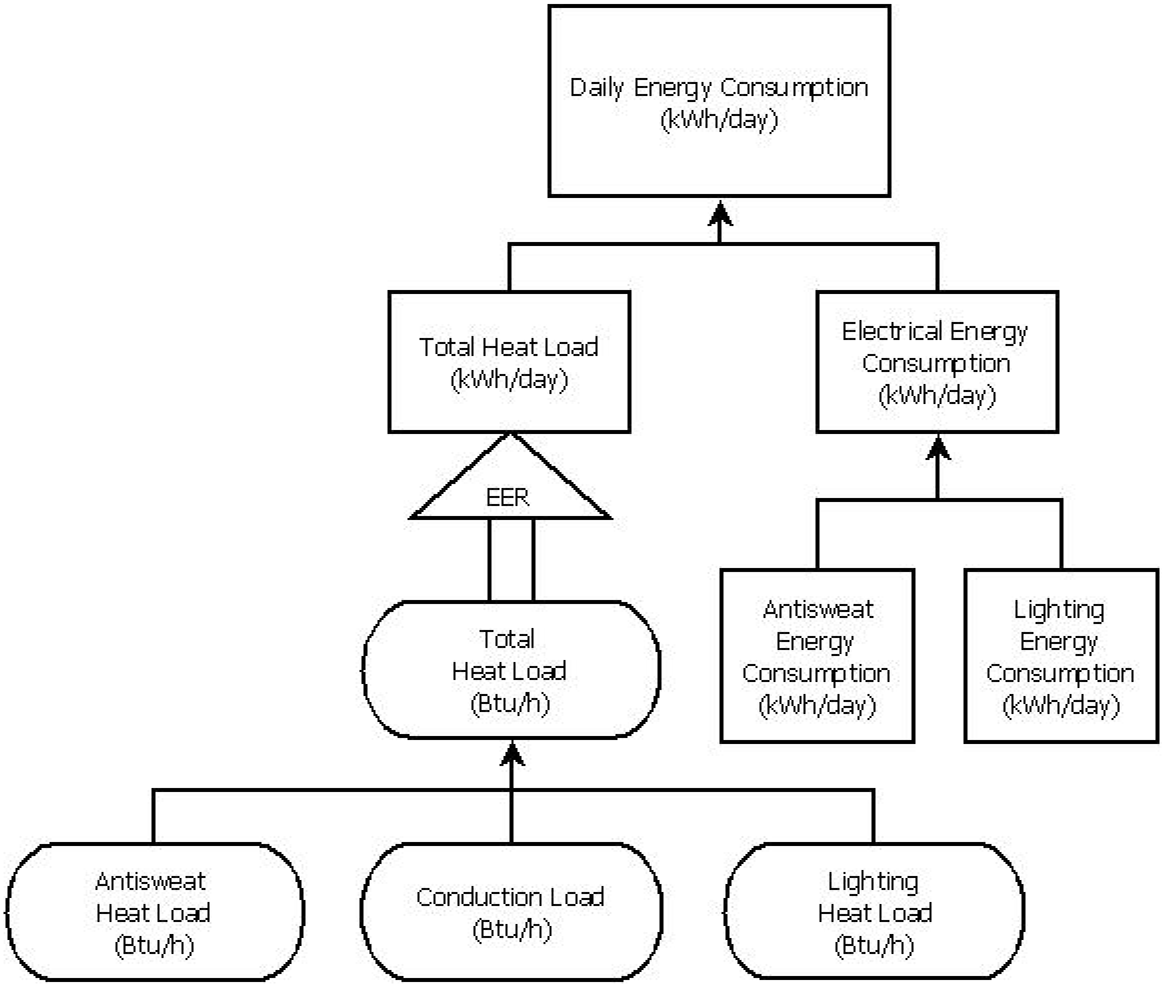

Figure 5.5.3 Overview of Display Door Engineering Analysis Calculations

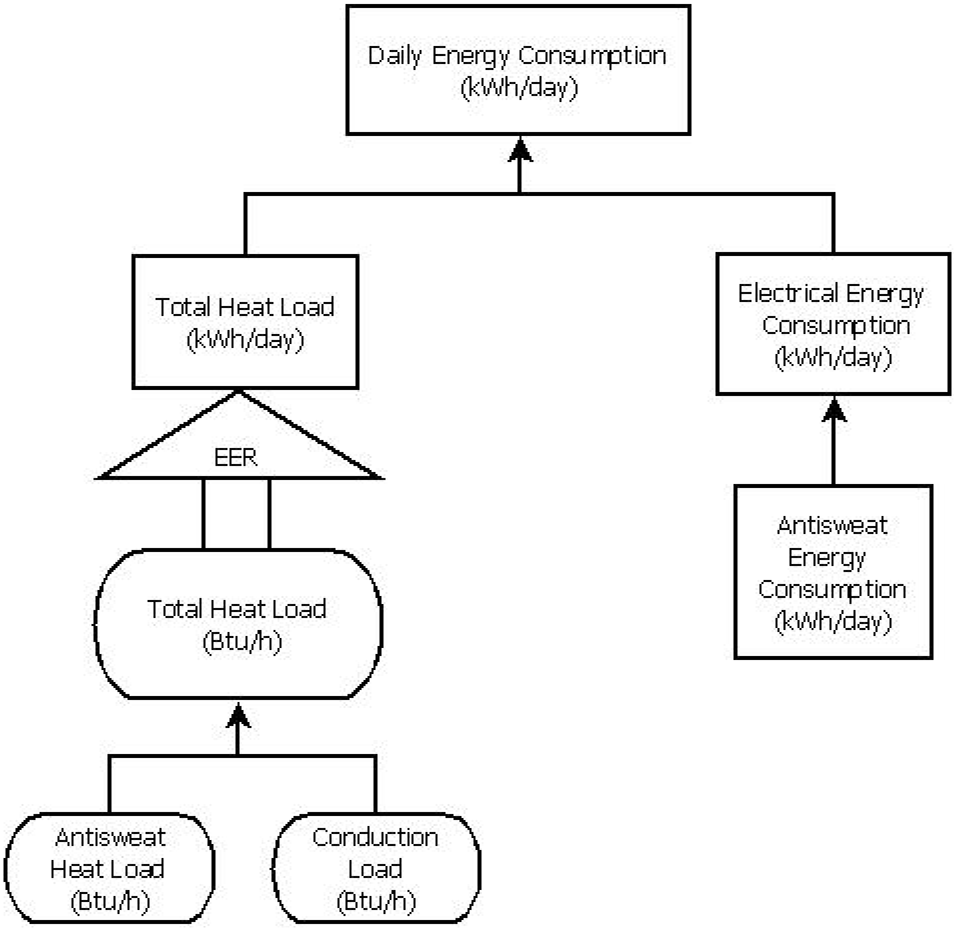

Figure 5.5.4 Overview of Non-Display Door Engineering Analysis Calculations

5.5.2.1 Display Door Heat Conduction Load

To determine the U-factor of the display doors used in the analysis, DOE used Lawrence Berkeley National Laboratory's (LBNL's) WINDOW 6.3[a] program, a widely used and verified tool for calculating performance of glass doors. DOE modeled each of the representative door sizes both at the baseline level and with the design options listed in chapter 4 of the TSD. The U-factor was affected by both the size of the door and the design option characteristics (*e.g.*, panes of glass). Each display door U-factor was combined with the temperature difference and surface area of the display door to determine the conduction heat load.

5.5.2.2 Non-Display Door Heat Conduction Load

In order to determine the conduction heat load for non-display doors, DOE first calculated an overall R-value for the non-display door. The overall R-value was determined by combining the R-value of the framing material, the R-value of the foam, and the R-value of the

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[a] http://windows.lbl.gov/software/window/6/index.html.

door's window. The R-value of the door window was calculated using WINDOW 6.3. DOE obtained data from a confidential source on the long-term thermal resistance of foam and estimated the thermal resistance of the framing material from market research. DOE calculated the overall thermal resistance of the door using equation 5.3, given that heat flows through the framing material, foam, and window in parallel. In equation 5.3, R_i, R_f, and R_w represent the area weighted thermal resistance of the insulation material, framing material, and window. DOE used the overall R-value, the surface area of the door, and the temperature difference to calculate the conduction heat load for the baseline door and each design option.

$$\frac{1}{R} = \frac{1}{R_i} + \frac{1}{R_f} + \frac{1}{R_w}$$

Eq. 5.3

Where:

R = the overall thermal resistance of the non-display door,
R_i = the area weighted thermal resistance of the insulation,
R_f = the area weighted thermal resistance of the framing material, and
R_w = the area weighted thermal resistance of the window.

5.5.2.3 Anti-Sweat Heater Electrical Load

Resistive heater wire is rated in units of watts per square foot. For a given display door or non-display door window, the glass surface area is calculated and multiplied by the wire rating to compute the total electrical load per door. The amount of time per day that the wire is powered is calculated using the assumed percent time off (PTO) corresponding to whether an anti-sweat controller is selected or not. In addition, more insulative glass packs require less heater wire so the amount of heater wire on the display door or window changes based on the design option level. With total wattage and operation time per day, the total energy consumption in kilowatt-hours per day is then directly calculated.

5.5.2.4 Lighting Electrical Load

The lighting electrical load in kilowatt-hours per day associated with display doors is calculated using the rated power of the light and assumptions about PTO based on the corresponding control system design option.

5.5.2.5 Additional Heat Load Due to Electrical Device Waste Heat

The walk-ins test procedure states that all electrical devices located on the interior face of the display or non-display door contribute an additional heat load to the door. The additional heat load equals 75 percent of the rated electrical energy consumption of such devices. DOE assumed that anti-sweat heater wire and display lighting are located on the internal face of a display door and contribute an additional heat load to the door's energy consumption. Anti-sweat heater wire is the only electrical device located on non-display doors and is also assumed to contribute an additional heat load to the door.

5.5.2.6 Energy Efficiency Ratio

In order to estimate the associated refrigeration equipment energy consumption due to the envelope energy losses, DOE implemented the use of refrigeration equipment energy efficiency ratio (EER). The EER represents the energy performance of refrigeration equipment as a ratio of units of thermal energy removed from the conditioned walk-in space to units of electrical energy input (to operate refrigeration compressors, fans, etc.). Therefore, this ratio represents an efficiency of the refrigeration equipment. The EER is not meant to represent the actual efficiency of the actual refrigeration system that would be paired with the component.

DOE assumed two different EER values that correspond to medium and low temperature refrigeration systems of 12.4 Btu/W-h and 6.3 Btu/W-h, respectively. The EER values are based on values specified in the WICF test procedure final rule. 76 FR 21580, April 15, 2011. Depending on the walk-in temperature corresponding to the component being analyzed, the envelope engineering analysis model selects the appropriate EER to convert the thermal energy into units of electrical energy used.

The EER value is applied to the total heat load of display and non-display doors. For display doors, this includes the heat lost through conduction, the heat from anti-sweat heater wire, and the heat from all display lighting. For non-display doors, the total heat load is the sum of the anti-sweat heater wire load and the heat lost through conduction. The total heat load is divided by the appropriate EER value to determine the amount of energy consumed by the walk-in refrigeration equipment in order to cool the total heat load. The energy consumed by the refrigeration equipment is converted to kilowatt-hours per day and added to the energy consumed by any electrical devices associated with the display or non-display door.

5.5.3 Model Structure: Refrigeration

The energy model for refrigeration systems analytically calculates AWEF using the same methodology as the test procedure. In the test procedure, the refrigeration system is tested under certain conditions to determine steady state capacity and power. Then an assumed non-refrigeration load attributed to the envelope is calculated. This methodology assumes that the refrigeration system is sized to the expected load, allowing refrigeration systems to be compared with each other even when the tester does not know the characteristics of the envelope with which the refrigeration system will ultimately be paired. From the steady state power, the capacity, and the expected load profile, the AWEF can be calculated.

Figure 5.5.5 and Figure 5.5.6 present schematics showing the components in the energy model for dedicated condensing systems and unit coolers connected to multiplex condensing systems, respectively.

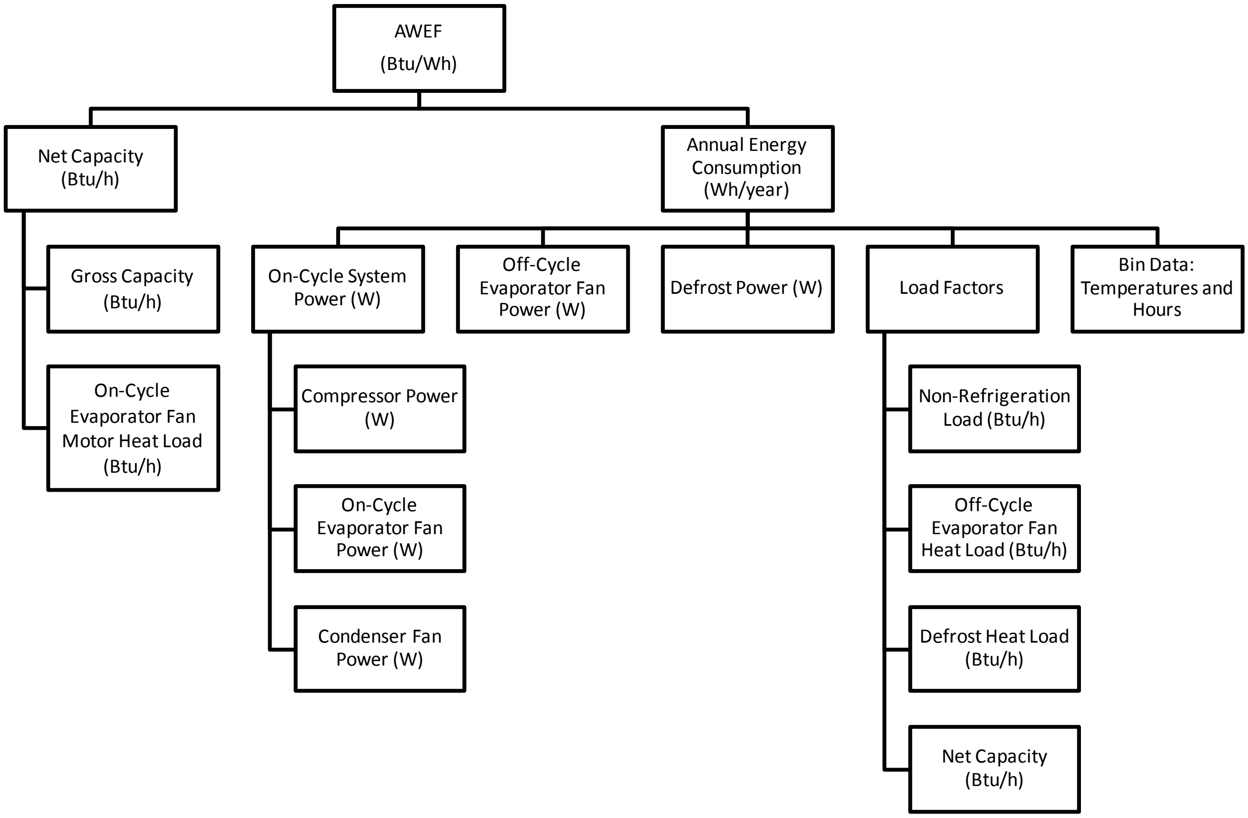

Figure 5.5.5 Energy Model for Dedicated Condensing Systems

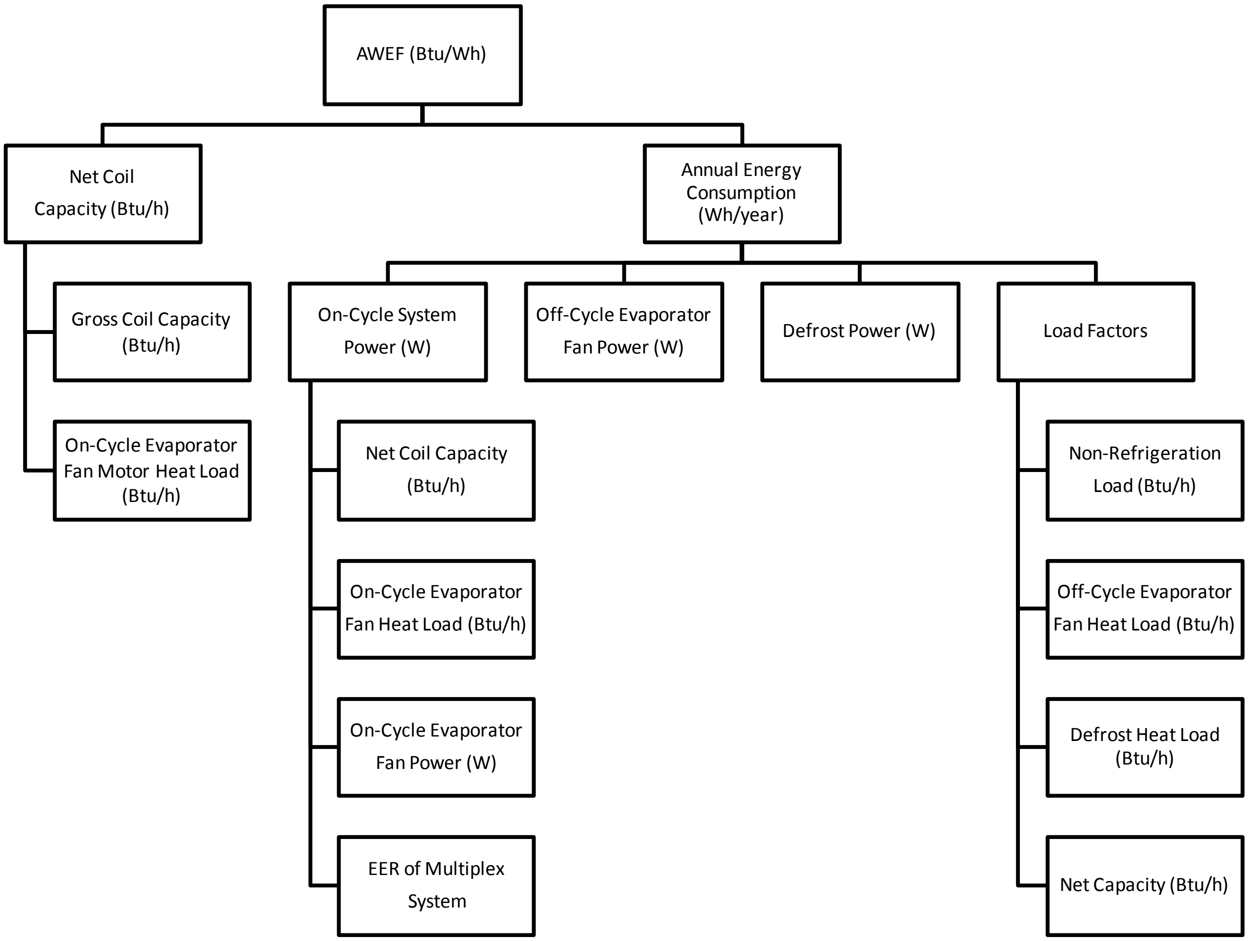

Figure 5.5.6 Energy Model for Unit Coolers Connected to Multiplex Condensing Systems

In general, the model uses a whole-system approach to analyzing the refrigeration system. The model finds the refrigerant properties (pressure, temperature, enthalpy, and entropy) at several points in the system: compressor entrance, compressor exit, condenser entrance, condenser exit, evaporator entrance, and evaporator exit. If one component is changed—for instance, the condenser—the refrigerant properties at each point are adjusted accordingly. In this way, interactive effects of certain design options can be determined.

5.5.3.1 Net Capacity

The net capacity is calculated as the gross capacity of the system, less the heat given off by the evaporator fans when the compressor is running. Defrost heat is not considered in the calculation of net capacity because it is measured with a separate test, and would not be accounted for in the test procedure during the test of net capacity.

For dedicated condensing systems, the gross capacity is calculated as follows. First, the evaporator capacity is fixed at the target capacity of the system, which can be determined from the last three characters of the analysis point code that indicate the capacity in kBtu/h. For example, DC.M.O.HER.006 has a target capacity of 6 kBtu/h, or 6000 Btu/h. Second, the compressor capacity needed to maintain the target capacity is calculated. This compressor capacity is the target capacity plus an extra 4 percent of the target capacity, which accounts for the suction line heat gain—that is, heat conducted from the ambient air to the refrigerant through the wall of the refrigerant pipe that runs between the evaporator exit and the compressor entrance. For multiplex condensing systems, the gross capacity is the same as the target capacity. The compressor capacity is not relevant to the walk-in capacity calculation because for multiplex condensing systems, the compressor system is connected to multiple pieces of equipment and therefore its available capacity is split among this equipment.

The system net capacity is calculated as the gross capacity minus the heat produced when all evaporator fans are running. Because the evaporator fans and fan motors are located fully inside the walk-in, all input power to the fans is eventually converted to heat inside the walk-in; therefore, the heat produced by the evaporator fans is calculated as the evaporator fan input power in watts converted to Btu/h by the conversion factor 3.412 Btu/h per watt. For a discussion of how the evaporator fan input power is calculated, see the following section.

5.5.3.2 On-Cycle System Power

For dedicated condensing systems, the on-cycle system power is the sum of the compressor power, the on-cycle evaporator fan power, and the condenser fan power.

Compressor Power

Compressor power is calculated by using the compressor model described in section 6.4 of American Heating and Refrigeration Institute (AHRI) Standard 540-2004 (AHRI 540), "Performance Rating of Positive Displacement Refrigerant Compressors and Compressor Units." This model is based on a 10-coefficient polynomial derived from empirical compressor performance data for power, mass flow, current, and efficiency. The coefficients are derived for each parameter as a function of saturated evaporator temperature (SET) and saturated condenser temperature (SCT). Compressor coefficients, or tabulated empirical data (from which coefficients can be derived), are available from compressor manufacturers. DOE researched available compressors in the range of capacities that would likely be used in walk-in equipment and downloaded compressor performance data.

Some of the rating conditions in AHRI 540 are different from those in AHRI 1250, the rating method for walk-in refrigeration systems; in particular, the return gas temperature (that is, the temperature of the refrigerant entering the compressor) is different for some types of equipment. DOE adjusted the compressor performance data to be consistent with the rating conditions in AHRI 1250.

The result of the compressor research is a database of compressor data in the energy model for refrigeration systems. The database contains a set of compressors in the capacity range for the covered equipment. DOE also assigned a cost for each compressor that was based on an analysis of available cost data, accounting for approximate purchase quantities. DOE plotted known costs against the baseline capacity of specific sets of compressor models where each set corresponds to a single type (hermetic, scroll, or semi-hermetic) at a temperature (medium or low) and determined a trendline for each set, thus calculating an average cost versus capacity for each compressor set. Then for all other compressors in the database corresponding to the same type and temperature, the expected cost was determined from the capacity using the cost versus capacity relationship defined by the trendline for the subset of known costs.

For each analysis point—that is, each individual refrigeration system analyzed—the model calculates the compressor power and cost using the compressor database, as follows. First, the gross capacity is calculated using the method described previously in section 5.5.3.1. Then, for each analysis point, the model chooses from the database the compressor model with the lowest capacity that is higher than the target capacity and the compressor model with the highest capacity that is lower than the target capacity, where the compressor capacity is calculated using the 10 capacity coefficients, the SET, and the SCT. For the two compressor models selected, the power is also calculated using the 10 power coefficients, the SET, and the SCT; and each compressor model also has an assigned cost in the database. Then, the model linearly interpolates between the two compressors—the higher and the lower model—to estimate the power and cost of a compressor at the target capacity. DOE interpolates the power and cost instead of using the power and cost of the compressor with the next highest capacity from the target capacity, because if only a single compressor from the database is used when analyzing a refrigeration system, incremental changes in the SET and SCT could cause large jumps in observed compressor power and cost for that refrigeration system if a different compressor model is chosen under the different conditions. DOE recognizes that, in reality, compressors are only available in discrete capacities, but accounts for this in the energy use analysis (chapter 7 of the TSD) as an overall “mismatch factor” that is averaged over the set of equipment analyzed.

Evaporator Fan Power

The energy model calculates the on-cycle evaporator fan input power as the output power in horsepower, converted to watts, divided by the fan efficiency. DOE assumed that the evaporator fans run at full speed continuously while the compressor is on.

Condenser Fan Power

The condenser fan power is also calculated as the output power in horsepower, converted to watts, divided by the fan efficiency. DOE assumed that the condenser fans run at full speed continuously while the compressor is on. At low ambient temperatures (59 °F and 35 °F), this increases the amount of heat transferred from the coil to the air, which increases the capacity of the system correspondingly. The energy model calculates the increase in capacity using the following equations:

$$\dot{Q}_{ref} = \dot{Q}_{air} \qquad \textbf{Eq. 5.4}$$

Where:

$\dot{Q}_{ref}$ = heat transferred from the refrigerant, and
$\dot{Q}_{air}$ = heat transferred to the air.

$$\dot{Q}_{ref} = \dot{m}_{ref} \times (h_2 - h_3)$$

Eq. 5.5

Where:

$\dot{m}_{ref}$ = mass flow rate of refrigerant,
h_2 = enthalpy (embodied heat energy) of the refrigerant at condenser entrance, and
h_3 = enthalpy of the refrigerant at condenser exit.

$$\dot{Q}_{air} = \dot{m}_{air} \times c_{p,air} \times (DAT - amb)$$

Eq. 5.6

Where:

$\dot{m}_{air}$ = mass flow rate of air,
$c_{p,air}$ = specific heat of air,
DAT = discharge air temperature (*i.e.*, temperature of air after it is blown across the condenser), and
amb = ambient air temperature (*i.e.*, temperature of air at condenser entrance).

With a higher capacity, the system does not need to run as often to reject the same amount of heat from the walk-in at low temperatures. The effect is accounted for in the load factors, discussed in section 5.5.3.4. System efficiency can be improved by varying the speed of the fans instead of cycling them; this effect is explained in section 5.5.6.5.

System Power for Unit Coolers Connected to Multiplex Condensing Systems

For multiplex condensing systems, the power attributed to the unit cooler is calculated by assuming a certain efficiency, or EER, for the multiplex system. In this case, the EER is assumed to be constant throughout the year, so energy consumption per day is multiplied by 365 to get annual energy consumption. The test procedure provides default tables of EER values for both medium and low temperature systems. The EER values are expressed in British thermal units (Btu) of heat rejection per Watt-hour (Wh) of energy used, as a function of adjusted dew point temperature. AHRI 1250-2009, the test procedure for refrigeration systems, provides that the adjusted dew point temperature for a medium temperature system shall be 19 °F and shall be -26 °F for a low temperature system, unless the unit cooler is rated at a suction dew point other than 19 °F for a refrigerator or -26 °F for a freezer, in which case the adjusted dew point value shall be 2 °F less than the unit cooler rating suction dew point. In this model, DOE used the EER values corresponding to an adjusted suction dew point temperature of 19 °F for medium temperature systems and -26 °F for low temperature systems.

5.5.3.3 Other Power Calculations

Other power calculations in the model include off-cycle evaporator fan power and defrost power, both of which contribute to the annual energy use of the refrigeration system.

Off-Cycle Evaporator Fan Power

Off-cycle evaporator fan power is calculated in the same manner as on-cycle fan power: that is, the output power in horsepower, converted to watts, divided by the fan efficiency. For more discussion on the frequency of operation of evaporator fans during the off-cycle period, see section 5.5.6.7.

Defrost Power

For low temperature systems that use electric defrost, manufacturers typically publish the wattage of the defrost heater. DOE examined typical defrost wattages for the range of systems being analyzed, and assigned a reasonable baseline defrost power value to each analysis point. The average defrost power consumption per hour was calculated based on the total energy consumed during all defrost periods over the course of the day divided by 24 hours. The number of defrost periods per day depends on the defrost design option selected, as explained in section 5.5.6.8, while the energy consumed during a single defrost period depends on the defrost wattage and defrost time. DOE assumed that all electric defrost systems were temperature-terminated; that is, the defrost ends when the coil reaches a certain temperature above freezing (assumed to be 45 °F). The energy model calculates the defrost time in three parts: time for the coil to warm from its original temperature (the SET; -10 °F for low temperature systems) to the melting temperature of ice (32 °F), time to melt the ice, and time for the coil to warm from 32 °F to the cutoff temperature of 45 °F.

The defrost time depends on the useful defrost heat generated, which is the defrost wattage converted to heat energy using the conversion of 3.412 Btu/h per watt, and accounting for convection losses. Convection losses refer to heat that dissipates into the walk-in and is not directed towards the coil itself. These losses occur because an electric defrost mechanism often takes the form of heater rods that are attached to the evaporator coil. Because the rods do not fully contact the coil, some heat produced by the rods escapes to the air surrounding the evaporator coil. DOE assumed that 60 percent of the heat produced by the defrost heater rods would be lost as convection.

The useful defrost heat generated is then used in the model's calculation for defrost time. The time it takes to warm the coil from -10 °F to 32 °F and from 32 °F to 45 °F is calculated using the following equation:

$$t = (m_{Al} \times c_{Al} + m_{Cu} \times c_{Cu}) \times \Delta T / Q_{def}$$

Eq. 5.7

Where:

t = defrost time,
m_{Al} = mass of aluminum in coil,
c_{Al} = specific heat of aluminum,
m_{Cu} = mass of copper in coil,
c_{Cu} = specific heat of copper,
ΔT = temperature difference between the higher and the lower temperature, and

Q_{def} = useful defrost heat generated.

Typical coils have aluminum fins and copper tubes. For each analysis point, DOE calculated the expected mass of aluminum based on the coil size and the fin thickness and spacing, and the expected mass of copper based on the tube length, size, wall thickness, and spacing.

The time it takes to melt the ice on the coil at 32 °F is calculated using the following equation:

$$t = m_{ice} \times h_{fus} / Q_{def}$$

Eq. 5.8

Where:

t = time to melt the ice,
m_{ice} = mass of the ice accumulated on the coil, and
h_{fus} = latent heat of fusion of ice (143.5 Btu/lb).

The mass of the ice accumulated on the coil over the course of the defrost cycle depends on the length of the cycle, the amount of water vapor infiltrated into the walk-in, and the humidity, or amount of water contained in the air. As a worst-case scenario, DOE assumed that all water in the infiltrated air would end up as ice on the coil over the course of the cycle. Therefore, the mass of frost on the coil (m_{ice}) is equal to the amount of water vapor in the infiltrated air. The amount of water vapor entering the walk-in during a defrost cycle can be calculated using the following equation:

$$\dot{m}_{water} = \dot{m}_{dry} \times (\omega_o - \omega_i)$$

Eq. 5.9

Where:

$\dot{m}_{water}$ = mass flow rate of water vapor,
$\dot{m}_{dry}$ = mass flow rate of dry air,
ω_o = humidity ratio of air infiltrating into the walk-in from outside, and
ω_i = humidity ratio of air after it has been cooled inside the walk-in.

The humidity ratios can be found on a psychrometric chart given the rating temperatures and relative humidities from the test procedure. The mass flow rate of dry air can be calculated as:

$$\dot{m}_{dry} = (AV)_{air} /((\overline{R} / M) \times (T / p_a))$$

Eq. 5.10

Where:

$(AV)_{air}$ = volumetric flow rate of air, known from test procedure conditions,
$\overline{R}$ = universal gas constant (1545 ft · lbf/lbmol · °R),
M = molecular weight of air (28.97 lbf/lbmol),
T = temperature of infiltrated air in °R (°F + 459.67), known from test procedure conditions, and
p_a = atmospheric pressure of air (14.453 psi, converted to lb/ft^2 to be consistent with other units).

5.5.3.4 Load Factors

The load factors represent the fraction of the time that the compressor is running at both a "high-load" period and a "low-load" period. The high-load period corresponds to the time during the day when the walk-in experiences a high heat load due to product being stored in the walk-in, employees entering and leaving, etc. The low-load period corresponds to the time during the day when the walk-in is not being accessed, and experiences a low heat load: night, off-business hours, etc. Consistent with the calculations in the test procedure, the energy model assumes that 1/3 of the time is experienced at a high load and 2/3 at a low load. The corresponding load factors, LFH (load factor at high load) and LFL (load factor at low load) are calculated from the heat load on the walk-in at a high and low period respectively (including non-refrigeration heat load, evaporator fan heat load, and defrost heat load), and the net capacity of the refrigeration system to reject this load. This determines how frequently the compressor must run at a high and low period.

$$LFH = \frac{W\dot{L}H(t_j)}{\dot{q}_{ss}(t_j)} \quad \text{(if } W\dot{L}H(t_j) > \dot{q}_{ss}(t_j),\ LFH = 1\text{)}$$

Eq. 5.11

$$LFL = \frac{W\dot{L}L(t_j)}{\dot{q}_{ss}(t_j)} \quad \text{(if } W\dot{L}L(t_j) > \dot{q}_{ss}(t_j),\ LFL = 1\text{)}$$

Eq. 5.12

Where:

$W\dot{L}H$ = heat load on the walk-in at a high period,
$W\dot{L}L$ = heat load on the walk-in at a low period, and
$\dot{q}_{ss}$ = net capacity.

WLH and WLL include all heat loads on the walk-in: non-refrigeration heat load, evaporator fan heat load, and defrost heat load:

$$W\dot{L}H(t_j) = B\dot{L}H(t_j) + 3.412 \times \dot{E}F_{comp,off}(1 - LFH) + \dot{Q}_{df}$$

Eq. 5.13

$$W\dot{L}L(t_j) = B\dot{L}L(t_j) + 3.412 \times \dot{E}F_{comp,off}(1 - LFL) + \dot{Q}_{df}$$

Eq. 5.14

Where:

$\dot{BLH}$ = non-refrigeration heat load at a high load period,
$\dot{BLL}$ = non-refrigeration heat load at a low load period,
$\dot{EF}_{comp,off}$ = evaporator fan motor power in watts (multiplied by 3.412 Btu/h/W to get heat load), and
$\dot{Q}_{df}$ = defrost heat load.

(The on-cycle evaporator fan motor heat is not included in this equation because it is already accounted for in the net capacity.)

The non-refrigeration heat loads are derived from the net capacity and, for outdoor units, an assumed temperature profile. As discussed above, this is because the methodology assumes that the refrigeration system is sized to the expected load, allowing refrigeration systems to be compared with each other even when the tester does not know the characteristics of the envelope that the refrigeration system will ultimately be paired with.

5.5.4 Baseline Equipment

For each representative equipment class and size selected, DOE identified a specific panel, display door, non-display door, and refrigeration unit as a fundamental design against which it would apply changes to improve the component's efficiency. DOE chose the least efficient component in each equipment class to be analyzed as the baseline model. Because there are no existing minimum energy conservation standards for walk-ins, the baseline efficiency was selected after reviewing products available in the current market. All baseline equipment was selected to meet the existing prescriptive standards. DOE defined specifications for each baseline unit that include, where applicable, dimensions, numbers of subcomponents, nominal power ratings, and other features necessary to calculate the performance for each unit. DOE established baseline specifications for each of the equipment classes modeled in the engineering analysis by reviewing available manufacturer data, selecting several representative units from available manufacturer data, and then aggregating the physical characteristics of the selected units. This process created representative units of varying sizes for each equipment class with typical characteristics for physical parameters (*e.g.*, wall area of panels), and baseline performance for energy-consuming components.

Table 5.5.1, Table 5.5.2, Table 5.5.3, Table 5.5.4, and Table 5.5.5 show the baseline specifications and calculated performance rating for panels, display doors, non-display doors, dedicated condensing refrigeration systems, and multiplex condensing refrigeration systems, respectively. Each performance rating below was determined though DOE's engineering analysis. As mentioned previously, performance ratings are expressed in terms of the metric on which the standards for each component are based: U-factor of panels, energy consumption of display and non-display doors, and AWEF of refrigeration systems.

Table 5.5.1 Specifications and Ratings of Baseline Panels

Analysis Point	Insulation Thickness	Insulation Material	Framing Material	Baseline U-factor *Btu/h-F-ft^2*
SP.M - Small	3.5 inches	Polyurethane	Wood	0.082
SP.M - Medium	3.5 inches	Polyurethane	Wood	0.061
SP.M - Large	3.5 inches	Polyurethane	Wood	0.056
SP.L - Small	4 inches	Polyurethane	Wood	0.0735
SP.L - Medium	4 inches	Polyurethane	Wood	0.054
SP.L - Large	4 inches	Polyurethane	Wood	0.050
FP.L - Small	3.5 inches	Polyurethane	Wood	0.071
FP.L - Medium	3.5 inches	Polyurethane	Wood	0.059
FP.L - Large	3.5 inches	Polyurethane	Wood	0.054

Table 5.5.2 Specifications and Ratings of Baseline Display Doors

Equipment Class	Glass Pack	Anti-Sweat Heater Control	Lighting Characteristics	Baseline Energy Use *kWh/day*
Cooler Display Door- Small	2 panes, hard coat low-e, argon fill	No Control	5 ft T8 Electronic, Normal Lumen Blub, Normal BF Electronic Ballast, No Sensor	2.5
Cooler Display Door- Medium	2 panes, hard coat, argon fill	No Control	5 ft T8 Electronic, Normal Lumen Blub, Normal BF Electronic Ballast, No Sensor	2.9
Cooler Display Door- Large	2 panes, hard coat, argon fill	No Control	6ft T8 Electronic, Normal Lumen Blub, Normal BF Electronic Ballast, No Sensor	3.8
Freezer Display Door- Small	3 panes, no low-e coating, argon fill	Control	5 ft T8 Electronic, Normal Lumen Blub, Normal BF Electronic Ballast, No Sensor	5.2
Freezer Display Door - Medium	3 panes, no low-e coating, argon fill	Control	5ft T8 Electronic, Normal Lumen Blub, Normal BF Electronic Ballast, No Sensor	6.5
Freezer Display Door - Large	3 panes, no low-e coating, argon fill	Control	6 ft T8 Electronic, Normal Lumen Blub, Normal BF Electronic Ballast, No Sensor	8.5

Table 5.5.3 Specifications and Ratings of Baseline Non-Display Doors

Equipment Class	Insulation Thickness	Insulation Material	Framing Material	Window Glass Pack	Anti-sweat Heater Control	Baseline Energy Use *kWh/day*
PD.M – Small	3.5 inches	Polyurethane	Wood	2 panes, hard coat low-e, argon fill	No Control	0.30
PD.M - Medium	3.5 inches	Polyurethane	Wood	2 panes, hard coat, argon fill	No Control	0.32
PD.M - Large	3.5 inches	Polyurethane	Wood	2 panes, hard coat, argon fill	No Control	0.36
PD.L - Small	4 inches	Polyurethane	Wood	3 panes, no low-e coating, argon fill	No Control	7.1
PD.L - Medium	4 inches	Polyurethane	Wood	3 panes, no low-e coating, argon fill	No Control	7.8
PD.L - Large	4 inches	Polyurethane	Wood	3 panes, no low-e coating, argon fill	No Control	9.0
FD.M - Small	3.5 inches	Polyurethane	Wood	2 panes, hard coat low-e, argon fill	No Control	0.39
FD.M - Medium	3.5 inches	Polyurethane	Wood	2 panes, hard coat, argon fill	No Control	0.65
FD.M - Large	3.5 inches	Polyurethane	Wood	2 panes, hard coat, argon fill	No Control	0.73
FD.L - Small	4 inches	Polyurethane	Wood	3 panes, no low-e coating, argon fill	No Control	10.3
FD.L - Medium	4 inches	Polyurethane	Wood	3 panes, no low-e coating, argon fill	No Control	13.7
FD.L - Large	4 inches	Polyurethane	Wood	3 panes, no low-e coating, argon fill	No Control	15.6

Table 5.5.4 Specifications and Ratings of Baseline Refrigeration Units (Dedicated Condensing)

Analysis Point	Saturated Condensing Temp. *°F*	Condenser Fan Power *hp*	# of Condenser Fans	Saturated Evaporating Temp. *°F*	Evaporator Fan Power *hp*	# of Evaporator Fans	Baseline AWEF *Btu/W-h*
DC.M.I.HER.006	115	1/15	1	25	1/15	1	3.78
DC.M.I.HER.018	115	1/15	2	25	1/15	2	4.52
DC.M.I.SCR.018	115	1/15	2	25	1/15	2	4.68
DC.M.I.SCR.054	115	1/3	1	25	1/4	2	4.49
DC.M.I.SCR.096	115	1/3	2	25	1/4	2	4.08
DC.M.I.SEM.006	115	1/15	1	25	1/15	1	4.44
DC.M.I.SEM.018	115	1/15	2	25	1/15	2	4.36
DC.M.I.SEM.054	115	1/3	1	25	1/4	2	4.70
DC.M.I.SEM.096	115	1/3	2	25	1/4	2	4.33
DC.M.O.HER.006	115	1/15	1	25	1/15	1	4.16
DC.M.O.HER.018	115	1/15	2	25	1/15	2	4.91
DC.M.O.SCR.018	115	1/15	2	25	1/15	2	5.52
DC.M.O.SCR.054	115	1/3	1	25	1/4	2	4.82
DC.M.O.SCR.096	115	1/3	2	25	1/4	2	4.47
DC.M.O.SEM.006	115	1/15	1	25	1/15	1	4.85
DC.M.O.SEM.018	115	1/15	2	25	1/15	2	4.82
DC.M.O.SEM.054	115	1/3	1	25	1/4	2	5.05
DC.M.O.SEM.096	115	1/3	2	25	1/4	2	4.61
DC.L.I.HER.006	110	1/15	2	-20	1/15	2	2.34
DC.L.I.HER.009	110	1/15	2	-20	1/15	2	2.77
DC.L.I.SCR.006	110	1/15	2	-20	1/15	2	2.42
DC.L.I.SCR.009	110	1/15	2	-20	1/15	2	3.04
DC.L.I.SCR.054	110	3/4	2	-20	1/4	2	3.28
DC.L.I.SEM.006	110	1/15	2	-20	1/15	2	2.36
DC.L.I.SEM.009	110	1/15	2	-20	1/15	2	2.64
DC.L.I.SEM.054	110	3/4	2	-20	1/4	2	3.02
DC.L.O.HER.006	110	1/15	2	-20	1/15	2	2.40
DC.L.O.HER.009	110	1/15	2	-20	1/15	2	2.91
DC.L.O.SCR.006	110	1/15	2	-20	1/15	2	2.86
DC.L.O.SCR.009	110	1/15	2	-20	1/15	2	3.70
DC.L.O.SCR.054	110	3/4	2	-20	1/4	2	4.09
DC.L.O.SEM.006	110	1/15	2	-20	1/15	2	2.47
DC.L.O.SEM.009	110	1/15	2	-20	1/15	2	2.78
DC.L.O.SEM.054	110	3/4	2	-20	1/4	2	3.36
DC.L.O.SEM.072	110	3/4	2	-20	1/4	2	3.41

Table 5.5.5 Specifications and Ratings of Baseline Refrigeration Units (Multiplex Condensing)

Analysis Point	Saturated Evaporating Temperature *°F*	Evaporator Fan Power *hp*	# of Evaporator Fans	Baseline AWEF *Btu/W-h*
MC.M.N.006.004.1	25	1/15	1	6.42
MC.M.N.006.009.2	25	1/15	2	6.80
MC.M.N.006.024.6	25	1/4	2	5.75
MC.M.N.004.004.1	25	1/15	1	6.42
MC.M.N.004.009.2	25	1/15	2	6.80
MC.L.N.006.004.1	-20	1/15	1	4.40
MC.L.N.006.009.2	-20	1/15	2	4.66
MC.L.N.006.018.2	-20	1/4	2	3.93
MC.L.N.004.004.1	-20	1/15	1	4.43
MC.L.N.004.009.2	-20	1/15	2	4.71
MC.L.N.004.018.2	-20	1/4	2	4.46
MC.L.N.004.040.2	-20	1/2	2	4.14

5.5.5 Design Options for Panels and Doors

In chapter 4 of the TSD, DOE lists the design options for each component remaining after the screening analysis. In the engineering analysis, DOE assigned each option a code and, in some cases, designated more than one level within a particular design option. For example, the increased insulation thickness option is split into incremental thicknesses increases, to 4 inches, 5 inches, and 6 inches. Table 5.5.6, Table 5.5.7, and Table 5.5.8 summarize the design option codes and descriptions for panels, display doors, and non-display doors, respectively. Sections 5.5.5.1 through 5.5.5.5 contain details for improved technologies for panels, display doors, and non-display doors.

Table 5.5.6 Design Option Codes and Descriptions for Panels

Design Option Code	Description
	Cooler Wall, Cooler Ceiling, and Freezer Floor Insulation Thickness
TCK1	Baseline thickness
TCK2	4 inch thick insulation
TCK3	5 inch thick insulation
TCK4	6 inch thick insulation
	Freezer Wall and Ceiling Insulation Thickness
TCK1	Baseline thickness
TCK2	5 inch thick insulation
TCK3	6 inch thick insulation
	Insulation Material
INS1	Baseline insulation material, polyurethane
HYB	Hybrid 1-VIP + INS1
	Structural Panel Framing Material
WOOD	Pine framing members
SOFTNOSE	Urethane framing members
NONE	No framing members
	Floor Panel Framing Material
WOOD	Pine framing members
SOFTNOSE	Urethane framing members

Table 5.5.7 Design Option Codes and Descriptions for Display Doors

Design Option Code	Description
	Display Door Enhancement
DR1	Baseline glass
DR2	Enhanced 1
DR3	Enhanced 2
DR4	Super-enhanced
	Anti-Sweat Heaters Controls (Cooler Door Only)
ASHNC	Baseline (no controller)
ASCTRL	Anti-sweat heater controls
	Lighting: Display
T8	T8 Electronic, Normal Lumen Blub, Normal Ballast Factor Electronic Ballast
LED	LED
	Control System
CS1	Baseline (no controller)
CS2	Lighting Sensors

Table 5.5.8 Design Option Codes and Descriptions for Non-Display Doors

Design Option Code	Description
	Cooler Door Insulation Thickness
TCK1	Baseline thickness
TCK2	4 inch thick insulation
TCK3	5 inch thick insulation
TCK4	6 inch thick insulation
	Freezer Door Insulation Thickness
TCK1	Baseline thickness
TCK2	5 inch thick insulation
TCK3	6 inch thick insulation
	Insulation Material
INS1	Baseline insulation material, polyurethane
HYB	Hybrid 1-VIP + INS1
	Framing Material
WOOD	Pine framing members
SOFTNOSE	Urethane framing members
	Window Enhancement
DR1	Baseline glass
DR2	Enhanced 1
DR3	Enhanced 2
DR4	Super-enhanced
	Anti-Sweat Heaters
ASHNC	Baseline (no controller)
ASCTRL	Anti-sweat heater controls

5.5.5.1 Improved Insulation

DOE considered three options to improve the insulation of walk-in panels and non-display doors. These improvements affect the insulation thickness, the insulation material, and the framing material.

Insulation Thickness

The thermal resistance of insulating materials increases approximately linearly with material thickness. Based on DOE's analysis and public comment, a baseline cooler panel, freezer floor panel, and cooler non-display door utilizes 3.5 inches of foam insulation and freezer panels and freezer non-display doors utilize 4 inches of foam insulation to slow the rate of heat conduction from the external environment to the internal cooled space of the walk-in. In addition, DOE found that many panel and non-display door manufacturers offer insulation in thicknesses of 4, 5, and 6 inches.

Therefore, in the engineering analysis, DOE considered insulation thickness as one of the three independent variables that impacts the R-value of wall, ceiling, and floor panels and non-display doors. DOE assessed the incremental increase in cost due to additional material cost and separately evaluated the impact on shipping cost.

DOE's analysis found that the incremental cost of manufacturing thicker products was dominated by material cost. The results of the analysis for panels and non-display doors, for the various thicknesses, are shown in Table 5.5.9. The impact on shipping is a more complex calculation. The shipping weight is independently impacted by both the total surface area of a walk-in and selected insulation thickness. Then, the cost of shipping is dependent on a base charge (based on density and shipping class) and a fuel surcharge based on the distance shipped and weight. To determine the cost of shipping one panel, DOE first calculated the shipping cost based on the final weight of an entire WICF envelope and then divided out the cost per square foot of panel.

Due to the multivariate nature of the shipping calculation, best fit linear equations were first developed to calculate the weight of a given product based on its surface area and thickness. Then, using the calculated weight for a given thickness and area, the base and fuel cost of shipping could be developed. Finally, linear best fits of the shipping cost calculations were made, and these equations then allowed the model to interpolate the shipping cost based on any thickness ranging from 2 to 7 inches in thickness. From this data, DOE calculated the cost of shipping an average small, medium, and large sized walk-in (the specifications for these average walk-ins are shown in Table 5.5.10), determined the square footage of panels in each walk-in, and determined the shipping cost per square foot of panels. DOE then weighted the shipping cost per square foot of panel for each sized walk-in to find an average shipping cost per square foot of panel. Based on the size and thickness of the panel, DOE calculated the shipping cost per panel, which is listed in Table 5.5.11. Table 5.5.12 shows the shipping cost per non-display door.

Table 5.5.9 Insulation Thickness Material and Labor Cost

Insulation Thickness ***in***	**Material**	**Material/Labor Cost for Non- Floor panels** ***$/ft^2***	**Material/Labor Cost for Floor Panels** ***$/ft^2***	**Material/Labor Cost for Passage Doors** ***$/ft^2***	**Material/Labor Cost for Freight Doors** ***$/ft^2***
3.5	Polyurethane	$5.06	$5.50	$6.07	$6.81
4	Polyurethane	$5.22	$5.64	$6.25	$7.02
5	Polyurethane	$5.58	$5.99	$6.60	$7.42
6	Polyurethane	$5.92	$6.33	$6.95	$7.84

Table 5.5.10 Representative Walk-In Sizes

Temperature	Size	Length *ft*	Width *Ft*	Height *ft*
Cooler	Small	12	8	8
	Medium	24	20	8
	Large	40	36	8
Freezer	Small	8	8	8
	Medium	20	12	8
	Large	40	20	8

Table 5.5.11 Total Shipping Cost for Panel Equipment Classes and Thicknesses Considered

Thickness *In*	3.5	4	5	6
Small Structural Cooler Panel	$9.71	$10.18	$11.13	$12.09
Medium Structural Cooler Panel	$25.89	$27.16	$29.69	$32.23
Large Structural Cooler Panel	$40.05	$42.01	$45.93	$49.85
Small Structural Freezer Panel	-	$10.18	$11.13	$12.09
Medium Structural Freezer Panel	-	$27.16	$29.69	$32.23
Large Structural Freezer Panel	-	$42.01	$45.93	$49.85
Small Freezer Floor Panel	$12.95	$13.58	$14.85	$16.11
Medium Freezer Floor Panel	$25.89	$27.16	$29.69	$32.23
Larger Freezer Floor Panel	$43.69	$45.83	$50.11	$54.38

Table 5.5.12 Total Shipping Cost for Non-Display Door Equipment Classes and Thicknesses Considered

Thickness *in*	3.5	4	5	6
Small Cooler Passage Door	$13.15	$13.79	$15.08	$16.37
Medium Cooler Passage Door	$16.99	$17.82	$19.49	$21.15
Large Cooler Passage Door	$24.27	$25.46	$27.84	$30.21
Small Freezer Passage Door	-	$13.79	$15.08	$16.37
Medium Freezer Passage Door	-	$17.82	$19.49	$21.15
Large Freezer Passage Door	-	$25.46	$27.84	$30.21
Small Cooler Freight Door	$32.36	$33.95	$37.12	$40.28
Medium Cooler Freight Door	$50.97	$53.47	$58.46	$63.45
Large Cooler Freight Door	$67.96	$71.29	$77.94	$84.60
Small Freezer Freight Door	-	$33.95	$37.12	$40.28
Medium Freezer Freight Door	-	$53.47	$58.46	$63.45
Large Freezer Freight Door	-	$71.29	$77.94	$84.60

Insulation Materials

Based on DOE analysis and stakeholder comments, DOE concluded that WICF panel and non-display door manufacturers almost exclusively currently use one of two foam insulation types: board stock extruded polystyrene (XPS) or foam-in-place polyurethane (PU). (Other insulation products such as expanded polystyrene, polyisocyanurate, and polyurethane board stocks are also used in WICF construction.) DOE also found that foam-in-place polyurethane has slightly better thermal resistance than extruded polystyrene. As mentioned in section 5.5.1, DOE obtained data on the long-term thermal resistance of foam; namely, extruded polystyrene has a long-term thermal resistance of approximately 5.89 ft^2-F-h/Btu and polyurethane has a long term thermal resistance of approximately 6.82 ft^2-F-h/Btu. Despite polyurethane's higher R-value, DOE found that extruded polystyrene is typically more expensive than polyurethane. The approximate cost of extruded polystyrene is $3.13 per pound and polyurethane is $1.61 per pound. DOE recognizes that extruded polystyrene has other benefits, like higher water resistance than polyurethane, but only thermal resistance is captured in this rulemaking. Additionally, as mentioned in chapter 3 of the TSD, DOE estimates that between 75 and 90 percent of panels are made from foam-in-place polyurethane. For these reasons—lower cost and higher market share—DOE used foam-in-place polyurethane as the baseline material for panels and non-display doors.

DOE found that several other insulating materials or systems are commercially available but have limited market penetration. These include, but are not limited to, vacuum insulated panels (VIPs), aerogel materials, and hybrids of these and traditional foam materials. These materials are more insulative than the foams currently used on the market, but are more expensive. Based on research and conversations with manufacturers, DOE determined that VIP and aerogels alone are not suitable to make up walk-in panels and doors. The R-value of vacuum insulated panels will deteriorate if the vacuum tight seal is broken, and unless the panel or door is visibly punctured it would be difficult to determine if the VIPs are intact inside a panel's or door's metal facing. Aerogels are not suitable for panel and door applications because they are highly brittle, and may shatter in the panel's or door's metal facing. DOE did evaluate a hybrid insulation made up of vacuum insulated panels and foamed-in-place polyurethane. (DOE did not consider a hybrid insulation containing aerogels because even when encased in polyurethane, these materials could shatter under use conditions typically experienced by walk-in panels.) The polyurethane insulation provides the structural support for the vacuum insulated panels and protects the VIP from being damaged. In the engineering analysis, DOE evaluated a 4-inch-thick hybrid insulation comprised of 50 percent of polyurethane and 50 percent VIP. The labor and material cost and thermal resistance for panels and non-display door with hybrid insulation can be found in Table 5.5.13 and Table 5.5.14, respectively. The shipping cost for hybrid panels and non-display doors can be found in Table 5.5.15 and Table 5.5.16, respectively.

Table 5.5.13 Details for Panel Insulation Materials

Code	**Description**	**Insulation Thickness** *in*	**R-value/inch**	**Material/Labor Cost for Non-Floor Panels** *\$/ft²*	**Material/Labor Cost for Floor Panels** *\$/ft²*
INS1	Polyurethane	4	6.82	$5.22	$5.64
HYB	Hybrid: 50% VIP + 50% INS1	4	21.91	$17.98	$18.40

Table 5.5.14 Details for Non-Display Door Insulation Materials

Code	**Description**	**Insulation Thickness** *in*	**R-value/inch**	**Material/Labor Cost for Passage Doors** *\$/ft²*	**Material/Labor Cost for Freight Doors** *\$/ft²*
INS1	Polyurethane	4	6.82	$6.25	$7.02
HYB	Hybrid: 50% VIP + 50% INS1	4	21.91	$18.02	$18.87

Table 5.5.15 Details for Hybrid Panel Shipping Cost

Equipment Class	Cost
Small Structural Cooler Panel	$9.99
Medium Structural Cooler Panel	$26.65
Large Structural Cooler Panel	$41.23
Small Structural Freezer Panel	$9.99
Medium Structural Freezer Panel	$26.65
Large Structural Freezer Panel	$41.23
Small Freezer Floor Panel	$13.33
Medium Freezer Floor Panel	$26.65
Larger Freezer Floor Panel	$44.97

Table 5.5.16 Details for Hybrid Non-Display Door Shipping Cost

Equipment Class	Cost
Small Cooler Passage Door	$13.79
Medium Cooler Passage Door	$17.82
Large Cooler Passage Door	$25.46
Small Freezer Passage Door	$13.79
Medium Freezer Passage Door	$17.82
Large Freezer Passage Door	$25.46
Small Cooler Freight Door	$33.95
Medium Cooler Freight Door	$53.47
Large Cooler Freight Door	$71.29
Small Freezer Freight Door	$33.95
Medium Freezer Freight Door	$53.47
Large Freezer Freight Door	$71.29

Framing Materials

Improved framing materials is the third type of insulation improvement that DOE evaluated in its engineering analysis for walk-in cooler and freezer panels and non-display doors. Framing materials border the foam insulation in a panel or non-display door and are designed to increase the strength of a panel and to provide structure during the foaming process. Wood frames are the least efficient framing material currently found on the market and were selected as the baseline material. Through manufacturer interviews, DOE also identified two improved framing designs, using high density polyurethane framing members and eliminating framing members. High density polyurethane is more insulative than wood, and can be used instead of wood framing materials. High density polyurethane framing members are already used to construct non-display doors and floor, ceiling, and wall panels for walk-in coolers and freezers, and can sustain typical loads experienced by walk-ins. DOE also evaluated walk-in panels without framing materials. By eliminating the framing member, the panel is completely made up of insulating foam, which has a higher thermal resistance than both wood and high density polyurethane. DOE applied a frameless design option to wall and ceiling panels only, and not floor panels, because floor panels can experience a heavy load from hand carts and pallet jacks. Eliminating frames from floor panels could result in the failure of the panel. DOE also did not consider eliminating framing members for non-display doors because it is critical for non-display doors to maintain their shape. If a non-display door warps or loses its original shape then the seal around the door can be compromised, which increases the air infiltration in the walk-in and thus reduces the utility of the door. The identifying code, cost, and thermal resistance of each framing option can be found in Table 5.5.17.

Table 5.5.17 Details for Insulation Materials

Code	Description	R-value/inch	Cost/ft^2 at 1 inch thickness
WOOD	Pine framing members	1.00	$0.60
SOFTNOSE	Urethane framing member	4.00	$1.13
NONE	No framing members	-	$1.24

5.5.5.2 Electronic Lighting Ballasts and High-Efficiency Lighting

Lighting: Display

EPCA specified a minimum efficacy of 40 lumens per watt, including ballast losses, for all lights. (42 U.S.C. 6313(f)(1)(G) Therefore, DOE did not consider any lighting systems that did not meet this limit. In addition, DOE's analysis indicated that the lighting industry had mostly shifted from magnetic ballasted lighting systems to high efficiency, electronic ballasted lighting systems. In DOE's proposed analysis, the baseline lighting associated with display doors is T8 bulbs with electronic ballasts. Light emitting diode (LED) lighting was selected as a design option to decrease the amount of energy consumed by walk-in display doors. Based on comments from manufacture interviews, DOE used 5-foot-long lights for display doors less than 6.5 feet tall and 6-foot lights for display doors greater than 6.5 feet tall. The associated performance and cost data used in the model are shown in Table 5.5.18 through Table 5.5.20. As explained in section 5.4.5.1, DOE used price projections to determine the cost of LED lights.

Table 5.5.18 Details for Lighting: Display Design Option, Performance Data

Code	Description	Total Power *W/bulb*
LT1	5-foot, T8 Electronic, Normal Lumen Blub, Normal BF Electronic Ballast	58
LT2	5-foot, LED	23.0
LT1	6-foot, T8 Electronic, Normal Lumen Blub, Normal BF Electronic Ballast	70
LT2	6-foot, LED	25

Table 5.5.19 Details for Lighting: Display Design Option, Performance Data Cont.

Code	Lamp Type	Number of Lamps/ Ballast	Ballast Factor	Total Power *W*
LT1	F58T8	1	0.94	58.0
LT2	-	1	-	23.0
LT1	F72T8	1	.9	70.0
LT2	-	1	1	25.0

Table 5.5.20 Details for Lighting: Display Design Option, Cost Data

Code	Description	Total Cost
LT1	5-foot, T8 Electronic, Normal Lumen Blub, Normal BF Electronic Ballast	$27.45
LT2	5-foot, LED	$24.77
LT1	6-foot, T8 Electronic, Normal Lumen Blub, Normal BF Electronic Ballast	$27.45
LT2	6-foot, LED	$35.38

5.5.5.3 Occupancy Sensors and Automatic Door Opening and Closing Systems

Lighting Control Systems

DOE reviewed a number of control system related design options. While most control systems are designed to intelligently control the refrigeration equipment and are described in section 5.5.6, there are a number of available features that are relevant to the envelope components only. DOE found that most display door manufacturers offer lighting control systems, but there was limited end-user demand or market penetration. Therefore, DOE considered the baseline design option to be a display door without a lighting control system, CS1-L.

The next design option (CS2-L) DOE considered is occupancy sensors to control lights. This allows for “on demand” use of lights and helps prevent accidental wasted energy. In the test procedure final rule, DOE adopted percent time off (PTO) values to allow manufacturers to rate the device’s decreased power use. 76 FR 33631, 33635, 33637 (June 9, 2011). The engineering analysis uses these PTO values to account for the amount of power saved by occupancy sensors. The cost estimates used for the various control system options were developed based on WICF manufacturer comments. The assumptions used in the analysis can be found in Table 5.5.21.

Table 5.5.21 Details for Control System Design Option

Code	Description	PTO Lights	Cost
CS1-L	Baseline No Control	25%	$ -
CS2-L	Lighting Sensors	50%	$120.82

5.5.5.4 Display and Window Glass System Insulation Enhancement

Display Door Enhancement

Heat conduction through glass display doors is one of the largest energy loss components of a walk-in. The heat that is transferred though the doors is primarily dependent on the door frame material and insulation, the number and spacing of glass panes, the type of inert gas fill and the use of various low-emissivity coatings. DOE found that typical display doors use vinyl composite frames and argon gas fill. EPCA specifies that, at a minimum, transparent reach-in doors and windows for walk-in coolers must have either double pane glass with heat reflective coating and glass fill or triple pane glass with either heat reflective coating or gas fill. For transparent reach-in doors and windows for walk-in freezers, EPCA specifies that there must be triple pane glass with either heat reflective coating or gas fill. Therefore, DOE selected these characteristics for the baseline options for coolers and freezers as shown in Table 5.5.24 and Table 5.5.25. Starting from this baseline, DOE then considered additional design options DR2, DR3, and DR4. DR2 reflects the display door characteristics widely available for high-performance display doors. DR2 for cooler doors was improved from the baseline by going from hard low emittance coating to soft low emittance coating. Hard low emittance coating is applied to the glass pane at high temperatures during the formation of the pane, and is extremely durable. Soft low emittance coating is less durable than hard low emittance coating, but has better performance characteristics. DR3 and DR4 incorporate multiple panes, additional coatings and higher performing gas fill corresponding to more efficient glass packs found on the market. DR4 incorporates two thin film layers in between two layers of glass. As mentioned in the screening analysis, no display door option incorporates four or more panes of glass, which DOE believes would be impracticable to manufacture and install. Four-pane display doors would impracticable to manufacture because the increased weight would be difficult to handle and the thickness of the glass would not fit into a typical display cases. Table 5.5.22 provides details for the improved glass packs.

Table 5.5.22 Details for Display Door Enhancement Design Option

Code	Description	Small Cooler *Btu/h-ft²-F*	Medium Cooler *Btu/h-ft²-F*	Large Cooler *Btu/h-ft²-F*	Small Freezer *Btu/h-ft²-F*	Medium Freezer *Btu/h-ft²-F*	Large Freezer *Btu/h-ft²-F*	Cooler Cost *$/ft²*	Freezer Cost *$/ft²*
DR1	Baseline Glass	0.247	0.256	0.267	0.188	0.194	0.202	$21.09	$35.15
DR2	Enhanced 1	0.156	0.162	0.168	0.095	0.097	0.101	$28.12	$49.21
DR3	Enhanced 2	0.096	0.099	0.102	0.080	0.082	0.085	$42.18	$63.38
DR4	Superenhanced	0.056	0.057	0.058	0.055	0.056	0.057	$98.53	$98.53

Due to limited availability of thermal performance data from display door manufacturers, DOE predicted the performance using WINDOW 6.3. The key assumptions, shown in Table 5.5.23, were used to generate the performance data shown in Table 5.5.22. The predicted U-factor from WINDOW 6.3 is a full door system prediction including the center of glass, door frame, etc.

Table 5.5.23 Details for Display Door Enhancement Design Option, WINDOW 6.3

Assumptions Used in WINDOW 6.3 calculations:
• Clear glass is 0.125 inch thick
• Low-E glass is 0.125 inch thick clear glass with low-E coating (emissivity=0.54)
• 0.5 inch thick gas layer for Argon, 0.3 inch for Krypton/Xenon
• 100% purity gas filled windows
• R-value of full thickness vinyl/composite frame = 2.15 ft²-F-h/Btu

Source: LBNL WINDOW 6.3 Software

Table 5.5.24 Details for Display Door Enhancement Design Option, WINDOW 6.3, Coolers

Design Option	Frame	Number of Panes/Films	Pane/ Film 1	Pane/ Film 2	Pane/ Film 3	Pane/ Film 4	Gas Fill
Baseline	**Vinyl/Composite**	2	Hard Coat Low-E	Clear	-	-	Argon
Enhanced 1	**Vinyl/Composite**	2	Soft Coat Low-E	Clear	-	-	Argon
Enhanced 2	**Vinyl/Composite**	3	Soft Coat Low-E	Clear	Soft Coat Low-E	-	Argon
Superenhanced	**Vinyl/Composite**	4	Soft Coat Low-E	Low-E	Low-E	Soft Coat Low-E	Krypton

Table 5.5.25 Details for Display Door Enhancement Design Option, WINDOW 6.3, Freezers

Design Option	Frame	Number of Panes/Films	Pane/ Film 1	Pane/ Film 2	Pane/ Film 3	Pane/ Film 4	Gas Fill
Baseline	**Vinyl/Composite**	3	Clear	Clear	Clear	-	Argon
Enhanced 1	**Vinyl/Composite**	3	Soft Coat Low-E	Clear	Soft Coat Low-E	-	Argon
Enhanced 2	**Vinyl/Composite**	3	Soft Coat Low-E	Clear	Soft Coat Low-E	-	Krypton
Superenhanced	**Vinyl/Composite**	4	Soft Coat Low-E	Low-E	Low-E	Soft Coat Low-E	Krypton

As the performance of the glass pack is improved, the amount of anti-sweat heater wire required for the glass pack decreases because the glass pack is more insulative and reduces the amount of heat transfer across the panes of glass. With a more insulative glass pack, the interior and exterior surface temperatures of the glass panes are closer to the interior and exterior air temperatures, respectively, so condensation does not form on the glass as easily. The decrease in the amount of anti-sweat heater wire also results in a decrease of the effectiveness of the anti-sweat heater wire controls, and this interactive effect is accounted for in the engineering analysis. Table 5.5.26 details the amount of anti-sweat heater wire power associated with each design option.

Table 5.5.26 Details for Display Door Enhancement Design Option

	Heater Wire Energy Consumption *W/ft²*	
Design Option	**Cooler**	**Freezer**
Baseline	2.97	15.23
Enhanced 1	2.37	9.92
Enhanced 2	1.86	6.66
Superenhanced	0	5.32

5.5.5.5 Anti-Sweat Heater Controls

Anti-Sweat Heaters

The external surface of glass display doors or glass windows typically cools to temperatures below the dew point of the surrounding air because of conduction through the glass. When this occurs, condensate or “sweat” begins to form on the exposed surface of the glass. It first appears as a fog, and if left unchecked, further condenses to droplets large enough to begin to roll and drip off the surface. The amount and rate of sweating is dependent on the relative humidity surrounding the walk-in and the temperature of the glass. To ensure the temperature of the glass stays above the dew point of the surroundings, electric resistive heater wire is installed around the frame of the door. Typical systems continuously power the heater wire, regardless of the relative humidity. This means that for a large portion of time, the door glass is heated to temperatures far higher than necessary to remain above the dew point, resulting in additional electricity consumption.

With the use of an anti-sweat heater control system that senses the relative humidity, the level of heating required to avoid condensate can be precisely matched to the conditions. The energy savings seen in practice for freezers and coolers is approximately 50 percent and 75 percent, respectively.

EPCA requires that walk-in coolers and freezers with anti-sweat heaters must have a controller if the cooler or freezer consumes 3.0 W/ft^2 of door opening or 7.1 W/ft^2 of door opening, respectively. The baseline glass pack for walk-in display doors used in DOE's proposed analysis consumes 2.97 W/ft^2 of heater wire and the baseline glass pack for walk-in freezers consumes 15.23 W/ft^2 of heater wire. Therefore, DOE set the baseline option for display cooler doors to not include anti-sweat heaters controls and the baseline option for display freezer doors to include anti-sweat heater controls as required by EPCA. The windows on non-display doors in DOE's proposed engineering analysis also have anti-sweat heater wire, but the heater wire on each window consumes less energy than would require a heater control. Thus, the baseline non-display door does not have an anti-sweat heater wire control for the window. Table 5.5.27 contains performance and cost details for the anti-sweat heater control design option.

Table 5.5.27 Details for Anti-Sweat Heaters Design Option

Code	Description	PTO Cooler	PTO Freezer	Cost
ASHNC	Baseline (No Controller)	0%	0%	$-
ASCTRL	Anti-Sweat Heater Controls	75%	50%	$65.90

5.5.6 Design Options for Refrigeration Systems

Table 5.5.28 summarizes the design option codes and descriptions for each refrigeration system design option. The following sections contain details for improved technologies for refrigeration systems.

Table 5.5.28 Design Option Codes and Descriptions for Refrigeration Systems

Design Option Code	Description
	High-Efficiency Compressor
CMP1	Baseline Compressor
CMP2	Variable Speed Compressor
	Improved Condenser Coil
CD1	Baseline Coil
CD2	Improved Coil
	High-Efficiency Condenser Fan Motors
PSC	Permanent Split Capacitor Motors
ECM	Electronically Commutated Motors
	Improved Condenser Fan Blades
CD1	Baseline Condenser Fan Blades
CD2	Improved Condenser Fan Blades
	Condenser Fan Control
SSCF	Single Speed Condenser Fans
VSCF	Variable Speed Condenser Fans
	Ambient Sub-cooling
NOASC	No Ambient Sub-cooling
ASC	Ambient Sub-cooling
	Improved Evaporator Fan Blades
EB1	Baseline Evaporator Fan Blades
EB2	Improved Evaporator Fan Blades
	Evaporator Fan Controls
SSEF	Single Speed Evaporator Fans
MEF	Modulating Evaporator Fans
VEF	Variable Speed Evaporator Fans
	Defrost Controls
NODFC	Time-initiated, Temperature-terminated Defrost
DFC1	Temperature-initiated, Temperature-terminated Defrost
	Hot Gas Defrost
ELD	Electric Defrost
HGD	Hot Gas Defrost
	Head Pressure Control
FXHP	Fixed Head Pressure
FHP	Floating Head Pressure
FHPEV	Floating Head Pressure with Electronic Expansion Valve

5.5.6.1 Variable Speed Compressors

The baseline for this design option is a standard single-speed compressor, while the second technology level is a variable speed compressor. This design option applies only to dedicated condensing, outdoor equipment classes and is restricted to the analysis points at capacities of 20,000 Btu/h and above. DOE is not aware of any variable speed compressors available on the market between 6,000 Btu/h (the smallest capacity analyzed) and 20,000 Btu/h.

The performance improvement for variable speed compressors is expressed as a reduction of the power output at a given outdoor temperature, which in turn reduces the total system energy consumption. DOE expressed the efficiency gains in this simplified manner because it was unable to find performance data for variable speed compressors that would allow it to analytically calculate the benefit within the energy model. However, DOE checked the validity of its assumptions using limited available data from an existing variable speed compressor model. DOE also expressed the cost associated with high-efficiency compressors as a multiplier on the baseline compressor cost and another multiplier on the overall system cost to account for additional manufacturing complexity of the system and added controls. The relationship between performance improvement and cost for variable speed compressors is shown in Table 5.5.29.

DOE is aware of other technology options that improve compressor performance and efficiency, such as two-speed and variable capacity (through cylinder unloading). Although DOE did not address these technologies in the analysis, manufacturers may use any of these options, or a combination thereof, to meet the proposed standard.

Table 5.5.29 Details for Variable Speed Compressors Design Option

	Compressor Power Multiplier (by Outdoor Rating Condition)			**Cost Multiplier**	
Design Option	**95 °F**	**59 °F**	**35 °F**	**Compressor**	**System**
Baseline Compressor	1	1	1	1	1
Variable Speed Compressor	0.8	0.8	0.9	2	0.1

5.5.6.2 Improved Condenser Coil

This design option applies only to DC equipment classes. DOE considered two technology levels: a baseline coil and an improved coil that was sized to run at an SCT that is cooler than that of the baseline coil. The assumptions for baseline SCT for each equipment class are listed in Table 5.5.30. The temperature difference, or TD, is defined as the difference between the SCT and the ambient air. For the engineering analysis, DOE used the ambient air temperatures specified in the rating conditions: 90 °F for indoor condensing systems and 95 °F, 59 °F, and 35 °F for outdoor condensing systems. DOE's baseline TD assumptions are presented in Table 5.5.30.

Table 5.5.30 Refrigeration System Baseline TD Assumptions

Class	**Ambient *°F***	**Baseline SCT *°F***	**Baseline TD *°F***
DC.M.I	90	115	25
DC.L.I	90	110	20
DC.M.O	95	115	20
DC.L.O	95	110	15

For the improved condenser coil, the face area of the condenser coil is increased by half. As the face area increases, the TD must decrease proportionally if the same rate of heat transfer is to be maintained. This in turn reduces the compressor power needed to maintain the same cooling capacity, as calculated by the 10-coefficient equations that incorporate SCT as described in section 5.5.6.1. The relationship between cooling capacity, TD, and coil area is expressed by the heat transfer equation:

$$\dot{Q} = U \times A \times LMTD$$

Eq. 5.15

Where:

$\dot{Q}$ = rate of heat transfer of the coil,
U = thermal conductivity of the coil materials,
A= face area of the coil, and
$LMTD$ = log mean temperature difference.

Log mean temperature difference (LMTD) is a way of representing the difference in temperature between the air and the refrigerant that is similar to, but more accurate than, simply using TD. Using LMTD is more accurate because it accounts for the fact that the air changes temperature as it is blown across the coil, getting warmer as heat is transferred from the refrigerant to the air; and the refrigerant changes temperature as it moves through the coil, cooling from a high temperature as hot gas exiting the compressor to the lower condensing temperature. The refrigerant used in the analysis, 404A, is a near-azeotropic refrigerant; that is, it does not significantly change temperature during a phase change. Thus, the temperature at the condenser exit is assumed to be the same as the saturated condensing temperature.

LMTD is calculated as:

$$LMTD = \frac{\Delta t_1 - \Delta t_2}{\ln(\Delta t_1 / \Delta t_2)}$$

Eq. 5.16

Where:

Δt_1 = temperature of refrigerant entering condenser minus temperature of air exiting condenser, and
Δt_2 = temperature of refrigerant exiting condenser minus temperature of air entering condenser.

DOE also calculated the additional fan power necessary to maintain the same rate of airflow and, consequently, the same air-side heat transfer across the coil – that is, 1.5 times the baseline airflow. For outdoor systems, this was calculated at the highest rating temperature (95 °F ambient). The model calculates the LMTD at the highest rating temperature using the revised SCT, which depends on the TD. Then, at lower temperatures, the revised LMTD is calculated and the airflow needed to maintain adequate heat transfer is also calculated. However, a change in required airflow affects the efficacy of the variable speed condenser fan option. Section 5.5.6.5 contains more details and calculations explaining this calculation.Decreasing the LMTD lowers the SCT. This in turn reduces the compressor power needed to maintain the same cooling capacity, as calculated by the 10-coefficient equations that incorporate SCT as described in section 5.5.6.1. Overall reductions in energy consumption result from the lower energy use of the compressor, even when the increased fan power is accounted for. For simplicity, DOE expressed the increase in area of the coil as an increase in the coil's width. DOE used the cost model to calculate the added cost of materials to produce the larger coil, including any additional fans.

5.5.6.3 Higher Efficiency Condenser Fan Motors

The condenser fan motor design option applies only to the dedicated condensing equipment classes. EPCA requires that all condenser fan motors under 1 horsepower be either electronically commutated (EC) (brushless DC motors), permanent split capacitor (PSC), or 3-phase. (42 U.S.C. 6313(f)(1)(F)) Currently, DOE considers PSC motors as the minimum technology and ECs as the maximum technology. DOE did not analyze 3-phase motors as a design option in the engineering analysis as discussed in chapter 4 of the TSD (although manufacturers may use this technology to improve the rated efficiency of their equipment).

Table 5.5.31 shows details for the condenser fan motor design option. The motor efficiency levels listed were updated from the values presented in the preliminary analysis based on comments from interested parties. Because condenser fan motors are outside the refrigerated space, efficiency improvements only affect the direct electrical consumption of the motors and not the heat load.

Because of the range of equipment sizes in the NOPR analysis, several condenser fan motor sizes were used. Similar to its cost analysis for compressors described in section 5.5.6.1, DOE used motor price data from various sources to generate a trendline for cost versus motor power, defined by a slope and a y-intercept (where cost is on the y-axis).

Table 5.5.31 Details for Condenser Fan Motor Design Option

Code	Description	Efficiency	Slope of Cost/Power Line *$/hp*	Y-Intercept of Cost/Power Line *$*
PSC	Permanent Split Capacitor	50%	$48.12/hp	$29.40
EC	Brushless DC	75%	$108.55/hp	$42.62

5.5.6.4 Improved Evaporator and Condenser Fan Blades

High-efficiency fan blades reduce motor shaft power requirements by moving air more efficiently. Most evaporator and condenser fans use stamped sheet metal or plastic axial fan blades that are paddle-shaped. These fan blades are lightweight and inexpensive. The blades are typically supplied by a fan blade manufacturer and mounted to the motor by the equipment manufacturer. The higher efficiency blades DOE considered typically have swept fins for improved airflow. DOE estimated that these fan blades could increase fan efficiency by 5 percent for the evaporator and condenser fans. DOE changed its assumption from 15 percent in the preliminary analysis based on comments from interested parties. This efficiency improvement is realized as lower energy consumption by the fan motor. DOE also calculated a fan blade cost per horsepower based on price data.

Table 5.5.32 Details for Improved Evaporator Fan Blades Design Option

Code	Description	Fan Power Multiplier	Cost Premium per Fan per hp
EB1	Baseline	1	$-
EB2	Improved	0.95	$82.20

Table 5.5.33 Details for Improved Condenser Fan Blades Design Option

Code	Description	Fan Power Multiplier	Cost Premium per Fan per hp
CB1	Baseline	1	$-
CB2	Improved	0.95	$33.96

5.5.6.5 Condenser Fan Control

This design option applies only to DC equipment classes. At high temperatures, condenser fans typically run at maximum speed when the compressor is on, and are off when the compressor is off. However, at lower ambient temperatures, less airflow is necessary to meet the air-side heat transfer requirements of the condenser coil. DOE assumed that in baseline systems, the refrigeration system would spend more time with the compressor cycled off at low ambient temperatures because the condenser would be more efficient at rejecting heat. The increased off-cycle time would be reflected in the load factors at low ambients. For the variable speed condenser fan option, instead of cycling the system, fans run at the speed necessary to produce the same average airflow to match the capacity to the load. Energy savings are realized through the fan power law, where airflow reduction causes a reduction in power cubed, as shown in equation 5.17.[4]

$$W_1 / W_2 = (Q_1 / Q_2)^3$$

Eq. 5.17

Where:

W = power, and
Q = volume airflow rate.

The exact energy savings achievable by the variable speed option are different for each system and for systems that implement other energy-saving options. For instance, floating head pressure, which decreases the coil temperature at low ambient temperatures and thus decreases the LMTD, tends to make variable speed condensing fans less efficacious because more airflow is needed to maintain the LMTD across the coil, and therefore fans run at full speed more often and the low speed function is used less. For floating head pressure details, refer to section 5.5.6.10. As another example, increasing the size of the condenser coil also decreases the LMTD, which in turn makes variable speed condensing fans less efficacious because the fans must run at a higher speed to maintain the correct level of air-side heat transfer. Because of the interactive effects of certain design options, DOE took the entire system configuration into account when calculating the energy effect of the variable speed condenser fan option.

Table 5.5.34 shows details for the condenser fan control design option. DOE assumed that a variable speed controller would cost more for a PSC motor than for an EC motor because EC motors typically have internal variable speed capability and therefore require fewer external controls than PSC motors.

Table 5.5.34 Details for Condenser Fan Control Design Option

Code	Description	Cost Premium for PSC Motor	Cost Premium for EC Motor
SSCF	Single Speed Condenser Fans	$-	$-
VSCF	Variable Speed Condenser Fans	$100.00	$50.00

5.5.6.6 Ambient Sub-Cooling

This option is applicable to outdoor equipment only. Ambient sub-cooling uses additional heat exchanger surface to further cool condensed refrigerant at low ambient temperatures. DOE assumed that the refrigerant would enter the ambient sub-cooling circuit as liquid refrigerant exiting the receiver, which holds a mixture of liquid and gas from the condenser exit. The ambient sub-cooling circuit decreases the liquid enthalpy of the refrigerant before the expansion valve, resulting in lower-enthalpy refrigerant entering the evaporator and an increase in evaporator capacity. A shorter cycle is needed to maintain the same refrigeration capacity, resulting in energy savings.

As with variable speed condenser fans, the efficacy of ambient sub-cooling is different for each system and depends on what other design options are implemented. DOE assumed that an ambient sub-cooling circuit would add a fraction of the condenser coil area to the existing coil, which would increase the material cost proportionally. A sub-cooling controls premium of $50.00 is also added to the sub-cooling circuit cost.

5.5.6.7 Evaporator Fan Control

Evaporator fan controls save energy by allowing the evaporator fans to run at variable speed, or cycle on and off, during periods when the compressor is off. Without fan controls, the evaporator fans run at a constant speed at all times unless turned off manually. The test procedure incorporates an off-cycle evaporator fan test to determine evaporator fan energy consumption during a compressor-off period. The test procedure measures the effect of any fan control, with the following constraint: “controls shall be adjusted so that the greater of a 25 percent duty cycle or the manufacturer default is used for measuring off-cycle fan energy. For variable-speed controls, the greater of 25 percent fan speed or the manufacturer’s default fan speed shall be used for measuring off-cycle fan energy. When a cyclic control is used, at least three full ‘stir cycles’ are measured.”

DOE proposes two types of controls for this design option: Modulated fan controls that cycle the fans when the compressor is off, and variable speed controls that adjust the fan speed when the compressor is off. For the preliminary analysis, DOE had considered controls that would modulate the fans at 25 percent of duty cycle or set the fan speed to 25 percent of full speed, but then determined that these may be more aggressive control schemes than many manufacturers would implement in their equipment. Various factors may affect the manufacturer default with regard to fan control. For instance, the controls must be set so that there is adequate air circulation throughout the walk-in to maintain food temperature. Also, some medium temperature systems rely on off-cycle airflow to defrost the coil. Therefore, DOE now estimates that modulated fan controls would effectively cycle the fans at 50 percent run time, and variable speed fan controls would approximate an overall 50 percent reduction in fan speed. Based on research into currently used fan controls, DOE has tentatively concluded that the controls it analyzed are limited such that food temperatures could be adequately maintained in either control case and the ability of systems to defrost will not be affected. An article published by the Industrial Refrigeration Consortium noted that cycling fans on for short periods could prevent temperature stratification resulting from "prolonged periods of fan inactivity;" furthermore, reducing fan speed by 50 percent using a variable frequency drive could result in higher energy savings.[5] Cascade Energy Engineering conducted a two-year demonstration of evaporator fan variable-speed controls in commercial cold storage facilities and found that even with controls achieving up to 86 percent energy savings (approximately consistent with a 50 percent reduction in fan speed), "temperature gradients within cold storage rooms were minimal at the demonstration sites."[6]A report published by the Refrigerating Engineers & Technicians association specifically recommended reducing fan speed to 50 percent because "additional speed reduction only diminishes air flow in the room."[7]

DOE assumed that a modulating fan control would cost $25.00 and a variable speed control would cost $50.00. DOE reduced its estimated cost from the preliminary analysis in response to comments from interested parties. DOE understands that EC fan motors required for evaporators typically have built-in variable speed drive capability, but DOE may also consider applying a per-fan cost in the variable speed option to account for fan motors that do not already have this capability and would need to add it for this option.

Table 5.5.35 Details for Evaporator Fan Control Design Option

Code	Description	Off-Cycle Fan Power Multiplier	Cost Premium
SSEF	Baseline (No Control), or Single Speed Fans	1	$-
MEF	Modulated Evaporator Fans	0.5	$20.00
VEF	Variable Speed Evaporator Fans	0.125	$50.00

5.5.6.8 Defrost Controls

Defrost cycle control can reduce energy consumption by reducing the frequency and duration of defrost periods. Most walk-in defrost systems are scheduled for certain times and last as long as it takes to melt the ice on the coil, as determined by a thermostat that senses coil temperature. This is called a time-initiated, temperature terminated or "time-temperature" system. As described in section 5.5.3.3, to determine the defrost time for a time-temperature system, DOE estimated the amount of ice that would build on the coil during the time between defrosts, and then added the time to heat the coil from its original temperature to freezing, the time to melt the ice, and the time to heat the dry coil to its set cutoff temperature. DOE assumed that the cutoff temperature was 45 °F. DOE then calculated the defrost energy used based on the defrost power, which would depend on whether the system uses electric defrost or hot gas defrost (see section 5.5.6.9 for more details).

Various control strategies could include only starting a defrost when necessary and then running for a set duration (temperature-initiated, time-terminated), or starting only when necessary and using temperature termination control (temperature-initiated, temperature-terminated). Still other strategies involve using an adaptive learning algorithm to predict when defrost will be needed. Methods of detecting when defrost is necessary and when a defrost cycle should terminate include optical sensing of frost on the evaporator coil or measurement of refrigerant temperature and pressure at various points on the refrigeration equipment.

Due to the complexity of the various control schemes, DOE did not attempt to analyze every one. However, in consultation with industry experts, DOE determined that without controls, most defrost cycles are scheduled to run more frequently and longer than necessary. In the preliminary analysis, DOE assumed that a control strategy would result in half the amount of defrost power required, implemented in the energy model as a reduction by half in the number of defrost cycles per day. However, following comments from interested parties that questioned such a large reduction, DOE changed its assumption to a control strategy that would result in a 40 percent reduction in defrost cycles. Therefore, the baseline number of defrosts per day is assumed to be 4 (one defrost every 6 hours) and the number of defrosts under a control strategy is assumed to be 2.4 (one defrost every 10 hours). Savings are realized as a reduction in the energy consumption of the defrost heating mechanism.

DOE also assumed that there are no pull-down loads associated with post-defrost periods. During electric defrost periods, the compressor (or the flow of refrigerant for remote condensing cases) stops and the coil warms to a temperature above freezing (aided by electric resistance heating in the case of electric defrosts). After the evaporator coil has been cleared of frost, any product in the walk-in will typically have warmed several degrees. The product must be returned to normal operating temperature when the refrigeration cycle resumes, adding an additional load to the condensing unit. Within the range of covered equipment, there is a large variation in defrost mechanisms, defrost cycle time, temperature recovery time, and product mass. Additionally, post-defrost pull-down load would not be captured in the rating methodology because the equipment is not rated with a measurable product load in place. For these reasons, DOE was unable to accurately calculate the defrost pull-down load and did not include it in the model.

Table 5.5.36 Details for Defrost Controls Design Option

Code	Description	Cycles per Day	Cost Premium
DF1	Baseline (Time-Temperature)	4	$0.00
DF2	Temperature-Temperature	2.4	$50.00

5.5.6.9 Hot Gas Defrost

This option is applicable for multiplex systems only. Hot gas defrost involves the recirculation of hot gas discharged from the compressor or compressor rack to warm the evaporator. During the hot gas defrost cycle, hot gas from the compressor exit is circulated through the heat exchanger using a reversing valve, which reverses the normal flow of refrigerant, or an extra pipe linking the compressor exit to the evaporator inlet. (For determining the added cost of a system that has hot gas defrost, DOE assumed a reversing valve mechanism). Compared to electric defrost, hot gas defrost can be used for much shorter periods and lower time intervals. This is because the hot gas circulates through the evaporator tubes, in contrast with electric defrost heater rods that are attached to the evaporator coil; as a consequence, there are little to no convection losses due to heat dissipating into the air surrounding the coil (see section 5.5.3.3 for further details about convection losses). In addition, the heat comes from an existing byproduct, in the form of hot refrigerant gas. Thus, energy is saved that would have been used to power electric defrost heater rods. Because hot gas defrost requires sophisticated controls and extra piping for the system to be effective, DOE used the cost model to calculate the extra cost for the hot gas defrost subsystem for each system implementing hot gas defrost. DOE did not include the cost of any extra piping between the unit cooler and the multiplex condenser because this cost would likely be incurred by the installer, not the manufacturer of the equipment.

DOE did not propose hot gas defrost as a design option for dedicated systems because it was unclear whether the energy savings from avoiding electric defrost energy would be outweighed by the energy use of the compressor running during the hot gas defrost cycle instead of cycling off as in an electric defrost cycle. For multiplex systems, on the other hand, hot gas is taken from the compressor rack, which is already operating to serve the other refrigeration equipment in the system; thus, no additional energy is used to generate the hot gas.

5.5.6.10 Floating Head Pressure

This design option only applies to DC equipment classes. The three technology levels for this design option are fixed head pressure, floating head pressure, and floating head pressure with electronic expansion valve. Fixed head pressure involves keeping the compressor discharge pressure at a constantly fixed setting to enable operation over a variety of ambient temperatures in outdoor units. Generally, this is fixed at a high value to ensure that enough refrigerant can flow through the system, and that no liquid refrigerant reaches the compressor, which damages the compressor. High head pressure also protects the condenser against freezing and maintains the necessary pressure difference across the expansion valve. However, this also keeps the condensing temperature fixed at a high level regardless of the ambient temperature.

With floating head pressure, the compressor pressure and the SCT "float" down such that the SCT is the minimum of the ambient temperature plus the TD or the lowest condensing temperature at which the compressor can operate. In this way, the model accounts for the interaction between the floating head pressure options and other design options that affect the TD, such as improved condenser coil. For hermetic and semi-hermetic compressors, the lowest condensing temperature at which the compressor can operate corresponds to an SCT of 70 °F. For scroll compressors, this minimum condensing temperature corresponds to an SCT of 50 °F; however, electronic expansion valves (EEVs) are needed to maintain such a low pressure. EEVs are significantly more costly than standard thermostatic expansion valves (TXVs), as reflected in Table 5.5.37. The energy model calculates compressor power at a particular SCT using the 10-coefficient equation described in section 5.5.3.2. Compressors tend to use less power at a lower SCT because they run more efficiently. Thus, reductions in the energy consumption due to floating head pressure are realized through lower compressor power usage at low ambient temperatures. Floating head pressure utilizes a control system to control the flow of refrigerant. A pressure transducer may also be wired to the controller for pressure and temperature sensing.

Table 5.5.37 Details for "Floating Head Pressure" Design Option

Code	Description	Minimum Condensing Temperature	Cost Premium
FXHP	Fixed Head Pressure	Equivalent to system SCT at high ambient rating temperature	$0.00
FHP	Floating Head Pressure	70 °F	$30.00
FHPEV	Floating Head Pressure with Electronic Expansion Valve	50 °F	$180.00

5.5.7 Non-Numerical Assumptions

In developing the energy model, DOE made certain non-numerical assumptions concerning the analysis. These include general assumptions about the analysis as well as specific assumptions regarding load components and design options.

5.5.7.1 Assumptions Concerning the Panel and Door Energy Calculations

The assumptions used in the engineering analysis were based on conditions specified in the WICF test procedure final rule. In the engineering analysis, DOE assumed that the internal and external walk-in temperatures were constant because the test procedure final rule did not account for changes to the external or internal air conditions. The walk-in test procedure final rule rates the performance of all walk-in panels and doors, designed for both the indoors and outdoors, in the same manner.

The engineering analysis for panels, display doors, or non-display doors did not account for food (or other) product variation, such as type of product, rate of product turnover, or product initial temperature. The walk-in test procedure final rule did not prescribe any conditions to account for a product load so the effect of a product load was not accounted for.

All of the components were modeled as if they were rated when newly manufactured. Foam R-value degradation caused by water infiltration was not considered. However, DOE used LTTR values of both XPS and PU foam for all of the heat conduction calculations because this LTTR measurement would be included in the equipment rating from the WICF test procedure. 76 FR at 33639.

Radiation heat transfer was not directly considered in the energy modeling of WICF components. Since outdoor conditions were not considered and it was assumed that walk-ins are not normally sited near high temperature radiative heat sources such as boilers or other high heat equipment, this is a reasonable assumption. However, radiation is indirectly considered in the U-value calculations used to measure the performance of display doors. The WINDOW 6.3 software models this form of heat transfer, which is largely reduced by low emissivity coatings.

The analysis did not account for any interaction between components because DOE is setting separate standards for walk-in panels, display doors, and non-display doors. DOE also implemented baseline specifications and design options so that they would only apply to one product. For instance, DOE's proposed analysis assumed that each display door had one light for illuminating the contents of the walk-in. DOE realizes that one light is often shared between two doors. However, DOE assumed the worst case energy consumption, which assumes that each door has a light. DOE also assumed that the design options for the lighting controls and anti-sweat heater wire controls were only applicable to one display or non-display door. DOE understands that one control could work for multiple doors, but DOE has accounted for the cost of a mid-range controller as if it were only applied to one door.

5.5.7.2 Assumptions Concerning the Refrigeration Energy Consumption

DOE assumed that all conditions are based on new equipment tested in a controlled-environment chamber subjected to AHRI 1250-2009, the refrigeration test procedure. Manufacturers that certify their equipment to comply with Federal standards will be required to test new units to this test method, which specifies certain ambient temperature, humidity, and other requirements.

Due to the ongoing phase-out of hydrochlorfluorocarbon (HCFC) refrigerants in the WICF industry, hydrofluorocarbon (HFC) refrigerants are most likely to be used in this equipment in the future. Other alternative refrigerants, such as ammonia, hydrocarbons, and carbon dioxide, were not considered in this analysis, as they are not currently used in domestically manufactured WICF refrigeration systems. Additionally, some of these refrigerants, including ammonia, could be limited by State and local building codes due to toxicity concerns. Common HFC refrigerants used in refrigeration equipment include R-507 and R-404A. DOE assumed that only HFC refrigerants will be utilized by WICF refrigeration systems and has based its analysis solely on equipment containing those refrigerants.

DOE assumed that there are no cyclic losses associated with the refrigeration system operation. A properly sized refrigeration system with a single-speed compressor cycles on and off to maintain the required temperature inside the walk-in. Going from off-cycle to on-cycle operation can take several minutes, during which time the refrigeration system does not operate at steady state capacity and experiences energy losses as a result. The cyclic losses are greater in systems having larger coil sizes as a result of the greater amount of refrigerant charge in such systems. However, because the proposed test procedure only measures the compressor energy consumption when the compressor is running at steady state, these losses are not accounted for.

5.5.8 Numerical Constants and Assumptions

The following tables contain numerical constants and assumed values used in the engineering analysis.

Table 5.5.38 Panel and Door Numerical Constants

Parameter	Value	Units	Source
External Dry Bulb Temperature	75	°F	Rating conditions prescribed by the WICF test procedure
Cooler- Internal Dry Bulb Temperature	35	°F	Rating conditions prescribed by the WICF test procedure
Freezer- Internal Dry Bulb Temperature	-10	°F	Rating conditions prescribed by the WICF test procedure
Cooler-EER	12.4	Btu/W-h	Rating conditions prescribed by the WICF test procedure
Freezer-EER	6.3	Btu/W-h	Rating conditions prescribed by the WICF test procedure
Daily Time Period	24	h	Assumed
Acceleration of Gravity	32.2	ft/s^2	Assumed
LTTR-XPS	5.89	ft^2-F-h/Btu	Data from confidential source
LTTR-Polyurethane (Foam-in-place at 2.4 lb/ft^3 density)	6.82	ft^2-F-h/Btu	Data from confidential source
External Equivalent Convective Film Coefficient	0.68	ft^2-F-h/Btu	Assumed
Internal Equivalent Convective Film Coefficient	0.25	ft^2-F-h/Btu	Assumed
Floor Equivalent Convective Film Coefficient	0	ft^2-F-h/Btu	Based on Finite Element Heat Transfer Model, DOE analysis
Average Shipping Distance to Distribution Center	1000	miles	DOE estimate
Percentage of anti-sweat heat transferred into the walk-in	75	%	Rating conditions prescribed by the WICF test procedure
Control System Average Power	5	W	Assumed

Table 5.5.39 Refrigeration System Constants Associated with Defrost

Constants Specified by the Test Procedure	**Value**	**Units**	**Source**
Infiltration coefficient k13	0.0001	cfm-hr/Btu	Test procedure
Infiltration coefficient k14	3.49	cfm	Test procedure
Humidity ratio of incoming air	0.0105	lb water/lb air	Test procedure
Density of incoming air	0.073	lb/ft^3	Test procedure
Physical Properties of Materials			
Specific heat of ice	0.487	Btu/lb-R	*ASHRAE Handbook of Fundamentals*, 2009[8]
Specific heat of water	1.00	Btu/lb-R	*ASHRAE Handbook of Fundamentals,2009*
Latent heat of fusion of water	143.5	Btu/lb	*ASHRAE Handbook of Fundamentals, 2009*
Meltwater temperature	32	°F	*ASHRAE Handbook of Fundamentals*, 2009

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CHAPTER 6. MARKUPS FOR EQUIPMENT PRICE DETERMINATION

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 6. MARKUPS FOR EQUIPMENT PRICE DETERMINATION

6.1 INTRODUCTION

To carry out the life-cycle cost (LCC) calculations described in chapter 8 of the technical support document (TSD), the U.S. Department of Energy (DOE) needs to determine the cost to the customer of walk-in coolers and freezers (walk-ins or WICF) refrigeration systems, panels, display doors, and non-display doors. These costs are determined for both baseline and higher efficiency equipment following a standardized methodology. In the first step of the process, the manufacturer's selling price (MSP) for both baseline equipment and the more-efficient equipment is estimated through a detailed engineering analysis and equipment tear-down (chapter 5 of the TSD). By applying a "markup" multiplier and a sales-tax multiplier to the MSP, DOE estimates the customer price of equipment. The markup multiplier depends on the specific set of distribution channels through which the equipment moves from the manufacturer to the end user and differs by market segment. This TSD chapter describes the methodology that DOE followed to develop the markup multipliers used to determine the end user prices.

6.2 GENERAL METHODOLOGY

WICF refrigeration systems and envelope components move from the manufacturer to the final customer through a set of distribution intermediaries at multiple hierarchical levels. A "Level 1" intermediary represents the first customer that the manufacturer sells to. Additional higher numbered levels represent subsequent downstream flow of the equipment through the distribution channel. For example, a replacement refrigeration system of a WICF unit for a convenience store owner may be purchased by the refrigeration contractor—a Level 2 intermediary—from a refrigeration system wholesaler—a Level 1 intermediary. As another example, when a refrigeration contractor purchases a new walk-in unit for a food service establishment, the refrigeration system of the walk-in unit moves through all the three levels of the distribution chain (*i.e.*, from the manufacturer of the refrigeration systems to the manufacturer of the complete WICF unit (Level 1), the food service equipment dealer (Level 2), and finally through a contractor (Level 3)) before reaching the customer. This is shown schematically in Figure 6.2.1, where all the four possible distribution paths are shown. In the shortest distribution path, there is no intermediary and the reaches the customer directly.

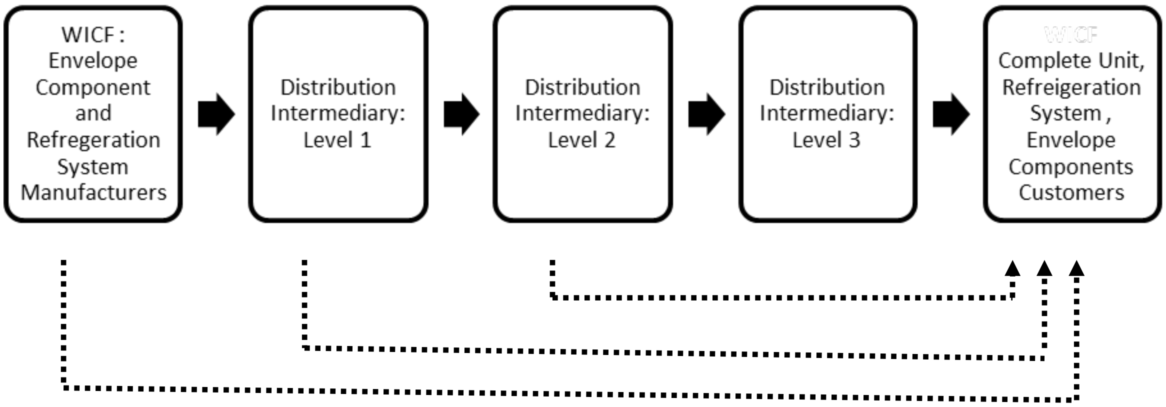

Figure 6.2.1 Distribution Path for WICF Envelope Components and Refrigeration Systems

Typically, the shortest path involves sale by the manufacturer directly to a national account. The following equation describes how DOE determined the equipment price if a customer purchases directly from the manufacturer through a national account or if the customer is an OEM (original equipment manufacturer) purchasing envelope components and refrigeration systems for assembly in the complete WICF unit:

$$P_{END} = P_{MFR} \times MU_{LEVEL-1} \times (1 + ST)$$

Eq. 6.1

Where:

P_{END} = equipment price to the customer ($),
P_{MFR} = manufacturer selling price of baseline equipment ($),
$MU_{LEVEL-1}$ = markup for a Level 1 distribution intermediary or an end user buying directly from the manufacturer (*e.g.*, national accounts), and
ST = sales tax rate.

The above applies to sales through all Level 1 intermediaries or end users buying directly from the manufacturers.

The following equation describes how DOE determined the equipment price if a Level 2 intermediary is also involved in the distribution chain, *e.g.*, mechanical contractors selling a WICF unit or a replacement refrigeration system procured from Level 1 distributors to the customer (final end user):

$$P_{END} = P_{MFR} \times MU_{LEVEL-1} \times MU_{LEVEL-2} \times (1 + ST)$$

Eq. 6.2

Where:

$MU_{LEVEL\text{-}2}$ = markup for a Level 2 distribution intermediary.

Finally, the end-user price for the equipment when a Level 3 distribution intermediary is also involved is given by:

$$P_{END} = P_{MFR} \times MU_{LEVEL-1} \times MU_{LEVEL-2} \times MU_{LEVEL-3} \times (1+ST)$$

Eq. 6.3

Where:

$MU_{LEVEL\text{-}3}$ = markup for a Level 3 distribution intermediary.

The overall markup is the product of the markups for all the levels in a distribution chain and sales tax multiplier. The overall markup multiplier in the equipment price varies directly with the number of distribution channels; for example, the markup multiplier increases as the number of levels in the distribution chain increases. DOE further differentiated between a baseline markup and an incremental markup, as described below.

6.2.1 Baseline Markups

Baseline markups are cost multipliers that relate the purchase cost to selling price for each step of the distribution channel for the refrigeration systems, panels, display doors, and non-display doors at the baseline level of efficiency. Baseline markups are defined as coefficients that relate the manufacturer price of baseline designs to the baseline sales price at different levels of the distribution chain, as shown in the following equations, where up to all three levels of distribution take part in the distribution chain:

$$P_{LEVEL-1\_BASE} = (P_{MFR\_BASE} \times MU_{LEVEL-1\_BASE})$$

Eq. 6.4

$$P_{LEVEL-2\_BASE} = (P_{LEVEL-1\_BASE} \times MU_{LEVEL-2\_BASE})$$

Eq. 6.5

$$P_{LEVEL-3\_BASE} = (P_{LEVEL-2\_BASE} \times MU_{LEVEL-3\_BASE})$$

Eq. 6.6

$$P_{END\_BASE} = P_{LEVEL-3\_BASE} \times (1+ST)$$

Eq. 6.7

Where:

P_{MFR_BASE} = MSP of baseline equipment ($),
$P_{LEVEL-1\_BASE}$ = Level 1selling price of baseline equipment ($),
$P_{LEVEL-2\_BASE}$ = Level 2 selling price of baseline equipment ($),
$P_{LEVEL-3\_BASE}$ = Level 3 selling price of baseline equipment ($),

P_{END_BASE} = end-user purchase price for baseline equipment ($),
$MU_{LEVEL-1\_BASE}$ = Level 1 markup for baseline equipment,
$MU_{LEVEL-2\_BASE}$ = Level 2 markup for baseline equipment,
$MU_{LEVEL-3\_BASE}$ = Level 3 markup for baseline equipment, and
ST = sales tax rate.

The sales tax is applied at the final level in the distribution chain as shown in Eq. 6.3, *e.g.*, if a Level 2 intermediary is the final seller of the equipment to the end user, sales tax is applied in the price equation for the Level 2 distribution intermediary.

6.2.2 Incremental Markups

Incremental markups are cost multipliers that relate incremental changes in the MSP of higher efficiency equipment to the distributor or contractor sales price as shown in the following equations, where all the three levels of distribution take part in the distribution of the component or the system from the manufacturer to the end user.

$$P_{LEVEL-1\_INCR} = (P_{MFR\_INCR} \times MU_{LEVEL-1\_INCR})$$

Eq. 6.8

$$P_{LEVEL-2\_INCR} = (P_{MFR\_INCR} \times MU_{LEVEL-1\_INCR}) \times MU_{LEVEL-2\_INCR}$$

Eq. 6.9

$$P_{LEVEL-3\_INCR} = (P_{MFR\_INCR} \times MU_{LEVEL-1\_INCR}) \times MU_{LEVEL-2\_INCR} \times MU_{LEVEL-3\_INCR}$$

Eq. 6.10

$$P_{END\_INCR} = P_{LEVEL-3\_INCR} \times (1 + ST)$$

Eq. 6.11

Where:

P_{MFR_INCR} = incremental manufacturer price for equipment with increased efficiency ($),
$P_{LEVEL-1\_INCR}$ = incremental selling price for equipment with increased efficiency ($),
$P_{LEVEL-2\_INCR}$ = incremental selling price for equipment with increased efficiency ($),
$P_{LEVEL-3\_INCR}$ = incremental selling price for equipment with increased efficiency ($),
P_{END_INCR} = incremental end-user price equipment with increased efficiency ($),
$MU_{LEVEL-1\_INCR}$ = incremental Level 1 markup for equipment with increased efficiency,
$MU_{LEVEL-2\_INCR}$ = incremental Level 2 markup for equipment with increased efficiency,
$MU_{LEVEL-3\_INCR}$ = incremental Level 3 markup for equipment with increased efficiency, and
ST = sales tax rate.

As before, the sales tax is applied at the final level in the distribution chain as shown in Eq. 6.3.

6.2.3 Overall Markups

Overall markups, including both overall baseline and overall incremental markups, relate the manufacturer price to the final customer price (P_{END}), as shown by the following equation:

$$P_{END} = (P_{END\_BASE} + P_{END\_INCR})$$

Eq. 6.12

6.3 REFRIGERATION SYSTEMS

6.3.1 Distribution Channels

For the refrigeration systems of the WICF units, the two equipment class groups used in the analysis of distribution channels are (1) dedicated condensing (DC) and (2) multiplex condensing (MC). The DC refrigeration systems are used primarily in the food service, convenience stores (C-stores), and institutional market segments and are less common in the food sales (groceries) segment. The refrigeration equipment of the MC group covered in this rulemaking includes only the unit coolers and not the rack compressor units. These unit coolers connected to the rack systems are used mostly in food sales and refrigerated warehouses. Due to the preponderance of usage in particular business segments, the two equipment class groups flow through somewhat different distribution channels.

6.3.1.1 Dedicated Condensing (DC) Refrigeration System

For the DC class equipment, the distribution channel structures and estimates of the relative shares of the channels across different market segments are shown in Figure 6.3.1. DOE did not have complete details for all the markets. For example, even direct sales and sales through refrigeration wholesalers (shown in in Figure 6.3.1) do not have the detailed second-tier characteristics of the OEM sales. DOE used the percentage distributions in the various market tiers to provide weights for the calculations of weighted average markup results at the end of the chapter. Different component product classes have different market channels, different weights, and therefore, different weighted average markups.

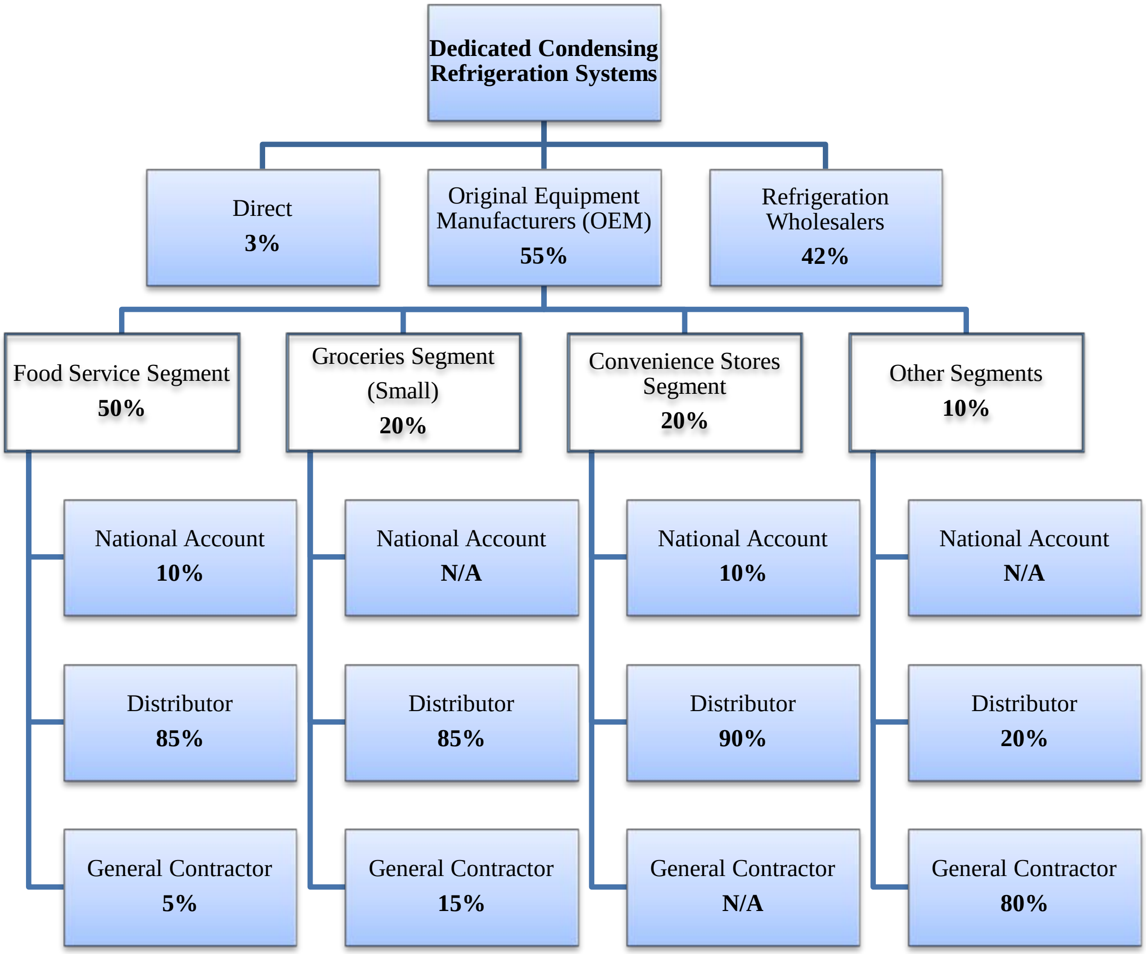

Figure 6.3.1 Distribution Channels for the DC Refrigeration Systems

For DC refrigeration systems, the two most important channels of distribution are the OEM channel and the refrigeration wholesaler channel. OEMs are mostly manufacturers of the envelope insulation panels who may also sell entire WICF units. Manufacturers of entire WICF units produce these units by assembling a combination of purchased and manufactured components at either the manufacturer's plant or at the customer site. Refrigeration wholesalers are wholesalers specializing in sales of refrigeration equipment. They source various components and whole systems from different manufacturers and cater to both the replacement and the new equipment market.

For the complete WICF units, estimated market shares of various business segments are also indicated in Figure 6.3.1 (under the OEM branch). The shares were estimated through the shipment analysis (chapter 9 of the TSD). For the complete WICF units, both in fully assembled and in kit-form, the OEMs have significant shares in all major business segments, including food service, C-stores, and small groceries market segments. The Level 2 distributors in the chart include both the food equipment distributors and the broadline distributors (sellers of both equipment and supplies). The food equipment distributors are organized under FEDA (the Food

Equipment Dealers Association). For the OEM market channel, a significant percentage of the sales are through distributors which account for as high as 90 percent for the convenience stores segment (Figure 6.3.1). In 2004, the North American Food Equipment Manufacturers (NAFEM)[1], a trade association representing the OEMs in the food service segment, estimated that sales share of the distributors for refrigeration equipment and ice machines were 75 percent. The “other” market segment in the chart represents the market of complete walk-in units for schools, hospitals, and other institutions where it is assumed that the general contractor constructing the facility procures the complete WICF unit mostly from the OEM directly.

6.3.1.2 Multiplex Condensing (MC) Refrigeration Systems

As mentioned earlier, only the unit coolers of the multiplex systems are covered in this rulemaking. Other unit coolers are included in the DC systems and no separate markup analysis is required. Thus, discussions in this section are not applicable to unit coolers for the DC systems. The MC systems are used predominantly in the large groceries, which are often business units of national chains. DOE assumed that the relative shares of the distribution channel for the unit coolers used in the MC systems are significantly different from the channel shares of the DC systems. As shown in Figure 6.3.2, DOE estimated that about 45 percent of the total sales of these are through refrigeration wholesalers, who cater significantly to the replacement market; 45 percent of total sales are to national accounts; and only 10 percent are to the OEM segment

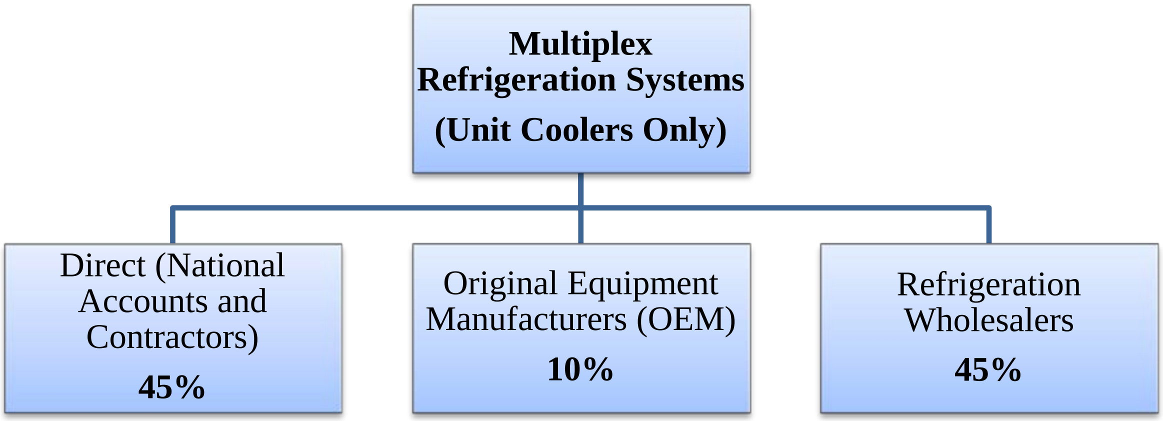

Figure 6.3.2 Estimation of First-Level Distribution Channels for the MC Refrigeration Systems

6.3.1.3 Differential Pricing of Refrigeration Systems

DOE estimated the average manufacturer’s prices of the refrigeration systems on an aggregate basis that included the cost of production and average manufacturer’s markup. The average manufacturer markup was determined based on aggregate sales across all distribution segments. Average manufacturer markups are presented in chapter 5 of the TSD; the refrigeration system manufacturer markup was calculated as 1.35. For the refrigeration systems, however, the prices paid by first level customers (including end users and distributors in the first level of the chain) are not uniform, but depend on the type of the customer. Based on the interviews with manufacturers, DOE estimated the price multipliers used to determine the separate sales prices to the three first level customers (Figure 6.3.2). These are presented in Table 6.3.1. These price multipliers are applied to the average sale price to determine separate sales prices for each type of customer.

Table 6.3.1 Manufacturer's Price Multipliers

First Level Customer	Price Multiplier
OEM	0.87
Refrigeration Wholesaler	1.15
Direct	1.27

Table 6.3.1 shows that the prices charged by the manufacturers to the OEM customers are 13 percent lower than the average sales price, while for the distributors the prices paid are 15 percent higher than the average sales price. This may appear unusual, but when the final end-user price is calculated for two alternate distribution channels, it can be seen that the end-user price of the refrigeration systems bought either as part of a complete WICF unit through a food equipment dealer or as a replacement unit through a refrigeration wholesaler are nearly equal. For the direct sales, DOE estimated that the prices charged are 27 percent higher than the average sales price.

Table 6.3.1 establishes the relative prices paid by the first level customers. While there is no additional markup associated for sales to "direct" customers, the markups for the other two Level 2 customers, *i.e.*, wholesalers and OEM customers (Figure 6.3.2), are discussed in the subsequent sections.

6.3.1.4 OEM Customers Markup

For the OEM segment, DOE set the pass-through markup multiplier for the refrigeration systems equal to the refrigeration system manufacturer's markup multiplier at1.33 based on data collected during the MIA analysis from manufacturers and other sources..

6.3.1.5 Refrigeration Wholesalers Markup

Assumptions and Approach

For the refrigeration wholesalers, DOE based the distributor markups on industry operating cost data of the industry association. DOE obtained the industry operating cost data from the Heating, Air-conditioning & Refrigeration Distributors International (HARDI), the trade association representing distributors of refrigeration and heating, ventilating, and air conditioning (HVAC) equipment, specifically, the controls and refrigeration specialists within the association. Distributors report median data in a confidential survey that HARDI conducted of member firms.[2] HARDI reported the following aggregate survey results: sales volume in dollars and itemized costs in certain cost categories, including cost of goods sold, labor expenses, occupancy expenses, other operating expenses, and profit. It reported data in terms of industry median values for various industry segments, including the Controls and Refrigeration industry segment, which is the specific business segment applicable for the WICF refrigeration systems.

DOE assumed that the disaggregated median cost and expenses derived from the Income Statement tables of the Profit Report reported by the association accurately represent the various average costs incurred by the wholesalers distributing the refrigeration systems. Although distributors tend to handle multiple product lines (including air conditioners, furnaces, and boilers), the data provide the most accurate available indication of distribution costs of refrigeration equipment for commercial customers.

DOE further assumed that distributor costs can be divided into two categories: (1) costs that vary in proportion to the MSP of equipment sold (variable costs); and (2) costs that do not vary with the MSP of equipment sold (fixed costs).The operating cost data itemize firm costs into a number of cost categories, including direct costs to purchase or install the equipment, operating labor and occupancy costs, and other operating costs and profit. In the analysis, DOE assumed that the labor and occupancy costs incurred by the distributors are fixed because these costs are not likely to increase as a result of a rise in cost of goods sold due to enhanced efficiency standards. All other expenses, as well as the net profit, are assumed to vary in proportion to cost of goods sold. Although some of the other expenses may not scale with cost of goods sold, DOE took a more conservative position and included these as variable costs. This assumption is central to DOE's methodology for calculating the incremental markup multipliers. Previous DOE analysis of the HVAC distributors, contractors, and consultants, including information obtained from the trade literature, supports this assumption.[3,4] This analysis indicates that distributor and contractor markups vary according to the quantity of labor and materials used to distribute and install appliances, with markups on labor tending to be much larger than markups on materials.

DOE also assumed that the changes in the efficiency of the goods sold are not expected to increase economic profits of the distributor. Thus, DOE calculates markups/gross margins to allow cost recovery for the wholesaler in the distribution chain (including changes in the cost of capital) without changes in enterprise profits. Efficiency improvements impact some distribution costs but not others. DOE set markups and distributor prices to cover the distribution costs expected to change with efficiency but not the distribution costs that are not expected to change with efficiency. In support of this assumption, DOE notes that the refrigeration and HVAC distributor industry is competitive, and customer demand for refrigeration and other HVAC equipment is relatively inelastic (*i.e.*, the demand is not expected to decrease significantly with an increase in price of equipment). The large number of distributor firms listed in the 2002 census indicates the competitive nature of the market. For example, there are almost 1,400 distributors of refrigeration equipment.[5] Following standard economic theory, competitive firms facing inelastic demand either set prices in line with costs or quickly go out of business.[6]

Wholesaler Baseline Markup

DOE summarizes the Income Statement tables from the HARDI 2012 Profit Report for the Controls and Refrigeration groups as cost per dollar sales revenue in Table 6.3.2. The full Income Statement tables from the HARDI 2012 Profit Report for the Controls and Refrigeration group can be found in appendix 7A. As shown in this column, the direct equipment expenses (cost of goods sold) represent about $0.71 per dollar sales revenue. In other words, for every $1 distributors take in as sales revenue, they use $0.71 to pay the direct equipment costs. Labor expenses account for $0.17 per dollar sales revenue, occupancy expenses account for $0.04, other operating expenses account for $0.04, and profit accounts for $0.04 per dollar sales revenue.

Table 6.3.2 Refrigeration Wholesaler Expenses and Markups

Descriptions	Per Dollar Sales Revenue	Per Dollar Cost of Goods
Direct Cost of Equipment Sales: Cost of goods sold	$0.71	$1.00
Labor Expenses: Salaries and benefits	$0.17	$0.23
Occupancy Expense: Rent, maintenance, and utilities	$0.04	$0.05
Other Operating Expenses: Depreciation, advertising, and insurance.	$0.04	$0.06
Profit	$0.04	$0.06
Baseline Revenue: Baseline revenue earned per dollar cost of goods sold		**$1.40**
Wholesaler Baseline Markup ($MU_{WHOLE\ BASE}$)		**1.403**
Incremental Revenue: Increased revenue per dollar increase cost of goods sold		**$1.12**
Incremental Markup ($MU_{WHOLE\ INCR}$)		**1.121**

Source: Heating, Air-conditioning & Refrigeration Distributors International. 2012. 2012 Profit Report (2011 Data).

The last column of Table 6.3.2 shows the data converted from costs per dollar revenue into revenue per dollar cost of goods sold. DOE did this conversion by dividing each cost category in the first data column of Table 6.3.2 by $0.71 (*i.e.*, equipment expenditure per dollar revenue). The data in the last column show that for every $1.00 the wholesaler spends on equipment costs, the wholesaler spends $0.23 to cover labor costs, $0.05 to cover occupancy expenses, and $0.06 for other operating expenses, and earns $0.06 in profits. This totals to approximately $1.40 in sales revenue earned for every $1.00 spent on cost of equipment sold. More exactly, the distributor baseline markup ($MU_{WHOLE\ BASE}$) is 1.403.

Wholesaler Incremental Markup

DOE also used the data in the last column to estimate the incremental markups. The incremental markup depends on which of the costs in Table 6.3.2 are variable and which are fixed. For example, for a $1.00 increase in the manufacturer equipment price, if all of the other costs scale with the MSP (*i.e.*, all costs are variable), the increase in distributor price will be $1.403, implying that the incremental markup is 1.403, or the same as the baseline markup. DOE assumed that the labor and occupancy costs are fixed and that the other operating costs and profit will scale with the manufacturer selling price (*i.e.*, be variable). In this case, for a $1.00 increase in the MSP, the distributor price will increase by $1.121, giving a distributor incremental markup ($MU_{WHOLE\ INCR}$) of 1.121.

6.3.1.6 Other Distribution Intermediaries (Second Level and Higher)

DOE also used data from other sources to estimate the baseline and incremental markups for other distribution intermediaries shown in Figure 6.2.1. These include the distributors selling complete WICF units manufactured by the OEMs, and general contractors or refrigeration contractors. The general contractors often play an important role for the purchases by the institutional segment customers. Refrigeration contractors play a key role in the procurement process for both the new equipment and the replacement markets.

6.3.1.7 Food Service Equipment Dealers Markup

For estimating the baseline and incremental markups for the food service equipment dealers, DOE used an approach similar to the one previously described in section 6.3.1.5 for the refrigeration wholesalers. These dealers are represented by FEDA. FEDA conducted a profit survey for its members in 2010 to create a financial and operating profile of the industry. This report is restricted only to the members who participate in the survey, and DOE could not obtain the required information in this report and used an alternative data source to estimate these markups.

DOE obtained the cost of goods sold and the wholesaler's margin from the U.S. Benchmark Input-Output Accounts, 2002 released by Bureau of Economic Analysis (BEA) in 2007. DOE used the data under the primary classification of Service Industry Machinery for the subgroup "HVAC and commercial refrigeration equipment." Although this product classification is a broad grouping covering even HVAC equipment used in the service industry, which includes other service activities in addition to food service, DOE assumed this data is the best available representative data that could be used for estimating the markups for the dealers selling WICF units. In Table 6.3.3 DOE has summarized the data in the same format as in Table 6.3.2.

Table 6.3.3 Food Service Equipment Dealer Expenses and Markups

Description	**Dealers Expenses or Revenue**	
	Per Dollar Sales Revenue	**Per Dollar Cost of Goods**
Direct Cost of Equipment Sales: Cost of goods sold	$0.82	$1.00
Gross Margin: Labor, occupancy, operating expenses, and profit	$0.18	$0.22
Revenue: Baseline revenue earned per dollar cost of goods		**$1.22**
Baseline Markup ($MU_{\text{FOOD EQPMNT DEALER BASE}}$)		**1.22**
Incremental Markup ($MU_{\text{FOOD EQPMNT DEALER INCR}}$)		**1.07**

Source: Appendix D. Input-Output Commodity Composition of NIPA Private Equipment and Software Expenditure Categories, in Producers' and Purchasers' Prices, 2002 Benchmark Input-Output Accounts, Bureau of Economic Analysis, 2007.

From these data, DOE estimated a distributor baseline markup ($MU_{FOOD\_EQUIP\_DEALER\_BASE}$) of 1.22. However, the data did not provide detail itemized breakup of the expenses to enable classification of expenses in fixed and variable category for use in the estimation of incremental markups. DOE estimated the fixed and the variable expenses by apportioning the total gross margin and used these for estimation of the incremental markup. For the refrigeration wholesalers, the fixed and the variable expenses ratio in the gross margin was calculated at 3:1 (appendix 7A). However, the total gross margin for the food service equipment distributors is at 18 percent of sales compared to a gross margin of 28.9 percent for the refrigeration system wholesalers. Consequently, DOE did not use the same ratio for apportionment. In view of the lower gross margin percent for the food service equipment distributors, DOE assumed that the fixed expenses for them would account for a higher proportion of the gross margin. Consequently, DOE used a fixed to variable expenses ratio of 2:1 and estimated the incremental markup for the food service equipment distributors ($MU_{FOOD\_EQUIP\_DEALER\_INCR}$) at 1.07.

6.3.1.8 General and Refrigeration Contractor’s Markup

DOE estimated markups for general contractors from U.S. Census Bureau data for Commercial and Institutional General (CIG) contractors (North American Industry Classification System 236220). This industry comprises establishments primarily responsible for the construction of commercial and institutional buildings and related structures. This sector includes commercial and institutional building general contractors, operative builders, design-build firms, and project construction management firms. The U.S. Census Bureau data for the CIG contractors include detailed statistics for establishments with payrolls, similar to the data reported by HARDI for refrigeration wholesalers. The primary difference is that the U.S. Census Bureau reports itemized revenues and expenses for the entire sector in total dollars rather than in median values for the businesses. Because of this, DOE assumed that the total dollar values that the U.S. Census Bureau reported, if converted to percentage basis, represented revenues and expenses for an average or typical contracting business. As with the data for refrigeration system wholesalers, Table 6.3.4 summarizes the expenses for CIG contractors, as expenses per dollar sales revenue, in the first data column (appendix 7B contains the full set of data). The direct cost of sales represents about $0.76 per dollar of sales revenue. Labor expenses account for $0.08 per dollar sales revenue, occupancy expenses account for $0.01 per dollar sales revenue, other operating expenses account for $0.02, and profit makes up $0.14 per dollar sales revenue.

DOE converted these expenses per dollar sales into revenue per dollar cost of goods sold by dividing each figure in the first data column by $0.76. The data in the last column show that for every $1.00 the CIG contractor spends on equipment costs, the CIG contractor spends $0.10 to cover labor costs, $0.01 to cover occupancy expenses, and $0.02 for other operating expenses, and earns $0.18 in profits. This totals to $1.31 in sales revenue earned for every $1.00 spent on cost of equipment sold. Therefore, the CIG contractor baseline markup ($MU_{CONTRACTOR_BASE}$) is approximately 1.31.

Table 6.3.4 Commercial and Institutional General Contractors Markups

Description	**Wholesale Firm Expenses or Revenue**	
	Per Dollar Sales Revenue	**Per Dollar Cost of Goods**
Direct Cost of Equipment Sales: Cost of goods sold	$0.76	$1.00
Labor Expenses: Salaries (indirect) and benefits	$0.08	$0.10
Occupancy Expense: Rent, Communications, maintenance, and utilities	$0.01	$0.01
Other Operating Expenses: Computing, Depreciation, Advertising, Insurance, and Others	$0.02	$0.02
Net Profit Before Taxes	$0.14	$0.18
Baseline Markup ($MU_{GEN\ CONT\ BASE}$): Revenue per dollar cost of goods		**1.31**
Incremental Markup ($MU_{GEN\ CONT\ INCR}$): Increased revenue per dollar increase cost of goods sold		**1.20**

Source: U.S. Census Bureau. Commercial and Institutional Building Construction. Sector 23: 236220. Construction: Industry Series: Preliminary Detailed Statistics for Establishments: 2007.

DOE was also able to use the data in the last column of the Table 6.3.4 to estimate the incremental markups by separating the fixed and variable costs. As in the earlier estimates, DOE assumed the labor and occupancy costs to be fixed and the other operating costs and profit to scale with the equipment price (*i.e.,* be variable). In this case, for a $1.00 increase in the equipment price, the CIG contractor's price will increase by $1.20, giving a CIG contractor's incremental markup of 1.20.

In the preliminary analysis, DOE estimated the markup of refrigeration contractors from U.S. Census Bureau data for plumbing, heating and air-conditioning contractors (PHAC) and derived markup multipliers of 1.52 and 1.23 respectively for baseline and incremental cases. DOE received comments from interested parties that the overall markup multipliers estimated in the preliminary analysis were significantly higher than corresponding values in the industry. DOE revisited the issue and concluded that the main reason that the markups appeared unreasonable is because DOE used the markup for the PHAC contractor as a multiplier in the derivation of overall markup in all cases, while for the walk-in market, this may not be the case. Consequently DOE used a different approach for the estimation of the markup of the refrigeration contractors in the NOPR.

DOE used RS Means mechanical cost data[7] for estimating the markups of refrigeration contractors whose usual responsibility for WICF equipment is limited to installation of the walk-in unit. DOE considered that the refrigeration contractor can profit as a trade intermediary for walk-ins only in a few situations. In the mechanical cost data book, RS Means estimates that installation contractors supplying and installing the walk-in unit may add a markup of 10 percent on the cost of the material. DOE used this to derive the markup multiplier in cases where the scope of supply of the refrigeration contractor includes the complete walk-in unit. To determine where the refrigeration contractor's markup could be applied, DOE examined all the major channels of distribution. For the OEM segment, where the refrigeration system is supplied either as a complete assembly or as a part of the complete kit for assembly at site, DOE did not have any data and assumed that about half of the refrigeration systems could be supplied as part of a fully assembled unit where the refrigeration contractor may not have any role, and hence on weighted basis provided for a markup of only 5 percent. For the direct customers of refrigeration systems, the transactions are "business to business" and the installation costs incurred by the direct customers are accounted for separately in the LCC calculations (see chapter 8 of the TSD). Again, for the sales through the refrigeration wholesalers, DOE assumed that a large fraction of the sales would be invoiced directly to the final commercial customer, so these customers would avoid paying markup to another intermediary. Thus, DOE did not include any markup for the refrigeration contractors for items sold through the refrigeration wholesalers.

6.4 ENVELOPE COMPONENTS

6.4.1 Distribution Channels

The set of envelope components covered in this rulemaking includes wall and floor insulation panels, passage and freight non-display doors, and display doors. Insulation panels and non-display doors may be manufactured by the same manufacturers. Display doors are manufactured by a separate set of manufacturers. For the panels and the non-display doors, DOE estimated that 45 percent of sales are through the national accounts or direct customers and the remaining 55 percent are sold either as fully assembled unit or as complete kits through different channels. DOE estimated that 80 percent of non-direct sales are through the food equipment distributors and follow the OEM distributor channel (Figure 6.2.1). The remaining 20 percent of non-direct sales are accounted for by general contractors for institutional sales who may purchase units directly from the OEM and by national accounts customers. For the display doors, DOE estimated that direct sales to national accounts from the manufacturer account for 30 percent, and the OEM channel accounts for the remaining 70 percent. For display doors, the sales through the OEM channel have same distribution of channel shares as the panels or non-display doors.

6.4.2 Estimation of Distribution Markups for the Envelope Components

6.4.2.1 National Accounts

Envelope components purchased through national accounts constitute about 70 percent of sales for the display doors and 45 percent for the panels and non-display doors. Large customers use national accounts to circumvent the typical distribution channel, allowing them to negotiate significantly lower equipment prices directly with the manufacturer. The manufacturer in turn must cover additional expenses related to the distribution of the equipment. For the refrigeration systems, DOE obtained information through manufacturer interviews that allowed it to estimate the additional price charged to direct customers to offset this expense. For the component manufacturers, DOE could not get any additional information on prices charged to different customer segments and established only average manufacturing markup. DOE has typically estimated the national account markup to be about one half of markups for the distributor channels. DOE has previously calculated that the baseline markup multiplier for the food service equipment distributors is 1.22 (section 6.3.1.7). Consequently, DOE estimated that for the OEM customers of components, the markup should be approximately 1.10 for both baseline and incremental markups. No detailed cost information was available to calculate different baseline and incremental markups..

6.4.2.2 Other channels

For the non-direct channels, DOE used the same markups as established previously in sections 6.3.1.6, 6.3.1.7, and 6.3.1.8. These are the markups for sales by an OEM channel for a refrigeration system that is part of a complete WICF unit or kits through other downstream channels, and should also be applicable for the panels, display doors, and non-display doors that make up the complete WICF units.

6.5 SALES TAX

The sales tax represents State and local sales taxes that are applied to the customer price of WICF units. The sales tax is a multiplicative factor that increases the customer equipment price. DOE derived sales taxes representative of the combined State and local sales tax rates from the Sales Tax Clearinghouse,[8] shown in Table 6.5.1. The State level combined tax rates can be applied to the end user price of WICF refrigeration systems and envelope components to obtain the total purchase cost to the customer located in any State.

The distribution of sales tax rates ranges from a minimum of zero percent to a maximum of 9.45 percent with a mean value of 6.6 percent. DOE applied sales taxes to the customer equipment price irrespective of the distribution channel and the market in which the customer is located.

A weighted-average national level sales tax rate is calculated by multiplying the shares of State level shipments by the tax rates in Table 6.5.1. The distribution of sales tax rates ranges from a minimum of zero percent to a maximum of 9.45 percent with a population-weighted mean value of 7.1 percent. DOE applied sales taxes to the customer equipment price irrespective of the distribution channel and the market in which the customer is located.

Table 6.5.1 State Sales Tax Rates

State	Combined State and Local Tax Rate	State	Combined State and Local Tax Rate	State	Combined State and Local Tax Rate
Alabama	8.50%	Kentucky	6.00%	North Dakota	5.85%
Alaska	1.35%	Louisiana	8.75%	Ohio	6.85%
Arizona	8.15%	Maine	5.00%	Oklahoma	8.30%
Arkansas	8.35%	Maryland	6.00%	Oregon	0.00%
California	8.20%	Massachusetts	6.25%	Pennsylvania	6.40%
Colorado	6.10%	Michigan	6.00%	Rhode Island	7.00%
Connecticut	6.35%	Minnesota	7.20%	South Carolina	7.10%
Delaware	0.00%	Mississippi	7.00%	South Dakota	5.35%
Dist. of Columbia	6.00%	Missouri	6.55%	Tennessee	9.45%
Florida	6.65%	Montana	0.00%	Texas	7.95%
Georgia	6.95%	Nebraska	6.00%	Utah	6.70%
Hawaii	4.40%	Nevada	7.85%	Vermont	6.05%
Idaho	6.05%	New Hampshire	0.00%	Virginia	5.00%
Illinois	8.15%	New Jersey	6.95%	Washington	8.90%
Indiana	7.00%	New Mexico	6.60%	West Virginia	6.05%
Iowa	6.85%	New York	8.40%	Wisconsin	5.45%
Kansas	8.00%	North Carolina	4.75%	Wyoming	4.00%

6.6 OVERALL MARKUP RESULTS

DOE multiplied the applicable markups for a given channel described in the previous sections to obtain the overall baseline and incremental markups shown in Table 6.6.1 through Table 6.6.6. The markups by distribution channel and overall markups are presented for both baseline and incremental refrigeration equipment in Table 6.6.1 Baseline Markups by Distribution Channel and Overall Weighted Average Markup for Dedicated Condensing Systems through Table 6.6.4. Table 6.6.5 and Table 6.6.6 display the markups for the envelope components.

Table 6.6.1 Baseline Markups by Distribution Channel and Overall Weighted Average Markup for Dedicated Condensing Systems

Market Segment	Percentage Share	Manufacturer's Price Multiplier	OEM Mark-up Multiplier	Trade and Intermediate Channel's Mark-up Multiplier	Refrigeration Contractor's Average Mark-up Multiplier	Aggregate Baseline Mark-up Multiplier
OEM	55%	0.87	1.33	1.21	1.05	1.45
Refrigeration Wholesalers	42%	1.15	-	1.40		1.60
Direct	3%	1.27	-	-		1.25

Weighted Average Baseline Mark-up	1.51

Table 6.6.2 Incremental Markups by Distribution Channel and Overall Weighted Average Markup for Dedicated Condensing Systems

Market Segment	Percentage Share	Manufacturer's Price Multiplier	OEM Mark-up Multiplier	Trade and Intermediate Channel's Mark-up Multiplier	Refrigeration Contractor's Average Mark-up Multiplier	Aggregate Incremental Mark-up Multiplier
OEM	55%	0.87	1.15	1.07	1.05	1.11
Refrigeration Wholesalers	42%	1.15	-	1.12		1.28
Direct	3%	1.27	-	-		1.25
Weighted Average Incremental Mark-up						1.19

Table 6.6.3 Baseline Markups by Distribution Channel and Overall Weighted Average Markup for Multiplex Systems

Market Segment	Percentage Share	Manufacturer's Price Multiplier	OEM Mark-up Multiplier	Trade and Intermediate Channel's Mark-up Multiplier	Refrigeration Contractor's Average Mark-up Multiplier	Aggregate Baseline Mark-up Multiplier
OEM	10%	0.87	1.33	1.21	1.05	1.45
Refrigeration Wholesalers	45%	1.15	-	1.40		1.60
Direct	45%	1.27	-	-		1.25
Weighted Average Baseline Mark-up						1.43

Table 6.6.4 Incremental Markups by Distribution Channel and Overall Weighted Average Markup for Multiplex Systems

Market Segment	Percentage Share	Manufacturer's Price Multiplier	OEM Mark-up Multiplier	Trade and Intermediate Channel's Mark-up Multiplier	Refrigeration Contractor's Average Mark-up Multiplier	Aggregate Incremental Mark-up Multiplier
OEM	10%	0.87	1.15	1.07	1.05	1.11
Refrigeration Wholesalers	45%	1.15	-	1.12		1.28
Direct	45%	1.27	-	-		1.25
Weighted Average Incremental Mark-up						1.25

Table 6.6.5 Markups by Distribution Channel and Overall Weighted Average Markup for Panels and Non-Display Doors

Market Segment	Percent Share	Manufacturer's Price Multiplier	National Account	Distributor	General Contractor	Overall
Assembled or Complete Kit	55%	1.00	7%	80%	14%	-
Baseline Mark-Up Multiplier	-	-	1.10	1.22	1.21	1.21
Incremental Mark-Up Multiplier	-	-	1.10	1.07	1.10	1.08
Components Only (National Accounts)	45%	1.00	100%	-	-	-
Baseline Mark-Up Multiplier	-	-	1.10	-	-	1.10
Incremental Mark-Up Multiplier	-	-	1.10	-	-	1.10
Weighted Average Baseline Mark-Up						1.16
Weighted Average Incremental Mark-Up						1.09

Table 6.6.6 Markups by Distribution Channel and Overall Weighted Average Markup for Display Doors

Market Segment	Percent Share	OEM Mark-up Multiplier	Manufacturer's Price Multiplier	National Account	Distributor	General Contractor	Overall
OEM	70%	1.33	0.96	7%	80%	14%	-
Baseline Mark-Up Multiplier	-	-	-	1.10	1.22	1.21	1.54
Incremental Mark-Up Multiplier	-	-	-	1.10	1.07	1.10	1.37
National Account	30%	-	1.10	100%	-	-	-
Baseline Mark-Up Multiplier							1.10
Incremental Mark-Up Multiplier							1.10
Weighted Average Baseline Mark-up							1.41
Weighted Average Incremental Mark-up							1.29

DOE used the overall markups to estimate the customer price of baseline equipment, given the manufacturer cost of baseline equipment. For example, if the manufacturer selling price of a baseline refrigeration direct condensing system is $1,000, DOE can multiply this by the weighted-average overall baseline markup to estimate that the baseline customer price of the WICF unit sold is $1,510. Similarly, DOE used the overall incremental markup to estimate changes in the customer price, given changes in the manufacturer selling price above the baseline due to increases in equipment efficiency. For example, if a new standard for multiplex equipment increases the WICF manufacturer selling price by $100, DOE can multiply this price ($100) by the weighted-average overall incremental markup (1.250) to estimate a customer price increase of $125. A sales tax multiplier would be charged on top the distribution channel overall markup.

These markups were used with the MSPs to generate customer prices for WICF refrigeration systems and envelope components.

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CHAPTER 7. ENERGY USE ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 7. ENERGY USE ANALYSIS

7.1 INTRODUCTION

This chapter presents the U.S. Department of Energy's (DOE's) analysis of annual energy usage at various efficiency levels of refrigeration systems and selected envelope components for walk-in coolers and freezers (WICF or walk-ins). These estimated values of annual energy consumption (AEC) in kilowatt-hours per year (kWh/yr) for the refrigeration systems and the envelope components (per unit area for panels and per each door) are key inputs to the determination of life-cycle cost (LCC) and payback period (PBP) analyses (chapter 8 of the technical support document (TSD)) and national impacts analyses (chapter 10 of the TSD).

The goal of the energy use analysis is to generate a mean value and a range of energy use values that reflect actual use of a WICF refrigeration system and the envelope components in commercial and institutional establishments. The DOE test procedure for envelope components (April 2011), which incorporates Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Standard 1250-2009 (AHRI 1250-2009),[1] produces standardized results that can be used to assess or compare the performance of this equipment operating under specified conditions. 76 FR 21580 (April 15, 2011) and 76 FR 33631 (June 9, 2011). Actual energy usage in the field often differs from that estimated by the test procedure because of variations in the system capacities chosen to serve the estimated load, operating conditions, user behaviors, and other factors.

7.2 OVERVIEW OF APPROACH TO ENERGY USE ANALYSIS IN THE PRELIMINARY ANALYSIS

In the preliminary analysis, DOE estimated the AEC of both the complete WICF envelope and a matched refrigeration system at a specific combination of efficiency levels using assumptions for product loading, duty cycle, and other associated conditions. DOE summed these to obtain the AEC for the complete WICF unit and used this total AEC for the PBP and LCC analyses. DOE considered three typical sizes in each of the six refrigeration system equipment classes and four envelope equipment classes as analysis points, and estimated the energy consumption for the complete WICF unit in a combination of these sizes.

The conduction load for the insulation panels, doors, and floor, and the infiltration load from the door opening events and product "pull-down" load based on the cubic volume of the envelope were estimated independently. The daily refrigeration load of the complete envelope was estimated by adding these to the heat produced by the components of the refrigeration systems inside the envelope, (*i.e.,* evaporator fans, defrost heaters and also by lights, anti-sweat heaters, and other powered components inside the envelope). DOE sized the refrigeration system assuming that the system has adequate hourly steady state cooling capacity for the "high load" condition of the envelope on an hourly basis, with some safety margin. DOE adopted the AHRI 1250-2009 assumptions for these safety factors (30 percent for coolers and 20 percent for freezers). DOE also modeled the "high load" factor, which is defined as the ratio of the high hourly load to the hourly average of the refrigeration load over a 24-hour period, to conform to the assumptions in AHRI 1250-2009 (section 6 of the document). The AHRI assumptions led to a high load factor of 2.33 for coolers and 1.5 for freezers. The run times for the refrigeration systems under "high load" conditions and "low load" conditions were also set to the corresponding values assumed in AHRI 1250-2009 (*i.e.*, 8 hours under high load conditions and 16 hours under low load conditions).

DOE used the above set of assumptions to estimate the required refrigeration capacity of the matched refrigeration system for a given WICF envelope, recognizing that an exact match for this calculated capacity may not be available in the market. To account for this mismatch, DOE multiplied the required refrigeration capacity by a mismatch factor greater than one – in other words, DOE assumed that the average refrigeration system capacity would be somewhat higher than needed to meet the calculated heat load.

Finally, DOE estimated the refrigeration system's AEC by multiplying the refrigeration capacity of the matched system by the modeled normalized energy consumption (defined as the AEC of the refrigeration system divided by its net capacity). To this DOE added the direct electrical energy consumed by the envelope components, which gave the total AEC of the complete WICF unit.

7.3 OVERVIEW OF APPROACH TO ENERGY USE ANALYSIS IN THE NOTICE OF PROPOSED RULEMAKING

In the notice of proposed rulemaking (NOPR), DOE adopted an approach for the energy use analysis that differed quite significantly from the approach used in the preliminary analysis. This arose because the scope of the proposed standards for the WICF units changed. In the preliminary analysis, DOE focused on developing the energy conservation standards for the refrigeration systems and the complete envelope combined as a system. In the NOPR, DOE proposes energy consumption standards separately for the refrigeration systems and a selected set of envelope components, not the complete walk-in units. Due to this change in the scope, in the NOPR, DOE is not explicitly matching refrigeration systems with specific sizes of envelopes in any given use category. Unlike the preliminary analysis, where the normalized energy consumption was calculated on the basis of test procedure protocols and used for computing the AEC of the matched refrigeration system, in the NOPR, DOE calculated the AEC of the refrigeration system of specific sizes matched with a hypothetical envelope such that the refrigeration capacity of the system exceeds the refrigeration load by a certain safety margin. The load profile for the specific refrigeration system is based on the sizing methodology, which assumes a predetermined degree of oversizing in relation to the daily modeled refrigeration load of the matched envelope. Further, for the refrigeration system, the sizing assumptions in the NOPR are aligned with industry practice rather than with the test procedure (AHRI 1250-2009) as was done in the preliminary analysis.

For the envelopes, because only certain specific envelope components are included in the scope of the standards, DOE is estimating the refrigeration and direct energy consumption for only the specific set of components. Consequently, for envelope components, DOE is not explicitly estimating the aggregate refrigeration load and associated energy consumption due to product temperature pull down, door opening event infiltration, and all other loads, but only for the constituents relevant to that component. In the NOPR, DOE calculated only the transmission loads per unit of a selected envelope component under test procedure conditions, and applied an efficiency metric of the refrigeration system to estimate the corresponding refrigeration energy consumption. To this DOE added the direct electrical energy consumption of the component (if any) to arrive at the annual refrigeration energy consumption for the specific component on a unit basis. For the doors, AEC is calculated per door for three specific sizes of door. For the insulation panels AEC is calculated on unit area basis.

7.4 ENERGY USE OF REFRIGERATION SYSTEMS

To estimate the AEC of the refrigeration systems at different efficiency levels in the product classes and for the specific capacities described in the engineering analysis (chapter 5 of the TSD), DOE used intermediate results of the energy model, which is also described in chapter 5. The objective of the energy model developed in the engineering analysis is primarily to calculate the AEC under the test procedure conditions and also to determine the system's annual walk-in energy factor (AWEF) . The energy model estimated refrigeration systems' net capacity and on-cycle system power at different ambient conditions, as well as the off-cycle evaporator fan power and the defrost power. To determine the AEC of the system, DOE used these power calculation results and calculated on-cycle run-hours that varied with the ambient temperature for outdoor systems but remained constant for the indoor and multiplex systems.

7.4.1 Refrigeration System Capacities and Product Classes Analyzed for Energy Use

DOE used the analysis points of refrigeration systems described in the engineering analysis (chapter 5 of the TSD). The capacities considered in each product class are detailed in Table 7.4.1.

Table 7.4.1 Capacities of Refrigeration Systems Considered

Condensing Type	Operating Temperature	Condenser Location	Class	Capacities Considered *kBtu/hr*
Multiplex	Medium	-	MC.M	4, 9, and 24
	Low	-	MC.L	4, 9, 18 and 40
Dedicated	Medium	Indoor	DC.M.I	6, 18, 54, and 96
	Low		DC.L.I	6, 9, and 54
	Medium	Outdoor	DC.M.O	6, 18, 54, and 96
	Low		DC.L.O	6, 9, 54, and 72

7.4.2 Sizing Methodology of Refrigeration Systems

7.4.2.1 Sizing Methodology in the Preliminary Analysis

In the preliminary analysis, DOE calculated the required size of the refrigeration system by assuming that the rated capacity of the refrigeration system was adequate to meet the refrigeration load of WICF system during the high load condition and that the load profile of WICF equipment broadly followed the load profile assumptions of AHRI 1250-2009.. The test procedure load profiles are discussed in detail in the engineering analysis (chapter 5 of the TSD). In AHRI 1250-2009, the refrigeration loads due to the envelope are assumed to have a high load period of 8 hours during a 24-hour daily cycle, for both coolers and freezers, that corresponds to frequent door openings, product loading events, and other design load factors. AHRI 1250-2009 also assumes a low load period for the remaining 16 hours of the 24-hour daily cycle, which corresponds to the low load conditions resulting from conduction, internal heat gains from non-refrigeration equipment, and steady-state infiltration across the envelope surfaces. AHRI 1250-2009 further assumes that the loads vary with the outdoor ambient temperature. During the high load period, the ratio of envelope load to the design point refrigeration system capacity is 70 percent for coolers and 80 percent for freezers. During the low load period, the ratio is 10 percent for refrigerators and 40 percent for freezers. The relevant load equations correspond to a duty cycle for the refrigeration systems where the system is run at full design point refrigeration capacity for 7.2 hours for coolers and 12.8 hours for freezers per day.

7.4.2.2 Sizing Methodology in the Notice of Proposed Rulemaking

During the preliminary analysis, interested parties commented on the duty cycle assumptions and the sizing methodology that was based on the above assumptions. In response, DOE revisited the issue in further detail by examining submissions of interested parties and technical literature of the manufacturers. DOE observed that it is a fairly widespread industry practice to calculate the daily heat load based on a 24-hour cycle and divide by 16 hours of nominal run time for coolers and 18 hours of nominal run time for freezers to calculate the capacity required for the "perfectly" sized refrigeration system. DOE also noted that it is customary in the industry to allow for a 10 percent safety margin to the aggregate 24-hour load, resulting in 10 percent oversizing[2]. DOE tentatively concluded that the duty cycle assumptions of AHRI 1250-2009 represent an unfavorable operating condition and do not represent the average conditions for WICF refrigeration systems DOE's key assumption in the preliminary analysis of equating the refrigeration capacity to the high box load is not practiced in the industry. The current sizing methodology followed by the industry does not consider the peak load, and no attempt is made to model it. DOE recognizes that the test procedure conditions are often created to effectively compare performance of different equipment under identical test conditions and are developed essentially to capture the difference in performances of equipment with different features, and hence actual operating conditions could be quite different from the test procedure conditions. Thus, in the NOPR energy use analysis, DOE assumed that the nominal size of a refrigeration system is estimated based on nominal run times of 16 hours for coolers and 18 hours for freezers such that the nominal run hours multiplied by the rated capacities of the refrigeration systems are equal to the 24-hour modeled refrigeration load. The nominal size so obtained is subsequently inflated by a safety margin multiplier for determining the actual design size,. Exceptions are made only in special situations, such as when there is hot gas defrost for freezers or when the temperature of the evaporator coil is above 32 °F.

Consequently, DOE adopted the above industry practice for calculating the energy use and load characterization. In the NOPR, DOE proposed a nominal run time of 16 hours per day for coolers and 18 hours per day for freezers for a “perfectly” sized refrigeration system. DOE also applied a fixed oversizing factor on the reference “perfect” size for calculating the actual run times. When this is taken into account, the actual run times assumed by DOE in the NOPR translate to 13.3 hours per day for coolers and 15 hours per day for freezers at full design point net capacity(q_{ss}). The reference outside ambient temperatures for the design point capacity conform to AHRI 1250-2009 conditions and are 95 °F and 90 °F for refrigeration systems with outdoor and indoor condensers, respectively. The load equations used for sizing are given in Eq. 7.1 and Eq. 7.2.

For coolers, the required net capacity is:

$$q_{ss} = (24 \times BLA \times SF)\ /16 \qquad \textbf{Eq. 7.1}$$

For freezers, the required net capacity is:

$$q_{ss} = (24 \times BLA \times SF)/\ 18 \qquad \textbf{Eq. 7.2}$$

BLA is the 24 hour average refrigeration load on the WICF unit and *SF* is the sizing factor—a multiplier set at 120 percent that reflects an overall 20 percent oversizing factor to account for both increased load under adverse conditions (a safety factor of 10 percent) combined additively with a mismatch factor of 10 percent described in section 7.4.2.3.

In another deviation from the AHRI 1250-2009 assumptions, DOE did not consider variation of the envelope refrigeration load with the outside air temperature. Considering that most of the walk-ins in different use categories have their envelopes residing in conditioned or semi-conditioned spaces, DOE assumed that the variation of the refrigeration load with the outside ambient condition would not be significant for the calculation of the refrigeration load representing the average situation. Consequently, a key assumption in DOE’s estimation methodology for the AEC is that the refrigeration load remains constant throughout the year; however, for refrigeration systems with dedicated condensing units located outdoors the refrigeration capacity available from the system changes with the ambient temperature. DOE did not consider a different sizing methodology for the walk-in units installed outdoors as it could not establish the proportion of walk-in envelopes located outdoors and did not have a separate energy model for the outdoor units.

7.4.2.3 Mismatch Factor

In the preliminary analysis sizing methodology, DOE multiplied the required capacity derived from the load equations by a mismatch factor to account for the possibility that the exact refrigeration system size required for a particular envelope may not be available in the market. For example, DOE assumed a mismatch situation where a required capacity of 9,000 Btu/hr was matched to the next available size of the refrigeration system having a capacity of 12,000 Btu/hr (1 ton of refrigeration = 12,000 Btu/hr), resulting in an oversize factor of 1.33. The oversize factors were computed in 0.5 ton intervals and plotted against the required capacities. From the resulting plot, DOE derived a logarithmic trend line and a mismatch equation. The mismatch factor was as high as 33 percent for the smaller refrigeration system sizes, and was somewhat smaller for the larger sized units. In the preliminary analysis, this mismatch oversizing factor was applied to the required refrigeration capacity at the high-load condition to determine the required capacity of the refrigeration system to be paired with a given envelope.

In the NOPR, DOE modified its approach to account for the mismatch in response to several comments from interested parties on the mismatch factor. DOE noted that, in the industry, if the exact calculated size of the refrigeration system with 10 percent safety margin is not available in the market, the user may settle for a close matching size, even with lower capacity, allowing the daily run times to be somewhat higher than their intended values. The designer recalculates the revised run time with the available lower capacity and compares it with the target run time of 16 hours for coolers and 18 hours for freezers. If this is within acceptable limits, then the chosen size of the refrigeration system is accepted and there is no mismatch oversizing. DOE also examined data on available capacities in several manufacturer catalogs and concluded that a scaled mismatch factor depending on the target capacity of the unit may not be applicable. In the NOPR analysis, DOE applied a uniform mismatch factor of 10 percent, added to the safety factor of 10 percent discussed previously over the entire capacity range of refrigeration systems.

7.4.3 Annual Energy Consumption

DOE estimated the refrigeration system’s daily energy consumption under actual use conditions by multiplying the system’s on-cycle power, off-cycle evaporator fan power, and defrost power by the number of corresponding daily run-hours under these system conditions, and aggregating them. DOE assumed that the daily on-cycle run-hours would vary with the outside ambient temperature for the dedicated systems with external condensers. For indoor units, the daily on-cycle runs hours were set at 13.3 hours for coolers and 15 hours for freezers. The engineering analysis (chapter 5 of the TSD) provides a detailed discussion of the approach and methodology of deriving the system on-cycle power, off-cycle evaporator fan power and defrost power at different ambient temperatures. For the dedicated condensing units with outdoor condensers, DOE used the ambient temperature bin hours defined in AHRI 1250-2009, Appendix D, which represent the population-weighted average ambient temperature conditions for the United States as a whole. This is presented in Table 7.4.2. Eq. 7.3 through Eq. 7.8 are used to represent DOE’s calculation methodology for annual energy consumption of dedicated condensing refrigeration systems with outdoor condensers.

$$Cap\_factor = q_{ss}(t_i)/q_{ss95}$$

Eq. 7.3

$$E_{total}(t_i) = (E_{ss}(t_i)\ x\ (Run\_hrs/cap\_factor)+(24-Run\_hrs/Cap\_factor)x\ E_{fanCompoff}+DF)/24$$

Eq. 7.4

$Run\_hrs(coolers) = 16/SF$

Eq. 7.5

$Run\_hrs(freezers) = 18/SF$

Eq. 7.6

$$AEC = \frac{\sum_{j=1}^{n} E_{total}(t_j) \times n(t_j)}{1000}$$

Eq. 7.7

Where:

Cap_Factor = capacity factor—the ratio of refrigeration capacities at a given temperature (t_j) and a reference temperature;
t_j = temperature in bin j;
q_{ss} (t_j) = system steady state refrigeration capacity at t_j, Btu/h;
q_{ss95} = system steady state refrigeration capacity at 95 °F outside ambient, Btu/h;
E_{Total} (t_j) = hourly average energy consumption over 24 hour period at t_j, Wh;
E_{ss} (t_j) = system energy consumption at ambient temperature of t_j,Wh;
Run_hrs = run hours when the system is on;
$E_{FanCompOff}$ = evaporator fan power consumption during compressor off period, W;
DF = daily average defrost energy, Wh;
SF = sizing factor (set at 1.2);
$n(t_j)$ = hours per year in the temperature bin, t_j; and
AEC = annual energy consumption, kWh/yr.

For walk-in units with condensers located indoors, q_{ss95} is replaced by the system steady state refrigeration capacity at 90 °F ambient, which is the rating condition in AHRI 1250-2009 in the corresponding equations. E_{Total} (t_j) is also calculated at 90 °F. Because the capacity factor is always one for the indoor systems, in the E_{Total} (t_j) calculations the run hours correspond to 13.3 hours and 15 hours of on-cycle operation per day for the coolers and freezers, respectively. The AEC in kWh is given by

$AEC = E_{total}(90\ °F) \times 8760/1000$

Eq. 7.8

For the unit coolers connected to multiplex systems, the sizing factor is applied in a similar way and, consequently, the run-hours for the on-cycle condition are the same as the run-hours for the indoor units. E_{ss} (t_j) is estimated by adding the evaporator fan power to the calculated power consumption of the condensing unit, which is derived by dividing the steady state refrigeration capacity of the cooler by the nominal energy efficiency ratio (EER) values prescribed in AHRI 1250-2009 for multiplex (rack) systems (12.4 for coolers and 6.3 for freezers at the assumed operating temperatures).

Table 7.4.2 Bin Temperatures and Bin Hours for AEC and Annual Energy Efficiency Ratio Calculation

Bin Temperature ***°F***	**Bin Hours** ***hr***
100.4	9
95	74
89.6	257
84.2	416
78.8	630
73.4	898
68	737
62.6	943
57.2	628
51.8	590
46.4	677
41	576
35.6	646
30.2	534
24.8	322
19.4	305
14	246
8.6	189
3.2	78
-2.2	5

7.4.3.1 Annual Energy Efficiency Ratio

To estimate the refrigeration energy consumption associated with the refrigeration load for each selected envelope components, DOE calculated the annual energy efficiency ratios (AEERs) for the refrigeration systems. The AEER represents the energy performance of the refrigeration system as a ratio of units of useful heat removed (Btu) from the conditioned walk-in space to units of electrical energy input (Wh) to operate the refrigeration system (compressor, condenser fans, evaporator fans, etc.). This ratio represents the efficiency of the refrigeration equipment. The refrigeration systems are paired with envelope components, and the AEERs of the refrigeration systems are used to convert the refrigeration load to electrical energy consumption. Section 7.5 contains more details on how this value is used in the envelope energy consumption calculations.

7.4.4 Energy Consumption Results For Refrigeration System Equipment Classes

Table 7.4.3 through Table 7.4.8 provide the annual energy consumption in kWh per year, AEER in Btu/Wh , and AWEF in Btu/Wh for each refrigeration system equipment class capacity point DOE analyzed at each TSL. Values recorded as N/A implies the specific efficiency level is not applicable for the specific equipment.

Table 7.4.3 Dedicated Condensing, Medium Temperature, Indoor Units

-	**Compressor Type**	HER	HER	SCR	SCR	SCR	SEM	SEM	SEM	SEM
	Capacity *kBtu/hr*	6	18	18	54	96	6	18	54	96
Efficiency Level	-	-	-	-	-	-	-	-	-	-
Baseline	AEC	6,559	15,315	14,741	43,636	83,369	5,526	15,959	41,464	77,988
	AEER	4.46	5.66	5.88	5.89	5.43	5.30	5.43	6.19	5.81
	AWEF	3.78	4.52	4.68	4.49	4.08	4.44	4.36	4.70	4.33
1	AEC	6,426	14,782	14,209	41,640	79,377	5,393	15,427	39,468	73,997
	AEER	4.55	5.87	6.10	6.17	5.71	5.43	5.62	6.51	6.12
	AWEF	4.12	5.12	5.31	5.22	4.78	4.88	4.91	5.49	5.10
2	AEC	6,326	14,383	13,810	40,143	76,383	5,293	15,028	37,971	71,003
	AEER	4.63	6.03	6.28	6.40	5.93	5.53	5.77	6.76	6.38
	AWEF	4.42	5.70	5.93	5.99	5.54	5.27	5.46	6.33	5.95
3	AEC	6,169	13,217	12,482	39,357	74,810	5,136	13,796	37,184	69,430
	AEER	4.74	6.56	6.95	6.53	6.05	5.70	6.28	6.91	6.52
	AWEF	4.53	6.19	6.55	6.11	5.65	5.43	5.94	6.46	6.08
4	AEC	6,153	12,745	12,011	34,510	65,501	5,120	13,324	33,504	62,812
	AEER	4.76	6.80	7.22	7.44	6.91	5.72	6.51	7.66	7.21
	AWEF	4.54	6.42	6.81	6.95	6.43	5.45	6.15	7.15	6.70
5	AEC	6,135	12,698	11,963	34,392	65,266	5,103	13,277	33,386	62,576
	AEER	4.78	6.83	7.25	7.47	6.94	5.75	6.53	7.69	7.24
	AWEF	4.57	6.44	6.83	6.97	6.46	5.49	6.17	7.18	6.73
6	AEC	5,529	12,629	11,894	34,131	64,744	4,572	13,208	33,125	62,055
	AEER	5.30	6.88	7.31	7.55	7.02	6.41	6.58	7.78	7.32
	AWEF	5.07	6.51	6.90	7.06	6.55	6.11	6.22	7.27	6.82

Table 7.4.4 Dedicated Condensing, Medium Temperature, Outdoor Units

-	**Compressor Type**	HER	HER	SCR	SCR	SCR	SEM	SEM	SEM	SEM
-	**Capacity** ***kBtu/hr***	6	18	18	54	96	6	18	54	96
Efficiency Level	-	-	-	-	-	-	-	-	-	-
Baseline	AEC	5,413	12,419	10,768	34,969	64,904	4,567	12,669	33,144	62,581
	AEER	5.19	6.70	7.73	7.04	6.69	6.15	6.57	7.43	6.94
	AWEF	4.16	4.91	5.52	4.82	4.47	4.85	4.82	5.05	4.61
1	AEC	5,249	11,762	10,111	32,502	59,964	4,403	12,012	30,678	57,641
	AEER	5.35	7.07	8.23	7.58	7.24	6.38	6.93	8.03	7.53
	AWEF	4.70	5.87	6.69	5.98	5.62	5.55	5.75	6.31	5.82
2	AEC	5,127	11,270	9,619	30,652	56,258	4,280	11,520	28,827	53,936
	AEER	5.48	7.38	8.65	8.04	7.72	6.57	7.22	8.54	8.05
	AWEF	5.23	6.91	8.01	7.38	7.05	6.24	6.75	7.84	7.35
3	AEC	4,670	10,152	8,436	27,253	50,558	3,829	10,170	25,328	47,634
	AEER	6.02	8.19	9.86	9.04	8.59	7.34	8.18	9.72	9.11
	AWEF	5.72	7.62	9.06	8.24	7.80	6.94	7.61	8.85	8.26
4	AEC	4,652	9,317	7,772	25,036	46,435	3,811	9,333	23,262	43,752
	AEER	6.04	8.93	10.70	9.84	9.35	7.37	8.91	10.59	9.92
	AWEF	5.74	8.27	9.79	8.92	8.44	6.98	8.25	9.58	8.93
5	AEC	4,539	9,281	7,536	24,447	44,220	3,699	9,297	22,677	41,571
	AEER	6.19	8.96	11.04	10.07	9.82	7.60	8.95	10.86	10.44
	AWEF	5.88	8.30	10.08	9.12	8.82	7.18	8.28	9.81	9.35
6	AEC	4,527	9,056	7,238	23,707	43,784	3,687	9,074	21,948	41,131
	AEER	6.22	9.19	11.49	10.39	9.92	7.64	9.17	11.22	10.56
	AWEF	5.91	8.50	10.45	9.38	8.91	7.23	8.47	10.11	9.45
7	AEC	4,144	8,770	6,645	20,119	40,494	3,378	8,796	20,382	38,108
	AEER	6.79	9.49	12.52	12.24	10.72	8.33	9.46	12.08	11.39
	AWEF	6.44	8.75	11.42	11.01	9.64	7.86	8.72	10.90	10.21
8	AEC	4,000	8,002	6,595	19,032	38,840	3,238	8,077	20,198	37,743
	AEER	7.04	10.40	12.65	12.94	11.18	8.69	10.30	12.23	11.55
	AWEF	6.65	9.60	11.56	11.53	9.98	8.18	9.51	11.08	10.39
9	AEC	3,570	7,953	6,192	18,850	38,484	2,805	8,029	17,633	33,042
	AEER	7.89	10.49	13.47	13.11	11.33	10.04	10.39	14.01	13.19
	AWEF	7.47	9.71	12.19	11.72	10.15	9.44	9.62	12.64	11.81
10	AEC	-	-	6,182	16,398	33,538	-	-	17,610	32,996
	AEER	-	-	13.49	15.07	13.00	-	-	14.03	13.21
	AWEF	-	-	12.21	13.41	11.60	-	-	12.66	11.83
11	AEC	-	-	-	16,374	33,489	-	-	-	-
	AEER	-	-	-	15.09	13.01	-	-	-	-
	AWEF	-	-	-	13.43	11.61	-	-	-	-

Table 7.4.5 Dedicated Condensing, Low Temperature, Indoor Units

-	**Compressor Type**	HER	HER	SCR	SCR	SCR	SEM	SEM	SEM
-	**Capacity *kBtu/hr***	6	9	6	9	54	6	9	54
Efficiency Level	-	-	-		-	-	-	-	-
Baseline	AEC	12,335	16,477	11,903	15,001	81,758	12,242	17,291	88,864
	AEER	2.57	2.96	2.66	3.25	3.53	2.59	2.82	3.25
	AWEF	2.34	2.77	2.42	3.04	3.28	2.36	2.64	3.02
1	AEC	12,117	16,259	11,686	14,784	80,125	12,024	17,073	87,231
	AEER	2.62	3.00	2.71	3.30	3.61	2.64	2.86	3.31
	AWEF	2.45	2.87	2.54	3.15	3.44	2.47	2.73	3.16
2	AEC	11,954	16,096	11,522	14,620	78,901	11,861	16,910	86,006
	AEER	2.65	3.03	2.75	3.34	3.66	2.67	2.88	3.36
	AWEF	2.55	2.95	2.65	3.25	3.58	2.57	2.81	3.28
3	AEC	11,899	16,041	11,468	14,566	77,086	11,807	16,856	81,924
	AEER	2.66	3.04	2.76	3.35	3.75	2.68	2.89	3.53
	AWEF	2.56	2.96	2.66	3.26	3.66	2.58	2.82	3.45
4	AEC	11,555	15,696	11,123	14,221	76,779	11,462	16,511	81,616
	AEER	2.74	3.11	2.85	3.43	3.76	2.76	2.95	3.54
	AWEF	2.64	3.02	2.74	3.34	3.69	2.66	2.88	3.48
5	AEC	11,516	14,571	11,084	14,182	76,597	11,423	15,258	81,208
	AEER	2.76	3.35	2.87	3.45	3.77	2.78	3.20	3.56
	AWEF	2.66	3.26	2.76	3.36	3.70	2.68	3.11	3.49
6	AEC	10,858	14,532	10,046	13,099	76,305	10,917	15,219	80,916
	AEER	2.93	3.36	3.17	3.73	3.80	2.91	3.21	3.58
	AWEF	2.82	3.28	3.05	3.63	3.73	2.81	3.13	3.52
7	AEC	10,803	14,473	9,991	13,040	76,305	10,863	15,160	77,045
	AEER	2.94	3.38	3.18	3.75	3.80	2.93	3.23	3.76
	AWEF	2.85	3.31	3.09	3.67	3.73	2.84	3.16	3.69

Table 7.4.6 Dedicated Condensing, Low Temperature, Outdoor Units

-	**Compressor Type**	HER	HER	SCR	SCR	SCR	SEM	SEM	SEM	SEM
-	**Capacity *kBtu/hr***	6	9	6	9	54	6	9	54	72
Efficiency Level	-	-	-		-	-	-	-	-	-
Baseline	AEC	10,533	13,996	8,715	10,820	56,861	10,206	14,656	70,215	89,899
	AEER	2.88	3.34	3.49	4.33	4.87	2.98	3.19	3.95	4.08
	AWEF	2.40	2.91	2.86	3.70	4.09	2.47	2.78	3.36	3.41
1	AEC	10,230	13,694	8,412	10,518	52,122	9,903	14,355	64,658	82,633
	AEER	2.97	3.42	3.61	4.45	5.32	3.07	3.26	4.29	4.43
	AWEF	2.62	3.10	3.14	3.98	4.44	2.69	2.96	3.63	3.70
2	AEC	10,003	13,468	8,185	9,583	49,742	9,675	14,129	62,252	79,018
	AEER	3.04	3.47	3.71	4.88	5.57	3.14	3.31	4.45	4.64
	AWEF	2.81	3.27	3.39	4.35	4.92	2.90	3.12	3.99	4.11
3	AEC	9,467	12,677	7,505	9,346	47,957	8,914	12,966	60,448	76,307
	AEER	3.21	3.69	4.05	5.01	5.78	3.41	3.61	4.58	4.80
	AWEF	2.97	3.47	3.70	4.64	5.38	3.15	3.40	4.32	4.50
4	AEC	8,483	11,350	6,791	8,451	43,306	8,021	11,638	54,676	68,889
	AEER	3.58	4.12	4.47	5.54	6.40	3.79	4.02	5.07	5.32
	AWEF	3.30	3.86	4.07	5.11	5.93	3.48	3.77	4.74	4.96
5	AEC	8,445	11,311	6,752	8,412	40,771	7,983	11,600	49,171	63,355
	AEER	3.60	4.14	4.50	5.56	6.80	3.80	4.03	5.63	5.78
	AWEF	3.31	3.87	4.09	5.13	6.27	3.50	3.78	5.24	5.36
6	AEC	8,428	11,066	6,509	8,167	40,330	7,743	11,358	48,168	62,905
	AEER	3.62	4.23	4.67	5.73	6.87	3.92	4.12	5.75	5.82
	AWEF	3.34	3.96	4.24	5.28	6.34	3.60	3.86	5.36	5.44
7	AEC	8,185	10,752	6,189	7,844	40,023	7,966	11,043	47,860	61,904
	AEER	3.73	4.35	4.91	5.97	6.92	3.83	4.24	5.79	5.92
	AWEF	3.43	4.07	4.44	5.48	6.43	3.52	3.96	5.43	5.53
8	AEC	7,873	10,733	6,170	7,823	38,962	7,726	10,234	47,707	61,673
	AEER	3.87	4.37	4.94	6.00	7.11	3.95	4.57	5.83	5.96
	AWEF	3.56	4.09	4.48	5.52	6.58	3.63	4.28	5.47	5.58
9	AEC	7,819	10,036	5,791	7,402	38,797	7,415	10,213	41,118	59,575
	AEER	3.90	4.68	5.27	6.34	7.17	4.11	4.59	6.76	6.17
	AWEF	3.62	4.38	4.79	5.86	6.64	3.77	4.30	6.37	5.79
10	AEC	7,798	9,977	5,736	6,979	33,238	7,360	10,154	40,244	51,583
	AEER	3.91	4.70	5.32	6.72	8.36	4.14	4.62	6.91	7.13
	AWEF	3.65	4.44	4.89	6.15	7.77	3.84	4.36	6.52	6.71
11	AEC	-	-	-	6,920	33,191	7,203	-	40,129	51,469
	AEER	-	-	-	6.78	8.38	4.23	-	6.93	7.14
	AWEF	-	-	-	6.25	7.78	3.93	-	6.54	6.72
12	AEC	-	-	-	-	32,625		-	-	-
	AEER	-	-	-	-	8.52		-	-	-
	AWEF	-	-	-	-	7.91		-	-	-

Table 7.4.7 Multiplex, Medium Temperature, Indoor Refrigeration System

-	**# Fins per Inch**	6	6	6	4	4
-	**Capacity *kBtu/hr***	4	9	24	4	9
	# Evaporator Fans	1	2	6	1	2
Efficiency Level	-	-	-	-	-	-
Baseline	AEC	2,113	4,608	13,738	2,113	4,608
	AEER	8.69	9.03	8.08	8.69	9.03
	AWEF	6.42	6.80	5.75	6.42	6.80
1	AEC	1,979	4,342	12,740	1,979	4,342
	AEER	9.28	9.58	8.71	9.28	9.58
	AWEF	7.68	8.04	7.02	7.68	8.04
2	AEC	1,168	2,607	7,262	1,168	2,607
	AEER	15.72	15.95	15.28	15.72	15.95
	AWEF	10.57	10.74	10.23	10.57	10.74
3	AEC	1,164	2,599	7,234	1,164	2,599
	AEER	15.83	16.05	15.40	15.83	16.05
	AWEF	10.65	10.82	10.32	10.65	10.82

Table 7.4.8 Multiplex, Low Temperature, Indoor Refrigeration System

-	**# Fins per Inch**	6	6	6	4	4	4	4
-	**Capacity *kBtu/hr***	4	9	18	4	9	18	40
	# Evaporator Fans	1	2	2	1	2	2	2
Efficiency Level	-	-	-	-	-	-	-	-
Baseline	AEC	4,267	9,262	20,349	4,247	9,204	18,961	43,911
	AEER	4.84	5.05	4.39	4.86	5.08	4.87	4.56
	AWEF	4.40	4.66	3.93	4.43	4.71	4.46	4.14
1	AEC	4,158	9,044	19,533	4,139	8,986	18,417	42,278
	AEER	4.97	5.17	4.57	4.99	5.21	5.01	4.74
	AWEF	4.62	4.89	4.25	4.66	4.94	4.73	4.46
2	AEC	3,220	6,947	14,014	3,192	6,864	13,833	30,477
	AEER	6.42	6.74	6.37	6.47	6.82	6.68	6.58
	AWEF	5.27	5.53	5.34	5.32	5.60	5.52	5.49
3	AEC	3,213	6,830	13,821	3,185	6,779	13,613	30,205
	AEER	6.45	6.85	6.46	6.51	6.90	6.78	6.64
	AWEF	5.29	5.63	5.42	5.34	5.67	5.61	5.55
4	AEC	3,152	6,816	13,414	3,137	6,766	13,169	29,659
	AEER	6.58	6.88	6.65	6.61	6.94	7.01	6.76
	AWEF	5.40	5.65	5.59	5.43	5.69	5.81	5.65
5	AEC	2,938	6,533	13,382	2,938	6,533	13,140	29,588
	AEER	7.05	7.18	6.71	7.05	7.18	7.05	6.81
	AWEF	5.82	5.91	5.62	5.82	5.91	5.84	5.68

7.5 ENERGY USE OF ENVELOPE COMPONENTS

DOE used the results of the engineering analysis for the envelope components to determine the annual electrical energy consumption associated with units of each envelope component. For panels, DOE considered area as the unit of analysis and calculation of the AEC. For doors, DOE considered each door as the representative unit. DOE obtained the total electrical energy consumption associated with one unit of each envelope component by adding the refrigeration energy directly traceable to the specific component and the direct electrical energy consumed by the unit of the envelope component. The refrigeration load associated with one unit of the component was calculated by multiplying the U-factor derived in the engineering analysis for different efficiency levels of the envelope components by the reference temperature difference between the exterior condition and the interior conditions of the walk-in. If the specific component also consumed electrical energy directly, then the refrigeration heat load associated with the electrical energy consumed was also accounted for and added to the load calculated on the basis of U-factors. For example, for the anti-sweat heaters, 75 percent of the electrical energy consumed is assumed to contribute to the refrigeration load in the form of heat added to the walk-in. The daily refrigeration load obtained in this manner was divided by the AEER of the refrigeration system considered for estimating the refrigeration energy consumption. To this, DOE added the daily electrical energy directly consumed by the component to estimate the total daily energy consumption. DOE multiplied the daily electrical energy consumption by the number of days per year to obtain the AEC (kWh/yr). DOE followed the test procedure conditions and the methodology discussed in chapter 5 of the TSD, with the exception that DOE used the actual AEER of the refrigeration system to be paired with the component instead of using the nominal EER values prescribed in the DOE test procedure. (The actual AEER for each refrigeration system analyzed is presented in the tables in section 7.4.4.)

7.5.1 Envelope Sizes and Equipment Classes Analyzed for Energy Use

DOE considered three sizes for each of the envelope components in the energy use analysis. Refer to the engineering analysis TSD chapter 5 for the envelope component sizes.

7.5.2 Energy Consumption Results for Envelope Equipment Classes

Table 7.5.1 through Table 7.5.9 provide the annual energy consumption for three analyzed sizes in each envelope component equipment class for each of the eight TSL options of the refrigeration system. Each TSL option for the refrigeration system is characterized by two weighted average AEERs – one for the medium temperature systems and a second one for the low temperature systems. These are based on shipment weights and actual AEER for the analyzed refrigeration systems (discussed in section 7.4.4). The methodology of development of the TSL options for the refrigeration system is discussed in detail in Appendix 10D of the technical support document. The weighted average AEER values for the TSL options of the refrigeration systems used to compute the AEC of the components are given in Table 7.5.10

Table 7.5.1 Energy Consumption for WICF Panels, Medium Temperature

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/sq.ft/yr*		
		Small	**Medium**	**Large**
0	0	4.1	3.0	2.8
0	1	2.3	2.1	2.1
0	2	2.0	1.9	1.9
0	3	1.6	1.5	1.5
0	4	1.3	1.3	1.2
0	5	1.2	1.2	1.2
0	6	0.6	0.6	0.6
1	0	3.2	2.4	2.2
1	1	1.8	1.7	1.6
1	2	1.6	1.5	1.4
1	3	1.3	1.2	1.2
1	4	1.0	1.0	1.0
1	5	0.9	0.9	0.9
1	6	0.4	0.4	0.4
2	0	2.9	2.1	2.0
2	1	1.6	1.5	1.5
2	2	1.4	1.3	1.3
2	3	1.1	1.1	1.1
2	4	1.0	0.9	0.9
2	5	0.8	0.8	0.8
2	6	0.4	0.4	0.4
3	0	2.7	2.0	1.8
3	1	1.5	1.4	1.4
3	2	1.3	1.2	1.2
3	3	1.1	1.0	1.0
3	4	0.9	0.8	0.8
3	5	0.8	0.8	0.8
3	6	0.4	0.4	0.4
4	0	2.2	1.7	1.5
4	1	1.2	1.2	1.2
4	2	1.1	1.0	1.0
4	3	0.9	0.8	0.8
4	4	0.7	0.7	0.7
4	5	0.7	0.7	0.7
4	6	0.3	0.3	0.3
5	0	2.1	1.5	1.4
5	1	1.1	1.1	1.1
5	2	1.0	0.9	0.9
5	3	0.8	0.8	0.8
5	4	0.7	0.6	0.6
5	5	0.6	0.6	0.6
5	6	0.3	0.3	0.3
6	0	2.4	1.8	1.7
6	1	1.4	1.3	1.3
6	2	1.2	1.1	1.1
6	3	1.0	0.9	0.9
6	4	0.8	0.8	0.7
6	5	0.7	0.7	0.7
6	6	0.3	0.3	0.3

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/sq.ft/yr*		
		Small	**Medium**	**Large**
7	0	2.1	1.5	1.4
7	1	1.2	1.1	1.1
7	2	1	1	0.9
7	3	0.8	0.8	0.8
7	4	0.7	0.6	0.6
7	5	0.6	0.6	0.6
7	6	0.3	0.3	0.3
8	0	2.1	1.5	1.4
8	1	1.1	1.1	1.1
8	2	1	0.9	0.9
8	3	0.8	0.8	0.8
8	4	0.7	0.6	0.6
8	5	0.6	0.6	0.6
8	6	0.3	0.3	0.3

Table 7.5.2 Energy Consumption for WICF Panels, Low Temperature

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/ sq.ft/ yr*		
		Small	**Medium**	**Large**
0	0	14.2	10.4	9.7
0	1	7.8	7.4	7.3
0	2	6.3	5.9	5.9
0	3	5.3	5.0	4.9
0	4	4.7	4.7	4.7
0	5	2.2	2.2	2.2
1	0	11.3	8.3	7.7
1	1	6.2	5.9	5.8
1	2	5.0	4.7	4.7
1	3	4.2	4.0	3.9
1	4	3.7	3.7	3.7
1	5	1.8	1.8	1.8
2	0	10.0	7.4	6.8
2	1	5.5	5.2	5.1
2	2	4.5	4.2	4.1
2	3	3.7	3.5	3.5
2	4	3.3	3.3	3.3
2	5	1.6	1.6	1.6
3	0	9.3	6.9	6.4
3	1	5.1	4.8	4.8
3	2	4.1	3.9	3.8
3	3	3.5	3.3	3.2
3	4	3.1	3.1	3.1
3	5	1.4	1.4	1.4
4	0	8.3	6.1	5.7
4	1	4.6	4.3	4.3
4	2	3.7	3.5	3.4
4	3	3.1	2.9	2.9
4	4	2.7	2.7	2.7
4	5	1.3	1.3	1.3
5	0	7.9	5.8	5.4

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/ sq.ft/ yr*		
		Small	**Medium**	**Large**
5	1	4.4	4.1	4.1
5	2	3.5	3.3	3.3
5	3	3.0	2.8	2.7
5	4	2.6	2.6	2.6
5	5	1.2	1.2	1.2
6	0	10.0	7.4	6.8
6	1	5.5	5.2	5.1
6	2	4.4	4.2	4.1
6	3	3.7	3.5	3.5
6	4	3.3	3.3	3.3
6	5	1.6	1.6	1.6
7	0	8.5	6.3	5.8
7	1	4.7	4.4	4.4
7	2	3.8	3.6	3.5
7	3	3.2	3.0	2.9
7	4	2.8	2.8	2.8
7	5	1.3	1.3	1.3
8	0	7.9	5.8	5.4
8	1	4.4	4.1	4.1
8	2	3.5	3.3	3.3
8	3	3	2.8	2.7
8	4	2.6	2.6	2.6
8	5	1.2	1.2	1.2

Table 7.5.3 Energy Consumption for WICF Floor Panels, Low Temperature

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/ sq.ft /yr*		
		Small	**Medium**	**Large**
0	0	10.6	8.8	8.1
0	1	6.1	5.9	5.8
0	2	5.4	5.2	5.2
0	3	4.4	4.3	4.2
0	4	3.7	3.6	3.6
0	5	2.7	2.3	2.1
1	0	8.5	7.0	6.4
1	1	4.9	4.7	4.6
1	2	4.3	4.2	4.1
1	3	3.5	3.4	3.4
1	4	3.0	2.9	2.8
1	5	2.2	1.8	1.7
2	0	7.5	6.2	5.7
2	1	4.3	4.2	4.1
2	2	3.8	3.7	3.6
2	3	3.1	3.0	3.0
2	4	2.6	2.5	2.5
2	5	1.9	1.6	1.5
3	0	7.0	5.8	5.3
3	1	4.0	3.9	3.8

Refrigeration System TSL Option	**Envelope Efficiency Level**	**AEC** *kWh/ sq.ft /yr*		
		Small	**Medium**	**Large**
3	2	3.6	3.4	3.4
3	3	2.9	2.8	2.8
3	4	2.5	2.4	2.3
3	5	1.8	1.5	1.4
4	0	6.2	5.2	4.7
4	1	3.6	3.5	3.4
4	2	3.2	3.1	3
4	3	2.6	2.5	2.5
4	4	2.2	2.1	2.1
4	5	1.6	1.3	1.3
5	0	5.9	4.9	4.5
5	1	3.4	3.3	3.2
5	2	3.0	2.9	2.9
5	3	2.5	2.4	2.4
5	4	2.1	2.0	2.0
5	5	1.5	1.3	1.2
6	0	7.5	6.2	5.7
6	1	4.3	4.2	4.1
6	2	3.8	3.7	3.6
6	3	3.1	3.0	3.0
6	4	2.6	2.5	2.5
6	5	1.9	1.6	1.5
7	0	6.4	5.3	4.8
7	1	3.7	3.5	3.5
7	2	3.2	3.1	3.1
7	3	2.7	2.6	2.5
7	4	2.2	2.2	2.1
7	5	1.6	1.4	1.3
8	0	5.9	4.9	4.5
8	1	3.4	3.3	3.2
8	2	3.0	2.9	2.9
8	3	2.5	2.4	2.4
8	4	2.1	2	2
8	5	1.5	1.3	1.2

Table 7.5.4 Energy Consumption for Passage Doors, Medium Temperature

Refrigeration System TSL Option	**Envelope Efficiency Level**	**AEC** *kWh/yr*		
		Small	**Medium**	**Large**
0	0	165.3	177.8	200.3
0	1	145.0	155.0	173.6
0	2	119.7	129.6	148.2
0	3	116.0	124.7	141.1
0	4	110.8	117.8	131.0
0	5	90.1	97.1	110.2
0	6	86.5	92.4	103.4
0	7	23.7	29.6	40.6
0	8	15.1	17.9	23.3

Refrigeration System TSL Option	**Envelope Efficiency Level**	**AEC** ***kWh/yr***		
		Small	**Medium**	**Large**
1	0	144.4	154.1	171.6
1	1	128.6	136.3	150.8
1	2	105.7	113.4	127.9
1	3	102.8	109.6	122.3
1	4	98.8	104.2	114.5
1	5	79.9	85.4	95.6
1	6	77.1	81.7	90.3
1	7	18.5	23.0	31.6
1	8	11.7	14.0	18.2
2	0	138.0	146.9	162.9
2	1	123.6	130.6	143.9
2	2	101.4	108.4	121.7
2	3	98.8	105.0	116.6
2	4	95.1	100.1	109.4
2	5	76.8	81.8	91.1
2	6	74.3	78.5	86.3
2	7	16.9	21.0	28.9
2	8	10.7	12.8	16.6
3	0	132.7	140.9	155.7
3	1	119.4	126.0	138.2
3	2	97.9	104.4	116.6
3	3	95.5	101.2	111.9
3	4	92.1	96.7	105.3
3	5	74.3	78.9	87.5
3	6	71.9	75.8	83.0
3	7	15.6	19.4	26.6
3	8	9.9	11.8	15.3
4	0	122.5	129.4	141.7
4	1	111.4	116.8	127.1
4	2	91.0	96.5	106.7
4	3	89.0	93.8	102.8
4	4	86.2	90.0	97.3
4	5	69.3	73.1	80.4
4	6	67.4	70.6	76.6
4	7	13.0	16.2	22.2
4	8	8.3	9.8	12.8
5	0	118.4	124.7	136.0
5	1	108.1	113.1	122.5
5	2	88.3	93.3	102.6
5	3	86.4	90.8	99.1
5	4	83.8	87.3	94.0
5	5	67.3	70.8	77.5
5	6	65.5	68.5	74.0
5	7	12.0	14.9	20.5
5	8	7.6	9.0	11.8
6	0	127.4	134.9	148.4
6	1	115.2	121.2	132.4
6	2	94.3	100.3	111.4
6	3	92.1	97.3	107.1
6	4	89.0	93.2	101.1

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/yr*		
		Small	**Medium**	**Large**
6	5	71.7	75.9	83.8
6	6	69.6	73.1	79.7
6	7	14.2	17.7	24.3
6	8	9.0	10.8	14.0
7	0	119.0	125.4	136.8
7	1	108.6	113.7	123.2
7	2	88.7	93.7	103.2
7	3	86.8	91.3	99.6
7	4	84.1	87.7	94.5
7	5	67.6	71.2	77.9
7	6	101.4	108.4	121.7
7	7	98.8	105.0	116.6
7	8	95.1	100.1	109.4
8	0	76.8	81.8	91.1
8	1	74.3	78.5	86.3
8	2	16.9	21.0	28.9
8	3	10.7	12.8	16.6
8	4	132.7	140.9	155.7
8	5	119.4	126.0	138.2
8	6	97.9	104.4	116.6
8	7	95.5	101.2	111.9
8	8	92.1	96.7	105.3

Table 7.5.5 Energy Consumption for WICF Passage Doors, Low Temperature

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/yr*		
		Small	**Medium**	**Large**
0	0	4,315.4	4,770.2	5,506.6
0	1	4,244.3	4,690.3	5,413.4
0	2	3,974.1	4,420.0	5,143.0
0	3	3,818.8	4,264.7	4,987.7
0	4	3,798.1	4,237.4	4,947.9
0	5	3,784.2	4,219.0	4,921.1
0	6	3,703.2	4,138.0	4,840.1
0	7	3,665.8	4,100.5	4,802.6
0	8	3,645.6	4,070.3	4,752.7
1	0	3,935.2	4,347.7	5,014.6
1	1	3,878.5	4,284.0	4,940.3
1	2	3,633.3	4,038.6	4,694.9
1	3	3,491.2	3,896.5	4,552.8
1	4	3,474.7	3,874.8	4,521.1
1	5	3,463.6	3,860.1	4,499.7
1	6	3,389.2	3,785.7	4,425.3
1	7	3,355.6	3,752.1	4,391.7
1	8	3,339.5	3,728.1	4,351.9
2	0	3,763.3	4,156.7	4,792.2
2	1	3,713.1	4,100.3	4,726.4
2	2	3,479.2	3,866.3	4,492.3
2	3	3,343.0	3,730.1	4,356.2
2	4	3,328.5	3,710.9	4,328.1

Refrigeration System TSL Option	**Envelope Efficiency Level**	**AEC *kWh/yr***		
		Small	**Medium**	**Large**
2	5	3,318.6	3,697.9	4,309.2
2	6	3,247.3	3,626.5	4,237.8
2	7	3,215.4	3,594.6	4,205.9
2	8	3,201.2	3,573.3	4,170.8
3	0	3,671.6	4,054.8	4,673.5
3	1	3,624.9	4,002.3	4,612.3
3	2	3,397.0	3,774.3	4,384.3
3	3	3,264.0	3,641.3	4,251.3
3	4	3,250.4	3,623.4	4,225.2
3	5	3,241.3	3,611.3	4,207.6
3	6	3,171.5	3,541.5	4,137.8
3	7	3,140.6	3,510.6	4,106.8
3	8	3,127.3	3,490.8	4,074.1
4	0	3,543.0	3,911.9	4,507.1
4	1	3,501.2	3,864.9	4,452.3
4	2	3,281.7	3,645.3	4,232.7
4	3	3,153.2	3,516.8	4,104.2
4	4	3,141.0	3,500.7	4,080.8
4	5	3,132.8	3,489.9	4,065.0
4	6	3,065.3	3,422.4	3,997.5
4	7	3,035.7	3,392.7	3,967.8
4	8	3,023.8	3,375.0	3,938.5
5	0	3,487.3	3,850.0	4,435.1
5	1	3,447.6	3,805.4	4,383.1
5	2	3,231.8	3,589.5	4,167.1
5	3	3,105.2	3,462.9	4,040.5
5	4	3,093.7	3,447.6	4,018.3
5	5	3,085.9	3,437.4	4,003.3
5	6	3,019.3	3,370.8	3,936.8
5	7	2,990.2	3,341.7	3,907.7
5	8	2,979.0	3,324.9	3,879.8
6	0	3,761.1	4,154.2	4,789.3
6	1	3,711.0	4,097.9	4,723.7
6	2	3,477.2	3,864.1	4,489.8
6	3	3,341.1	3,728.0	4,353.7
6	4	3,326.6	3,708.8	4,325.7
6	5	3,316.8	3,695.8	4,306.8
6	6	3,245.4	3,624.5	4,235.4
6	7	3,213.6	3,592.6	4,203.6
6	8	3,199.4	3,571.3	4,168.5
7	0	3,564.2	3,935.5	4,534.6
7	1	3,521.6	3,887.6	4,478.8
7	2	3,300.8	3,666.6	4,257.8
7	3	3,171.5	3,537.4	4,128.5
7	4	3,159.1	3,521.0	4,104.7
7	5	3,150.8	3,510.0	4,088.6
7	6	3,082.8	3,442.1	4,020.7
7	7	3,053.0	3,412.2	3,990.8
7	8	3,040.9	3,394.1	3,960.9
8	0	3,487.3	3,850.0	4,435.1

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/yr*		
		Small	Medium	Large
8	1	3,447.6	3,805.4	4,383.1
8	2	3,231.8	3,589.5	4,167.1
8	3	3,105.2	3,462.9	4,040.5
8	4	3,093.7	3,447.6	4,018.3
8	5	3,085.9	3,437.4	4,003.3
8	6	3,019.3	3,370.8	3,936.8
8	7	2,990.2	3,341.7	3,907.7
8	8	2,979.0	3,324.9	3,879.8

Table 7.5.6 Energy Consumption for WICF Freight Doors, Medium Temperature

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/yr*		
		Small	Medium	Large
0	0	224.7	370.6	421.2
0	1	194.2	333.0	376.2
0	2	168.7	264.4	307.7
0	3	159.2	249.8	287.8
0	4	145.6	229.0	259.7
0	5	124.8	206.7	237.3
0	6	115.6	192.6	218.2
0	7	52.8	175.8	201.4
0	8	29.2	143.1	168.6
0	9	N/A	46.5	59.0
1	0	190.6	316.4	355.9
1	1	166.9	287.1	320.8
1	2	143.9	222.6	256.3
1	3	136.4	211.2	240.8
1	4	125.8	195.0	218.9
1	5	107.0	176.2	200.1
1	6	99.8	165.2	185.2
1	7	41.1	151.0	170.9
1	8	22.8	121.1	141.0
1	9	N/A	36.3	45.9
2	0	180.2	299.8	335.9
2	1	158.5	273.1	303.9
2	2	136.3	209.8	240.6
2	3	129.5	199.4	226.4
2	4	119.8	184.6	206.4
2	5	101.5	166.9	188.7
2	6	95.0	156.9	175.1
2	7	37.5	143.4	161.6
2	8	20.8	114.4	132.6
2	9	N/A	33.1	42.0
3	0	171.7	286.3	319.5
3	1	151.7	261.6	290.0
3	2	130.1	199.3	227.7
3	3	123.8	189.7	214.7
3	4	114.9	176.1	196.2

Refrigeration System TSL Option	**Envelope Efficiency Level**	**AEC *kWh/yr***		
		Small	**Medium**	**Large**
3	5	97.0	159.3	179.4
3	6	91.0	150.0	166.8
3	7	34.6	137.2	154.0
3	8	19.2	108.9	125.7
3	9	N/A	30.5	38.7
4	0	155.1	259.8	287.6
4	1	138.4	239.2	262.9
4	2	118.0	178.9	202.6
4	3	112.7	170.9	191.7
4	4	105.3	159.5	176.3
4	5	88.3	144.4	161.2
4	6	83.3	136.7	150.7
4	7	28.9	125.0	139.1
4	8	16.0	98.2	112.2
4	9	N/A	25.5	32.3
5	0	148.3	249.1	274.7
5	1	132.9	230.1	252.0
5	2	113.0	170.6	192.4
5	3	108.2	163.2	182.4
5	4	101.3	152.8	168.2
5	5	84.8	138.4	153.8
5	6	80.2	131.3	144.2
5	7	26.6	120.1	133.0
5	8	14.7	93.9	106.8
5	9	N/A	23.5	29.7
6	0	163.0	272.5	302.9
6	1	144.7	250.0	275.9
6	2	123.8	188.7	214.6
6	3	118.0	179.9	202.7
6	4	109.9	167.5	185.9
6	5	92.5	151.5	169.9
6	6	87.0	143.1	158.4
6	7	31.7	130.9	146.2
6	8	17.5	103.3	118.7
6	9	N/A	27.9	35.4
7	0	149.3	250.7	276.6
7	1	133.8	231.5	253.6
7	2	113.8	171.9	194.0
7	3	108.9	164.4	183.8
7	4	101.9	153.8	169.4
7	5	85.3	139.3	154.9
7	6	80.6	132.1	145.2
7	7	27.0	120.9	133.9
7	8	14.9	94.5	107.6
7	9	N/A	23.8	30.1
8	0	148.3	249.1	274.7
8	1	132.9	230.1	252.0
8	2	113.0	170.6	192.4
8	3	108.2	163.2	182.4
8	4	101.3	152.8	168.2

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/yr*		
		Small	**Medium**	**Large**
8	5	84.8	138.4	153.8
8	6	80.2	131.3	144.2
8	7	26.6	120.1	133.0
8	8	14.7	93.9	106.8
8	9	N/A	23.5	29.7

Table 7.5.7 Energy Consumption for WICF Freight Doors, Low Temperature

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/yr*		
		Small	**Medium**	**Large**
0	0	6,249.6	8,353.5	9,516.7
0	1	6,143.3	8,222.2	9,359.7
0	2	5,872.9	7,668.2	8,805.7
0	3	5,717.6	7,394.0	8,531.3
0	4	5,664.0	7,311.3	8,419.6
0	5	5,627.8	7,255.6	8,344.4
0	6	5,546.9	7,113.1	8,201.8
0	7	5,509.4	7,042.7	8,131.4
0	8	5,437.3	6,923.4	7,965.3
1	0	5,686.8	7,590.3	8,637.4
1	1	5,602.1	7,485.7	8,512.3
1	2	5,356.6	6,976.9	8,003.5
1	3	5,214.5	6,731.7	7,758.2
1	4	5,171.8	6,665.8	7,669.2
1	5	5,143.0	6,621.5	7,609.2
1	6	5,068.6	6,491.5	7,479.3
1	7	5,035.0	6,428.7	7,416.5
1	8	4,977.6	6,333.7	7,284.1
2	0	5,432.4	7,245.3	8,239.9
2	1	5,357.4	7,152.7	8,129.2
2	2	5,123.3	6,664.3	7,640.8
2	3	4,987.1	6,432.3	7,408.7
2	4	4,949.3	6,374.0	7,330.0
2	5	4,923.8	6,334.8	7,276.9
2	6	4,852.5	6,210.5	7,152.7
2	7	4,820.6	6,151.2	7,093.3
2	8	4,769.8	6,067.1	6,976.2
3	0	5,296.7	7,061.2	8,027.8
3	1	5,226.9	6,975.1	7,924.8
3	2	4,998.8	6,497.6	7,447.3
3	3	4,865.8	6,272.6	7,222.2
3	4	4,830.6	6,218.3	7,148.9
3	5	4,806.9	6,181.8	7,099.6
3	6	4,737.1	6,060.6	6,978.4
3	7	4,706.1	6,003.1	6,920.9
3	8	4,658.9	5,924.9	6,811.9
4	0	5,106.3	6,803.1	7,730.4
4	1	5,043.8	6,726.0	7,638.2
4	2	4,824.2	6,263.7	7,176.0

Refrigeration System TSL Option	**Envelope Efficiency Level**	**AEC *kWh/yr***		
		Small	**Medium**	**Large**
4	3	4,695.6	6,048.6	6,960.7
4	4	4,664.1	6,000.0	6,895.1
4	5	4,642.9	5,967.3	6,850.9
4	6	4,575.4	5,850.4	6,734.0
4	7	4,545.7	5,795.5	6,679.1
4	8	4,503.4	5,725.4	6,581.5
5	0	5,023.9	6,691.3	7,601.7
5	1	4,964.6	6,618.1	7,514.1
5	2	4,748.6	6,162.5	7,058.5
5	3	4,622.0	5,951.6	6,847.5
5	4	4,592.1	5,905.5	6,785.2
5	5	4,571.9	5,874.4	6,743.3
5	6	4,505.3	5,759.4	6,628.2
5	7	4,476.2	5,705.6	6,574.4
5	8	4,436.0	5,639.0	6,481.7
6	0	5,429.2	7,240.9	8,234.8
6	1	5,354.3	7,148.5	8,124.3
6	2	5,120.3	6,660.3	7,636.2
6	3	4,984.2	6,428.5	7,404.2
6	4	4,946.5	6,370.3	7,325.6
6	5	4,921.0	6,331.1	7,272.7
6	6	4,849.7	6,206.9	7,148.5
6	7	4,817.8	6,147.7	7,089.2
6	8	4,767.1	6,063.7	6,972.3
7	0	5,137.7	6,845.7	7,779.6
7	1	5,074.1	6,767.1	7,685.5
7	2	4,853.0	6,302.4	7,220.8
7	3	4,723.7	6,085.6	7,003.9
7	4	4,691.6	6,036.1	6,937.1
7	5	4,670.0	6,002.7	6,892.0
7	6	4,602.1	5,885.1	6,774.4
7	7	4,572.2	5,829.8	6,719.0
7	8	4,529.1	5,758.4	6,619.6
8	0	5,023.9	6,691.3	7,601.7
8	1	4,964.6	6,618.1	7,514.1
8	2	4,748.6	6,162.5	7,058.5
8	3	4,622.0	5,951.6	6,847.5
8	4	4,592.1	5,905.5	6,785.2
8	5	4,571.9	5,874.4	6,743.3
8	6	4,505.3	5,759.4	6,628.2
8	7	4,476.2	5,705.6	6,574.4
8	8	4,436.0	5,639.0	6,481.7

Table 7.5.8 Energy Consumption for WICF Display Doors, Medium Temperature

Refrigeration System TSL Option	**Envelope Efficiency Level**	**AEC *kWh/yr***		
		Small	**Medium**	**Large**
0	0	950.4	1,086.0	1,384.5
0	1	636.9	772.5	981.5

Refrigeration System TSL Option	**Envelope Efficiency Level**	**AEC** ***kWh/yr***		
		Small	**Medium**	**Large**
0	2	322.9	357.2	423.3
0	3	297.3	324.5	380.7
0	4	228.6	255.8	306.1
0	5	207.6	228.8	270.7
0	6	140.1	140.2	152.2
1	0	892.5	1,020.0	1,300.8
1	1	597.4	725.0	921.5
1	2	301.9	334.1	396.2
1	3	278.5	304.1	356.9
1	4	213.9	239.5	286.7
1	5	194.6	214.6	253.9
1	6	131.4	131.4	142.7
2	0	874.7	999.8	1,275.3
2	1	585.4	710.4	903.2
2	2	295.5	327.0	387.9
2	3	272.8	297.9	349.7
2	4	209.4	234.5	280.8
2	5	190.6	210.2	248.8
2	6	128.8	128.8	139.8
3	0	860.2	983.3	1,254.3
3	1	575.5	698.5	888.2
3	2	290.3	321.2	381.1
3	3	268.1	292.7	343.7
3	4	205.7	230.4	275.9
3	5	187.3	206.6	244.6
3	6	126.6	126.6	137.5
4	0	832.0	951.1	1,213.5
4	1	556.2	675.3	859.0
4	2	280.0	310.0	367.9
4	3	258.9	282.8	332.1
4	4	198.5	222.4	266.5
4	5	181.0	199.7	236.4
4	6	122.3	122.4	132.9
5	0	820.5	938.0	1,196.9
5	1	548.4	665.9	847.1
5	2	275.8	305.4	362.5
5	3	255.2	278.7	327.4
5	4	195.6	219.1	262.6
5	5	178.4	196.8	233.1
5	6	120.6	120.6	131.0
6	0	845.5	966.5	1,233.0
6	1	565.4	686.4	873.0
6	2	284.9	315.4	374.2
6	3	263.3	287.5	337.7
6	4	201.9	226.2	271.0
6	5	184.0	203.0	240.4
6	6	124.4	124.4	135.1
7	0	822.2	939.9	1,199.3
7	1	549.5	667.3	848.8
7	2	276.5	306.1	363.3

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/yr*		
		Small	**Medium**	**Large**
7	3	255.7	279.3	328.1
7	4	196.0	219.6	263.2
7	5	178.8	197.2	233.6
7	6	120.9	120.9	131.3
8	0	820.5	938.0	1,196.9
8	1	548.4	665.9	847.1
8	2	275.8	305.4	362.5
8	3	255.2	278.7	327.4
8	4	195.6	219.1	262.6
8	5	178.4	196.8	233.1
8	6	120.6	120.6	131.0

Table 7.5.9 Energy Consumption for WICF Display Doors, Low Temperature

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/yr*		
		Small	**Medium**	**Large**
0	0	1,990.8	2,417.1	3,149.8
0	1	1,588.3	2,013.8	2,635.9
0	2	1,504.1	1,929.6	1,819.3
0	3	1,041.8	1,319.1	1,314.4
0	4	759.6	945.7	1,222.9
0	5	639.6	788.4	1,012.7
0	6	639.6	788.4	1,012.7
1	0	1,824.0	2,215.4	2,888.2
1	1	1,456.5	1,847.3	2,418.6
1	2	1,379.2	1,770.0	1,668.5
1	3	955.0	1,209.6	1,205.2
1	4	695.7	866.7	1,121.1
1	5	586.1	722.8	928.8
1	6	586.1	722.8	928.8
2	0	1,748.6	2,124.2	2,769.9
2	1	1,397.0	1,772.0	2,320.3
2	2	1,322.8	1,697.8	1,600.4
2	3	915.7	1,160.1	1,155.8
2	4	666.9	830.9	1,075.2
2	5	562.0	693.1	890.9
2	6	562.0	693.1	890.9
3	0	1,708.4	2,075.6	2,706.8
3	1	1,365.2	1,731.9	2,267.9
3	2	1,292.6	1,659.3	1,564.0
3	3	894.8	1,133.7	1,129.5
3	4	651.5	811.9	1,050.6
3	5	549.1	677.3	870.6
3	6	549.1	677.3	870.6
4	0	1,652.0	2,007.4	2,618.3
4	1	1,320.6	1,675.6	2,194.4
4	2	1,250.4	1,605.3	1,513.1
4	3	865.4	1,096.6	1,092.6
4	4	629.9	785.1	1,016.2

Refrigeration System TSL Option	Envelope Efficiency Level	AEC *kWh/yr*		
		Small	**Medium**	**Large**
4	5	531.0	655.1	842.2
4	6	531.0	655.1	842.2
5	0	1,627.5	1,977.8	2,580.0
5	1	1,301.3	1,651.2	2,162.6
5	2	1,232.1	1,581.9	1,491.0
5	3	852.7	1,080.6	1,076.6
5	4	620.6	773.5	1,001.3
5	5	523.2	645.5	830.0
5	6	523.2	645.5	830.0
6	0	1,747.7	2,123.1	2,768.4
6	1	1,396.2	1,771.1	2,319.1
6	2	1,322.0	1,696.9	1,599.5
6	3	915.2	1,159.5	1,155.2
6	4	666.5	830.5	1,074.6
6	5	561.7	692.7	890.4
6	6	561.7	692.7	890.4
7	0	1,661.3	2,018.6	2,632.9
7	1	1,328.0	1,684.9	2,206.6
7	2	1,257.4	1,614.2	1,521.5
7	3	870.3	1,102.8	1,098.7
7	4	633.5	789.5	1,021.9
7	5	534.0	658.8	846.9
7	6	534.0	658.8	846.9
8	0	1,627.5	1,977.8	2,580.0
8	1	1,301.3	1,651.2	2,162.6
8	2	1,232.1	1,581.9	1,491.0
8	3	852.7	1,080.6	1,076.6
8	4	620.6	773.5	1,001.3
8	5	523.2	645.5	830.0
8	6	523.2	645.5	830.0

Table 7.5.10 Capacity Weighted AEERs for Refrigeration TSL Options

Refrigeration System TSL Option	Capacity Weighted AEER	
	Medium Temp.	Low Temp.
0 (Baseline)	7.0	3.8
1	9.0	4.8
2	9.9	5.4
3	10.7	5.8
4	12.9	6.5
5	14.0	6.8
6	11.7	5.4
7	13.8	6.4
8	14.0	6.8

7.6 STATE-BY-STATE ANNUAL ENERGY CONSUMPTION

To account for regional variability in energy use with outdoor condenser systems, DOE calculated the average annual energy use for each WICF refrigeration system with outdoor condenser systems for all 237 typical meteorological year (TMY2) stations in the United States.[3] DOE mapped each TMY2 station to a certain state, based on its location. Within each state, DOE assigned a relative weight to each TMY2 station, based on the total population of identifiable population centers (cities, towns, other) that can be shown to be most climatically similar to the TMY2 location. The detailed methodology for developing the weighting factors is discussed in appendix 7A. The AEC data for the TMY2 locations were then weighted to obtain AEC data for each state. DOE expressed the state-wise AEC for each system analyzed as a percentage of the annual energy consumption derived using the average outdoor temperature bin conditions described in AHRI 1250-2009 (see Table 7.4.2). These state-wise results are shown in Table 7.6.1 through Table 7.6.14. These tables cover condensing units in capacity ranges from 6 to 18 kBtu/hr units only as subsequent analysis requiring state wise AEC excluded capacities larger than 18kBtu/hr.

Table 7.6.1 Energy Use Factors by State for Dedicated Condensing, Medium Temperature Outdoor Units (6 kBtu/hr Hermetic Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9
AEC (kWh/yr)	5,413	5,249	5,127	4,670	4,652	4,539	4,527	4,144	4,000	3,570
Location	-	-	-	-	-	-	-	-	-	-
AL	107%	108%	108%	109%	109%	109%	109%	109%	110%	107%
AK	85%	84%	84%	82%	82%	82%	82%	80%	79%	83%
AZ	114%	114%	115%	118%	118%	118%	118%	121%	123%	120%
AR	105%	106%	106%	106%	106%	106%	107%	107%	108%	106%
CA	106%	106%	106%	105%	105%	105%	105%	104%	104%	101%
CO	96%	96%	96%	95%	95%	95%	95%	94%	94%	95%
CT	97%	97%	97%	96%	96%	96%	96%	95%	95%	95%
DE	100%	100%	100%	99%	99%	99%	99%	99%	99%	98%
DC	100%	100%	100%	100%	100%	100%	100%	99%	99%	99%
FL	115%	115%	116%	118%	118%	118%	118%	120%	122%	118%
GA	106%	107%	107%	107%	107%	107%	107%	107%	108%	106%
HI	118%	118%	119%	122%	122%	122%	122%	125%	127%	123%
ID	95%	95%	95%	94%	94%	94%	94%	93%	93%	94%
IL	96%	96%	96%	95%	95%	95%	95%	95%	94%	95%
IN	98%	98%	98%	97%	97%	97%	97%	97%	96%	97%
IA	95%	95%	95%	94%	94%	94%	94%	93%	93%	94%
KS	100%	100%	100%	100%	100%	100%	100%	100%	101%	101%
KY	100%	100%	100%	100%	100%	100%	100%	99%	99%	99%
LA	110%	111%	111%	112%	112%	112%	112%	113%	114%	111%
ME	93%	92%	92%	91%	91%	90%	90%	89%	88%	90%
MD	100%	100%	100%	100%	100%	100%	100%	99%	99%	99%
MA	96%	96%	96%	95%	95%	95%	95%	94%	93%	94%
MI	95%	94%	94%	93%	93%	93%	93%	92%	91%	93%
MN	92%	92%	92%	91%	91%	90%	90%	90%	89%	91%
MS	107%	108%	108%	109%	109%	109%	109%	109%	110%	108%
MO	100%	101%	101%	101%	101%	101%	101%	101%	101%	100%
MT	92%	92%	92%	91%	91%	91%	91%	90%	89%	91%
NE	97%	97%	97%	96%	96%	96%	96%	96%	96%	96%
NV	105%	106%	106%	107%	107%	107%	107%	108%	109%	108%

Efficiency Level	0	1	2	3	4	5	6	7	8	9
AEC (kWh/yr)	5,413	5,249	5,127	4,670	4,652	4,539	4,527	4,144	4,000	3,570
Location	-	-	-	-	-	-	-	-	-	-
NH	93%	93%	92%	91%	91%	91%	91%	90%	90%	91%
NJ	99%	99%	99%	99%	99%	99%	99%	98%	98%	98%
NM	101%	101%	101%	101%	101%	101%	101%	101%	101%	100%
NY	98%	98%	98%	97%	97%	97%	97%	97%	96%	96%
NC	104%	104%	104%	104%	104%	104%	104%	104%	104%	102%
ND	91%	90%	90%	89%	89%	89%	89%	88%	87%	90%
OH	97%	96%	96%	95%	95%	95%	95%	95%	94%	95%
OK	104%	104%	104%	105%	105%	105%	105%	106%	106%	105%
OR	98%	98%	98%	97%	97%	97%	97%	95%	95%	94%
PA	98%	98%	97%	97%	97%	97%	97%	96%	96%	96%
RI	97%	96%	96%	95%	95%	95%	95%	94%	94%	94%
SC	106%	106%	106%	107%	107%	107%	107%	107%	107%	105%
SD	93%	93%	93%	92%	92%	92%	92%	91%	91%	93%
TN	104%	105%	105%	105%	105%	105%	105%	105%	106%	104%
TX	110%	110%	111%	112%	112%	112%	112%	113%	115%	112%
UT	98%	98%	98%	98%	98%	98%	98%	97%	97%	97%
VT	93%	92%	92%	91%	91%	91%	91%	90%	89%	91%
VA	101%	101%	101%	101%	101%	101%	101%	101%	101%	100%
WA	97%	96%	96%	95%	95%	95%	95%	93%	92%	92%
WV	99%	99%	99%	98%	98%	98%	98%	97%	97%	97%
WI	93%	93%	92%	91%	91%	91%	91%	90%	89%	91%
WY	92%	92%	92%	90%	90%	90%	90%	89%	88%	90%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.2 Energy Use Factors by State for Dedicated Condensing, Medium Temperature Outdoor Units (18 kBtu/hr Hermetic Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9
AEC (kWh/yr)	12,419	11,762	11,270	10,152	9,317	9,281	9,056	8,770	8,002	7,953
Location	-	-	-	-	-	-	-	-	-	-
AL	107%	108%	108%	109%	110%	110%	110%	111%	108%	108%
AK	85%	84%	83%	80%	79%	79%	79%	77%	82%	82%
AZ	113%	114%	115%	119%	122%	122%	122%	124%	121%	122%
AR	105%	106%	106%	107%	108%	108%	108%	108%	106%	106%
CA	106%	106%	107%	106%	105%	105%	105%	106%	101%	101%
CO	96%	96%	96%	95%	94%	94%	94%	93%	94%	94%
CT	97%	97%	97%	96%	95%	95%	95%	95%	95%	95%
DE	100%	100%	100%	99%	99%	99%	99%	99%	98%	98%
DC	100%	100%	100%	100%	100%	100%	100%	99%	99%	99%
FL	114%	115%	116%	120%	121%	121%	121%	123%	119%	119%
GA	106%	107%	107%	108%	108%	108%	108%	109%	106%	106%
HI	117%	118%	120%	124%	126%	126%	126%	128%	124%	124%
ID	95%	95%	95%	94%	93%	93%	93%	92%	93%	93%
IL	96%	96%	96%	95%	94%	94%	94%	94%	95%	95%
IN	98%	98%	98%	97%	97%	97%	97%	96%	97%	97%
IA	95%	95%	94%	93%	93%	93%	93%	92%	94%	94%
KS	100%	100%	100%	100%	101%	101%	101%	101%	101%	101%
KY	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%
LA	110%	111%	111%	113%	114%	114%	114%	115%	112%	112%
ME	93%	92%	92%	90%	89%	89%	89%	88%	89%	89%
MD	100%	100%	100%	100%	100%	100%	100%	99%	99%	99%
MA	97%	96%	96%	95%	94%	94%	94%	93%	93%	93%
MI	95%	94%	94%	93%	92%	92%	92%	91%	92%	92%
MN	92%	92%	91%	90%	89%	89%	89%	88%	91%	90%
MS	107%	108%	108%	110%	110%	110%	110%	111%	109%	109%
MO	100%	101%	101%	101%	101%	101%	101%	101%	100%	100%
MT	93%	92%	91%	90%	89%	89%	89%	88%	90%	90%
NE	97%	97%	97%	96%	96%	96%	96%	95%	96%	96%
NV	105%	105%	106%	107%	109%	109%	109%	110%	108%	108%
NH	93%	93%	92%	91%	90%	90%	90%	89%	91%	91%
NJ	99%	99%	99%	99%	98%	98%	98%	98%	98%	98%

Efficiency Level	0	1	2	3	4	5	6	7	8	9
AEC (kWh/yr)	12,419	11,762	11,270	10,152	9,317	9,281	9,056	8,770	8,002	7,953
Location	-	-	-	-	-	-	-	-	-	-
NM	101%	101%	101%	101%	101%	101%	101%	101%	100%	100%
NY	98%	98%	98%	97%	97%	97%	97%	96%	96%	96%
NC	104%	104%	104%	104%	104%	104%	104%	105%	103%	103%
ND	91%	90%	89%	88%	87%	87%	87%	86%	89%	89%
OH	97%	96%	96%	95%	94%	94%	94%	94%	94%	94%
OK	104%	104%	105%	105%	106%	106%	106%	106%	105%	105%
OR	98%	98%	98%	97%	96%	96%	96%	95%	94%	94%
PA	98%	98%	97%	97%	96%	96%	96%	96%	96%	96%
RI	97%	97%	96%	95%	94%	94%	94%	94%	94%	94%
SC	106%	106%	107%	107%	107%	107%	108%	108%	106%	106%
SD	94%	93%	92%	91%	91%	91%	91%	90%	92%	92%
TN	104%	105%	105%	106%	106%	106%	106%	106%	105%	105%
TX	85%	84%	83%	80%	79%	79%	79%	77%	82%	82%
UT	85%	84%	83%	80%	79%	79%	79%	77%	82%	82%
VT	85%	84%	83%	80%	79%	79%	79%	77%	82%	82%
VA	85%	84%	83%	80%	79%	79%	79%	77%	82%	82%
WA	85%	84%	83%	80%	79%	79%	79%	77%	82%	82%
WV	85%	84%	83%	80%	79%	79%	79%	77%	82%	82%
WI	85%	84%	83%	80%	79%	79%	79%	77%	82%	82%
WY	85%	84%	83%	80%	79%	79%	79%	77%	82%	82%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.3 Energy Use Factors by State for Dedicated Condensing, Medium Temperature Outdoor Units (18 kBtu/hr Scroll Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	10,768	10,111	9,619	8,436	7,772	7,536	7,238	6,645	6,595	6,192	6,182
Location	-	-	-	-	-	-	-	-	-	-	-
AL	110%	110%	111%	112%	112%	112%	113%	110%	110%	114%	114%
AK	80%	78%	77%	75%	73%	73%	70%	77%	77%	69%	69%
AZ	118%	120%	122%	126%	130%	131%	133%	128%	129%	135%	135%
AR	107%	108%	108%	109%	109%	110%	110%	108%	108%	111%	111%
CA	107%	107%	108%	106%	105%	105%	105%	100%	100%	105%	105%
CO	95%	94%	94%	93%	92%	92%	91%	93%	92%	91%	91%
CT	96%	96%	95%	94%	93%	93%	93%	93%	93%	92%	92%
DE	99%	99%	99%	98%	98%	98%	98%	97%	97%	98%	98%
DC	100%	100%	100%	99%	99%	99%	99%	98%	98%	99%	99%
FL	120%	121%	123%	126%	128%	128%	130%	125%	125%	132%	132%
GA	108%	109%	110%	110%	110%	110%	111%	108%	108%	111%	111%
HI	124%	126%	128%	132%	134%	135%	137%	131%	131%	140%	140%
ID	93%	93%	92%	91%	91%	90%	90%	91%	91%	89%	89%
IL	95%	94%	94%	93%	92%	92%	92%	93%	93%	91%	91%
IN	97%	97%	97%	96%	95%	95%	95%	95%	95%	94%	94%
IA	93%	93%	92%	91%	91%	91%	90%	92%	92%	89%	89%
KS	100%	100%	100%	101%	101%	101%	101%	101%	101%	101%	101%
KY	100%	100%	100%	99%	99%	99%	99%	98%	98%	98%	98%
LA	113%	115%	116%	117%	118%	118%	120%	115%	115%	121%	121%
ME	90%	89%	88%	86%	85%	85%	84%	86%	86%	83%	83%
MD	100%	100%	100%	99%	99%	99%	99%	98%	98%	99%	99%
MA	95%	94%	94%	92%	91%	91%	90%	91%	91%	89%	90%
MI	93%	92%	91%	90%	89%	89%	88%	90%	90%	87%	87%
MN	90%	89%	88%	87%	86%	86%	85%	88%	88%	84%	84%
MS	110%	111%	111%	112%	113%	113%	114%	111%	111%	115%	115%
MO	101%	101%	101%	101%	101%	101%	101%	101%	101%	101%	101%
MT	90%	89%	88%	87%	86%	86%	84%	87%	87%	83%	84%
NE	96%	96%	95%	95%	94%	94%	94%	95%	95%	94%	94%
NV	107%	108%	108%	110%	112%	112%	113%	111%	111%	114%	114%
NH	91%	90%	89%	88%	87%	87%	85%	88%	88%	85%	85%
NJ	99%	99%	99%	98%	97%	97%	97%	97%	97%	97%	97%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	10,768	10,111	9,619	8,436	7,772	7,536	7,238	6,645	6,595	6,192	6,182
Location	-	-	-	-	-	-	-	-	-	-	-
NM	101%	102%	102%	101%	101%	101%	101%	100%	100%	101%	101%
NY	97%	97%	97%	96%	95%	95%	95%	95%	95%	94%	94%
NC	105%	105%	105%	105%	105%	105%	105%	103%	103%	105%	105%
ND	88%	86%	85%	84%	84%	83%	82%	86%	86%	81%	81%
OH	95%	95%	94%	93%	92%	92%	91%	92%	92%	91%	91%
OK	105%	106%	106%	107%	108%	108%	108%	107%	107%	109%	109%
OR	97%	97%	96%	94%	93%	93%	92%	91%	91%	91%	91%
PA	97%	96%	96%	95%	94%	94%	94%	94%	94%	93%	93%
RI	95%	95%	94%	93%	92%	92%	91%	92%	92%	90%	90%
SC	108%	108%	109%	109%	109%	109%	110%	107%	107%	110%	110%
SD	91%	90%	90%	89%	88%	88%	87%	90%	90%	87%	87%
TN	106%	106%	107%	107%	107%	107%	108%	106%	106%	108%	108%
TX	113%	114%	115%	117%	118%	119%	120%	116%	116%	121%	121%
UT	97%	97%	97%	96%	96%	96%	96%	96%	96%	96%	96%
VT	90%	89%	88%	87%	86%	86%	85%	87%	87%	84%	84%
VA	101%	102%	102%	101%	101%	101%	101%	99%	99%	100%	100%
WA	95%	94%	94%	91%	90%	90%	89%	89%	88%	88%	88%
WV	98%	98%	98%	97%	96%	96%	96%	95%	95%	95%	95%
WI	90%	90%	89%	87%	87%	86%	85%	88%	88%	84%	84%
WY	90%	89%	88%	86%	85%	85%	84%	87%	87%	83%	83%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.4 Energy Use Factors by State for Dedicated Condensing, Medium Temperature Outdoor Units (54 kBtu/hr Scroll Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11
AEC (kWh/yr)	34,969	32,502	30,652	27,253	25,036	24,447	23,707	20,119	19,032	18,850	16,398	16,374
Location	-	-	-	-	-	-	-	-	-	-	-	-
AL	108%	109%	110%	111%	111%	111%	112%	109%	112%	113%	110%	110%
AK	83%	81%	79%	77%	76%	76%	74%	79%	72%	72%	76%	77%
AZ	116%	118%	120%	124%	127%	128%	129%	126%	131%	131%	128%	128%
AR	106%	107%	108%	108%	109%	109%	109%	107%	110%	110%	108%	108%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11
AEC (kWh/yr)	34,969	32,502	30,652	27,253	25,036	24,447	23,707	20,119	19,032	18,850	16,398	16,374
Location	-	-	-	-	-	-	-	-	-	-	-	-
CA	106%	106%	107%	105%	104%	104%	104%	100%	104%	104%	102%	102%
CO	95%	95%	94%	93%	93%	93%	92%	93%	92%	92%	93%	93%
CT	97%	96%	96%	95%	94%	94%	93%	94%	93%	93%	93%	93%
DE	99%	99%	99%	99%	98%	98%	98%	98%	98%	98%	98%	98%
DC	100%	100%	100%	99%	99%	99%	99%	98%	99%	99%	98%	99%
FL	117%	119%	121%	123%	125%	125%	127%	122%	129%	129%	125%	125%
GA	107%	108%	109%	109%	109%	109%	110%	107%	110%	110%	108%	108%
HI	121%	123%	125%	129%	131%	131%	133%	128%	135%	136%	131%	131%
ID	94%	94%	93%	92%	91%	91%	91%	92%	90%	90%	91%	91%
IL	96%	95%	95%	94%	93%	93%	93%	94%	92%	92%	93%	93%
IN	98%	97%	97%	96%	96%	96%	95%	96%	95%	95%	95%	95%
IA	94%	94%	93%	92%	92%	92%	91%	93%	90%	90%	92%	92%
KS	100%	100%	100%	101%	101%	101%	101%	101%	101%	101%	101%	101%
KY	100%	100%	100%	99%	99%	99%	99%	98%	99%	99%	98%	98%
LA	112%	113%	114%	115%	116%	116%	117%	114%	118%	118%	116%	116%
ME	91%	90%	89%	88%	87%	86%	85%	88%	84%	84%	86%	86%
MD	100%	100%	100%	99%	99%	99%	99%	98%	99%	99%	98%	99%
MA	95%	95%	94%	93%	92%	92%	91%	92%	91%	91%	91%	91%
MI	93%	93%	92%	91%	90%	90%	89%	91%	88%	88%	90%	90%
MN	91%	90%	89%	88%	87%	87%	86%	89%	86%	86%	88%	88%
MS	109%	109%	110%	111%	112%	112%	112%	110%	113%	113%	111%	111%
MO	101%	101%	101%	101%	101%	101%	101%	100%	101%	101%	101%	101%
MT	91%	90%	89%	88%	87%	87%	86%	89%	85%	85%	87%	87%
NE	96%	96%	96%	95%	95%	95%	95%	96%	94%	94%	95%	95%
NV	106%	107%	108%	109%	111%	111%	111%	110%	112%	112%	111%	111%
NH	92%	91%	90%	89%	88%	88%	87%	89%	86%	86%	88%	88%
NJ	99%	99%	99%	98%	97%	97%	97%	97%	97%	97%	97%	97%
NM	101%	101%	101%	101%	101%	101%	101%	100%	101%	101%	100%	100%
NY	98%	97%	97%	96%	95%	95%	95%	95%	95%	95%	95%	95%
NC	104%	104%	105%	104%	104%	104%	104%	102%	105%	105%	103%	103%
ND	89%	88%	87%	86%	85%	85%	84%	88%	83%	83%	86%	86%
OH	96%	95%	95%	94%	93%	93%	92%	93%	92%	92%	93%	93%
OK	105%	105%	106%	106%	107%	107%	107%	106%	108%	108%	107%	107%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11
AEC (kWh/yr)	34,969	32,502	30,652	27,253	25,036	24,447	23,707	20,119	19,032	18,850	16,398	16,374
Location	-	-	-	-	-	-	-	-	-	-	-	-
OR	97%	97%	97%	95%	93%	93%	93%	92%	92%	92%	92%	92%
PA	97%	97%	96%	95%	95%	95%	94%	95%	94%	94%	94%	94%
RI	96%	95%	95%	93%	92%	92%	92%	92%	91%	91%	92%	92%
SC	107%	107%	108%	108%	108%	108%	109%	106%	109%	109%	107%	107%
SD	92%	91%	91%	90%	90%	90%	89%	91%	88%	88%	90%	90%
TN	105%	105%	106%	106%	106%	106%	107%	105%	107%	107%	106%	106%
TX	112%	113%	114%	115%	117%	117%	118%	115%	119%	119%	117%	116%
UT	98%	97%	97%	97%	97%	97%	96%	97%	96%	96%	96%	96%
VT	91%	90%	90%	88%	87%	87%	86%	89%	85%	85%	87%	87%
VA	101%	101%	101%	101%	100%	100%	100%	100%	100%	100%	100%	100%
WA	95%	95%	94%	92%	91%	90%	90%	90%	89%	89%	89%	89%
WV	99%	98%	98%	97%	96%	96%	96%	96%	96%	96%	96%	96%
WI	92%	91%	90%	89%	88%	88%	87%	89%	86%	86%	88%	88%
WY	91%	90%	89%	88%	87%	86%	86%	88%	85%	85%	87%	87%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.5 Energy Use Factors by State for Dedicated Condensing, Medium Temperature Outdoor Units (6 kBtu/hr Semi-Hermetic Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9
AEC (kWh/yr)	4,567	4,403	4,280	3,829	3,811	3,699	3,687	3,378	3,238	2,805
Location	-	-	-	-	-	-	-	-	-	-
AL	107%	108%	108%	108%	108%	109%	109%	109%	110%	108%
AK	85%	84%	83%	82%	82%	82%	82%	80%	78%	82%
AZ	114%	114%	115%	118%	118%	119%	119%	122%	124%	122%
AR	105%	106%	106%	106%	106%	106%	106%	107%	108%	106%
CA	106%	106%	106%	104%	104%	104%	104%	103%	104%	100%
CO	96%	96%	96%	95%	95%	95%	95%	94%	94%	94%
CT	97%	97%	97%	96%	96%	96%	96%	95%	95%	95%
DE	100%	100%	100%	99%	99%	99%	99%	99%	98%	98%
DC	100%	100%	100%	100%	100%	100%	100%	99%	99%	99%
FL	115%	116%	116%	118%	118%	118%	118%	120%	122%	119%
GA	106%	107%	107%	107%	107%	107%	107%	107%	108%	106%
HI	118%	119%	120%	122%	122%	123%	123%	125%	128%	124%
ID	95%	95%	95%	94%	94%	94%	94%	93%	92%	93%
IL	96%	96%	96%	95%	95%	95%	95%	95%	94%	95%
IN	98%	98%	98%	97%	97%	97%	97%	97%	96%	96%
IA	95%	95%	94%	94%	94%	94%	94%	93%	92%	94%
KS	100%	100%	100%	100%	100%	100%	100%	101%	101%	101%
KY	100%	100%	100%	100%	100%	100%	100%	99%	99%	99%
LA	110%	111%	111%	112%	112%	112%	112%	113%	114%	112%
ME	92%	92%	92%	90%	90%	90%	90%	89%	88%	89%
MD	100%	100%	100%	100%	100%	100%	100%	99%	99%	99%
MA	96%	96%	96%	95%	95%	95%	95%	93%	93%	93%
MI	94%	94%	94%	93%	93%	93%	93%	92%	91%	92%
MN	92%	92%	91%	91%	91%	90%	90%	90%	89%	91%
MS	107%	108%	108%	109%	109%	109%	109%	109%	110%	108%
MO	100%	101%	101%	101%	101%	101%	101%	101%	101%	100%
MT	92%	92%	91%	91%	91%	90%	90%	90%	88%	90%
NE	97%	97%	97%	96%	96%	96%	96%	96%	95%	96%
NV	105%	106%	106%	107%	107%	107%	107%	109%	110%	109%
NH	93%	93%	92%	91%	91%	91%	91%	90%	89%	91%
NJ	99%	99%	99%	99%	99%	99%	99%	98%	98%	97%

Efficiency Level	0	1	2	3	4	5	6	7	8	9
AEC (kWh/yr)	4,567	4,403	4,280	3,829	3,811	3,699	3,687	3,378	3,238	2,805
Location	-	-	-	-	-	-	-	-	-	-
NM	101%	101%	101%	101%	101%	101%	101%	101%	101%	100%
NY	98%	98%	98%	97%	97%	97%	97%	96%	96%	96%
NC	104%	104%	104%	104%	104%	104%	104%	103%	104%	102%
ND	90%	90%	89%	89%	89%	89%	89%	88%	87%	89%
OH	97%	96%	96%	95%	95%	95%	95%	94%	94%	94%
OK	104%	104%	105%	105%	105%	105%	105%	106%	106%	105%
OR	98%	98%	98%	96%	96%	96%	96%	95%	94%	93%
PA	98%	97%	97%	97%	97%	96%	96%	96%	95%	95%
RI	97%	96%	96%	95%	95%	95%	95%	94%	93%	93%
SC	106%	106%	106%	106%	106%	106%	106%	107%	107%	105%
SD	93%	93%	93%	92%	92%	92%	92%	92%	91%	92%
TN	104%	105%	105%	105%	105%	105%	105%	105%	106%	104%
TX	110%	111%	111%	112%	112%	112%	112%	114%	115%	113%
UT	98%	98%	98%	98%	98%	98%	98%	97%	97%	97%
VT	93%	92%	92%	91%	91%	91%	91%	90%	89%	90%
VA	101%	101%	101%	101%	101%	101%	101%	100%	100%	100%
WA	97%	96%	96%	94%	94%	94%	94%	93%	92%	91%
WV	99%	99%	99%	98%	98%	98%	98%	97%	97%	96%
WI	93%	92%	92%	91%	91%	91%	91%	90%	89%	91%
WY	92%	92%	91%	90%	90%	90%	90%	89%	88%	90%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.6 Energy Use Factors by State for Dedicated Condensing, Medium Temperature Outdoor Units (18 kBtu/hr Semi-Hermetic Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9
AEC (kWh/yr)	12,669	12,012	11,520	10,170	9,333	9,297	9,074	8,796	8,077	8,029
Location	-	-	-	-	-	-	-	-	-	-
AL	108%	109%	109%	109%	110%	110%	110%	111%	108%	108%
AK	84%	83%	81%	80%	78%	78%	78%	77%	82%	82%
AZ	114%	116%	117%	121%	124%	124%	124%	126%	123%	123%
AR	106%	106%	107%	107%	108%	108%	108%	108%	106%	106%
CA	106%	106%	107%	105%	104%	104%	104%	104%	100%	100%
CO	96%	95%	95%	94%	94%	94%	94%	93%	94%	94%
CT	97%	97%	97%	95%	95%	95%	95%	94%	95%	95%
DE	100%	100%	100%	99%	98%	98%	98%	98%	98%	98%
DC	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%
FL	116%	117%	118%	120%	122%	122%	122%	124%	120%	120%
GA	107%	107%	108%	108%	108%	108%	108%	109%	106%	106%
HI	119%	120%	122%	125%	127%	127%	127%	129%	125%	125%
ID	95%	94%	94%	93%	93%	92%	92%	92%	93%	93%
IL	96%	96%	95%	95%	94%	94%	94%	93%	95%	95%
IN	98%	98%	98%	97%	96%	96%	96%	96%	96%	96%
IA	95%	94%	94%	93%	93%	93%	92%	92%	94%	93%
KS	100%	100%	100%	100%	101%	101%	101%	101%	101%	101%
KY	100%	100%	100%	99%	99%	99%	99%	99%	98%	98%
LA	111%	112%	112%	113%	114%	114%	114%	116%	112%	112%
ME	92%	91%	91%	89%	88%	88%	88%	87%	89%	89%
MD	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%
MA	96%	96%	95%	94%	93%	93%	93%	92%	93%	93%
MI	94%	94%	93%	92%	91%	91%	91%	90%	92%	92%
MN	92%	91%	90%	89%	89%	89%	89%	88%	91%	91%
MS	108%	109%	109%	110%	110%	110%	110%	111%	109%	109%
MO	101%	101%	101%	101%	101%	101%	101%	101%	100%	100%
MT	92%	91%	91%	89%	89%	89%	88%	88%	90%	90%
NE	97%	97%	96%	96%	96%	96%	95%	95%	96%	96%
NV	106%	106%	107%	108%	109%	109%	110%	110%	109%	109%
NH	93%	92%	91%	90%	89%	89%	89%	88%	91%	91%
NJ	99%	99%	99%	98%	98%	98%	98%	98%	97%	97%

Efficiency Level	0	1	2	3	4	5	6	7	8	9
AEC (kWh/yr)	12,669	12,012	11,520	10,170	9,333	9,297	9,074	8,796	8,077	8,029
Location	-	-	-	-	-	-	-	-	-	-
NM	101%	101%	101%	101%	101%	101%	101%	101%	100%	100%
NY	98%	98%	98%	97%	96%	96%	96%	96%	96%	96%
NC	104%	104%	104%	104%	104%	104%	104%	104%	102%	102%
ND	90%	89%	88%	88%	87%	87%	87%	86%	89%	89%
OH	96%	96%	96%	95%	94%	94%	94%	93%	94%	94%
OK	104%	105%	105%	106%	106%	106%	106%	107%	105%	105%
OR	98%	98%	98%	96%	94%	94%	94%	94%	93%	93%
PA	97%	97%	97%	96%	95%	95%	95%	95%	95%	95%
RI	96%	96%	96%	94%	93%	93%	93%	93%	93%	93%
SC	106%	107%	107%	107%	107%	107%	107%	108%	105%	105%
SD	93%	92%	92%	91%	91%	91%	91%	90%	92%	92%
TN	105%	105%	105%	105%	106%	106%	106%	106%	104%	104%
TX	111%	111%	112%	114%	115%	115%	115%	116%	113%	113%
UT	98%	98%	98%	97%	97%	97%	97%	97%	97%	97%
VT	92%	91%	91%	90%	89%	89%	89%	88%	90%	90%
VA	101%	101%	101%	101%	100%	100%	100%	101%	100%	100%
WA	96%	96%	96%	93%	92%	92%	92%	91%	91%	91%
WV	99%	99%	99%	98%	97%	97%	97%	97%	96%	96%
WI	92%	92%	91%	90%	89%	89%	89%	88%	91%	91%
WY	92%	91%	90%	89%	88%	88%	88%	87%	90%	89%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.7 Energy Use Factors by State for Dedicated Condensing, Medium Temperature Outdoor Units (54 kBtu/hr Semi-Hermetic Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	33,144	30,678	28,827	25,328	23,262	22,677	21,948	20,382	20,198	17,633	17,610
Location	-	-	-	-	-	-	-	-	-	-	-
AL	107%	108%	109%	110%	110%	110%	111%	108%	108%	106%	106%
AK	85%	83%	81%	79%	78%	77%	76%	82%	81%	86%	86%
AZ	114%	116%	117%	121%	125%	125%	127%	123%	123%	120%	119%
AR	106%	106%	107%	107%	108%	108%	109%	106%	106%	105%	105%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	33,144	30,678	28,827	25,328	23,262	22,677	21,948	20,382	20,198	17,633	17,610
Location	-	-	-	-	-	-	-	-	-	-	-
CA	106%	106%	107%	105%	104%	104%	105%	100%	100%	98%	98%
CO	96%	95%	95%	94%	93%	93%	93%	94%	94%	95%	95%
CT	97%	97%	97%	95%	94%	94%	94%	94%	94%	95%	95%
DE	100%	100%	100%	99%	98%	98%	98%	98%	98%	98%	98%
DC	100%	100%	100%	100%	99%	99%	99%	99%	99%	98%	98%
FL	115%	117%	118%	121%	123%	123%	125%	120%	120%	116%	116%
GA	106%	107%	108%	108%	108%	108%	109%	106%	106%	104%	104%
HI	118%	120%	122%	126%	128%	128%	130%	125%	125%	120%	120%
ID	95%	94%	94%	93%	92%	92%	92%	93%	93%	94%	94%
IL	96%	96%	95%	94%	94%	94%	93%	95%	94%	95%	95%
IN	98%	98%	97%	97%	96%	96%	96%	96%	96%	97%	97%
IA	95%	94%	94%	93%	92%	92%	92%	93%	93%	95%	95%
KS	100%	100%	100%	100%	101%	101%	101%	101%	101%	101%	101%
KY	100%	100%	100%	99%	99%	99%	99%	98%	98%	98%	98%
LA	110%	112%	113%	114%	115%	115%	116%	112%	112%	109%	109%
ME	92%	91%	91%	89%	88%	88%	87%	89%	89%	91%	91%
MD	100%	100%	100%	100%	99%	99%	99%	99%	99%	98%	98%
MA	96%	96%	95%	94%	93%	93%	92%	93%	93%	93%	93%
MI	94%	94%	93%	92%	91%	91%	90%	92%	92%	93%	93%
MN	92%	91%	90%	89%	88%	88%	87%	90%	90%	93%	93%
MS	108%	108%	109%	110%	111%	111%	112%	109%	109%	106%	106%
MO	101%	101%	101%	101%	101%	101%	101%	100%	100%	100%	100%
MT	92%	91%	90%	89%	88%	88%	87%	90%	90%	92%	92%
NE	97%	97%	96%	96%	95%	95%	95%	96%	96%	97%	97%
NV	105%	106%	107%	108%	110%	110%	111%	109%	109%	107%	107%
NH	93%	92%	91%	90%	89%	89%	88%	91%	91%	92%	93%
NJ	99%	99%	99%	98%	98%	98%	98%	97%	97%	97%	97%
NM	101%	101%	102%	101%	101%	101%	101%	100%	100%	100%	100%
NY	98%	98%	98%	97%	96%	96%	96%	96%	96%	96%	96%
NC	104%	104%	105%	104%	104%	104%	104%	102%	102%	101%	101%
ND	90%	89%	88%	87%	86%	86%	85%	89%	89%	92%	92%
OH	96%	96%	96%	94%	94%	94%	93%	94%	94%	95%	95%
OK	104%	105%	105%	106%	106%	106%	107%	105%	105%	104%	104%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	33,144	30,678	28,827	25,328	23,262	22,677	21,948	20,382	20,198	17,633	17,610
Location	-	-	-	-	-	-	-	-	-	-	-
OR	98%	98%	98%	96%	94%	94%	94%	93%	93%	93%	93%
PA	98%	97%	97%	96%	95%	95%	95%	95%	95%	96%	96%
RI	96%	96%	96%	94%	93%	93%	93%	93%	93%	94%	94%
SC	106%	107%	107%	107%	107%	108%	108%	105%	105%	104%	103%
SD	93%	92%	92%	91%	90%	90%	89%	92%	92%	94%	94%
TN	104%	105%	105%	106%	106%	106%	106%	104%	104%	103%	103%
TX	110%	111%	112%	114%	115%	115%	117%	113%	113%	110%	110%
UT	98%	98%	98%	97%	97%	97%	97%	97%	97%	98%	98%
VT	92%	92%	91%	89%	88%	88%	87%	90%	90%	92%	92%
VA	101%	101%	102%	101%	101%	101%	101%	100%	100%	99%	99%
WA	97%	96%	96%	93%	92%	92%	91%	91%	91%	91%	91%
WV	99%	99%	99%	98%	97%	97%	97%	96%	96%	96%	96%
WI	93%	92%	91%	90%	89%	89%	88%	90%	90%	92%	92%
WY	92%	91%	90%	89%	88%	88%	87%	89%	89%	91%	92%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.8 Energy Use Factors by State for Dedicated Condensing, Low Temperature Outdoor Units (6 kBtu/hr Hermetic Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	10,533	10,230	10,003	9,467	8,483	8,445	8,428	8,185	7,873	7,819	7,798
Location	-	-	-	-	-	-	-	-	-	-	-
AL	105%	105%	106%	105%	106%	106%	106%	106%	106%	107%	105%
AK	90%	89%	88%	89%	87%	87%	87%	87%	86%	85%	89%
AZ	109%	110%	110%	111%	115%	115%	115%	115%	117%	117%	114%
AR	104%	104%	104%	104%	105%	105%	105%	105%	105%	105%	104%
CA	104%	104%	104%	103%	102%	102%	102%	102%	102%	102%	100%
CO	97%	97%	97%	97%	96%	96%	96%	96%	96%	96%	96%
CT	98%	98%	98%	98%	97%	97%	97%	97%	96%	96%	97%
DE	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%	99%
DC	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%
FL	110%	111%	111%	111%	113%	113%	113%	113%	115%	115%	112%
GA	104%	105%	105%	104%	105%	105%	105%	105%	105%	105%	103%
HI	112%	113%	114%	114%	116%	116%	116%	116%	118%	119%	114%
ID	97%	96%	96%	96%	95%	95%	95%	95%	95%	95%	96%
IL	97%	97%	97%	97%	96%	96%	96%	96%	96%	96%	97%
IN	99%	99%	98%	98%	98%	98%	98%	98%	97%	97%	98%
IA	97%	96%	96%	96%	96%	96%	96%	96%	95%	95%	96%
KS	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
KY	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%
LA	107%	107%	108%	107%	108%	108%	108%	108%	110%	110%	107%
ME	95%	95%	94%	94%	93%	93%	93%	93%	92%	92%	94%
MD	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%
MA	97%	97%	97%	97%	96%	96%	96%	96%	95%	95%	96%
MI	96%	96%	96%	96%	95%	95%	95%	95%	94%	94%	95%
MN	95%	94%	94%	94%	93%	93%	93%	93%	92%	92%	94%
MS	105%	105%	106%	105%	106%	106%	106%	106%	107%	107%	105%
MO	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
MT	95%	94%	94%	94%	93%	93%	93%	93%	92%	92%	94%
NE	98%	98%	98%	98%	97%	97%	97%	97%	97%	97%	98%
NV	104%	104%	104%	104%	106%	106%	106%	106%	107%	107%	105%
NH	95%	95%	95%	95%	94%	94%	94%	94%	93%	93%	95%
NJ	100%	100%	100%	99%	99%	99%	99%	99%	98%	98%	98%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	10,533	10,230	10,003	9,467	8,483	8,445	8,428	8,185	7,873	7,819	7,798
Location	-	-	-	-	-	-	-	-	-	-	-
NM	101%	101%	101%	101%	100%	100%	100%	100%	100%	100%	100%
NY	99%	99%	99%	98%	97%	97%	97%	97%	97%	97%	97%
NC	103%	103%	103%	102%	102%	102%	102%	102%	102%	102%	101%
ND	93%	93%	93%	93%	92%	92%	92%	92%	91%	91%	94%
OH	98%	97%	97%	97%	96%	96%	96%	96%	96%	96%	96%
OK	103%	103%	103%	103%	104%	104%	104%	104%	104%	104%	103%
OR	99%	99%	99%	98%	96%	96%	96%	96%	96%	96%	96%
PA	98%	98%	98%	98%	97%	97%	97%	97%	97%	97%	97%
RI	98%	97%	97%	97%	96%	96%	96%	96%	95%	95%	96%
SC	104%	104%	105%	104%	104%	104%	104%	104%	105%	105%	103%
SD	95%	95%	95%	95%	95%	95%	95%	95%	94%	94%	96%
TN	103%	103%	103%	103%	103%	103%	103%	103%	104%	104%	103%
TX	107%	107%	108%	107%	109%	109%	109%	109%	110%	110%	108%
UT	99%	99%	99%	99%	98%	98%	98%	98%	98%	98%	98%
VT	95%	95%	94%	94%	93%	93%	93%	93%	92%	92%	94%
VA	101%	101%	101%	101%	100%	100%	100%	100%	100%	100%	100%
WA	98%	98%	97%	96%	95%	95%	95%	95%	94%	94%	95%
WV	99%	99%	99%	99%	98%	98%	98%	98%	98%	98%	98%
WI	95%	95%	95%	95%	93%	93%	94%	94%	93%	93%	94%
WY	95%	94%	94%	94%	93%	93%	93%	93%	92%	92%	94%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.9 Energy Use Factors by State for Dedicated Condensing, Low Temperature Outdoor Units (9 kBtu/hr Hermetic Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	13,996	13,694	13,468	12,677	11,350	11,311	11,066	10,752	10,733	10,036	9,977
Location	-	-	-	-	-	-	-	-	-	-	-
AL	106%	106%	106%	106%	106%	106%	106%	107%	107%	106%	106%
AK	88%	88%	87%	88%	86%	86%	86%	85%	85%	87%	87%
AZ	110%	111%	111%	112%	116%	116%	116%	117%	117%	116%	116%
AR	104%	104%	105%	104%	105%	105%	105%	105%	105%	104%	104%
CA	105%	105%	105%	103%	102%	102%	102%	102%	102%	100%	100%
CO	97%	97%	97%	97%	96%	96%	96%	95%	95%	96%	96%
CT	98%	98%	98%	97%	96%	96%	96%	96%	96%	96%	96%
DE	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%	99%
DC	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%
FL	111%	112%	112%	112%	114%	114%	114%	116%	116%	114%	114%
GA	105%	105%	105%	105%	105%	105%	105%	106%	106%	104%	104%
HI	114%	114%	115%	115%	118%	118%	118%	119%	119%	117%	117%
ID	96%	96%	96%	96%	95%	95%	95%	95%	95%	95%	95%
IL	97%	97%	97%	97%	96%	96%	96%	96%	96%	96%	96%
IN	98%	98%	98%	98%	97%	97%	97%	97%	97%	97%	97%
IA	96%	96%	96%	96%	95%	95%	95%	95%	95%	95%	95%
KS	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
KY	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%
LA	108%	108%	108%	108%	109%	109%	109%	110%	110%	108%	108%
ME	94%	94%	94%	94%	92%	92%	92%	91%	91%	92%	92%
MD	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%
MA	97%	97%	97%	96%	95%	95%	95%	95%	95%	95%	95%
MI	96%	96%	95%	95%	94%	94%	94%	94%	94%	94%	94%
MN	94%	94%	93%	94%	93%	93%	93%	92%	92%	93%	93%
MS	106%	106%	106%	106%	107%	107%	107%	107%	107%	106%	106%
MO	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
MT	94%	94%	94%	94%	93%	93%	93%	92%	92%	93%	93%
NE	98%	98%	97%	98%	97%	97%	97%	97%	97%	97%	97%
NV	104%	104%	104%	105%	106%	106%	106%	107%	107%	106%	106%
NH	95%	94%	94%	94%	93%	93%	93%	92%	92%	93%	93%
NJ	100%	100%	100%	99%	98%	98%	98%	98%	98%	98%	98%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	13,996	13,694	13,468	12,677	11,350	11,311	11,066	10,752	10,733	10,036	9,977
Location	-	-	-	-	-	-	-	-	-	-	-
NM	101%	101%	101%	101%	100%	100%	101%	101%	101%	100%	100%
NY	99%	99%	99%	98%	97%	97%	97%	97%	97%	97%	97%
NC	103%	103%	103%	103%	102%	102%	102%	103%	103%	102%	102%
ND	93%	92%	92%	92%	92%	92%	92%	91%	91%	92%	92%
OH	97%	97%	97%	97%	96%	96%	96%	96%	96%	96%	96%
OK	103%	103%	103%	103%	104%	104%	104%	104%	104%	104%	104%
OR	99%	99%	99%	98%	96%	96%	96%	96%	96%	95%	95%
PA	98%	98%	98%	98%	97%	97%	97%	97%	97%	97%	97%
RI	97%	97%	97%	97%	96%	96%	96%	95%	95%	95%	95%
SC	105%	105%	105%	104%	105%	105%	105%	105%	105%	104%	104%
SD	95%	95%	94%	95%	94%	94%	94%	93%	93%	95%	95%
TN	103%	104%	104%	103%	104%	104%	104%	104%	104%	103%	103%
TX	108%	108%	108%	108%	110%	110%	110%	111%	111%	109%	109%
UT	99%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
VT	94%	94%	94%	94%	93%	93%	93%	92%	92%	93%	93%
VA	101%	101%	101%	101%	100%	100%	100%	100%	100%	100%	100%
WA	98%	97%	97%	96%	95%	95%	95%	94%	94%	94%	94%
WV	99%	99%	99%	99%	98%	98%	98%	98%	98%	97%	97%
WI	94%	94%	94%	94%	93%	93%	93%	92%	92%	93%	93%
WY	94%	94%	93%	93%	92%	92%	92%	92%	92%	93%	93%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.10 Energy Use Factors by State for Dedicated Condensing, Low Temperature Outdoor Units (6 kBtu/hr Scroll Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	8,715	8,412	8,185	7,505	6,791	6,752	6,509	6,189	6,170	5,791	5,736
Location	-	-	-	-	-	-	-	-	-	-	-
AL	109%	109%	109%	108%	108%	108%	109%	110%	110%	107%	107%
AK	82%	81%	80%	82%	81%	81%	80%	78%	78%	83%	83%
AZ	117%	118%	119%	120%	124%	124%	125%	127%	127%	123%	123%
AR	106%	107%	107%	106%	107%	107%	107%	108%	108%	106%	106%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	8,715	8,412	8,185	7,505	6,791	6,752	6,509	6,189	6,170	5,791	5,736
Location	-	-	-	-	-	-	-	-	-	-	-
CA	106%	106%	106%	102%	101%	101%	101%	101%	101%	98%	98%
CO	95%	95%	95%	95%	94%	94%	94%	93%	93%	94%	94%
CT	96%	96%	96%	95%	94%	94%	94%	94%	94%	94%	94%
DE	99%	99%	99%	98%	98%	98%	98%	98%	98%	98%	98%
DC	100%	100%	100%	99%	99%	99%	99%	98%	98%	98%	98%
FL	118%	119%	120%	119%	121%	121%	121%	123%	123%	119%	119%
GA	107%	108%	108%	106%	107%	107%	107%	108%	108%	105%	105%
HI	122%	123%	124%	123%	126%	126%	126%	129%	129%	124%	124%
ID	94%	94%	93%	94%	93%	93%	93%	92%	92%	93%	93%
IL	95%	95%	95%	95%	94%	94%	94%	93%	93%	95%	95%
IN	97%	97%	97%	97%	96%	96%	96%	96%	96%	96%	96%
IA	94%	94%	93%	94%	93%	93%	93%	92%	92%	94%	94%
KS	100%	100%	100%	100%	101%	101%	101%	101%	101%	101%	101%
KY	100%	100%	100%	99%	98%	98%	98%	98%	98%	98%	98%
LA	112%	113%	113%	112%	113%	113%	113%	115%	115%	111%	111%
ME	91%	90%	90%	90%	89%	89%	88%	87%	87%	89%	89%
MD	100%	100%	100%	99%	99%	99%	99%	98%	98%	98%	98%
MA	95%	95%	95%	94%	93%	93%	92%	92%	92%	92%	92%
MI	93%	93%	93%	93%	91%	91%	91%	90%	90%	92%	92%
MN	91%	90%	90%	91%	90%	90%	90%	88%	88%	91%	91%
MS	109%	109%	110%	108%	109%	109%	109%	110%	110%	108%	108%
MO	101%	101%	101%	100%	100%	100%	100%	101%	101%	100%	100%
MT	91%	90%	90%	91%	89%	89%	89%	88%	88%	90%	90%
NE	96%	96%	96%	96%	96%	96%	96%	95%	95%	96%	96%
NV	107%	107%	107%	108%	109%	110%	110%	111%	111%	109%	109%
NH	92%	91%	91%	91%	90%	90%	90%	89%	89%	91%	91%
NJ	99%	99%	99%	98%	97%	97%	97%	97%	97%	97%	97%
NM	101%	101%	101%	100%	100%	100%	100%	100%	100%	100%	100%
NY	98%	97%	97%	96%	96%	96%	96%	95%	95%	95%	95%
NC	104%	104%	104%	103%	103%	103%	103%	103%	103%	101%	101%
ND	89%	88%	88%	89%	88%	88%	88%	87%	87%	90%	90%
OH	96%	95%	95%	95%	94%	94%	94%	93%	93%	94%	94%
OK	105%	105%	105%	105%	106%	106%	106%	106%	106%	105%	105%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	8,715	8,412	8,185	7,505	6,791	6,752	6,509	6,189	6,170	5,791	5,736
Location	-	-	-	-	-	-	-	-	-	-	-
OR	97%	97%	97%	95%	93%	93%	93%	92%	92%	92%	92%
PA	97%	97%	97%	96%	95%	95%	95%	94%	94%	95%	95%
RI	95%	95%	95%	94%	93%	93%	93%	92%	92%	93%	93%
SC	107%	107%	107%	106%	106%	106%	106%	107%	107%	104%	105%
SD	92%	92%	91%	92%	92%	92%	92%	91%	91%	93%	93%
TN	105%	105%	105%	104%	105%	105%	105%	105%	105%	104%	104%
TX	112%	113%	113%	112%	114%	114%	114%	116%	116%	112%	113%
UT	98%	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%
VT	91%	91%	90%	91%	89%	89%	89%	88%	88%	90%	90%
VA	101%	101%	101%	100%	100%	100%	100%	100%	100%	99%	99%
WA	95%	95%	95%	93%	91%	91%	91%	90%	90%	90%	90%
WV	98%	98%	98%	97%	96%	96%	96%	96%	96%	96%	96%
WI	91%	91%	91%	91%	90%	90%	90%	89%	89%	91%	91%
WY	91%	90%	90%	90%	89%	89%	89%	87%	87%	90%	90%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.11 Energy Use Factors by State for Dedicated Condensing, Low Temperature Outdoor Units (9 kBtu/hr Scroll Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11
AEC (kWh/yr)	10,820	10,518	9,583	9,346	8,451	8,412	8,167	7,844	7,823	7,402	6,979	6,920
Location	-	-	-	-	-	-	-	-	-	-	-	-
AL	109%	110%	109%	109%	109%	109%	110%	110%	110%	108%	112%	112%
AK	81%	80%	81%	80%	79%	79%	78%	76%	76%	81%	73%	73%
AZ	118%	119%	121%	121%	126%	126%	126%	129%	129%	125%	131%	131%
AR	107%	107%	107%	107%	108%	108%	108%	108%	108%	107%	109%	109%
CA	106%	107%	103%	103%	102%	102%	102%	102%	102%	100%	104%	104%
CO	95%	95%	94%	94%	93%	93%	93%	93%	93%	94%	92%	92%
CT	96%	96%	95%	95%	94%	94%	94%	93%	93%	94%	93%	93%
DE	99%	99%	99%	99%	98%	98%	98%	98%	98%	98%	98%	98%
DC	100%	100%	99%	99%	99%	99%	99%	99%	99%	98%	99%	99%
FL	119%	120%	120%	120%	122%	123%	123%	125%	125%	121%	128%	128%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11
AEC (kWh/yr)	10,820	10,518	9,583	9,346	8,451	8,412	8,167	7,844	7,823	7,402	6,979	6,920
Location	-	-	-	-	-	-	-	-	-	-	-	-
GA	108%	108%	107%	107%	107%	107%	108%	108%	108%	106%	110%	110%
HI	123%	124%	124%	125%	128%	128%	128%	131%	131%	127%	134%	135%
ID	94%	93%	93%	93%	92%	92%	92%	91%	91%	93%	90%	90%
IL	95%	95%	95%	95%	94%	94%	94%	93%	93%	94%	92%	92%
IN	97%	97%	97%	97%	96%	96%	96%	95%	95%	96%	95%	95%
IA	94%	93%	94%	93%	92%	92%	92%	92%	92%	93%	91%	91%
KS	100%	100%	100%	100%	101%	101%	101%	101%	101%	101%	101%	101%
KY	100%	100%	99%	99%	99%	99%	99%	98%	98%	98%	99%	98%
LA	113%	114%	112%	113%	114%	114%	114%	116%	116%	113%	118%	118%
ME	90%	90%	89%	89%	88%	88%	87%	86%	86%	88%	85%	85%
MD	100%	100%	99%	99%	99%	99%	99%	99%	99%	98%	99%	99%
MA	95%	95%	94%	93%	92%	92%	92%	91%	91%	92%	91%	91%
MI	93%	92%	92%	92%	91%	91%	91%	90%	90%	91%	89%	89%
MN	90%	90%	90%	90%	89%	89%	89%	88%	88%	90%	86%	86%
MS	109%	110%	109%	109%	110%	110%	110%	111%	111%	109%	113%	113%
MO	101%	101%	101%	101%	101%	101%	101%	101%	101%	100%	101%	101%
MT	90%	90%	90%	90%	88%	88%	88%	87%	87%	89%	86%	86%
NE	96%	96%	96%	96%	96%	95%	95%	95%	95%	96%	94%	94%
NV	107%	107%	108%	108%	110%	110%	110%	111%	111%	110%	112%	112%
NH	91%	91%	91%	90%	89%	89%	89%	88%	88%	90%	87%	87%
NJ	99%	99%	98%	98%	97%	97%	97%	97%	97%	97%	97%	97%
NM	101%	101%	101%	101%	100%	100%	100%	101%	101%	100%	101%	101%
NY	97%	97%	96%	96%	95%	95%	95%	95%	95%	95%	95%	95%
NC	104%	105%	103%	103%	103%	103%	103%	103%	103%	102%	104%	104%
ND	88%	87%	89%	88%	87%	87%	87%	86%	86%	89%	84%	84%
OH	95%	95%	95%	94%	93%	93%	93%	93%	93%	93%	92%	92%
OK	105%	106%	105%	105%	106%	106%	106%	107%	107%	106%	108%	108%
OR	97%	97%	95%	95%	93%	93%	93%	92%	92%	92%	92%	92%
PA	97%	97%	96%	96%	95%	95%	95%	94%	94%	95%	94%	94%
RI	95%	95%	94%	94%	93%	93%	93%	92%	92%	93%	91%	91%
SC	107%	108%	106%	106%	107%	107%	107%	107%	107%	106%	109%	109%
SD	91%	91%	92%	92%	91%	91%	91%	90%	90%	92%	89%	89%
TN	105%	106%	105%	105%	105%	105%	105%	106%	106%	105%	107%	107%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11
AEC (kWh/yr)	10,820	10,518	9,583	9,346	8,451	8,412	8,167	7,844	7,823	7,402	6,979	6,920
Location	-	-	-	-	-	-	-	-	-	-	-	-
TX	113%	113%	113%	113%	115%	115%	115%	117%	117%	114%	118%	119%
UT	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%	96%	96%
VT	90%	90%	90%	90%	89%	88%	88%	87%	87%	89%	86%	86%
VA	101%	101%	100%	100%	100%	100%	100%	100%	100%	99%	100%	100%
WA	95%	95%	93%	92%	91%	91%	90%	90%	90%	90%	89%	89%
WV	98%	98%	97%	97%	96%	96%	96%	96%	96%	96%	96%	96%
WI	91%	90%	91%	90%	89%	89%	89%	88%	88%	90%	87%	86%
WY	90%	89%	90%	89%	88%	88%	88%	87%	87%	89%	85%	85%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.12 Energy Use Factors by State for Dedicated Condensing, Low Temperature Outdoor Units (54kBtu/hr Scroll Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11	12
AEC (kWh/yr)	56,861	52,122	49,742	47,957	43,306	40,771	40,330	40,023	38,962	38,797	33,238	33,191	32,625
Location	-	-	-	-	-	-	-	-	-	-	-	-	-
AL	109%	108%	108%	109%	109%	111%	111%	111%	112%	112%	110%	110%	110%
AK	81%	83%	81%	80%	79%	76%	76%	76%	73%	73%	77%	77%	77%
AZ	117%	119%	120%	121%	126%	129%	128%	129%	131%	131%	128%	128%	128%
AR	107%	106%	107%	107%	108%	109%	108%	108%	110%	110%	108%	108%	108%
CA	106%	103%	103%	103%	102%	103%	103%	103%	105%	105%	102%	102%	102%
CO	95%	95%	94%	94%	93%	92%	93%	93%	92%	92%	93%	93%	93%
CT	96%	96%	95%	95%	94%	93%	94%	93%	93%	93%	94%	94%	93%
DE	99%	99%	99%	99%	98%	98%	98%	98%	98%	98%	98%	98%	98%
DC	100%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	98%
FL	118%	118%	119%	120%	122%	125%	125%	125%	128%	128%	124%	124%	125%
GA	108%	106%	107%	107%	108%	109%	108%	108%	110%	110%	108%	108%	108%
HI	122%	122%	124%	125%	128%	131%	131%	131%	134%	134%	130%	130%	131%
ID	94%	94%	93%	93%	92%	91%	91%	91%	90%	90%	92%	92%	91%
IL	95%	95%	95%	95%	94%	93%	93%	93%	92%	92%	93%	93%	93%
IN	97%	97%	97%	97%	96%	95%	96%	96%	95%	95%	96%	96%	96%
IA	94%	94%	94%	93%	92%	91%	92%	92%	91%	91%	92%	92%	92%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11	12
AEC (kWh/yr)	56,861	52,122	49,742	47,957	43,306	40,771	40,330	40,023	38,962	38,797	33,238	33,191	32,625
Location	-	-	-	-	-	-	-	-	-	-	-	-	-
KS	100%	100%	100%	100%	101%	101%	101%	101%	101%	101%	101%	101%	101%
KY	100%	99%	99%	99%	99%	98%	99%	98%	99%	99%	98%	98%	98%
LA	112%	111%	112%	113%	114%	116%	116%	116%	118%	118%	115%	115%	115%
ME	91%	90%	90%	89%	88%	86%	86%	86%	85%	85%	87%	87%	87%
MD	100%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	98%
MA	95%	94%	94%	94%	92%	91%	92%	91%	91%	91%	92%	92%	91%
MI	93%	93%	92%	92%	91%	90%	90%	90%	89%	89%	90%	90%	90%
MN	90%	91%	90%	90%	89%	87%	88%	88%	86%	86%	88%	88%	88%
MS	109%	108%	109%	109%	110%	112%	111%	111%	113%	113%	111%	111%	111%
MO	101%	100%	101%	101%	101%	101%	101%	101%	101%	101%	101%	101%	101%
MT	90%	91%	90%	90%	88%	87%	87%	87%	86%	86%	88%	88%	87%
NE	96%	96%	96%	96%	95%	95%	95%	95%	94%	94%	95%	95%	95%
NV	107%	107%	108%	108%	110%	111%	111%	111%	112%	112%	111%	111%	111%
NH	91%	92%	91%	90%	89%	88%	88%	88%	87%	87%	89%	89%	88%
NJ	99%	98%	98%	98%	97%	97%	97%	97%	97%	97%	97%	97%	97%
NM	101%	101%	101%	101%	101%	101%	101%	101%	101%	101%	100%	100%	100%
NY	98%	97%	97%	96%	96%	95%	95%	95%	95%	95%	95%	95%	95%
NC	104%	103%	103%	103%	103%	104%	104%	104%	105%	105%	103%	103%	103%
ND	88%	89%	89%	88%	87%	85%	86%	86%	84%	83%	86%	87%	86%
OH	96%	95%	95%	94%	93%	92%	93%	93%	92%	92%	93%	93%	93%
OK	105%	105%	105%	105%	106%	107%	107%	107%	108%	108%	106%	106%	107%
OR	97%	95%	95%	95%	93%	92%	93%	93%	93%	93%	92%	92%	92%
PA	97%	96%	96%	96%	95%	94%	94%	94%	94%	94%	94%	95%	94%
RI	95%	95%	94%	94%	93%	92%	92%	92%	92%	92%	92%	92%	92%
SC	107%	106%	106%	107%	107%	108%	107%	108%	109%	109%	107%	107%	107%
SD	92%	93%	92%	92%	91%	90%	90%	90%	88%	88%	90%	90%	90%
TN	105%	104%	105%	105%	105%	106%	106%	106%	107%	107%	106%	106%	106%
TX	112%	112%	113%	113%	115%	117%	117%	117%	119%	119%	116%	116%	116%
UT	98%	98%	97%	97%	97%	97%	97%	97%	96%	96%	97%	97%	97%
VT	91%	91%	90%	90%	89%	87%	87%	87%	86%	86%	88%	88%	88%
VA	101%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
WA	95%	93%	93%	93%	91%	90%	90%	90%	89%	89%	90%	90%	89%
WV	99%	98%	97%	97%	96%	96%	96%	96%	96%	96%	96%	96%	96%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11	12
AEC (kWh/yr)	56,861	52,122	49,742	47,957	43,306	40,771	40,330	40,023	38,962	38,797	33,238	33,191	32,625
Location	-	-	-	-	-	-	-	-	-	-	-	-	-
WI	91%	91%	91%	90%	89%	88%	88%	88%	86%	86%	88%	88%	88%
WY	90%	90%	90%	89%	88%	86%	87%	87%	85%	85%	87%	87%	87%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.13 Energy Use Factors by State for Dedicated Condensing, Low Temperature Outdoor Units (6 kBtu/hr Semi-Hermetic Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11
AEC (kWh/yr)	10,206	9,903	9,675	8,914	8,021	7,983	7,743	7,966	7,726	7,415	7,360	7,203
Location	-	-	-	-	-	-	-	-	-	-	-	-
AL	106%	106%	107%	105%	106%	106%	106%	106%	106%	107%	107%	106%
AK	88%	87%	86%	89%	87%	87%	87%	87%	87%	85%	85%	87%
AZ	111%	112%	112%	113%	117%	117%	117%	117%	117%	119%	119%	117%
AR	104%	105%	105%	104%	105%	105%	105%	105%	105%	105%	105%	105%
CA	105%	105%	105%	101%	100%	100%	100%	100%	100%	101%	101%	100%
CO	97%	97%	96%	96%	96%	96%	96%	96%	96%	95%	95%	96%
CT	98%	98%	97%	97%	96%	96%	96%	96%	96%	96%	95%	96%
DE	100%	100%	100%	99%	98%	98%	98%	98%	98%	98%	98%	98%
DC	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%	99%	99%
FL	112%	113%	113%	112%	114%	114%	114%	114%	114%	116%	116%	114%
GA	105%	105%	106%	104%	104%	104%	104%	104%	104%	105%	105%	104%
HI	115%	115%	116%	115%	118%	118%	118%	118%	118%	120%	120%	118%
ID	96%	96%	96%	96%	95%	95%	95%	95%	95%	94%	94%	95%
IL	97%	97%	97%	97%	96%	96%	96%	96%	96%	95%	95%	96%
IN	98%	98%	98%	98%	97%	97%	97%	97%	97%	97%	97%	97%
IA	96%	96%	95%	96%	95%	95%	95%	95%	95%	95%	95%	95%
KS	100%	100%	100%	100%	100%	100%	100%	100%	100%	101%	101%	100%
KY	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%	99%	99%
LA	108%	109%	109%	107%	109%	109%	109%	109%	109%	110%	110%	109%
ME	94%	93%	93%	93%	92%	92%	92%	92%	92%	91%	91%	92%
MD	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%	99%	99%
MA	97%	97%	97%	96%	95%	95%	95%	95%	95%	94%	94%	95%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10	11
AEC (kWh/yr)	10,206	9,903	9,675	8,914	8,021	7,983	7,743	7,966	7,726	7,415	7,360	7,203
Location	-	-	-	-	-	-	-	-	-	-	-	-
MI	95%	95%	95%	95%	94%	94%	94%	94%	94%	93%	93%	94%
MN	94%	93%	93%	94%	93%	93%	93%	93%	93%	92%	92%	93%
MS	106%	106%	107%	105%	106%	106%	106%	106%	106%	107%	107%	106%
MO	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
MT	94%	93%	93%	94%	93%	93%	93%	93%	93%	92%	92%	93%
NE	98%	97%	97%	98%	97%	97%	97%	97%	97%	97%	97%	97%
NV	104%	105%	105%	105%	107%	107%	107%	107%	107%	108%	108%	107%
NH	94%	94%	94%	94%	93%	93%	93%	93%	93%	92%	92%	93%
NJ	99%	99%	99%	99%	98%	98%	98%	98%	98%	98%	98%	98%
NM	101%	101%	101%	100%	100%	100%	100%	100%	100%	100%	100%	100%
NY	99%	98%	98%	98%	97%	97%	97%	97%	97%	97%	96%	97%
NC	103%	103%	103%	102%	102%	102%	102%	102%	102%	102%	102%	101%
ND	92%	92%	91%	93%	92%	92%	92%	92%	92%	91%	91%	92%
OH	97%	97%	97%	97%	96%	96%	96%	96%	96%	95%	95%	96%
OK	103%	104%	104%	103%	104%	104%	104%	104%	104%	104%	104%	104%
OR	98%	98%	98%	96%	95%	95%	95%	95%	95%	95%	94%	95%
PA	98%	98%	98%	97%	97%	97%	97%	97%	97%	96%	96%	97%
RI	97%	97%	97%	96%	95%	95%	95%	95%	95%	95%	95%	95%
SC	105%	105%	105%	104%	104%	104%	104%	104%	104%	104%	105%	104%
SD	94%	94%	94%	95%	94%	94%	94%	94%	94%	94%	94%	94%
TN	104%	104%	104%	103%	103%	103%	103%	103%	103%	104%	104%	103%
TX	108%	109%	109%	108%	109%	109%	109%	109%	109%	111%	111%	109%
UT	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
VT	94%	94%	93%	94%	93%	93%	93%	93%	93%	92%	92%	93%
VA	101%	101%	101%	100%	100%	100%	100%	100%	100%	100%	100%	100%
WA	97%	97%	97%	95%	93%	93%	93%	93%	93%	93%	93%	93%
WV	99%	99%	99%	98%	97%	97%	97%	97%	97%	97%	97%	97%
WI	94%	94%	93%	94%	93%	93%	93%	93%	93%	92%	92%	93%
WY	94%	93%	93%	94%	92%	92%	92%	92%	92%	91%	91%	92%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.14 Energy Use Factors by State for Dedicated Condensing, Low Temperature Outdoor Units (9 kBtu/hr Semi-Hermetic Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	14,656	14,355	14,129	12,966	11,638	11,600	11,358	11,043	10,234	10,213	10,154
Location	-	-	-	-	-	-	-	-	-	-	-
AL	106%	106%	106%	105%	106%	106%	106%	107%	106%	106%	106%
AK	88%	87%	87%	88%	86%	86%	86%	85%	87%	87%	86%
AZ	111%	111%	112%	113%	117%	117%	117%	118%	117%	117%	117%
AR	104%	105%	105%	104%	105%	105%	105%	105%	105%	105%	105%
CA	105%	105%	105%	102%	101%	101%	101%	101%	100%	100%	100%
CO	97%	97%	97%	97%	96%	96%	96%	95%	96%	96%	96%
CT	98%	98%	98%	97%	96%	96%	96%	96%	96%	96%	96%
DE	100%	100%	100%	99%	99%	99%	99%	99%	98%	98%	98%
DC	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%
FL	112%	112%	113%	112%	114%	114%	114%	115%	115%	115%	115%
GA	105%	105%	106%	104%	105%	105%	105%	105%	104%	104%	104%
HI	114%	115%	115%	115%	118%	118%	118%	119%	118%	118%	118%
ID	96%	96%	96%	96%	95%	95%	95%	95%	95%	95%	95%
IL	97%	97%	97%	97%	96%	96%	96%	96%	96%	96%	96%
IN	98%	98%	98%	98%	97%	97%	97%	97%	97%	97%	97%
IA	96%	96%	96%	96%	95%	95%	95%	95%	95%	95%	95%
KS	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
KY	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%
LA	108%	109%	109%	108%	109%	109%	109%	110%	109%	109%	109%
ME	94%	94%	94%	94%	92%	92%	92%	91%	92%	92%	92%
MD	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%
MA	97%	97%	97%	96%	95%	95%	95%	95%	95%	95%	95%
MI	96%	95%	95%	95%	94%	94%	94%	94%	94%	94%	94%
MN	94%	93%	93%	94%	93%	93%	93%	92%	93%	93%	93%
MS	106%	106%	106%	106%	106%	106%	106%	107%	106%	106%	106%
MO	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
MT	94%	94%	93%	94%	93%	93%	93%	92%	93%	93%	93%
NE	98%	97%	97%	98%	97%	97%	97%	97%	97%	97%	97%
NV	104%	104%	105%	105%	107%	107%	107%	107%	107%	107%	107%
NH	94%	94%	94%	94%	93%	93%	93%	93%	93%	93%	93%
NJ	100%	100%	100%	99%	98%	98%	98%	98%	98%	98%	98%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	14,656	14,355	14,129	12,966	11,638	11,600	11,358	11,043	10,234	10,213	10,154
Location	-	-	-	-	-	-	-	-	-	-	-
NM	101%	101%	101%	100%	100%	100%	100%	100%	100%	100%	100%
NY	99%	99%	99%	98%	97%	97%	97%	97%	97%	97%	97%
NC	103%	103%	103%	102%	102%	102%	102%	102%	102%	102%	102%
ND	92%	92%	92%	93%	92%	92%	92%	91%	92%	92%	92%
OH	97%	97%	97%	97%	96%	96%	96%	95%	95%	95%	95%
OK	103%	103%	104%	103%	104%	104%	104%	104%	104%	104%	104%
OR	99%	99%	99%	97%	96%	96%	96%	95%	95%	95%	95%
PA	98%	98%	98%	98%	97%	97%	97%	96%	97%	97%	96%
RI	97%	97%	97%	97%	95%	95%	95%	95%	95%	95%	95%
SC	105%	105%	105%	104%	104%	104%	104%	105%	104%	104%	104%
SD	95%	94%	94%	95%	94%	94%	94%	94%	94%	94%	94%
TN	104%	104%	104%	103%	103%	103%	103%	104%	103%	103%	103%
TX	108%	108%	109%	108%	110%	110%	110%	110%	110%	110%	110%
UT	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
VT	94%	94%	94%	94%	93%	93%	93%	92%	93%	93%	93%
VA	101%	101%	101%	100%	100%	100%	100%	100%	100%	100%	100%
WA	97%	97%	97%	96%	94%	94%	94%	94%	93%	93%	93%
WV	99%	99%	99%	98%	98%	98%	98%	97%	97%	97%	97%
WI	94%	94%	94%	94%	93%	93%	93%	92%	93%	93%	93%
WY	94%	93%	93%	94%	92%	92%	92%	92%	92%	92%	92%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.6.15 Energy Use Factors by State for Dedicated Condensing, Low Temperature Outdoor Units (54 kBtu/hr Semi-Hermetic Compressor)

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	70,215	64,658	62,252	60,448	54,676	49,171	48,168	47,860	47,707	41,118	40,244
Location	-	-	-	-	-	-	-	-	-	-	-
AL	107%	105%	105%	106%	108%	109%	108%	108%	108%	106%	105%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	70,215	64,658	62,252	60,448	54,676	49,171	48,168	47,860	47,707	41,118	40,244
Location	-	-	-	-	-	-	-	-	-	-	-
AK	86%	88%	88%	87%	82%	80%	81%	81%	81%	86%	87%
AZ	113%	113%	114%	115%	120%	125%	124%	124%	124%	120%	119%
AR	105%	104%	104%	105%	106%	107%	107%	107%	107%	105%	104%
CA	105%	101%	101%	101%	102%	101%	101%	101%	101%	98%	97%
CO	96%	96%	96%	96%	95%	94%	94%	94%	94%	95%	95%
CT	97%	97%	97%	96%	95%	94%	95%	95%	95%	95%	95%
DE	100%	99%	99%	99%	99%	98%	98%	98%	98%	98%	98%
DC	100%	99%	99%	99%	99%	99%	99%	99%	99%	98%	98%
FL	114%	112%	113%	114%	118%	121%	120%	120%	120%	116%	115%
GA	106%	104%	104%	105%	106%	107%	106%	106%	106%	104%	103%
HI	117%	115%	116%	117%	123%	126%	124%	125%	125%	120%	119%
ID	95%	96%	96%	95%	94%	93%	93%	93%	93%	94%	95%
IL	96%	97%	96%	96%	95%	94%	94%	94%	94%	95%	96%
IN	98%	98%	98%	98%	97%	96%	96%	96%	96%	97%	97%
IA	95%	96%	96%	95%	94%	93%	93%	93%	93%	95%	95%
KS	100%	100%	100%	100%	100%	101%	101%	101%	101%	101%	101%
KY	100%	99%	99%	99%	99%	98%	99%	99%	99%	98%	98%
LA	109%	108%	108%	109%	112%	113%	112%	112%	112%	109%	108%
ME	93%	93%	93%	93%	90%	88%	89%	89%	89%	91%	91%
MD	100%	99%	99%	99%	99%	99%	99%	99%	99%	98%	98%
MA	96%	96%	96%	95%	94%	92%	93%	93%	93%	93%	93%
MI	95%	95%	95%	94%	93%	91%	92%	92%	92%	93%	93%
MN	93%	94%	94%	93%	91%	89%	90%	90%	90%	93%	94%
MS	107%	106%	106%	106%	108%	109%	109%	109%	109%	107%	106%
MO	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
MT	93%	94%	93%	93%	91%	89%	90%	90%	90%	92%	93%
NE	97%	98%	97%	97%	96%	96%	96%	96%	96%	97%	97%
NV	105%	105%	106%	106%	108%	110%	109%	109%	109%	108%	107%
NH	93%	94%	94%	93%	91%	90%	91%	90%	90%	92%	93%
NJ	99%	99%	98%	98%	98%	97%	97%	97%	97%	97%	97%
NM	101%	100%	100%	100%	101%	100%	100%	100%	100%	100%	99%
NY	98%	98%	97%	97%	97%	96%	96%	96%	96%	96%	96%
NC	103%	102%	102%	102%	103%	103%	102%	102%	102%	101%	100%

Efficiency Level	0	1	2	3	4	5	6	7	8	9	10
AEC (kWh/yr)	70,215	64,658	62,252	60,448	54,676	49,171	48,168	47,860	47,707	41,118	40,244
Location	-	-	-	-	-	-	-	-	-	-	-
ND	91%	93%	93%	92%	89%	88%	89%	89%	89%	92%	93%
OH	97%	96%	96%	96%	95%	94%	94%	94%	94%	95%	95%
OK	104%	103%	103%	104%	105%	106%	105%	105%	105%	104%	104%
OR	98%	96%	96%	96%	95%	93%	93%	93%	93%	93%	92%
PA	98%	97%	97%	97%	96%	95%	95%	95%	95%	96%	96%
RI	97%	96%	96%	96%	94%	93%	93%	93%	93%	94%	94%
SC	105%	104%	104%	104%	106%	106%	106%	106%	106%	104%	103%
SD	94%	95%	95%	94%	92%	92%	92%	92%	92%	94%	95%
TN	104%	103%	103%	103%	104%	105%	105%	105%	105%	103%	103%
TX	109%	108%	109%	109%	112%	114%	113%	113%	113%	111%	110%
UT	98%	98%	98%	98%	97%	97%	97%	97%	97%	98%	98%
VT	93%	94%	93%	93%	91%	89%	90%	90%	90%	92%	93%
VA	101%	100%	100%	100%	100%	100%	100%	100%	100%	99%	99%
WA	97%	95%	95%	94%	93%	91%	91%	91%	91%	91%	91%
WV	99%	98%	98%	98%	97%	96%	96%	96%	96%	96%	96%
WI	93%	94%	94%	93%	91%	90%	90%	90%	90%	92%	93%
WY	93%	93%	93%	93%	90%	89%	89%	89%	89%	91%	92%
USA	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

8.1 INTRODUCTION

This chapter describes the analysis the U.S. Department of Energy (DOE) conducts to evaluate the economic impacts on individual customers that would be required to comply with proposed energy conservation standards for walk-in coolers and freezers (walk-ins or WICF). Based on the component-level approach DOE is adopting in the current analysis, DOE is considering setting separate energy conservation standards for the WICF refrigeration systems and envelope components, which include panels, display doors, and non-display doors. Life-cycle cost (LCC) and payback period (PBP) results are reported separately for the WICF equipment considered in the notice of proposed rulemaking (NOPR) analysis and as a whole because a walk-in cooler or freezer operates as a combined unit.

This chapter describes the three metrics used in this analysis to determine the impact of standards on individual customers:

- LCC is the total (discounted) customer cost over the analysis period, including purchase price, operating costs (including energy expenditures), and installation costs. LCC savings is the reduction in LCC that a customer would benefit from by switching to more efficient equipment.
- PBP is the number of years it takes a customer to recover the generally higher purchase price of more energy-efficient equipment through the operating cost savings of using the more energy-efficient equipment. The PBP is calculated as the change between standard and baseline in initial cost divided by the change in operating costs in the first year.
- 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.

While the three metrics are different, they share the same basic implication: the lower the value, the more financially attractive a piece of equipment is in the long run (at any given level of service). An efficiency improvement that is financially attractive will typically have a low LCC (or a high LCC savings) and low PBPs.

DOE developed LCC and PBP spreadsheet models that incorporate both Monte Carlo simulation and probability distributions by using Microsoft Excel spreadsheets combined with Crystal Ball (a commercially available add-in program). DOE developed two spreadsheets in the current analysis: one for the refrigeration systems and another for the panels, display doors, and non-display doors. The spreadsheets are available for download at www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/26. Appendix 8A presents details and instructions for using the spreadsheet.

This chapter is organized as follows: The remainder of section 8.1 outlines the general approach for the LCC and PBP analyses and broadly describes the inputs. Sections 8.2 and 8.3 discuss inputs to the LCC and PBP, respectively, in greater detail. Key variables and calculations are presented for each metric used to determine the impact of standards on individual consumers.

Section 8.4 presents summary results for the LCC savings. In addition, appendix 8B provides details of the Monte Carlo analysis—characterizing uncertainty and variability in the life-cycle cost analysis. Appendix 8C includes the discount rate distributions; appendix 8D provides the equipment price trends and estimates for walk-in refrigeration systems; appendix 8E provides results for the LCC and PBP for all analyzed refrigeration systems using discrete inputs; and appendices 8F and 8G provide the distribution of consumer LCC impacts for refrigeration systems and for envelope components, respectively. Discussions in each section of this chapter address WICF refrigeration systems and envelope components.

8.1.1 General Approach for Life-Cycle Cost and Payback Period Analyses

In the current analysis, DOE conducted the LCC and PBP analyses in two steps. First, DOE estimated the installed costs and annual operating costs for WICF refrigeration systems, both in the base case and at the efficiency levels used in the engineering analysis. Chapter 5 of this TSD provides more details about the different efficiency levels. Because those efficiency levels are candidates for potential standards for the WICF refrigeration systems and envelope components, DOE refers to them as candidate standard levels (CSLs) in the LCC and PBP analyses and in the following chapters. Second, DOE repeated the process for the WICF envelope components (panels, display doors, and non-display doors) at various refrigeration system efficiency levels selected from the independent LCC and PBP analyses for the WICF refrigeration system. With this information, the LCC and PBP analyses can be conducted in the following manner:

- For the LCC analysis, DOE discounts all annual operating costs across the expected lifetime of WICF equipment, adds them together, and then adds that sum to the installed costs to find the LCC. The LCC at each CSL is then subtracted from the baseline LCC to find the LCC savings for that CSL.
- For the PBP analysis, DOE calculates the total installed costs to the consumer of the equipment for each efficiency level and the average annual operating expenditures for each efficiency level in the first year.

The flow for these analyses is illustrated in Figure 8.1.1. To calculate the installed costs for both the LCC and the PBP analyses, DOE produces estimates of purchase costs of WICF refrigeration systems and envelope components (including sales taxes and other markups), shipping costs, and installation costs. Those estimates are discussed further in section 8.2.2. To calculate the operating costs, DOE produces estimates of electricity costs (based on annual electricity use and electricity prices), maintenance costs, and replacement costs.

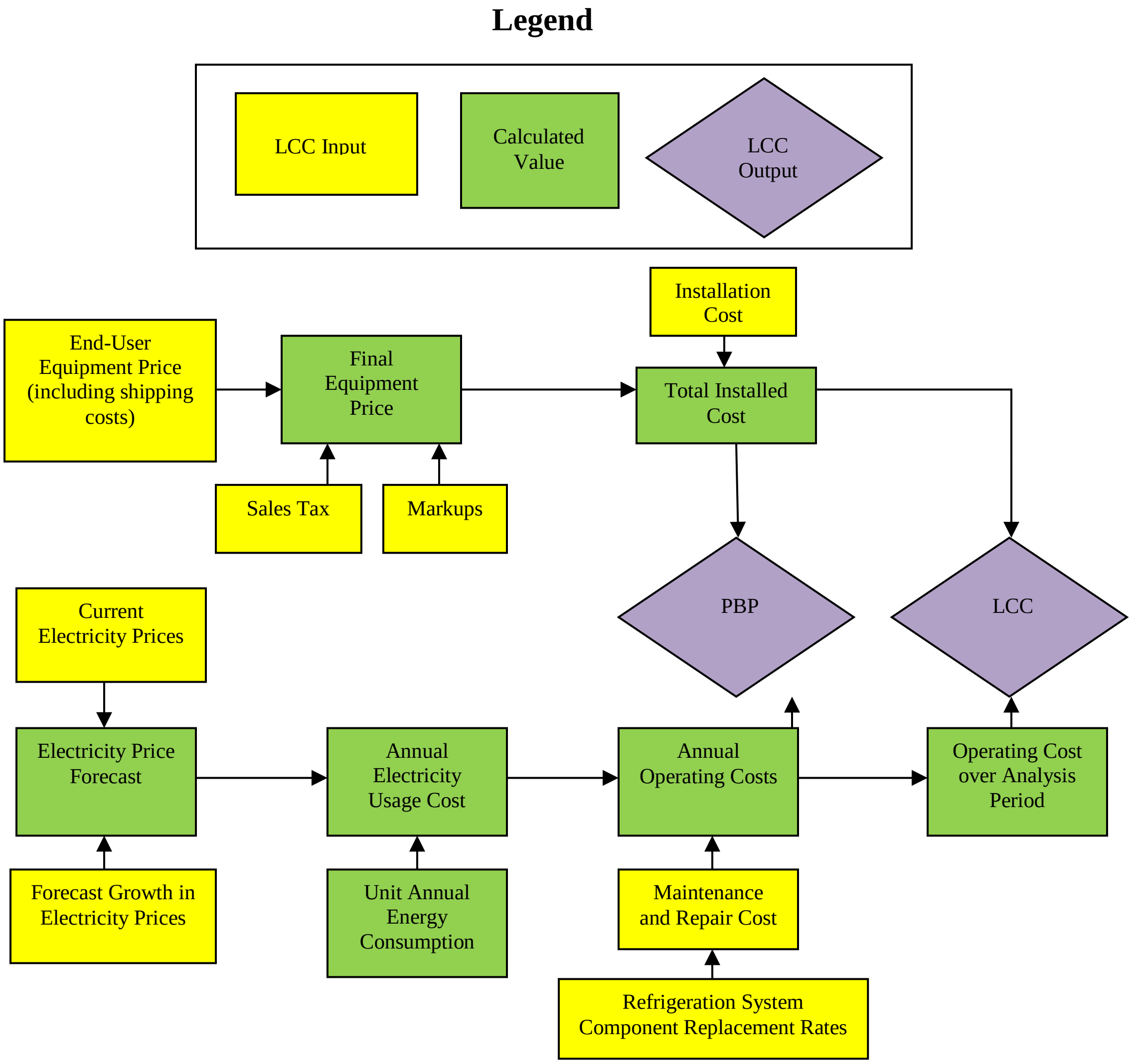


Figure 8.1.1 LCC and PBP Flowchart for WICF Refrigeration Systems and Envelope Components

8.1.2 Overview of Life-Cycle Cost and Payback Period Inputs

The LCC represents the total customer expense over the analysis period, including purchase expenses, operating costs (including energy expenditures), and installation costs. DOE discounts future operating costs to the time of purchase and sums them over the analysis period. The PBP represents the number of years it takes customers to recover the purchase price of more energy-efficient equipment through lower operating costs. The PBP is calculated as the change in first cost divided by the change in operating costs per year.

For the current analysis, DOE performed a Monte Carlo analysis that characterized several of the operating cost inputs with probability distributions that captured the input’s uncertainty and/or variability across U.S. states. Appendix 8B of the TSD provides more details of this analysis.

DOE categorizes inputs to the LCC and PBP analysis as follows: (1) inputs for establishing the purchase expense, otherwise known as the total installed cost; and (2) inputs for calculating the expenses incurred during operation of the walk-in equipment, otherwise known as the operating costs. The primary inputs for establishing the LCC and PBP are shown in Table 8.1.1. Each row of the table also lists the chapter of the TSD that provides more detailed information about this input.

Table 8.1.1 Summary Information of Inputs for the LCC and PBP Analyses

Factor	TSD Reference Section
Total Installed Cost Primary Inputs	
Manufacturer Selling Price	Chapters 5 and 6
Distributer Markup and Sales Tax	Chapter 6
Installation Cost	Chapter 8
Operating Cost Primary Inputs	
Annual Energy Consumed	Chapter 7
Current Electricity Prices	Chapter 8
Electricity Price Trends	Chapter 8
Discount Rate	Chapter 8
Walk-in Lifetime	Chapter 8

Sections 8.2 and 8.3 discuss the inputs of installed costs and operating costs that are depicted in this table.

8.2 LIFE-CYCLE COST INPUTS

8.2.1 Definition of Life-Cycle Cost

LCC is the total customer cost over the life of a good, including total installed costs and operating costs. Future operating costs are discounted to the analysis start year (*i.e.*, 2017) and summed over the analysis period. The LCC is defined by the following equation:

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

Eq. 8.1

Where:

LCC = life-cycle cost,
IC = total installed cost,
N = analysis period,
$\sum$ = sum over the analysis period, from year 1 to year N,
OC = annual operating cost in year t,
r = discount rate, and
t = year for which operating cost is determined.

DOE expresses all the costs in its LCC and PBP analyses in 2012$.

8.2.2 Total Installed Cost Inputs

The total installed cost of walk-in equipment to the customer is defined by the following equation:

$$IC = FEP + INST$$

Eq. 8.2

Where:

FEP = final WICF equipment price (*i.e.*, customer price for the equipment only), and
INST = installation cost or the customer price to install the WICF equipment (*i.e.*, the cost for labor and materials).

The final equipment price represents the average cost of walk-in equipment (refrigeration system or envelope component) before installation costs. DOE then applies installation costs where necessary to derive the total installed costs for use in the LCC. The installation cost, including labor and overhead, represents all costs required to install the walk-in except the final equipment price. DOE calculates the final equipment cost for each walk-in component analyzed based on the following equation:

$$FEP = PRICE \times MU \times (1 + ST)$$

Eq. 8.3

Where:

FEP = final WICF equipment price,
PRICE = WICF equipment manufacturer selling price (including shipping costs),
MU = distribution channel markup, and
ST = sales tax.

DOE calculates the manufacturer selling price for both WICF refrigeration systems and envelope components in the engineering analysis, which is discussed in chapter 5 of the TSD. The markup represents DOE estimates of the additional costs to the customer of obtaining WICF equipment through whatever distribution channel the customer uses. The sales tax represents state and local sales taxes applied to the end-user equipment price. It is added to one to produce a multiplicative factor that increases the final equipment price. The markup analysis, found in chapter 6 of the TSD, provides detail on the markup and sales tax.

8.2.2.1 Manufacturer Selling Price

As noted in equation 8.3 above, the manufacturer selling price represents the average cost of WICF equipment (refrigeration systems or envelope components) to distributors before distributor markup, installation costs, and sale tax. It is described in the chapter 5 of the TSD, which details the engineering analysis.

8.2.2.2 Installation Costs

As described in the previous equation, the total installed cost equals the end-user final equipment price, plus the installation cost. However, this section only addresses the costs required to install the system. The installation cost discussed in this section includes labor and overhead and represents the cost per system.

WICF equipment is generally installed from two different vendors; *i.e.*, one vendor supplies the envelope components and the other vendor supplies the components of the refrigeration system. Generally, a specialized crew installs the enclosures in the field from the insulated panels, doors, and other components supplied by the WICF envelope manufacturer. A different crew installs the refrigeration system components and electrical components associated with the envelope, such as lights and air curtains. For some smaller systems, the entire assembly composed of both the enclosure and the refrigeration system is sometimes factory assembled and mounted on a trailer for final delivery to the customer site. Consequently, DOE estimated the installation costs separately in the NOPR analyses for the WICF equipment, refrigeration systems, and envelope components. Refrigeration system installation costs were separated further into the unit cooler in the enclosure and the condensing unit. For dedicated condensing systems, the installation cost includes the condensing unit and the number of unit coolers. For the systems coupled with multiplex systems, DOE only considered the unit cooler installation cost because the multiplex condensing systems are usually shared with other equipment.

For estimating the installation costs of the WICF subsystems, DOE used installation cost data for the specific subsystems from an industry publication, *RSMeans Mechanical Cost Data* (2012) handbook.[1] As applicable, the installation cost data for different sizes or capacities of a specific piece of equipment were pooled, and a linear relationship was sought between the installation cost and the size/capacity. However, DOE noticed that using a single pool of data and using a linear relationship across the entire range of sizes could lead to considerable estimation errors around range extremities. Consequently, DOE partitioned the whole range into smaller subranges over which a linear relationship could be established and used with smaller errors of estimates. R^2 parameters of the regression analysis were used as an indicator of the goodness-of-fit. DOE assumed installation costs do not vary across WICF equipment efficiency levels.

Unit Coolers. For estimating the installation cost of the unit coolers, DOE extracted the installation labor hours data for the unit coolers of different capacities tabulated in the RSMeans handbook.[1] Though the installation cost of a specific unit cooler is not entirely determined by its capacity (which is measure in British thermal units per hour or Btu/hr), other parameters were not considered for reasons of simplicity.

DOE obtained plots showing the installation labor hours against the capacities of the unit coolers in three different capacity ranges. DOE assumed that using pooled data for unit coolers with somewhat differing specifications resulted in installation cost plots for generic unit coolers. The plots obtained from the pooled data are shown in Figure 8.2.1 for small-capacity (less than 10 kBtu/hr), Figure 8.2.2 for medium-capacity (greater than 10 kBtu/hr and less than 35 kBtu/hr), and Figure 8.2.3 for large-capacity (greater than 35 kBtu/hr) unit coolers. Note that the large-capacity unit coolers were not included in the later stages of the LCC and PBP analyses because none of the refrigeration system equipment class capacity points required large-capacity unit coolers. Consequently, the information presented on the large-capacity coolers is only included in this section for completeness.

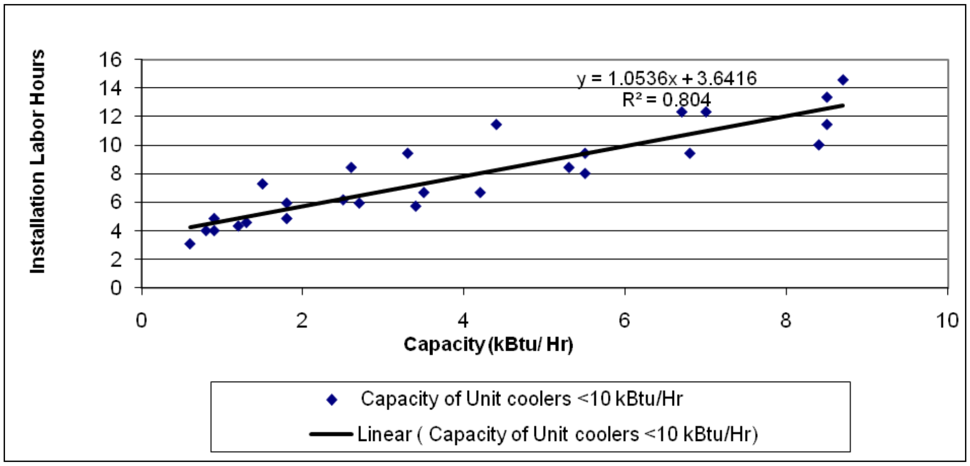


Figure 8.2.1 Installation Labor Hours for Small Unit Coolers

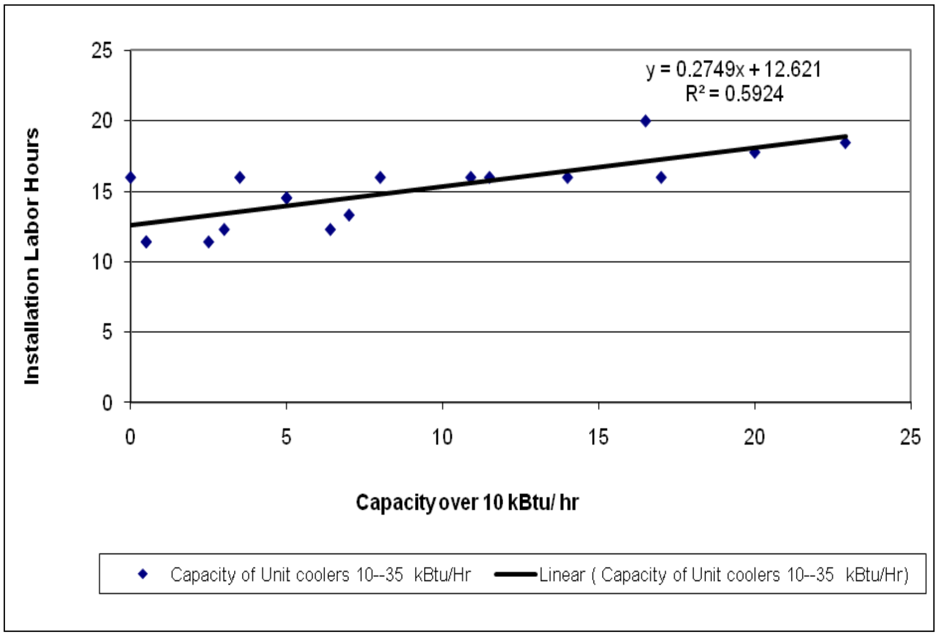


Figure 8.2.2 Installation Labor Hours for Medium Unit Coolers

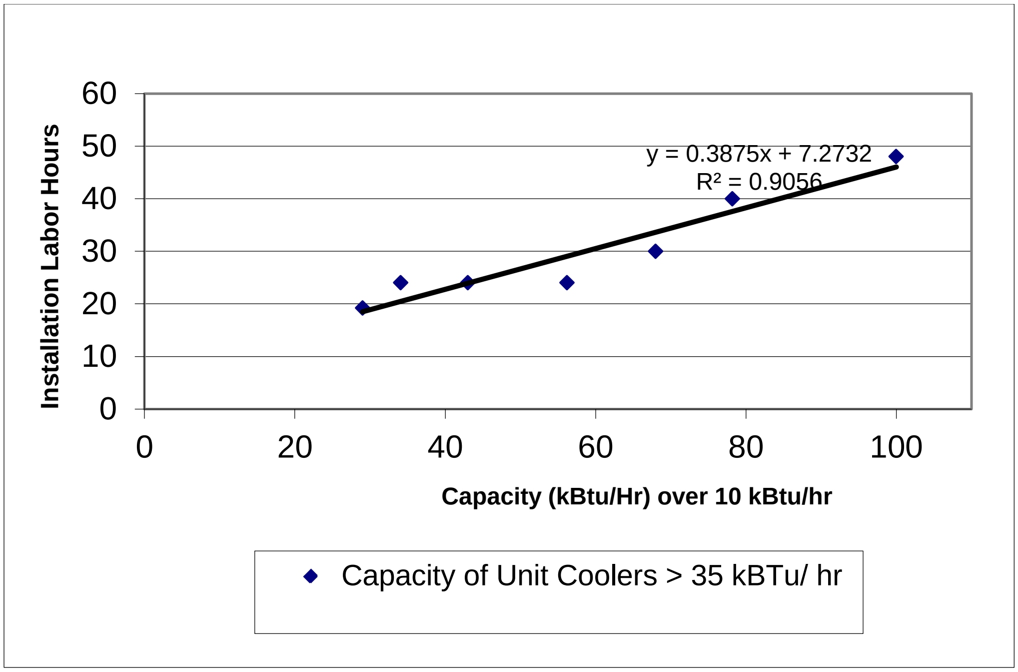


Figure 8.2.3 Installation Labor Hours for Large Unit Coolers

The slopes and the intercepts were directly converted to the corresponding intercept and slope for the installation cost regression line using a labor hourly rate multiplier of US$75.60/hour obtained from the *RSMeans Mechanical Cost Data* (2012) handbook[1] (p. 622). The labor hour rate includes the bare labor costs, overheads, and profit. From the installation cost versus capacity plots for the unit coolers, linear regression lines were fitted, and the intercept and the slopes of the line and R^2 values were obtained. The results of this analysis are shown in Table 8.2.1 and have been used to estimate the unit cooler installation costs, per unit cooler, used in this LCC analysis.

Table 8.2.1 Slope and Intercept Values Used for Estimation of Installation Costs of Unit Coolers (per Unit Cooler)

Size Designation	Unit Cooler Capacity Range *Btu/hr*	Labor Hour Plot		Installation Cost *$*	
		Slope	Intercept	Slope	Corrected Intercept
Small	<10,000	1.05	3.64	79.6	275*
Medium	<35,000	0.27	12.62	20.8	954
Large	>35,000	0.39	7.27	29.3	550

*An intercept correction was not applied to the lowest capacity range data.

Unit cooler installation costs were only included for the refrigeration system equipment classes using dedicated condensing units. Once capacity-based unit cooler installation costs were computed per unit cooler, the unit cooler installation cost was reduced by 50 percent for refrigeration system equipment class capacity points less than18 kBtu/hr. This cost modifier was applied to the smaller refrigeration system equipment classes because vendor catalogues show that small (8 ft by 8 ft) preassembled WICF installations include the installation of the refrigeration system. Given the component-level approach, DOE applied a cost modifier to achieve more representative installation costs for WICF refrigeration system components.

Condensing Units. To estimate the installation cost for the condensing units, labor cost data for installing the packaged compressor and condensing units were extracted from the reference version of the *RSMeans Mechanical Cost Data* handbook. The unit cooler capacities, provided in tons, were multiplied by a factor of 12 kBtu/hr, and the labor hours for condensing units were multiplied by the labor hourly rate multiplier of US$75.60/hour obtained from the RSMeans handbook.[1] The plots for the labor cost for installation and the capacity of the condensing unit in kBtu/hr for smaller sized units with capacity less than 60 kBtu/hr (5 tons) are shown in Figure 8.2.4. The intercept of the slope of the regression line in the plot was set to zero to avoid negative installation costs for small-capacity condensing units, less than 60 kBtu/hr (5 tons).

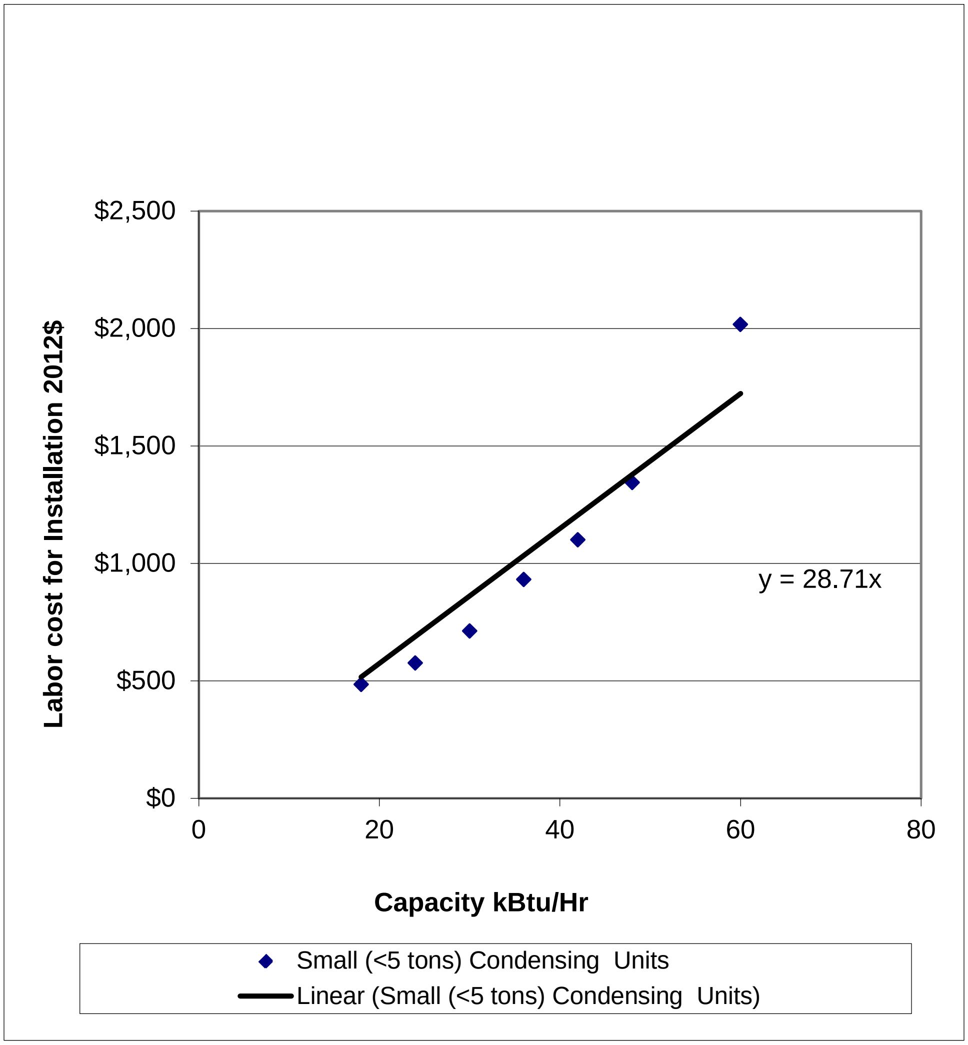


Figure 8.2.4 Installation Cost in Dollars for Small (under 60 kBtu/hr) Condensing Units

For the larger sized condensing units, the RSMeans reference handbook reports installation costs over a range of sizes up to 1,200 kBtu/hr (100 tons).. The plot of the labor cost for installation against the differential capacity over 60 kBtu/hr is presented in Figure 8.2.5.

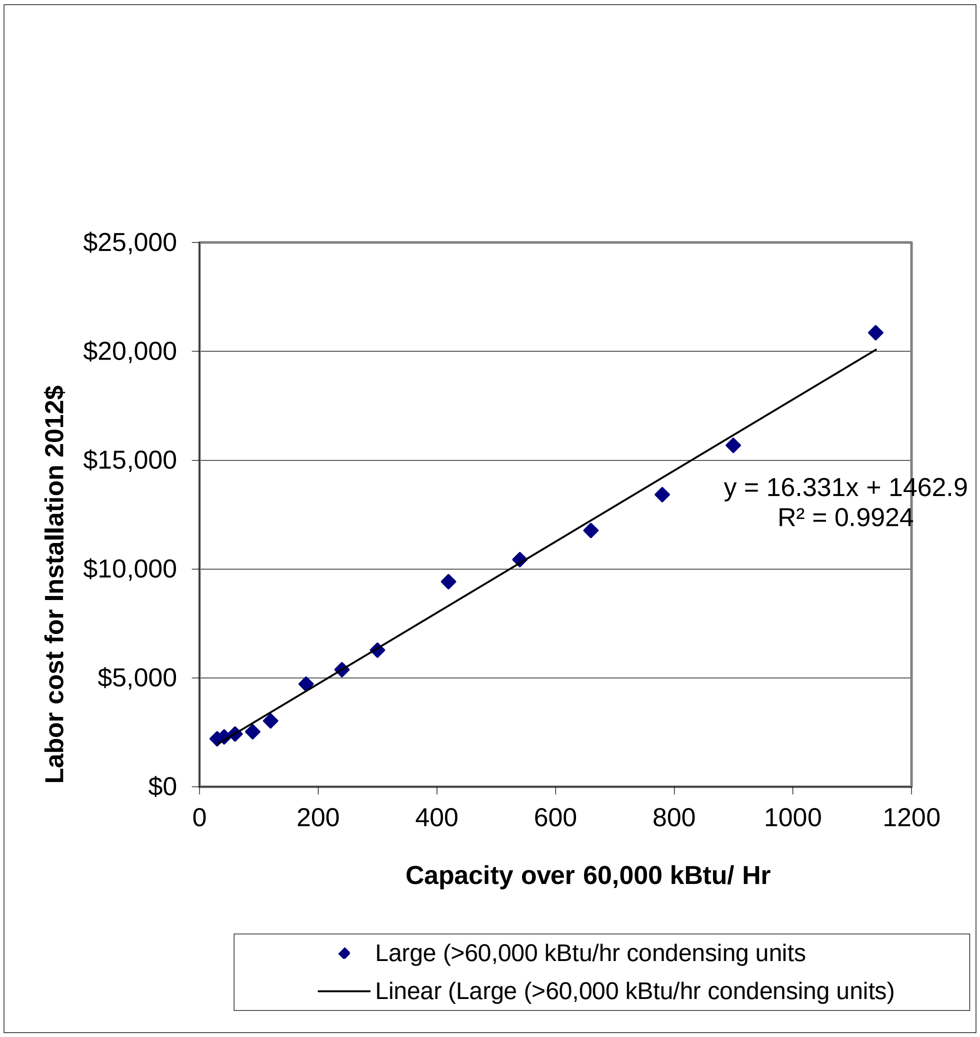


Figure 8.2.5 Installation Cost in Dollars for Large (over 60 kBtu/hr) Condensing Units

The slope and the intercept values used in the two ranges for projecting the labor cost of installing the condensing units of different sizes are shown in Table 8.2.2. The difference in the intercept values in the plots and the table value is due to the difference in the definition of the x-axis variables and the intercept corrections. As was done for unit cooler installation costs discussed previously, to obtain representative condensing unit installation costs, a 50 percent cost modifier was applied for refrigeration systems having capacities less than 18 kBtu/hr.

Table 8.2.2 Slope and Intercept Values Used for Estimation of Installation Costs of Refrigeration Systems

Size Designation	**Capacity** ***kBtu/hr***	**Plot for Installation Cost** ***$***	
		Slope	**Corrected Intercept**

Small	<60	28.7	0
Large	>60	16.3	1463

Table 8.2.3 summarizes the WICF refrigeration installation costs DOE used in the NOPR analysis.

Table 8.2.3 WICF Refrigeration Installation Costs

WICF Refrigeration System Type	Capacity *kBtu/hr*	No. of Unit Coolers	Unit Cooler Capacity *kBtu/hr*	Base System Installation Costs *$*	Cost Modifier	System Installation Costs *$*
Dedicated Condensing	6	1	6	463	0.5	925
	9	1	9	625	0.5	1,251
	18	2	9	1,251	0.5	2,501
	54	3	18	4,995	1	4,995
	72	4	18	6,252	1	6,252
	96	4	24	6,902	1	6,902
Multiplex	4	-	-	594	1	594
	9	-	-	992	1	992
	18	-	-	1,328	1	1,328
	24	-	-	1,453	1	1,453
	40	-	-	1,785	1	1,785

Envelope Components. DOE used the 2012 *RSMeans Mechanical Cost Data* handbook to determine envelope component installation costs. Envelope installation costs considered by DOE in this current analysis include panels, display doors, and non-display doors for medium- and low-temperature applications.

Envelope panel installation costs per square foot of panel were determined by taking the envelope installation cost per floor area without doors, provided by *RSMeans Mechanical Cost Data* handbook, multiplying by the floor area of the envelope equipment class, then dividing by the total external surface area of the respective envelope equipment class size. The NOPR TSD chapter 9 describes the envelope equipment classes, but for convenience Table 8.2.4 shows the envelope equipment class sizes and areas used to determine envelope component installation costs. Chapter 9 of the TSD discusses the envelope equipment class baseline specifications.

Table 8.2.4 Basis for Envelope Component Installation Costs

	Storage Cooler Small	**Storage Cooler Medium**	**Storage Cooler Large**	**Display Cooler Small**	**Display Cooler Medium**	**Display Cooler Large**	**Storage Freezer Small**	**Storage Freezer Medium**	**Storage Freezer Large**	**Display Freezer Small**	**Display Freezer Medium**	**Display Freezer Large**
Height *ft*	7.6	9.5	15.0	7.5	7.5	13.3	7.6	9.5	15.0	7.5	7.5	13.3
Length *ft*	12.0	24.0	40.0	16.0	40.0	60.0	8.0	20.0	40.0	8.0	32.0	40.0
Width *ft*	8.0	20.0	36.0	8.0	8.0	15.0	8.0	12.0	20.0	8.0	8.0	15.0
Total External Surface area ft^2	495.3	1796.0	5160.0	616.0	1360.0	3787.5	371.2	1088.0	3400.0	368.0	1112.0	2657.5
Floor Area ft^2	96.0	480.0	1440.0	128.0	320.0	900.0	64.0	240.0	800.0	64.0	256.0	600.0
Number of Display Doors	0.0	0.0	0.0	6.0	15.0	45.0	0.0	0.0	0.0	3.0	12.0	30.0
Number of Passage Doors	1.0	2.0	2.0	1.0	1.0	2.0	1.0	2.0	2.0	1.0	1.0	2.0
Number of Freight Doors	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0

The reference version of the *RSMeans Mechanical Cost Data* handbook provided the bare labor cost for installing cold storage rooms (division number 13 21 26.50) without doors and refrigeration system for coolers and freezers. After applying the installing contractors overhead and profit of 53.9 percent for this category of labor (carpenters), the final cost per square foot of floor area used by DOE was $7.43 for coolers and $9.93 for freezers. For units taller than 7 ft 6 in, DOE increased the panel installation cost by 5 percent, as reported in RSMeans.

Three panel installation costs were calculated by averaging the panel installation cost per panel area across the respective envelope size (*e.g.*, small storage coolers and freezers, and small display coolers and freezer panel installation costs were averaged to calculate the small panel installation costs). DOE calculated the medium and large panel installation costs in the same manner.

For envelope door installation costs, DOE also referenced the *RSMeans Mechanical Cost Data* handbook. DOE used the installation cost for passage doors based on 3 ft by 7 ft aluminum doors, 4 inches and 6 inches thick, for medium- and low-temperature applications, respectively. For both medium- and low-temperature application freight doors, DOE used the installation cost for 9 ft by10 ft manual operation doors. Note that RSMeans showed there was no difference in installation costs for freight doors of varying thickness; however, there were installation cost differences for passage doors of varying thickness. Because DOE could not find installation costs in the RSMeans handbook for display doors, DOE estimated that display door installation costs were approximately half of freight door installation costs. Distributor markups (discussed further in section 8.2.2.3) were then applied to the installation costs of the envelope components. Table 8.2.5 lists the envelope component base (before markups are applied) installation costs as provided by RSMeans 2012—with the exception for display doors, and the installation costs DOE used in the current LCC and PBP analyses.

Table 8.2.5 Envelope Component Installation Costs

Envelope Component Equipment Class	Size	Temperature Application	Base Installation Cost *$/ft^2* or *$/Door*	Installation Cost *$/ft^2* or *$/Door*
Structural panel & floor panel*	Small	Medium & low	1.74	0.78
	Medium		2. 25	1.01
	Large		2.37	1.06
Display doors	Small, medium, and large	Medium & low	300.00**	90.00
Passage door	Small, medium, and large	Medium	571.36	257.11
Passage door	Small, medium, and large	Low	775.46	348.96
Freight	Small, medium, and large	Medium & low	638.60	287.37

* Floor panels are only analyzed for low temperature applications

** Based on DOE estimate

8.2.2.3 Distributor Markup and Sales Tax

As noted in Section 8.2.2, DOE calculates the end-user equipment price by multiplying the manufacturer selling price by a distributor markup to determine the final equipment price. This markup includes both a distributor markup component and a sales tax component.

Different markups are calculated for different equipment classes based on their distribution channels. Specifically, the markups analysis distinguishes between dedicated condensing units and multiplex refrigeration systems. For the current LCC and PBP analyses, DOE calculated and used a national average sales tax. For the Monte Carlo analysis, detailed in appendix 8B, DOE intends to use state-specific sales taxes. DOE then applies the sales tax to complete the conversion of the end-user equipment price to the final equipment price. The markups analysis, discussed in chapter 6 of the TSD, describes the distributor markup and sales tax markup in detail.

8.2.3 Operating Cost Inputs

DOE defines the operating cost as the sum of energy cost, repair cost, and maintenance cost, as shown in the following equation:

$$OC = EC + RC + MC \tag{Eq. 8.4}$$

Where:

OC = operating cost ($),
EC = energy cost ($),
RC = repair cost ($), and
MC = maintenance cost ($).

The operating cost represents the costs incurred in operating the walk-in equipment. This includes energy costs, maintenance costs, and repair costs. Table 8.2.6 lists the inputs for operating costs. The analysis period, discount rate, and effective date of the amended standard are required for determining the operating cost and for establishing the operating cost present value. A primary driver of the operating costs is the electricity consumption for the baseline, and other CSLs are examined to enable comparison of standard operating costs.

Table 8.2.6 Inputs for Operating Costs

Annual Electricity Consumption (kWh)
Electricity Prices ($/kWh)
Electricity Price Trend
Maintenance Costs
Equipment Lifetimes (years)
Discount Rate (%)
Repair Costs ($/year)
Effective Date of Standard

8.2.3.1 Electricity Price Analysis

The annual energy costs for each WICF unit are important inputs to the LCC and PBP analyses. Since walk-ins are almost exclusively powered by electricity, DOE defined energy costs in any given year as the electricity use per year multiplied by the electricity price in that year.

Subdivision of the Country. Because of the wide variation in electricity consumption patterns, wholesale costs, and retail rates across the country, it is important to consider regional differences in electricity prices. For this reason, DOE divided the United States into the 50 states and the District of Columbia. DOE used reported average effective commercial electricity prices at the state level from the EIA publication *Form EIA-826 Database Monthly Electric Utility Sales and Revenue Data*.[2] The prices used from this source are for the calendar year 2012. These were adjusted to represent 2012$ prices using the gross domestic product (GDP) price deflator from *AEO2013*.[3] Table 8.2.7 provides data on the adjusted electricity prices.

Table 8.2.7 Commercial Electricity Prices by State (2012 cents/kWh)

State	Commercial Electricity Price *cents/kWh*	State	Commercial Electricity Price *cents/kWh*	State	Commercial Electricity Price *cents/kWh*
Alabama	10.44	Kentucky	8.78	North Dakota	7.77
Alaska	14.55	Louisiana	8.93	Ohio	9.29
Arizona	9.23	Maine	12.28	Oklahoma	7.07
Arkansas	7.84	Maryland	10.32	Oregon	8.32
California	12.14	Massachusetts	14.67	Pennsylvania	9.27
Colorado	9.31	Michigan	10.74	Rhode Island	13.98
Connecticut	14.91	Minnesota	9	South Carolina	9.69
Delaware	10.2	Mississippi	9.73	South Dakota	7.97
Dist. of Col.	11.92	Missouri	7.81	Tennessee	10.03
Florida	9.66	Montana	9.29	Texas	8.07
Georgia	9.66	Nebraska	8.18	Utah	7.77
Hawaii	34.91	Nevada	8.68	Vermont	14.34
Idaho	6.84	New Hampshire	13.78	Virginia	7.91
Illinois	7.77	New Jersey	12.05	Washington	7.78
Indiana	9.37	New Mexico	9.2	West Virginia	8.29
Iowa	7.95	New York	15.01	Wisconsin	10.56
Kansas	9.31	North Carolina	8.53	Wyoming	8.26

DOE recognized that different kinds of businesses typically use electricity in different amounts at different times of the day, week, and year, and therefore face different effective prices. To make this adjustment, DOE used the 2003 Commercial Buildings Energy Consumption Survey (CBECS) data set to identify the average prices paid by the seven kinds of businesses in this analysis compared with the average prices paid by all commercial customers. Since multi-line retail is not explicitly recognized as a CBECS building type, it was identified by identifying retail stores with data indicating the presence of walk-in refrigeration and other commercial refrigeration on the premises. Equation 8.5 shows the ratios of prices paid by the five types of businesses that were used to increase or decrease the average commercial prices.

$$EPRICE_{COM\ BLDGTYPE\ STATE\ 2012} = EPRICE_{COM\ STATE\ 2012} \times \left(\frac{EPRICE_{BLDGTYPE\ US\ 2003}}{EPRICE_{COM\ US\ 2003}}\right)$$

Eq. 8.5

Where:

$EPRICE_{COM\ BLDGTYPE\ STATE\ 2012}$ = average commercial sector electricity price in a specific building type (such as supermarkets, convenience stores, and restaurants) in a specific state in 2012,
$EPRICE_{COM\ STATE\ 2012}$ = average commercial sector electricity price in a specific state in 2012,
$EPRICE_{BLDGTYPE\ US\ 2003}$ = national average commercial sector electricity price in a specific building type in 2003 CBECS, and
$EPRICE_{COM\ US\ 2003}$ = national average commercial sector electricity price in 2003 CBECS.

8.2.3.2 Electricity Price Trend

The electricity price trend projects the future cost of electricity to 2045. DOE normalizes the *AEO2013* scenarios to the 2012 electricity prices and then uses that electricity price factor to scale up the electricity prices over time through 2035. The *AEO2013* price projections do not continue past 2040, so for the years 2041–2045, DOE uses a logarithmic extrapolation of the 2030–2040 electricity price projections. Figure 8.2.6 shows the commercial price trends, respectively, based on the *AEO2013* projections. Note that the commercial sector is forecasted to experience a decrease in electricity prices (measured in real dollars) before the analysis period but rising electricity prices during the analysis period.

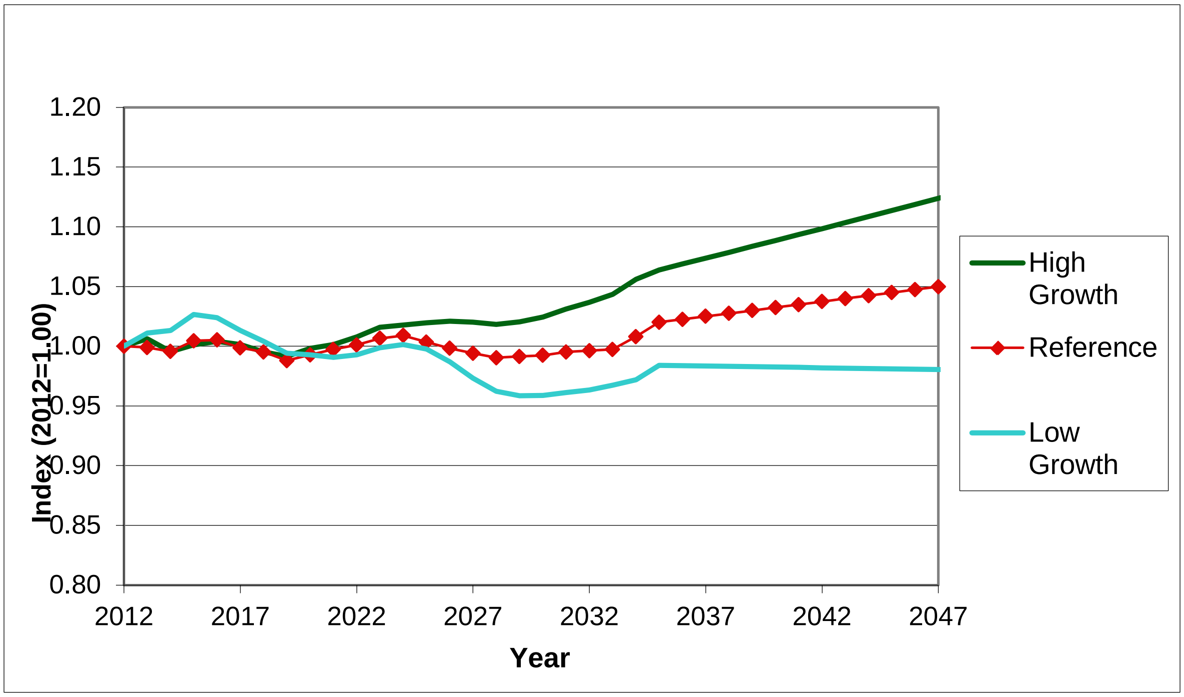


Figure 8.2.6 Commercial Electricity Price Projections by *AEO* Reference Case

In the LCC spreadsheet, these electricity price trends are used to project electricity prices into the future, which are then multiplied by the annual energy usage. The resulting operating costs are presented in the LCC spreadsheets. Please note that due to changing generation mixes, the energy prices of the low growth scenario are temporarily higher in the early years of the analysis.

8.2.3.3 Maintenance Costs

The maintenance cost is the cost to the consumer of maintaining equipment operation. In this analysis, DOE only considered the costs associated with general maintenance of walk-ins (*e.g.*, checking and maintaining refrigerant charge levels, checking settings, cleaning heat exchanger coils). Given the component-level based approach, DOE apportioned the general WICF maintenance costs between the refrigeration system and envelope doors. Annual maintenance costs for the envelope wall and floor panels were assumed to be negligible and were not considered.

DOE took annualized maintenance costs for WICF equipment (classification 1095) from *RSMeans Facilities Maintenance & Repair Cost Data*[4] as it provides estimates on the labor hours, labor rates, and materials required to maintain walk-ins. Of the total annual maintenance costs for a walk-in unit, which ranges from $170 to $262, DOE assumed $150 would be spent on the refrigeration system and the rest would be spent on the display and non-display doors of the envelope. DOE made this assumption based on comments and research that pointed to this value as the likely amount needed to cover refrigeration system-related costs. The RSMeans maintenance cost data covered walk-ins with external coolers only, including display walk-in coolers and freezers, but only non-display walk-in freezers; equipment walk-in sizes were not indicated. Based on the information available, DOE assumed that:

- maintenance costs do not vary with size,
- there is no difference in maintenance costs between walk-ins with internal and external condensing units,
- maintenance costs for storage coolers equal those for storage freezers, and
- maintenance costs do not vary with equipment efficiency.

Furthermore, based on the descriptions of maintenance activities in the RSMeans 2012 mechanical maintenance data book and manufacturer interviews, DOE assumed that minimal general maintenance is associated with the panels. Therefore, DOE did not include maintenance costs for panels in its analysis.

DOE performed a series of calculations to obtain maintenance costs for WICF doors. First, stock share distributions of envelope class sizes were applied to the number of door sizes in each of the envelope classes and summed for each envelope class. Then, the maintenance cost available for the envelope class was divided by the stock-weighted, total number of doors for the respective envelope class. These values were rounded to the nearest dollar. As stated previously, maintenance costs were assumed to be the same across small, medium, and large doors. Note that the display door maintenance costs do not include the maintenance costs associated with the non-display doors found in display walk-ins. Table 8.2.8 summarizes the maintenance costs per door for display and non-display doors.

Table 8.2.8 General Maintenance Costs for WICF Doors (2012$)

Type of Door	**Maintenance Cost per Door** ***$***
Display Door, Medium	3
Non-Display Door,* Medium	14
Display Door, Low	11
Non-Display Door*, Low	14

*Passage doors and freight doors are assumed to have the same maintenance cost per door.

Table 8.2.9 shows the annualized maintenance costs for the envelope components.

Table 8.2.9 Envelope Component Annualized Maintenance Costs for LCC Analysis (2012$)

Product ID	**Efficiency Level**			**Labor Maintenance Cost**
	0 (Baseline)	**1**	**2 through 10**	
DD.M.X.SML	$10	$10	$3	$4
DD.M.X.MED	$10	$10	$10	$4
DD.M.X.LRG	$10	$10	$10	$4
DD.L.X.SML	$18	$18	$11	$4
DD.L.X.MED	$18	$18	$18	$4
DD.L.X.LRG	$18	$18	$18	$4
MD.M.X.SML	$14	$14	$14	$0
MD.M.X.MED	$14	$14	$14	$0
MD.M.X.LRG	$14	$14	$14	$0
MD.L.X.SML	$14	$14	$14	$0
MD.L.X.MED	$14	$14	$14	$0
MD.L.X.LRG	$14	$14	$14	$0
FD.M.X.SML	$14	$14	$14	$0
FD.M.X.MED	$14	$14	$14	$0
FD.M.X.LRG	$14	$14	$14	$0
FD.L.X.SML	$14	$14	$14	$0
FD.L.X.MED	$14	$14	$14	$0
FD.L.X.LRG	$14	$14	$14	$0

*DOE assumed wall and floor panels do not have maintenance costs.

In addition to the preventative maintenance, DOE considered replacements of lamps and ballasts and other lighting maintenance activities as an essential maintenance activity for WICF display doors. Different sizes of WICF equipment in different equipment classes have several efficiency options that DOE considered. The engineering analysis included changes to the lighting configuration (lamp, ballast, or use of light emitting diodes (LED) lighting systems) among its design option list. Because the lighting configurations can vary by efficiency level, DOE estimated the relative maintenance costs for lighting for each analyzed equipment type. DOE's methodology was to estimate the frequency of failure and replacement of individual lighting components, to estimate the cost of replacement in the field, and to develop an annualized maintenance cost (in 2012$).

In the current analysis, annualized lighting maintenance costs were based on the replacement of fluorescent lamps (T8) once every 3 years. DOE based cost estimates for fluorescent lamps (T8) on a review of the original equipment manufacturer (OEM) costs used in the engineering analysis and RSMeans estimates. The final approach was to estimate the costs of field replacement using labor cost hours from *RSMeans Electrical Cost Data*[5] for typical lamp or ballast replacement from other lighting fixtures, and to provide a 100 percent multiplier on OEM costs for lamps to reflect retail pricing.

8.2.3.4 Lifetime

Equipment lifetime is an important input to the LCC analysis. Because the operating costs must be summed across each year in the lifetime of the equipment, the longer the lifetime, the more important the annual operating cost savings become relative to the increase in installation cost. In the preliminary analysis, DOE included the replacement of WICF refrigeration systems and doors based on the envelope lifetime because the envelopes had the longest lifetime. There was a relationship between the door and refrigeration system lifetimes to the envelope age in the preliminary analysis. Since DOE adopts a component-level approach in the current analysis, there is no longer a lifetime dependency between any of the WICF equipment. Consequently, the current LCC and PBP analyses do not replace the refrigeration systems and envelope components. Instead, operating costs, including costs for maintenance and repair, are calculated over the WICF equipment lifetime on an annual basis. The following figures illustrate the lifetime curves of WICF equipment in terms of their failure rates. Refer to the shipment analysis in chapter 9 of the TSD for further description of the WICF equipment lifetimes used in the NOPR analysis.

Figure 8.2.7 Refrigeration System Failure Rates

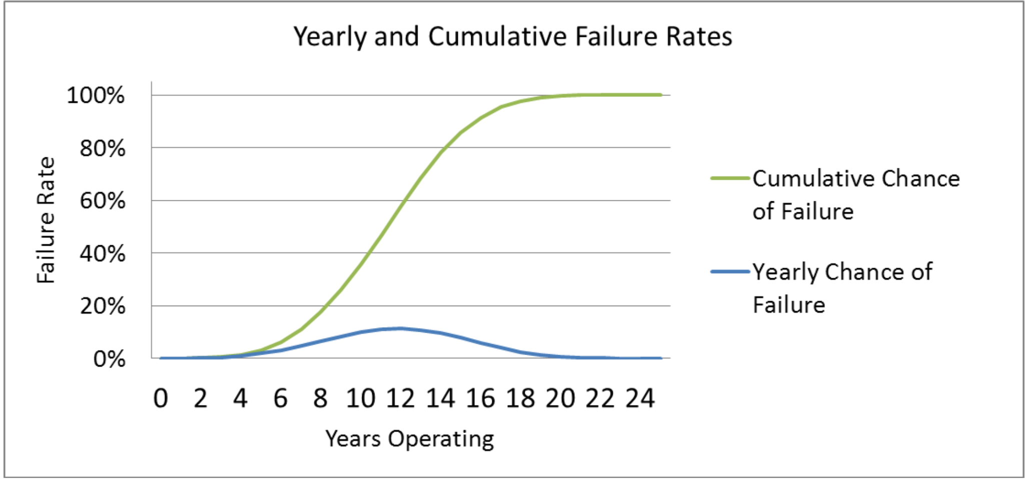


Figure 8.2.8 Display, Freight, and Passage Door Failure Rates

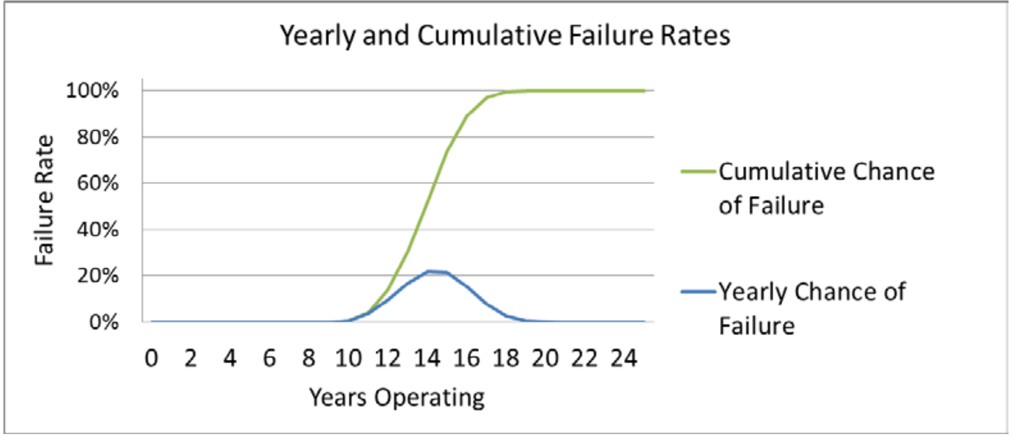
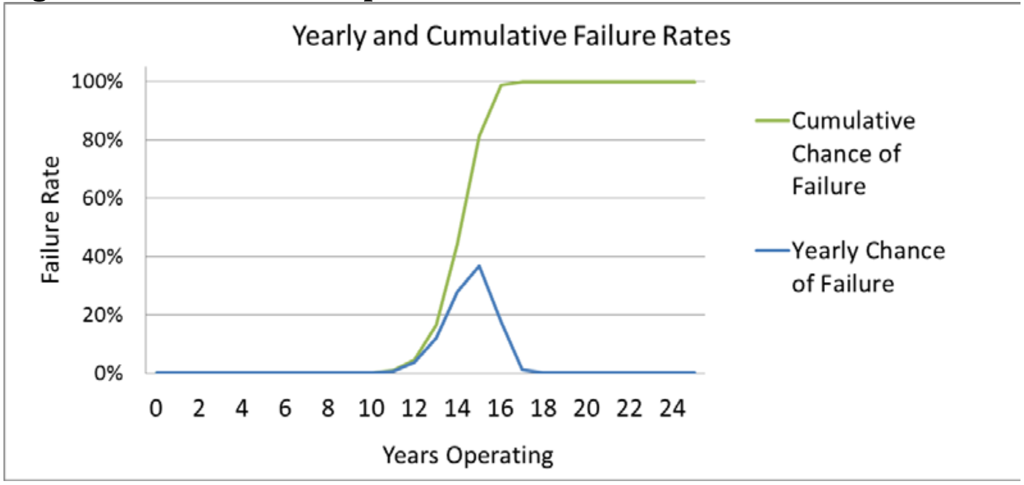


Figure 8.2.9 WICF Envelope Panel Failure Rates



8.2.3.5 Repair Costs

Annualized repair costs were calculated for key components of WICF refrigeration systems. Stakeholder comments in the preliminary analysis stated that usually only the main components of refrigeration systems are replaced, instead of purchasing a complete new refrigeration system. Consequently, DOE selected the compressor, condenser, and evaporator fans as refrigeration components needing replacement. Annualized repair costs for the WICF refrigeration systems are listed in Table 8.2.10 and Table 8.2.11. Repair costs shown in these tables include a 1.45 factor markup. Based on manufacturer interviews and DOE estimates, the replacement rates for compressor, condenser fan, and evaporator fans were estimated to be 5, 15, and 10 percent, respectively.

Table 8.2.10 Annualized Repair Costs ($) for WICF Refrigeration Systems, Efficiency Levels 0 (Baseline) Through 6 (2012$)

Refrigeration System ID	No. of Unit Coolers	Unit Cooler Capacity *kBtu/hr*	Repair cost $ for Materials at Efficiency Level							Labor Cost *$*
			0	**1**	**2**	**3**	**4**	**5**	**6**	
DC.M.I.HER.006.H	1	6	34	34	34	38	38	38	38	40
DC.M.I.HER.018.H	2	9	64	64	64	63	68	68	68	93
DC.M.I.SCR.018.H	2	9	83	83	83	83	87	87	87	94
DC.M.I.SCR.054.H	3	18	107	107	107	115	114	114	114	80
DC.M.I.SCR.096.H	4	24	162	162	162	171	169	169	169	148
DC.M.I.SEM.006.H	1	4	44	44	44	48	48	48	47	41
DC.M.I.SEM.018.H	2	9	103	103	103	101	106	106	106	94
DC.M.I.SEM.054.H	3	18	155	155	155	164	161	161	161	80
DC.M.I.SEM.096.H	4	24	223	223	223	232	225	225	225	148
DC.M.O.HER.006.H	1	4	34	34	34	34	34	38	38	40
DC.M.O.HER.018.H	2	9	64	64	64	64	64	64	69	93
DC.M.O.SCR.018.H	2	9	83	83	83	83	83	87	87	94
DC.M.O.SCR.054.H	3	18	107	107	107	107	107	116	116	80
DC.M.O.SCR.096.H	4	24	163	163	163	163	163	163	172	148
DC.M.O.SEM.006.H	1	4	45	45	45	45	45	49	49	41
DC.M.O.SEM.018.H	2	9	104	104	104	104	104	104	108	94
DC.M.O.SEM.054.H	3	18	157	157	157	157	157	166	166	80
DC.M.O.SEM.096.H	4	24	228	228	228	228	228	228	236	148
DC.L.I.HER.006.H	1	6	45	45	45	45	49	49	49	69
DC.L.I.HER.009.H	1	9	48	48	48	48	53	51	51	69
DC.L.I.SCR.006.H	1	6	66	66	66	66	71	71	70	70
DC.L.I.SCR.009.H	1	9	68	68	68	68	73	73	72	70
DC.L.I.SCR.054.H	3	18	187	187	187	196	196	196	196	98
DC.L.I.SEM.006.H	1	6	88	88	88	88	92	92	90	70
DC.L.I.SEM.009.H	1	9	94	94	94	94	99	96	96	70

Table 8.2.10 (continued)

Refrigeration System ID	No. of Unit Coolers	Unit Cooler Capacity *kBtu/hr*	Repair cost $ (materials) at Efficiency Level							Labor Cost for Repairs *$*
			0	1	2	3	4	5	6	
DC.L.I.SEM.054.H	3	18	246	246	246	261	261	261	261	98
DC.L.O.HER.006.H	1	6	46	46	46	46	46	46	46	69
DC.L.O.HER.009.H	1	9	49	49	49	49	49	49	54	69
DC.L.O.SCR.006.H	1	6	67	67	67	67	67	67	71	70
DC.L.O.SCR.009.H	1	9	69	69	69	69	69	69	73	70
DC.L.O.SCR.054.H	3	18	189	189	189	189	189	189	198	98
DC.L.O.SEM.006.H	1	6	89	89	89	89	89	89	93	70
DC.L.O.SEM.009.H	1	9	97	97	97	97	97	97	101	70
DC.L.O.SEM.054.H	3	18	263	263	263	263	263	263	278	98
DC.L.O.SEM.072.H	3	24	338	338	338	338	338	338	338	123
MC.M.N.006.004.1	-	-	9	9	9	9	9	9	9	12
MC.M.N.006.009.2	-	-	17	17	17	17	17	17	17	23
MC.M.N.006.024.6	-	-	24	24	24	24	24	24	24	23
MC.M.N.004.004.1	-	-	9	9	9	9	9	9	9	12
MC.M.N.004.009.2	-	-	17	17	17	17	17	17	17	23
MC.L.N.006.004.1	-	-	9	9	9	9	9	9	9	12
MC.L.N.006.009.2	-	-	17	17	17	17	17	17	17	23
MC.L.N.006.018.2	-	-	24	24	24	24	24	24	24	23
MC.L.N.004.004.1	-	-	9	9	9	9	9	9	9	12
MC.L.N.004.009.2	-	-	17	17	17	17	17	17	17	23
MC.L.N.004.018.2	-	-	43	43	43	43	43	43	43	58
MC.L.N.004.040.2	-	-	33	33	33	33	33	33	33	23

Table 8.2.11 Annualized Repair Costs for WICF Refrigeration Systems, Efficiency Levels 7 through 12

Refrigeration System ID	**No. of Unit Coolers**	**Unit Cooler Capacity *kBtu/hr***	**Repair cost $ (materials) at Efficiency Level**						**Labor Cost for Repairs ($)**
			7	8	9	10	11	12	
DC.M.O.HER.006.H	1	4	38	38	38				40
DC.M.O.HER.018.H	2	9	69	68	68				93
DC.M.O.SCR.018.H	2	9	87	87	87	87			94
DC.M.O.SCR.054.H	3	18	115	115	115	195	195		80
DC.M.O.SCR.096.H	4	24	170	170	170	313	313		148
DC.M.O.SEM.006.H	1	4	49	49	47				41
DC.M.O.SEM.018.H	2	9	108	108	108				94
DC.M.O.SEM.054.H	3	18	162	162	289	289			80
DC.M.O.SEM.096.H	4	24	229	229	401	401			148
DC.L.I.HER.006.H	1	6	49						69
DC.L.I.HER.009.H	1	9	51						69
DC.L.I.SCR.006.H	1	6	70						70
DC.L.I.SCR.009.H	1	9	72						70
DC.L.I.SCR.054.H	3	18	196						98
DC.L.I.SEM.006.H	1	6	90						70
DC.L.I.SEM.009.H	1	9	96						70
DC.L.I.SEM.054.H	3	18	244						98

Table 8.2.11 (continued)

Refrigeration System ID	No. of Unit Coolers	Unit Cooler Capacity *kBtu/hr*	Repair cost $ (materials) at Efficiency Level						Labor Cost for Repairs ($)
			7	8	9	10	11	12	
DC.L.O.HER.006.H	1	6	50	50	50	49			69
DC.L.O.HER.009.H	1	9	54	54	52	52			69
DC.L.O.SCR.006.H	1	6	71	71	70	70	70		70
DC.L.O.SCR.009.H	1	9	73	73	73	73	73		70
DC.L.O.SCR.054.H	3	18	198	198	198	431	431	421	98
DC.L.O.SEM.006.H	1	6	89	93	93	93	92		70
DC.L.O.SEM.009.H	1	9	101	98	98	98			70
DC.L.O.SEM.054.H	3	18	278	278	527	492	493		98
DC.L.O.SEM.072.H	3	24	353	353	335	584	584		123

Other than the lighting costs associated with the WICF display doors, which were considered as part of the envelope component maintenance costs, DOE did not consider repair costs for the envelope components. Refer to section 8.2.3.3 for a discussion of the envelope component maintenance costs.

8.2.3.6 Discount Rate

A discount rate is a rate at which future expenditures are discounted to establish their present value. The greater the discount rate used in an analysis, the less that future expenditures will be valued compared to current expenditures. Different market sectors frequently apply different discount rates to future expenditures, *e.g.*, discount rates in the residential sector are typically not the same as commercial sector discount rates. For the WICF LCC analysis, DOE intends to use discount rates that are appropriate for each type of owner of WICF equipment. As detailed in the shipments analysis in chapter 9 of the TSD, one way to classify WICF owners is by building or commercial establishment type—grocery stores, convenience stores, food service establishments, restaurants, or "other."

The discount rate is the rate at which future expenditures are discounted to establish their present value. DOE derived the discount rates for the commercial refrigeration equipment analysis by estimating the cost of capital for companies that purchase commercial refrigeration equipment. The cost of capital is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment. Most companies use both debt and equity capital to fund investments, so their cost of capital is the weighted average of the cost to the company of equity and debt financing.

DOE estimated the cost of equity financing by using the Capital Asset Pricing Model (CAPM).[6] The CAPM, among the most widely used models to estimate the cost of equity financing, assumes that the cost of equity is proportional to the amount of systemic risk associated with a company. The cost of equity financing tends to be high when a company faces a large degree of systemic risk, and it tends to be low when the company faces a small degree of systematic risk.

DOE determined the cost of equity financing by using several variables, including the risk coefficient of a company, β (beta); the expected return on "risk free" assets (R_f); and the additional return expected on assets facing average market risk, also known as the equity risk premium or *ERP*. The risk coefficient of a company, β, indicates the degree of risk associated with a given firm relative to the level of risk (or price variability) in the overall stock market. Risk coefficients usually vary between 0.5 and 2.0. A company with a risk coefficient of 0.5 faces half the risk of other stocks in the market; a company with a risk coefficient of 2.0 faces twice the overall stock market risk.

The following equation gives the cost of equity financing for a particular company:

$$k_e = R_f + (\beta \times ERP) \qquad \textbf{Eq. 8.6}$$

Where:

k_e = the cost of equity for a company (%),
R_f = the expected return of the risk free asset (%),
β = the risk coefficient, and
ERP = the expected equity risk premium (%).

DOE defined the risk-free rate as the 40-year geometric average yield on long-term government bonds. The risk free rate was calculated using Federal Reserve data for the period 1971 to 2010,[7] with a resulting rate of 6.41 percent. DOE used a 3.99 percent estimate for the *ERP* based on data from the Damodaran Online[8] site.

The cost of debt financing (k_d) is the interest rate paid on money borrowed by a company. The cost of debt is estimated by adding a risk adjustment factor (R_a) to the risk-free rate:

$$k_d = R_f + R_a$$

Eq. 8.7

Where:

k_d = the cost of debt financing for each firm (%),
R_f = the expected return on risk-free assets (%), and
R_a = the risk adjustment factor to risk-free rate for each firm (%).

The risk adjustment factor depends on the variability of stock returns represented by standard deviations in stock prices and was taken from Damodaran Online individual company cost of capital worksheets.[9] The weighted-average cost of capital (WACC) of a company is the weighted-average cost of debt and equity financing:

$$k = k_e \times w_e + k_d \times w_d$$

Eq. 8.8

Where:

k = the (nominal) cost of capital (%),
k_e = the expected rate of return on equity (%),
k_d = the expected rate of return on debt (%),
w_e = the proportion of equity financing in total annual financing, and
w_d = the proportion of debt financing in total annual financing.

The cost of capital is a nominal rate, because it includes anticipated future inflation in the expected returns from stocks and bonds. The real discount rate or WACC deducts expected inflation (r) from the nominal rate. DOE calculated expected inflation (3.83 percent) as the 40-year average GDP deflator derived from U.S. Bureau of Labor Statistics data covering the 1971–2010 period.[10]

To estimate the WACC of commercial refrigeration equipment purchasers, DOE used a sample of companies involved in grocery and multi-line retailing and restaurants drawn from a database of U.S. companies given on the Damodaran Online individual company worksheet cited earlier. The Damodaran database includes most of the publicly traded companies in the United States.

DOE divided the companies into categories according to their type of activity (*e.g.*, Small Grocery & Convenience, which covers convenience stores with and without gasoline stations). DOE used financial information for all of the firms in the Damodaran database engaged in each of the seven classes of business. Two classes—Other Food Service and Gas Station with Convenience Store—were not identifiable and therefore were calculated differently.

The average after-tax discount rates used were 3.98 percent for grocery stores, 5.37 percent for convenience stores, and 4.27 percent for food service establishments. For restaurants and "other" WICF categories, DOE used 6.94 percent and 4.23 percent, respectively.

The basis for the discount rate estimates used in the 2009 CRE Final Rule was DOE estimates of the cost of capital for companies that purchase commercial refrigeration equipment. The cost of capital is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment. Most companies use both debt and equity capital to fund investments, so their cost of capital is the weighted average of the cost to the company of equity and debt financing. As explained above, DOE estimated the cost of equity financing by using the capital asset pricing model (CAPM). The CAPM, which is among the most widely used models to estimate the cost of equity financing, assumes that the cost of equity is proportional to the amount of systematic risk associated with a company.

8.2.3.7 Effective Date of Standard

The effective date is the date when a standard becomes operative (*i.e.*, the date by which walk-in manufacturers must manufacture only equipment that complies with a standard). DOE's publication of a final rule in this standards rulemaking is scheduled for completion by January 1, 2014. The effective date of any energy conservation standards for these walk-ins must be at least 3 years after the final rule is published (42 U.S.C. 6295(g)(4)(C)), which will be January 2017. DOE calculates the LCCs for all customers as if each would purchase new equipment in the year the standard takes effect. However, DOE bases the cost of the equipment on the most recent available data; all dollar values are expressed in 2012$.

8.3 PAYBACK PERIOD INPUTS

8.3.1 Definition

The PBP is the amount of time it takes the customer to recover the assumed higher purchase cost of more energy-efficient equipment as a result of lower operating costs. Numerically, the PBP is the ratio of the increase in purchase cost (*i.e.*, from a less efficient design to a more efficient design) to the decrease in annual operating expenditures. This type of calculation is known as a "simple" PBP because it does not take into account changes in operating cost over time or the time value of money. That is, the calculation is done at an effective discount rate of zero percent.

The equation for PBP is the following:

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

Eq. 8.9

Where:

PBP = payback period,
ΔIC = difference in the total installed cost between the more efficacious standard level; equipment (CSL 1, 2, etc.) and baseline (CSL 0) equipment, and
ΔOC = difference in annual operating costs.

PBPs are expressed in years. PBPs greater than the life of the equipment indicate that the increased total installed cost of the more efficacious equipment is not recovered in reduced operating costs over its lifetime.

8.3.2 Rebuttable Presumption Payback Period

Section 325(o)(2)(B)(iii) of the Energy Policy and Conservation Act (EPCA) establishes a rebuttable presumption that an amended standard for walk-ins is economically justified if the Secretary of Energy (Secretary) finds that "the additional cost to the consumer of purchasing a product complying with an energy conservation standard level will be less than three times the value of the energy savings during the first year that the consumer will receive as a result of the standard, as calculated under the applicable test procedure." (42 U.S.C. 6295(o)(2)(B)(iii)) This rebuttable presumption test is an alternative path to establishing an economic justification compared to consideration of the seven factors set forth in 42 U.S.C. 6295(o)(2)(B)(i)(I)–(VII).

8.3.3 Inputs

The data inputs to PBP are the total installed cost of the equipment to the customer for each CSL and the annual (first year) operating costs for each CSL. The inputs to the total installed cost are the final equipment price and the installation cost. The inputs to the operating costs are the walk-in input power rating, annual operating hours, and electricity cost. The PBP uses the same inputs as the LCC calculation described in section 8.2, except that electricity price trends are not required. Since the PBP is "simple" (undiscounted), the required electricity cost is only for the year in which an amended energy conservation standard is to take effect (*i.e.*, 2017). The electricity price DOE uses in the PBP calculation for electricity cost is the undiscounted projected price for 2017, expressed in 2012$.

8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

This section presents the results of the life-cycle cost (LCC) and payback period (PBP) analyses for the considered efficiency levels for the refrigeration systems, doors, and panels of walk-ins. DOE used probability distributions to characterize the uncertainty in many of the analytical inputs. DOE used a Monte Carlo simulation technique to perform the LCC calculations on data pertaining to the business types of this analysis. For each set of sample consumers who use this equipment in each product class, DOE calculated the average LCC, the LCC savings, and the median PBP for each standard level. LCC and PBP calculations were performed 10,000 times by picking from distributions of business types, and state populations. 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 efficiency level, DOE calculated the percentage of consumers who would experience a net LCC benefit, a net LCC cost, or no impact. DOE considered a consumer to receive no impact at a given efficiency level if the base-case product DOE assigned to that consumer had the same or higher efficiency than that of the new standard being evaluated. Note that the average LCC savings and the median PBP at each efficiency level are relative to the base-case efficiency distribution, not the baseline efficiency level. For that reason, average LCC impacts are not equal to the difference between the LCC of a specific efficiency level and the LCC of the baseline product. DOE calculated the average LCC savings and median PBPs at each efficiency level by excluding those users that would not be affected by the standard. As stated earlier, DOE conducts a series of LCC calculations for the WICF refrigeration system and component equipment classes. Key inputs include the engineering analysis (TSD chapter 5), current electricity prices from EIA, long-term electricity price growth rates from *AEO2013*, and the equipment's lifetime.

When a standard results in positive LCC savings, this indicates that the LCC of the standard-compliant system is less than the LCC of the base-case system, and the customer enjoys a financial benefit of the amount of the LCC savings. When a standard results in negative LCC savings, it indicates that WICF customers would suffer a net financial loss of this amount were the standard to be set at that level.

8.4.1 Life-Cycle Cost Savings and Payback Period Summary Results

This section presents summary LCC savings results. Table 8.4.1 through Table 8.4.9 provide LCC savings results for each of the WICF equipment classes and proposed trial standard levels (TSL). Refer to the national impact analysis in chapter 10 of the TSD for a description of the proposed TSLs.

DOE noted that for all classes of refrigeration systems, customer LCCs were positive up through TSL 6, which corresponds to the maximum technologically feasible (max-tech) refrigeration level. The calculated PBP values vary between 1 and 8 years for the dedicated condensing unit (DC) classes and were less than 3 years for the multiplex classes. DOE also noted that more benefits are experienced by users of larger-capacity systems than by users of the smaller-capacity systems. DOE's LCC and PBP analysis results for all envelope component product classes at each TSL are reported in Table 8.4.7 through Table 8.4.9. DOE analyzed three sizes (small, medium and large) in each component class. Results for the weighted average size of the component are reported in these tables. Table 8.4.7 shows that for the structural panels, LCC savings are significantly negative and payback periods are very high at the max-tech level (TSL 6) for medium-temperature panels and at earlier levels for low-temperature standard panels and floor panels (TSL 3). From the LCC and PBP results for the display doors in Table 8.4.8, DOE notes that LCC savings are negative and PBPs are high at the max-tech levels. Table 8.4.9 shows similar results for the non-display doors.

Table 8.4.1 Summary of LCC and PBP Results for Medium-Temperature Dedicated Condensing Refrigeration Systems – Outdoor Condenser

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings** *2012$*				**Payback Period** *years*
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings**	**% of Consumers that Experience**			**Median**
						Net Cost	**No Impact**	**Net Benefit**	
Small Capacity (6 kBtu/hr)									
	Baseline	3,104	6,348	9,452	0				
TSL1	6-SEM	4,326	4,536	8,862	590	0	0	100	2.1
TSL2	8-SEM	4,557	4,146	8,704	748	0	0	100	3.2
TSL3	6-SEM	4,557	4,146	8,704	748	0	0	100	3.2
TSL4	8-SEM	4,326	4,536	8,862	590	0	0	100	2.1
TSL5	9-SEM	4,890	3,743	8,633	819	3	0	97	4.3
TSL6	9-SEM	4,890	3,743	8,633	819	3	0	97	4.3
Medium Capacity (18 kBtu/hr)									
	Baseline	5,033	12,452	17,486					
TSL1	3-SCR	6,905	8,763	15,668	1,817	0	0	100	1.0
TSL2	10-SCR	7,812	6,799	14,611	2,874	0	0	100	2.5
TSL3	3-SCR	6,905	8,763	15,668	1,817	0	0	100	1.0
TSL4	10-SCR	7,812	6,799	14,611	2,874	0	0	100	2.5
TSL5	10-SCR	7,812	6,799	14,611	2,874	0	0	100	2.5
TSL6	10-SCR	7,812	6,799	14,611	2,874	0	0	100	2.5
Large Capacity (54 kBtu/hr)									
	Baseline	7,812	37,652	45,465					
TSL1	9-SCR	15,124	17,847	32,971	12,494	0	0	100	1.0
TSL2	11-SCR	16,746	15,651	32,396	13,068	0	0	100	1.7
TSL3	9-SCR	15,124	17,847	32,971	12,494	0	0	100	1.0
TSL4	11-SCR	16,746	15,651	32,396	13,068	0	0	100	1.7
TSL5	11-SCR	16,746	15,651	32,396	13,068	0	0	100	1.7
TSL6	11-SCR	16,746	15,651	32,396	13,068	0	0	100	1.7

Table 8.4.2 Summary of LCC and PBP Results for Medium-Temperature Dedicated Condensing Refrigeration Systems – Indoor Condenser

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings** *2012$*				**Payback Period** *years*
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings**	**% of Consumers that Experience**			**Median**
						Net Cost	**No Impact**	**Net Benefit**	
Small Capacity (6 kBtu/hr)									
	Baseline	3,053	7,018	10,071					
TSL1	1-SEM	4,097	5,904	10,001	70	1	0	99	3.4
TSL2	6-SEM	4,490	5,211	9,701	370	5	0	95	4.9
TSL3	1-SEM	4,097	5,904	10,001	70	1	0	99	3.4
TSL4	6-SEM	4,490	5,211	9,701	370	5	0	95	4.9
TSL5	6-SEM	4,490	5,211	9,701	370	5	0	95	4.9
TSL6	6-SEM	4,490	5,211	9,701	370	5	0	95	4.9
Large Capacity (18 kBtu/hr)									
	Baseline	4,977	15,528	20,504					
TSL1	3-HER	6,568	12,586	19,154	1,350	0	0	100	2.2
TSL2	6-SCR	7,184	11,484	18,668	1,838	0	0	100	2.1
TSL3	3-HER	6,568	12,586	19,154	1,350	0	0	100	2.2
TSL4	6-SCR	7,184	11,484	18,668	1,838	0	0	100	2.1
TSL5	6-SCR	7,184	11,484	18,668	1,838	0	0	100	2.1
TSL6	6-SCR	7,184	11,484	18,668	1,838	0	0	100	2.1

Table 3 Summary of LCC and PBP Results for Low-Temperature Dedicated Condensing Refrigeration Systems – Outdoor Condenser

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings** *2012$*				**Payback Period** *years*
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings**	**% of Consumers that Experience**			**Median**
						Net Cost	**No Impact**	**Net Benefit**	
Small Capacity (6 kBtu/hr)									
	Baseline	3,504	11,007	14,511					
TSL1	9-HER	4,600	8,077	12,677	1,833	0	0	100	2.0
TSL2	7-SCR	5,031	6,699	11,730	1,814	0	0	100	1.7
TSL3	9-HER	4,600	8,077	12,677	1,833	0	0	100	2.0
TSL4	7-SCR	5,031	6,699	11,730	1,814	0	0	100	1.7
TSL5	10-SCR	5,441	6,260	11,700	1,844	0	0	100	2.8
TSL6	10-SCR	5,441	6,260	11,700	1,844	0	0	100	2.8
Medium Capacity (9 kBtu/hr)									
	Baseline	3,763	12,055	15,818					
TSL1	2-SCR	5,116	9,642	14,759	1,060	0	0	100	0.7
TSL2	10-SCR	6,085	7,425	13,510	2,308	0	0	100	2.8
TSL3	2-SCR	5,116	9,642	14,759	1,060	0	0	100	0.7
TSL4	10-SCR	6,085	7,425	13,510	2,308	0	0	100	2.8
TSL5	11-SCR	6,170	7,375	13,545	2,273	0	0	100	3.0
TSL6	11-SCR	6,170	7,375	13,545	2,273	0	0	100	3.0
Large Capacity (54 kBtu/hr)									
	Baseline	12,870	60,299	73,169					
TSL1	7-SCR	22,927	36,116	59,043	14,126	0	0	100	0.5
TSL2	8-SCR	23,182	35,397	58,579	14,590	0	0	100	0.6
TSL3	7-SCR	22,927	36,116	59,043	14,126	0	0	100	0.5
TSL4	8-SCR	23,182	35,397	58,579	14,590	0	0	100	0.6
TSL5	12-SCR	29,585	29,823	59,409	13,761	0	0	100	3.1
TSL6	12-SCR	29,585	29,823	59,409	13,761	0	0	100	3.1

Table 8.4.4 Summary of LCC and PBP Results for Low-Temperature Dedicated Condensing Refrigeration Systems – Indoor Condenser

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
						Net Cost	No Impact	Net Benefit	
Small Capacity (6 kBtu/hr)									
	Baseline	3,439	12,351	15,789					
TSL1	6-HER	4,449	10,552	15,001	788	0	0	100	3.3
TSL2	6-SCR	4,983	9,882	14,864	1,120	0	0	100	2.6
TSL3	6-HER	4,449	10,552	15,001	788	0	0	100	3.3
TSL4	6-SCR	4,983	9,882	14,864	1,120	0	0	100	2.6
TSL5	7-SCR	5,068	9,835	14,903	1,081	0	0	100	3.0
TSL6	7-SCR	5,068	9,835	14,903	1,081	0	0	100	3.0
Large Capacity (9 kBtu/hr)									
	Baseline	3,689	15,340	19,029					
TSL1	1-SCR	4,993	13,894	18,887	142	0	0	100	2.1
TSL2	6-SCR	5,447	12,470	17,917	1,112	0	0	100	2.8
TSL3	1-SCR	4,993	13,894	18,887	142	0	0	100	2.1
TSL4	6-SCR	5,447	12,470	17,917	1,112	0	0	100	2.8
TSL5	7-SCR	5,532	12,420	17,952	1,077	0	0	100	3.2
TSL6	7-SCR	5,532	12,420	17,952	1,077	0	0	100	3.2

Table 8.4.5 Summary of LCC and PBP Results for Medium-Temperature Multiplex Refrigeration Systems (Unit Coolers Only)

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
						Net Cost	No Impact	Net Benefit	
Capacity (9 kBtu/hr)									
	Baseline	1,583	6,143	7,726					
TSL1	EL3	2,251	3,759	6,010	1,715	0	0	100	0.6
TSL2	EL2	2,231	3,771	6,002	1,724	0	0	100	0.5
TSL3	EL3	2,251	3,759	6,010	1,715	0	0	100	0.6
TSL4	EL2	2,231	3,771	6,002	1,724	0	0	100	0.5
TSL5	EL3	2,251	3,759	6,010	1,715	0	0	100	0.6
TSL6	EL3	2,251	3,759	6,010	1,715	0	0	100	0.6

Table 8.4.6 Summary of LCC and PBP Results for Low-Temperature Multiplex Refrigeration Systems (Unit Coolers Only)

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
						Net Cost	No Impact	Net Benefit	
Capacity (9 kBtu/hr)									
	Baseline	1,583	10,295	11,878					
TSL1	EL5	2,776	7,252	10,028	1,849	0	0	100	2.5
TSL2	EL2	2,231	7,585	9,817	2,061	0	0	100	0.4
TSL3	EL5	2,776	7,252	10,028	1,849	0	0	100	2.5
TSL4	EL2	2,231	7,585	9,817	2,061	0	0	100	0.4
TSL5	EL5	2,776	7,252	10,028	1,849	0	0	100	2.5
TSL6	EL5	2,776	7,252	10,028	1,849	0	0	100	2.5

Table 8.4.7 Summary of LCC and PBP Results for Standard and Floor Panels (Weighted across All Sizes)

Trial Standard Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period *years*
	Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
					Net Cost	No Impact	Net Benefit	
Medium-Temperature Standard Panel								
Baseline	1,007	97	1,104					
TSL1	1,007	97	1,104	16	14	0	86	3.8
TSL2	977	119	1,095	0	0	100	0	N/A
TSL3	1,043	85	1,128	-9	75	0	25	6.8
TSL4	1,007	80	1,088	8	34	0	66	4.5
TSL5	1,043	65	1,109	-22	93	0	7	9.0
TSL6	3,206	19	3,225	-2,139	100	0	0	146.4
Low-Temperature Standard Panel								
Baseline	1,122	278	1,400					
TSL1	1,122	278	1,400	122	2	0	98	2.9
TSL2	1,010	399	1,410	0	0	100	0	N/A
TSL3	1,373	215	1,588	-66	79	0	21	7.4
TSL4	1,122	216	1,338	72	7	0	93	3.6
TSL5	1,373	161	1,533	-140	94	0	6	10.0
TSL6	3,208	76	3,284	-1,890	100	0	0	43.0
Low-Temperature Floor Panel								
Baseline	1,202	243	1,445					
TSL1	1,202	243	1,445	66	6	0	94	3.5
TSL2	1,103	318	1,421	0	0	100	0	N/A
TSL3	1,348	166	1,515	-4	62	0	38	6.0
TSL4	1,202	189	1,390	30	28	0	72	4.5
TSL5	1,348	124	1,473	-65	88	0	12	8.0
TSL6	2,982	79	3,061	-1,653	100	0	0	48.7

Table 8.4.8 Summary of LCC and PBP Results for Display Doors (Weighted across All Sizes)

Trial Standard Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period (years)
	Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
					Net Cost	No Impact	Net Benefit	
Medium-Temperature Display Door								
Baseline	1,100	530	1,630					
TSL1	1,205	186	1,391	239	0	0	100	2.1
TSL2	1,205	180	1,385	228	0	0	100	2.2
TSL3	1,205	186	1,391	239	0	0	100	2.1
TSL4	1,205	180	1,385	228	0	0	100	2.2
TSL5	1,205	177	1,382	222	0	0	100	2.2
TSL6	4,182	73	4,255	-2,650	100	0	0	37.6
Low-Temperature Display Door								
Baseline	1,594	1,412	3,006					
TSL1	1,756	1,033	2,789	217	0	0	100	-0.1
TSL2	1,756	954	2,710	200	0	0	100	-0.1
TSL3	2,046	972	3,019	-12	64	0	36	6.0
TSL4	1,756	954	2,710	200	0	0	100	-0.1
TSL5	1,756	942	2,698	198	0	0	100	-0.1
TSL6	4,242	371	4,613	-1,717	100	0	0	18.5

Table 8.4.9 Summary of LCC and PBP Results for Non-Display Doors (Weighted across All Sizes)

Trial Standard Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period (years)
	Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
					Net Cost	No Impact	Net Benefit	
Medium-Temperature Passage Door								
Baseline	691	89	780					
TSL1	691	89	780	2	27	0	73	4.5
TSL2	683	91	774	0	0	100	0	N/A
TSL3	691	89	780	2	27	0	73	4.5
TSL4	691	83	774	0	52	0	48	5.5
TSL5	691	80	772	0	64	0	36	6.0
TSL6	1,637	19	1,655	-884	100	0	0	78.7
Low-Temperature Passage Door								
Baseline	1,070	2,205	3,274					
TSL1	1,070	2,205	3,274	74	14	0	86	4.3
TSL2	880	2,261	3,142	0	0	100	0	N/A
TSL3	1,226	2,138	3,364	-16	66	0	34	6.2
TSL4	1,070	2,020	3,090	52	27	0	73	4.7
TSL5	1,226	1,937	3,163	-52	75	0	25	7.0
TSL6	1,863	1,913	3,776	-665	100	0	0	18.3
Medium-Temperature Freight Door								
Baseline	1,277	147	1,424					
TSL1	1,277	143	1,420	3	25	0	75	4.5
TSL2	1,265	144	1,409	0	0	100	0	N/A
TSL3	1,277	143	1,420	3	25	0	75	4.5
TSL4	1,277	131	1,408	1	50	0	50	5.4
TSL5	1,277	126	1,403	0	62	0	38	5.9
TSL6	2,511	49	2,560	-1,157	100	0	0	81.5

Table 8.4.9 (Continued)

Trial Standard Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period (years)
	Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
					Net Cost	No Impact	Net Benefit	
Low-Temperature Freight Door								
Baseline	1,670	3,424	5,094					
TSL1	1,670	3,424	5,094	152	6	0	94	3.8
TSL2	1,426	3,491	4,917	0	0	100	0	N/A
TSL3	1,914	3,305	5,219	28	56	0	44	5.8
TSL4	1,543	3,237	4,780	136	1	0	99	2.9
TSL5	1,914	2,987	4,901	-32	69	0	31	6.5
TSL6	3,273	2,932	6,205	-1,337	100	0	0	21.7

Figure 8.4.1 through Figure 8.4.4 illustrate life cycle cost savings and payback periods for small medium-temperature standard WICF panels and medium-temperature dedicated condensing units.

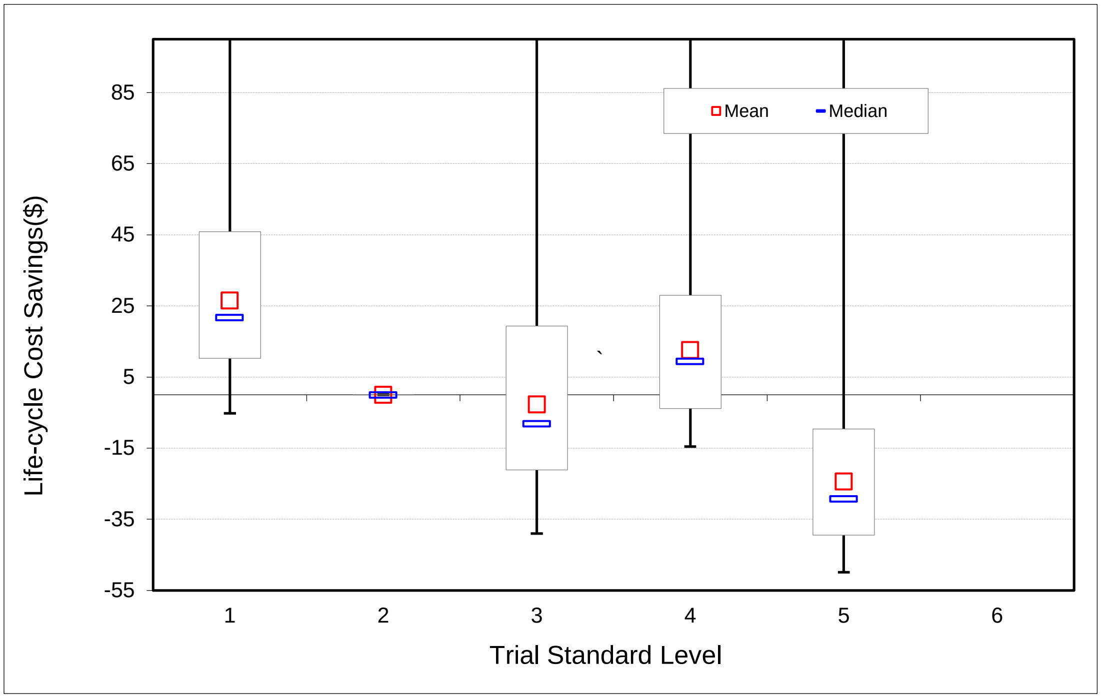


Figure 8.4.1 Life Cycle Cost Savings for Small Medium-Temperature WICF Standard Panels

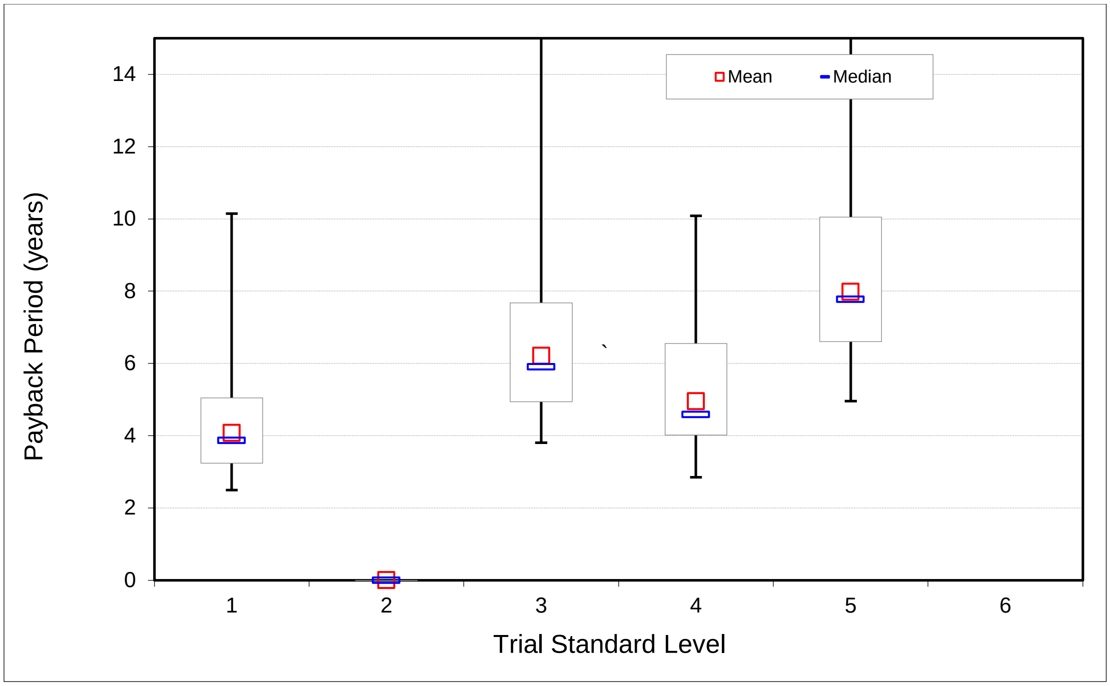


Figure 8.4.2 Payback Period for Small Medium-Temperature WICF Standard Panels

Please note that data at TSL 6 has been excluded from Figure 8.4.1 and Figure 8.4.2; the negative LCC savings results are too low to fit on the y-axis.

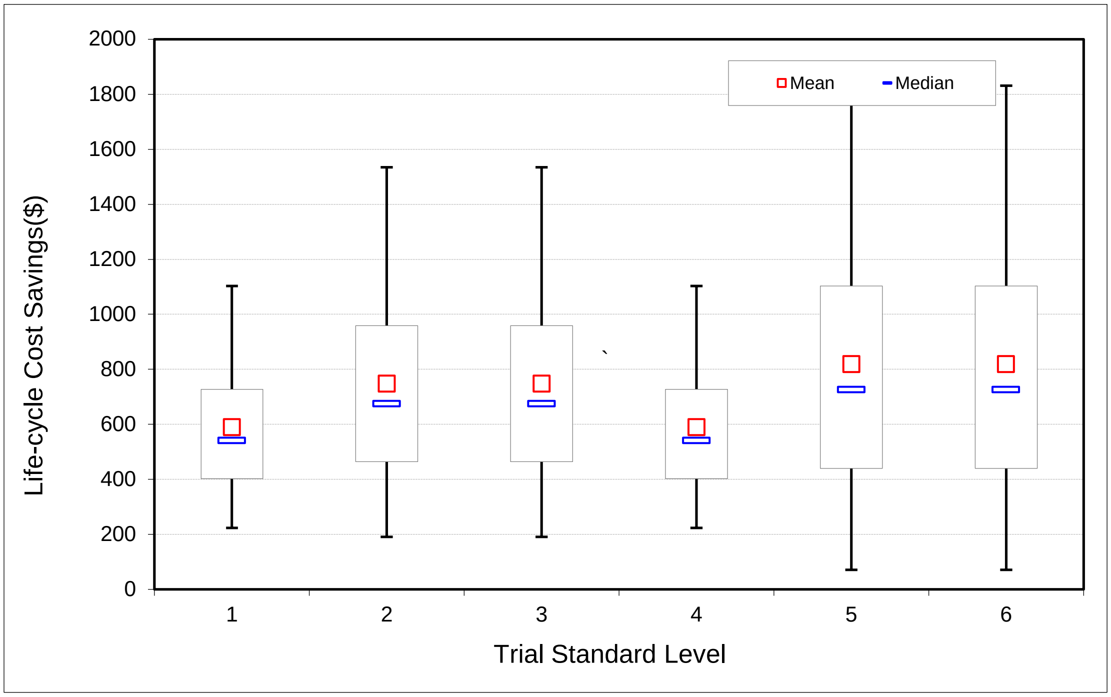


Figure 8.4.3 Life Cycle Cost Savings for Medium-Temperature Dedicated Condensing Units (6 kBtu/hr)

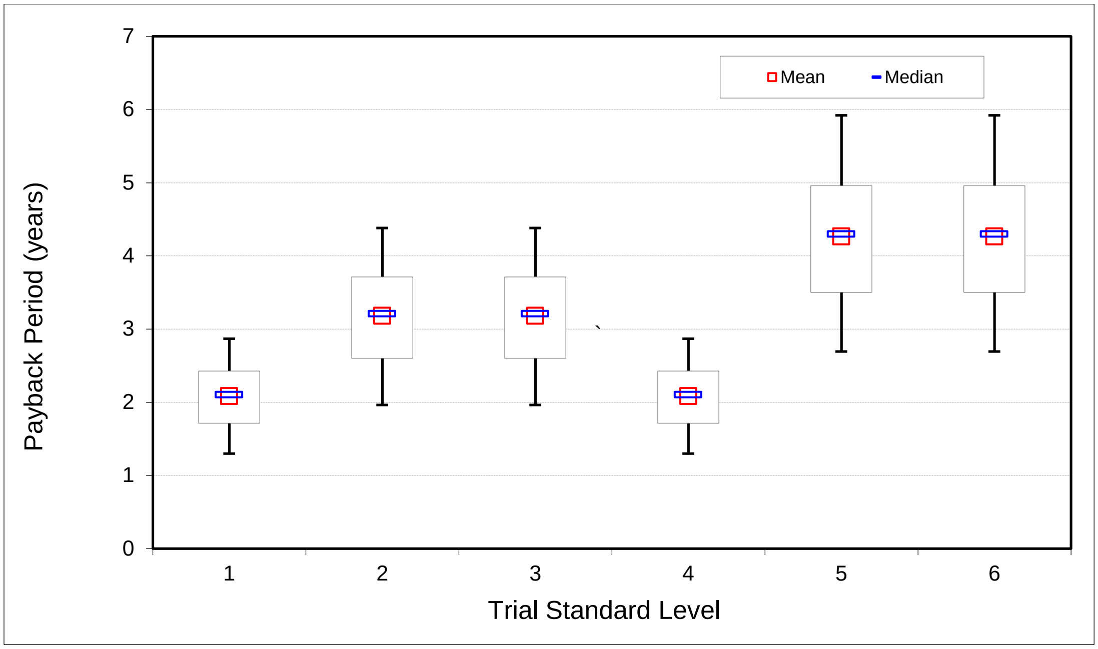


Figure 8.4.4 Payback Period for Medium-Temperature Dedicated Condensing Units (6 kBtu/hr)

8.4.2 Life-Cycle Cost Savings for Refrigeration Equipment with Discrete Inputs

Appendix 8E provides detailed life cycle cost (LCC) and payback period (PBP) results for the refrigeration system for all the sizes analyzed in the engineering analysis. The LCC savings are computed using the baseline efficiency level of the same equipment of same specification. The results could be used to specifically analyze effectiveness of the design options used to determine equipment class size effectiveness.

8.4.3 Rebuttable Payback Period Summary Results

EPCA, as amended, establishes a rebuttable presumption that a standard is economically justified if the Secretary finds that the additional cost to the consumer of purchasing a product that complies with an energy conservation standard level will be less than three times the value of the consumer's first-year energy (and, as applicable, water) savings derived as a result of the standard, as calculated under the test procedure in place for that standard. (42 U.S.C. 6295(o)(2)(B)(iii)) For each considered efficiency level, DOE determined the value of the first year's energy savings by calculating the quantity of those savings in accordance with the applicable DOE test procedure, and multiplying that amount by the average energy price forecast for the year in which compliance with the new standard would be required. DOE then calculated a rebuttable presumption payback period at each TSL for WICF equipment. Rather than using distributions for input values, DOE used discrete values and, as required by EPCA, based the calculation on the assumptions in the DOE test procedures for WICFs. As a result, DOE calculated a single rebuttable presumption payback value, rather than a distribution of payback periods. Table 8.4.10 through Table 8.4.13 list the rebuttable PBP at each TSL for the WICF equipment class sizes DOE analyzed.

Table 8.4.10 WICF Refrigeration Systems Rebuttable Payback Periods

Equipment Class	Capacity kBtu/hr	Rebuttable Payback Period (Years)					
		TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
DC.M.I	6	1.4	4.7	1.4	4.7	4.7	4.7
	18	1.6	1.8	1.6	1.8	1.8	1.8
DC.M.O	6	2.1	3.9	2.1	3.9	5.9	5.9
	18	0.8	3.1	0.8	3.1	3.1	3.1
	54	1.1	2.2	1.1	2.2	2.2	2.2
DC.L.I	6	2.4	2.1	2.4	2.1	2.3	2.3
	9	0.9	2.3	0.9	2.3	2.6	2.6
DC.L.O	6	1.9	1.7	1.9	1.7	2.8	2.8
	9	0.7	3.1	0.7	3.1	3.3	3.3
	54	0.5	0.6	0.5	0.6	3.4	3.4
MC.M.N	9	1.0	0.8	1.0	0.8	1.0	1.0
MC.L.N	9	3.7	0.7	3.7	0.7	3.7	3.7

Table 8.4.11 WICF Envelope Components Rebuttable Payback Periods for Small Sizes

Equipment Class	Rebuttable Payback Period (Years)					
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
SP.M	5.3	-	8.1	5.3	8.1	113.0
SP.L	3.1	-	6.9	3.1	6.9	30.8
FP.L	3.8	-	6.8	3.8	6.8	37.2
DD.M	2.5	2.5	2.5	2.5	2.5	33.9
DD.L	N/A	N/A	6.4	N/A	N/A	16.9
PD.M	6.2	-	6.2	6.2	6.2	71.5
PD.L	4.7	-	6.9	4.7	6.9	16.3
FD.M	6.0	-	6.0	6.0	6.0	93.9
FD.L	4.6	-	7.1	3.5	7.1	22.1

Dashes represent components at baseline efficiency and therefore do not have a payback period.

Table 8.4.12 WICF Envelope Components Rebuttable Payback Periods for Medium Sizes

Equipment Class	Rebuttable Payback Period (Years)					
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
SP.M	5.2	-	9.4	5.2	9.4	158.8
SP.L	3.8	-	10.1	3.8	10.1	43.8
FP.L	4.6	-	7.8	4.6	7.8	47.6
DD.M	2.2	2.2	2.2	2.2	2.2	36.9
DD.L	N/A	N/A	6.3	N/A	N/A	18.0
PD.M	6.1	-	6.1	6.1	6.1	76.4
PD.L	4.7	-	6.9	4.7	6.9	17.6
FD.M	6.0	-	6.0	6.0	6.0	96.9
FD.L	3.8	-	5.9	2.4	5.9	19.6

Dashes represent components at baseline efficiency and therefore do not have a payback period.

Table 8.4.13 WICF Envelope Components Rebuttable Payback Periods for Large Sizes

Equipment Class	Rebuttable Payback Period (Years)					
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
SP.M	5.2	-	9.4	5.2	9.4	158.8
SP.L	3.8	-	10.1	3.8	10.1	43.8
FP.L	4.6	-	7.8	4.6	7.8	47.6
DD.M	2.2	2.2	2.2	2.2	2.2	36.9
DD.L	N/A	N/A	6.3	N/A	N/A	18.0

PD.M	6.1	-	6.1	6.1	6.1	76.4
PD.L	4.7	-	6.9	4.7	6.9	17.6
FD.M	6.0	-	6.0	6.0	6.0	96.9
FD.L	3.8	-	5.9	2.4	5.9	19.6

Dashes represent components at baseline efficiency and therefore do not have a payback period.

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CHAPTER 9. SHIPMENTS ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

Estimates of future equipment 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 shipments and presents results for each set of equipment being considered for this standards rulemaking.

In the current analysis, DOE adopted a component-level approach for developing performance standards for walk-in coolers and walk-in freezers (WICF or walk-ins). With the adoption of a component-level performance standards approach, DOE will set separate standards for WICF panels, display doors, non-display doors, and refrigeration systems. Consequently, in the notice of proposed rulemaking (NOPR) analysis, DOE developed individual shipment models for complete WICF units, refrigeration systems, and envelope components. The envelope component shipment model included the shipments for display and non-display doors but did not separately model shipments of the panels because the panel shipments could be directly calculated from the results of the shipment model for complete WICF units.

The shipment models are in Microsoft Excel spreadsheet format and are accessible on the Internet at: www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/26. Appendix 9A of this technical support document (TSD) will provide instructions for using the spreadsheet.

Subsequent sections of this chapter discuss each of the shipment models in greater detail. Section 9.2 presents a general overview of the shipment models DOE developed and the relationship between them. Section 9.3 presents the equations used to calculate stock, as well as component lifetimes, age distributions, and price elasticity applied to each of the shipment models. Section 9.4 describes the inputs specific to each of the shipment models and presents shipments results. The energy conservation standards for WICF refrigeration system and envelope components will set the minimum efficiency or maximum energy consumption for all equipment within an equipment class.

For clarity, the following sections use the following terminology to distinguish between the various components of a complete WICF unit: the term “envelope” refers only to the enclosure of a complete WICF unit; “envelope components” refers to the panels, display doors, and non-display doors; “component” applies to any equipment related to a complete WICF unit (envelope, refrigeration system, panel, display door, and non-display door); “use category” refers to the type of complete WICF units (small, medium and large storage and display coolers, and small, medium, and large storage and display freezers; and “equipment class” refers to a certain category of equipment distinguished by the type of energy used, capacity, and performance-related features that affect consumer utility or efficiency, which include the refrigeration system and envelope component classes (for a list of the covered equipment classes, see TSD chapter 3).

9.2 MODEL OVERVIEW AND INTERRELATIONSHIP

The shipment model for the complete WICF units is the core shipment model. The output from the WICF complete units shipment model forms the basis of the shipment models for the refrigeration systems and envelope components. A significant proportion of the total walk-in shipments are the components of new WICF units because each walk-in unit consists of a refrigeration system and an envelope. However, the annual shipped quantities of complete WICF units and refrigeration systems are not equal because complete WICF units and refrigeration systems are replaced at different rates. DOE first estimated the stock of complete WICF units in 2007 and used these results to derive the initial stock of panels, refrigeration systems, display doors, and non-display doors. DOE then estimated the age distribution of the initial stock (by combining historical data with lifetime estimates of components) to estimate replacements for the refrigeration and envelope components. Next, DOE developed a distribution of failure rates by age, and combined it with the ages of the initial stocks. This process was applied to determine the number of failed components that must be replaced in 2007, and the process is continued through the analysis period by aging the stock and then recalculating component failures at their new, older age. Future additions to stock are calculated and then aged in a similar manner.

The results of the WICF shipment models for the refrigeration system and envelope components are driven primarily by the complete WICF unit initial stock estimates and assumptions about the stock growth and turnover rates. In DOE's shipments model, shipments of walk-in units and components are driven by new purchases and stock replacements due to failures. The envelope component and refrigeration system shipments models take an accounting approach, tracking market shares of each component class at different efficiency levels and the vintage of units in the existing stock, including Energy Independence and Security Act (EISA)-compliant and non-EISA-compliant units. Stock accounting uses component shipments as inputs to estimate the age distribution of in-service component stocks for all years. The age distribution of in-service component stocks is a key input to calculations of both the National Energy Savings (NES) and consumer Net Present Value (NPV) in chapter 10 because operating costs and costs for replacement units for any year depend on the age distribution of the stock. All three shipment models assume that, in each year, any given piece of existing WICF unit and component stock either ages by 1 year or fails. DOE forecasts shipments for each complete WICF unit use category, and for each class of refrigeration systems and envelope components. In addition, the refrigeration shipment model produces capacity-weighted shipments by multiplying the shipped numbers of refrigeration systems by their respective capacities in British thermal units per hour (Btu/h) and aggregating them. The flow chart presented in Figure 9.2.1 outlines the relationship between the complete WICF unit and envelope components and refrigeration system shipment models.

Figure 9.2.2, Figure 9.2.3, and Figure 9.2.4 illustrate the shipment models DOE developed in the current analysis.

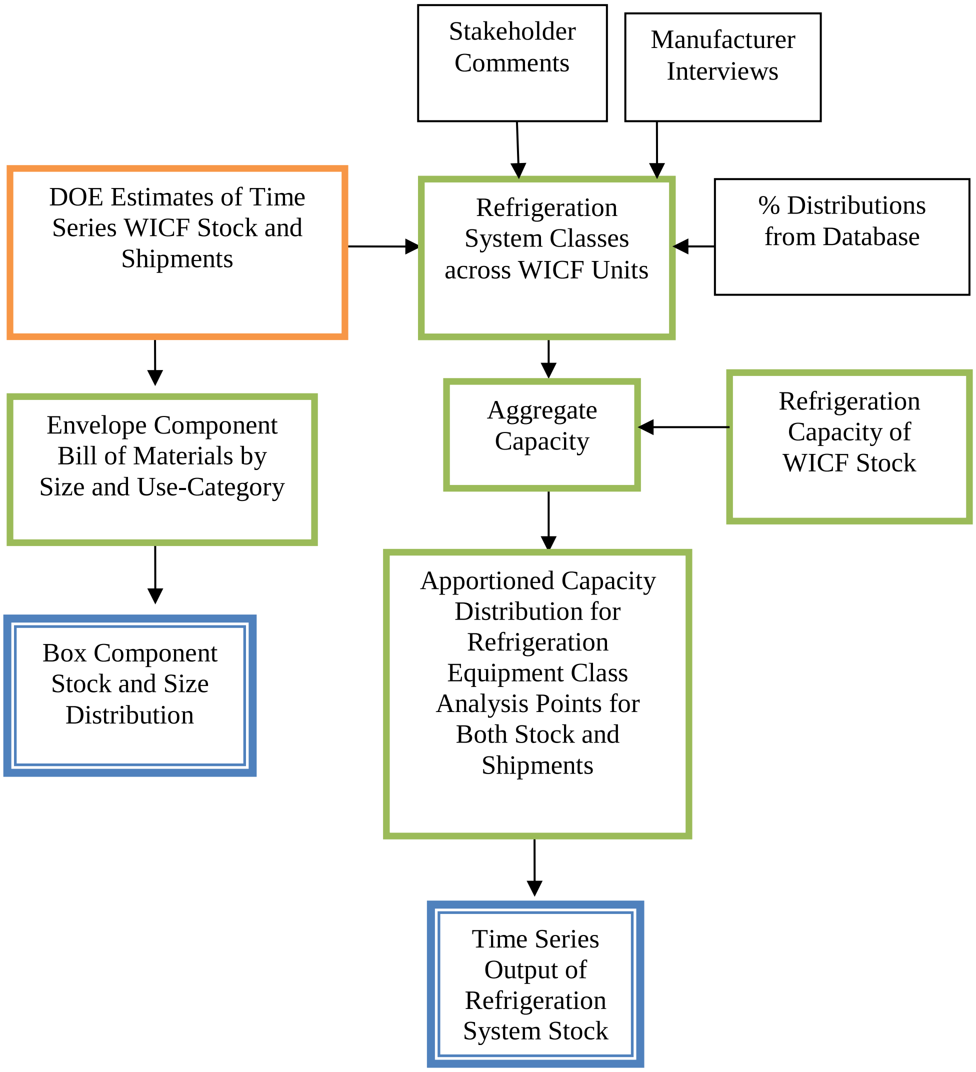

Figure 9.2.1 Relationship Between Complete Walk-in Unit and Refrigeration and Envelope Component Stock

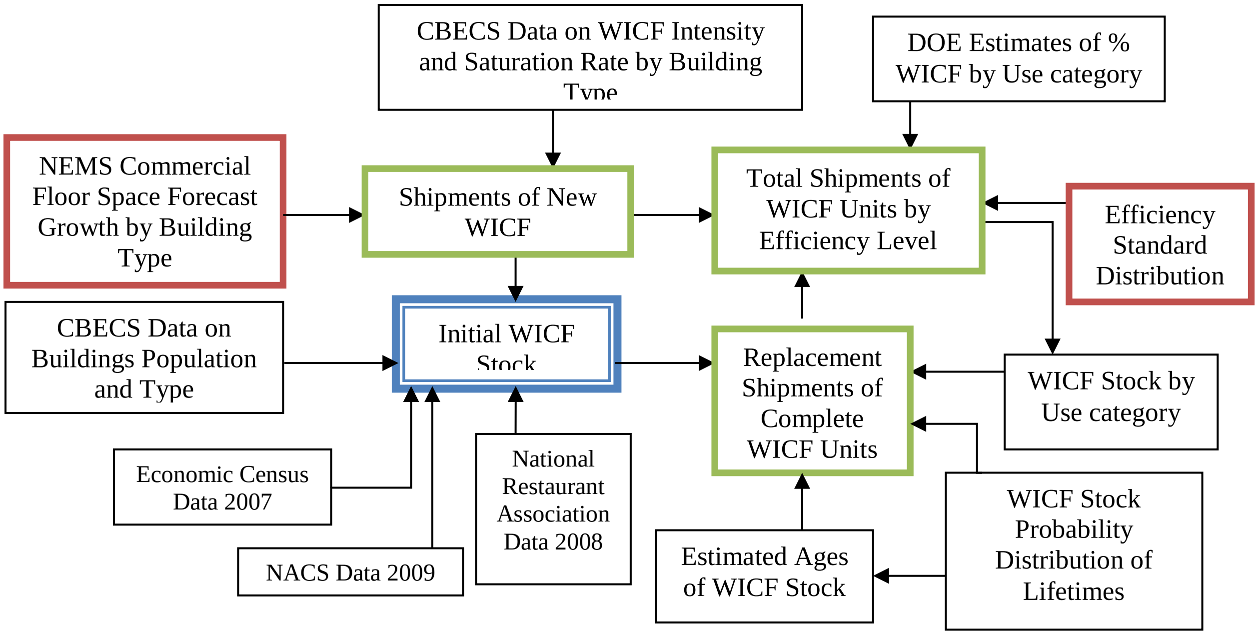

Figure 9.2.2 Flow Chart Showing Inputs to the Complete WICF Unit Shipment Model

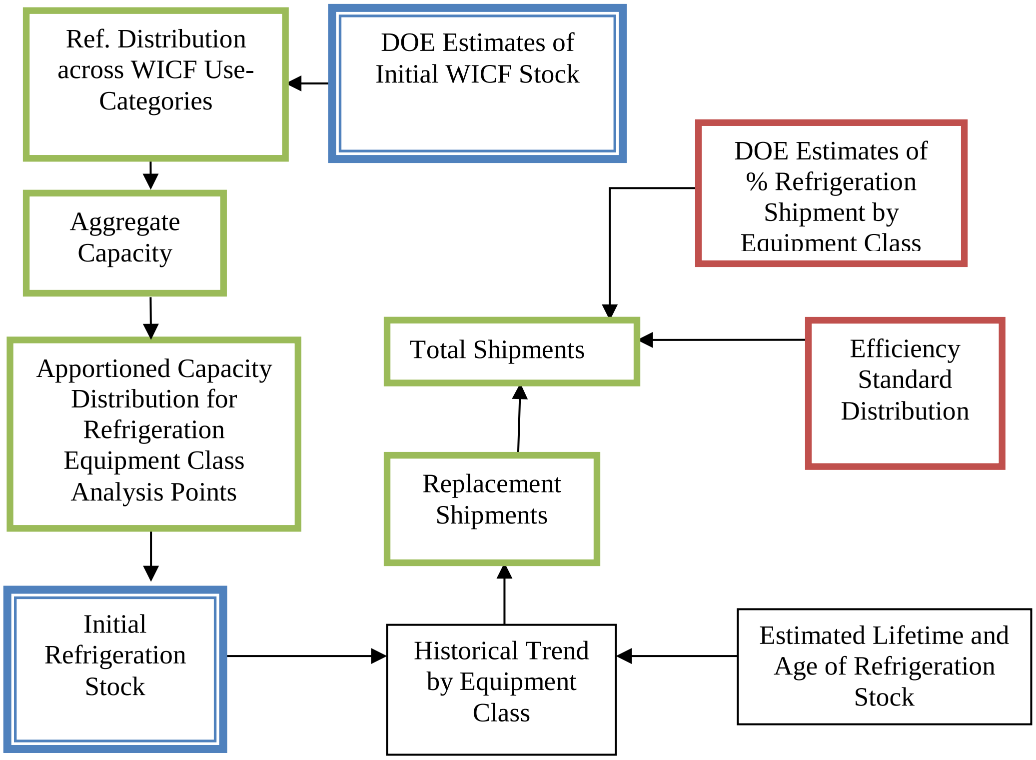

Figure 9.2.3 Flow Chart Showing Inputs to the Refrigeration Shipment Model

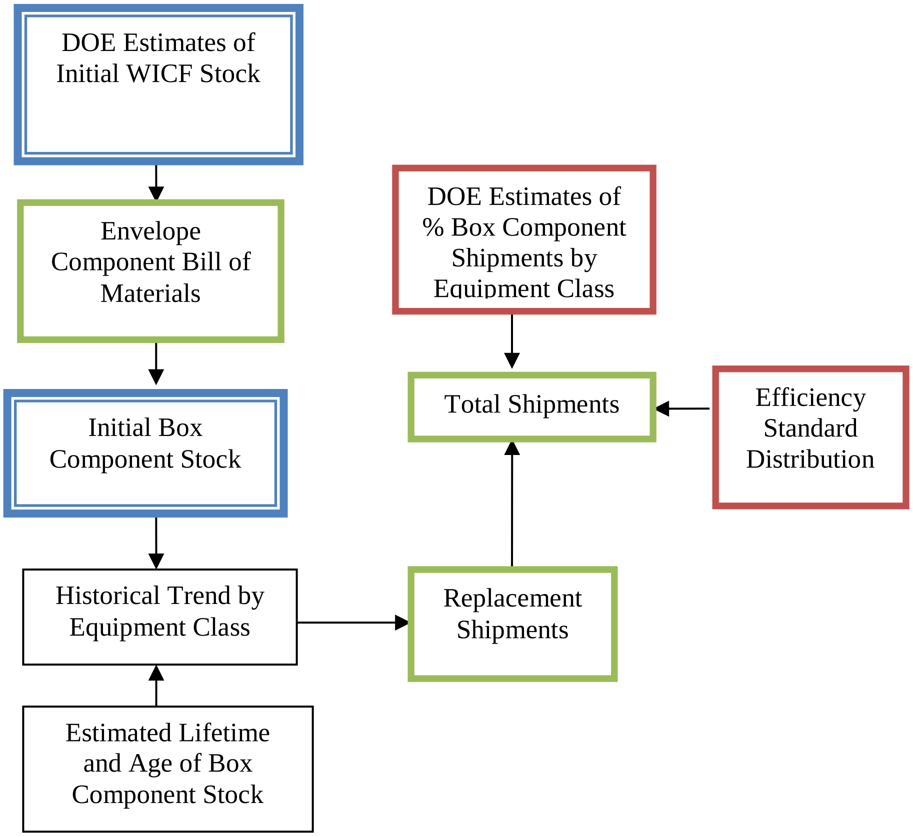

Figure 9.2.4 Flow Chart Showing Inputs to the Envelope Components Shipment Model

9.3 GENERAL METHODOLOGY

The shipment models address component stock flow as a function of time and equipment age. The equations presented in this chapter apply to all individual entities considered in the shipment analyses, which include complete WICF units, refrigeration systems, display doors, and non-display doors. Furthermore, the equations are applied to each WICF unit use category and components independently; the shipments results are then aggregated for each WICF unit use category and component class. DOE formulates the equations as updates of the distribution of stock in year *t* as a function of stock age. The equations consider the age of the WICF unit and components.

Because the complete WICF unit stock and shipments form the basis for the refrigeration system and display and non-display door stock and shipments, DOE's approach first combines estimates of the existing stock of WICF units with expected growth rates to derive the total stock of walk-ins from 2017 through 2046 for each type of WICF unit. DOE estimates these growth rates as functions of the extent of relevant commercial floor space. Sales of new and replacement WICF units are recorded by the year of the equipment, and each annual vintage is depreciated over the estimated life of the equipment to determine the rate of replacement shipments necessary to sustain the stock at the forecasted level.

9.3.1 Mathematical Formulation of the Shipment Model

The shipment models estimate the number of shipments of each type of WICF unit and component in a given year by tracking stock age and type. At the end of each year, these entities either age by 1 year or are replaced. Whenever new equipment replaces failed equipment, the new equipment is, by definition, zero years old. Similarly, whenever new stock is added through market growth, this new equipment is also zero years old. Therefore, in a given year, shipments of WICF components are equal in quantity to the number of units at age zero.

In the shipment modeling for the preliminary analysis, DOE combined the complete WICF envelope and refrigeration shipments so that the failure of one affected the shipments of the other. Since DOE adopts a component-level approach to the standards in the NOPR, the shipments of one WICF component are now independent of other WICF components. For example, the failure of a refrigeration system does not initiate the replacement of another envelope component, such as a non-display door. Also, DOE assumes that during the analysis time horizon, all WICF components are replaced with standards-compliant components. The shipment models track the number of shipments and size of the stock of the components, and age distribution in each year. Thus, the total stock, *STOCK*, for any entity in the year *t* is the sum of the following:

$$STOCK_t = \sum_{EC_{WC}, CSL_{WC}, a_{WC}} (STOCK_{EC_{WC}, CSL_{WC}, a_{WC}, t})$$

Eq. 9.1

Where:

$t =$ year,
$EC_{WC} =$ WICF unit or component,
$CSL_{WC} =$ WICF component standard level, and
$a_{WC} =$ age of the WICF component.

9.3.1.1 Size of the Stock

Because the complete WICF unit shipments model forms the basis for the refrigeration system, display doors, and non-display doors shipment models, the following discussion describes the how stocks were derived for the complete WICF unit shipments model.
DOE assumes that the major driver of complete WICF unit stock is commercial floor space of the major establishments that use walk-ins: restaurants, institutional food service establishments (education and healthcare), food sales establishments (consisting of grocery stores and supermarkets), convenience stores, and “other” (encompassing a wide variety of minor walk-in applications, *e.g.,* lodging, office, and florists). For simplicity, the following text refers to all these categories as “building types.” DOE did not have sufficient information to forecast the change over time in intensity of walk-ins per square foot of commercial floor space. Therefore, in the complete WICF unit shipment model, the stock of walk-ins is assumed to be a function of commercial building floor space only. On the other hand, commercial floor space is expected to grow over time; hence, DOE forecasts that the installed stock of walk-ins nationwide will also grow over time. However, limited data available from the U.S. Economic Census[1] suggest that

the walk-in market may not have shown significant growth from the period 1997 to 2007. In the preliminary analysis, DOE used two different approaches to estimate stock trends over time. The market and technology assessment extrapolation indicated a very low rate of growth in the complete WICF unit market while the shipment model suggested a higher future shipments growth rate. DOE assumed an average commercial floor space growth rate of 1 percent in the current analysis—this agrees with the stakeholder comment on the preliminary analysis that the shipment analysis should use a maximum growth rate of 1 percent.

For each of the five building types (restaurants, institutional foodservice, grocery stores, convenience stores, and other), the complete WICF unit shipment model estimates stock each year in the following manner:

$$STOCK_{B,t} = STOCK_{B,0} \times SF_t \times I_B$$

Eq. 9.2

Where:

$STOCK_{B,t}$ = the stock of walk-ins in building type *B* in the year *t*,
$STOCK_{B,0}$ = the stock of walk-ins in building type *B* in year zero (the first year before the analysis period (2016),
SF_t = square footage of building type *B* in year *t*, and
I_B = walk-in intensity, *i.e.*, the number of walk-ins per square foot for building type *B*.

This equation is repeated across all complete WICF unit use-categories, and summing across these, and all building types, yields the total number of walk-ins in the market.

Stock for the refrigeration systems was derived from the complete WICF unit stock in each use category (Table 9.4.4), estimated size distribution of the WICF units in three size categories (Table 9.4.5) and an estimate of the refrigeration capacity in British thermal units per hour of the corresponding matched refrigeration systems (Table 9.4.9). DOE derived the aggregate refrigeration capacities of installed stock across each refrigeration system equipment class. Manufacturer interview data and DOE estimates were used to calculate apportioned capacity of refrigeration systems stock across the refrigeration system class capacity points shown in Table 9.4.8. For deriving the aggregate refrigeration capacity of the installed stock for a refrigeration system equipment class, apportioned stocks for each capacity point were aggregated for every year of the analysis period. Likewise, stock for the envelope components was derived from the complete WICF unit stock across the use-categories using the bill of materials shown in Table 9.4.14

9.3.1.2 Replacement Events

The WICF component shipment models estimate shipments based on the size and age of the stock in each year. In any given year, *t*, the models estimate shipments as the sum of growth (*i.e.*, any increase in total stock relative to the previous year) plus any new units that are shipped to replace failed units. The number of failed units is therefore a key element of the shipment models. For the purpose of characterizing replacement rates for the shipment model, DOE refers to component failures. Failed components are replaced with components of the same type, and when a new component ships (either to replace failed components or as part of market growth), it is required to meet the prevailing efficiency standards. In this way, energy-efficient components are modeled as percolating into the stock over time. In addition, new components can be shipped into new commercial floor space, and old components can be removed through demolitions (not shown in Figure 9.2.2).

The number of replacement units in any given year equals the number of units that fail or are discarded. All replacements are assumed to comply with current efficiency standards in the given year, whereas existing units may or may not be standards-compliant. Replacements made in the NOPR shipment models result from equipment failure and are not associated with the end of an "economic lifetime." Though in the case of walk-in equipment, economic lifetimes could be lower than the physical lifetimes, DOE has not considered this in the current shipment models. Replacements in the WICF component shipment models are made only when equipment experiences a mechanical failure.

The WICF component replacement rate is equal to the probability of failure, F_{WC}, (percentage) for that WICF component (envelope, refrigeration system, display and non-display doors), as shown in the following equation:

$$F_{WC}(a_{WC}) = W_{WC}(a_{WC})$$

Eq. 9.3

Where:

F_{WC} = probability that the WICF component fails, and
W_{WC} = probability of WICF component failure at envelope age a_{WC} based on the Weibull lifetime distributions given in Table 9.3.2.

To accurately estimate the share of consumers that would be affected by a standard at a particular efficiency level, DOE's life-cycle cost analysis considers the projected distribution of component efficiencies that consumers purchase under the base case (that is, the case without new energy efficiency standards). DOE refers to this distribution of component efficiencies as a base-case efficiency distribution. DOE assumed that for refrigeration systems, 75 percent of the equipment sold under the base case would be at DOE's assumed baseline level—that is, the equipment would comply with the existing standards in the Energy Policy and Conservation Act but have no additional features that improve efficiency. The remaining 25 percent of equipment would have features that would increase its efficiency. The current analysis assumes that all customers purchase only the minimum standards-compliant equipment from 2017, when the WICF standard is in effect. For the display doors in the installed stock, 80 percent are assumed to be at the base case efficiency level and the remaining 20 percent of the display doors are assumed to be at higher efficiency levels. For further details on DOE's estimate of base-case efficiency distributions, see chapter 10 of the TSD.

Lifetimes for each of the WICF components are an important input to the shipment models. As the modeled lifetimes of WICF components become shorter, the shipments of such equipment will need to be more frequent to sustain a given level of stock. The preliminary analysis used refrigeration system, envelope, and door lifetimes of approximately 7, 15, and 8 years, respectively. While DOE was unable to obtain detailed data on the distribution of lifetimes by WICF component type in the current analysis, stakeholder comments and manufacturer interviews provided revised walk-in equipment lifetime estimates for the NOPR analysis. These estimates are listed below in Table 9.3.1.

Table 9.3.1 Walk-in Equipment Lifetime Estimates

WICF component	Estimated Lifetime *years*
Envelope	15
Refrigeration System	12
Display Doors	14
Passage Doors	
Freight Doors	

DOE observed wide variations in the available estimates of equipment lifetime and concluded that the lifetime of walk-in equipment is significantly variable. Stakeholder comments during the preliminary analysis provided envelope lifetime estimates ranging between 8 and 20 years, with some stakeholders suggesting that the envelope lifetime depended on the type of use (wear and tear). DOE continues to assume a 15-year average lifetime for panels in the current analysis.

A comment during the preliminary analysis stated that economic lifetimes are different from physical lifetimes, as used for the walk-in equipment, and suggested that DOE use both economic and physical lifetimes, depending on the building type in which the walk-in resides to determine WICF unit failures. For clarity, the physical lifetime refers to the duration before the equipment fails or is replaced, whereas the economic lifetime refers to the duration before the walk-in equipment is taken out of service because the owner is no longer in business. The NOPR analysis initially attempted an economic lifetime study for the restaurant sector. The economic lifetime study included alternative Weibull probability distributions, which attempted to capture the effects of a reduced economic lifetime of WICF units for small restaurants. However, due to the increased complexity of both the shipments and national impact analysis models resulting from the component-level approach, and lack of data on reduced lifetimes due to change of ownership of walk-in equipment, DOE decided to minimize additional complexity and did not incorporate restaurant sector economic lifetime considerations in the NOPR shipment models.

Instead of assuming a single lifetime for all units, DOE created distributions of potential lifetimes for both envelope components and refrigeration systems based on the lifetime estimates in Table 9.3.1. The distributions were assumed to take the form of a Weibull curve, a common shape for equipment failure rates. For the components, the estimates of the failed entities from Weibull distribution were modified to reflect service repairs of the failed components. For example, refrigeration system failure that is due to failure of the compressors often results in replacement of the compressor rather than replacement of the entire system, particularly in early years of service. True Weibull distributions trend toward infinity at ever smaller shares, *i.e.*, there might be miniscule chance of a unit lasting for many hundreds of years. For analytical tractability, it was necessary to truncate the maximum possible lifetime of walk-ins modeled at some cutoff point. DOE therefore assumed that no WICF unit would last beyond 25 years. The resultant lifetime cumulative failure rates are shown in Table 9.3.2. Table 9.3.3 lists the Weibull distribution parameter values used to derive the average age of failure for each of the walk-in components. The year-wise failure rate distributions computed using the Weibull distribution parameter values are presented in Table 9.3.4.

As shown in Table 9.3.1, refrigeration systems typically have a shorter lifetime than envelope components. Consequently, the refrigeration system may be expected to fail even when the associated envelope components still have useful life remaining. The shorter refrigeration system lifetime yields greater refrigeration system shipments than the complete WICF unit shipments, even though the refrigeration system and complete WICF units are used in a 1:1 ratio.

Table 9.3.2 WICF Component Cumulative Failure Rates

Equipment Age *years*	**Assumed Envelope Cumulative Failure Rate**	**Assumed Refrigeration System Cumulative Failure Rate**	**Assumed Display Door Cumulative Failure Rate**	**Assumed Passage Door Cumulative Failure Rate**	**Assumed Freight Door Cumulative Failure Rate**
0	0%	0%	0%	0%	0%
1	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%
4	0%	1%	0%	0%	0%
5	0%	3%	0%	0%	0%
6	1%	7%	0%	0%	0%
7	1%	12%	1%	0%	0%
8	3%	18%	3%	0%	0%
9	5%	27%	6%	3%	3%
10	9%	37%	12%	8%	8%
11	14%	49%	20%	16%	16%
12	21%	60%	30%	27%	27%
13	30%	71%	43%	40%	40%
14	41%	80%	56%	53%	53%
15	52%	87%	68%	66%	66%
16	64%	93%	79%	77%	77%
17	75%	96%	87%	85%	85%
18	85%	98%	93%	91%	91%
19	92%	99%	97%	95%	95%
20	96%	100%	99%	98%	98%
21	98%	100%	100%	99%	99%
22	99%	100%	100%	100%	100%
23	100%	100%	100%	100%	100%
24	100%	100%	100%	100%	100%
25	100%	100%	100%	100%	100%

Table 9.3.3 WICF Component Weibull Distribution Parameters and Results

WICF Component	**Input Parameters**			**Output Values**		
	Scale	**Shape**	**Delay**	**Maximum Age** *years*	**Minimum Age of Failure** *years*	**Average Age of Failure** *years*
Envelope	16.4	4.9	1	25	2	15.12
Refrigeration System	12.8	3.5	1	25	2	11.62
Display Door	15.1	3.4	5	25	6	14.07
Passage Door	15.3	2.6	7.5	25	8	14.43

Freight Door	15.3	2.6	7.5	25	8	14.43

Table 9.3.4 Failure Rate Distribution of Initial Stock

Equipment Age *years*	Panels	Refrigeration System	Display Doors	Passage Doors	Freight Doors
0	0%	0%	0%	0%	0%
1	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%
4	0%	1%	0%	0%	0%
5	0%	2%	0%	0%	0%
6	0%	3%	0%	0%	0%
7	1%	5%	1%	0%	0%
8	1%	7%	2%	0%	0%
9	2%	9%	3%	2%	2%
10	4%	10%	6%	5%	5%
11	5%	11%	8%	8%	8%
12	7%	11%	10%	11%	11%
13	9%	11%	12%	13%	13%
14	11%	9%	13%	13%	13%
15	12%	7%	13%	13%	13%
16	12%	5%	11%	11%	11%
17	11%	3%	8%	9%	9%
18	9%	2%	6%	6%	6%
19	7%	1%	4%	4%	4%
20	4%	0%	2%	2%	2%
21	2%	0%	1%	1%	1%
22	1%	0%	0%	1%	1%
23	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%
25	0%	0%	0%	0%	0%

9.3.1.3 Price Elasticity

Economic theory suggests that changes in the price of WICF components resulting from this standard might affect the number of shipments due to price elasticity of demand. This might take the form of either a decrease in shipments, in cases where purchase costs increase; or an increase in shipments, in cases where life-cycle costs decrease.

However, in practice, DOE has no information with which to calibrate such a relationship in the complete WICF unit market. In addition, manufacturer interviews conducted to date do not indicate that manufacturers believe that this relationship is significant in either direction in the walk-in market. Therefore, as was done in the preliminary analysis, DOE presumes that the shipments do not change between the base case and standards case in the current NOPR analysis.

9.4 SHIPMENT MODELS DESCRIPTIONS

Subsequent discussions in this section discuss the structure and inputs specific to each of the shipment models considered in the NOPR analysis.

9.4.1 Shipment Model for Complete WICF units

For developing the shipment model for complete WICF units, DOE described different use categories for the WICF units and estimated both the stocks and annual shipments of WICF units in these categories. The definitions of these use-categories are identical to the envelope equipment class definitions used in the preliminary analysis and include (1) non-display coolers (SC); (2) non-display freezers (SF); (3) display coolers (DC); and (4) display freezers (DF). Three typical sizes were chosen in each WICF unit use category to represent the different sizes used in several market segments. (Refer to section 9.4.1.2 for the discussion on market sectors considered.)

Table 9.4.1 gives details of the dimensions of the envelopes, the respective WICF units use category, and size code. In later discussions, the envelopes are identified by the composite code that comprises the WICF unit use category code and the size code, *e.g.*, the code display cooler-small (DCS) refers to the small-sized display cooler.

Table 9.4.1 WICF Units Use category and Sizes for Shipments Analysis

Use Category	**Dimensions [length × width × height]** ***ft***			
	Small	**Medium**	**Large**	
Size Code	**S**	**M**	**L**	**Use Category Code**
Non-Display Cooler	12′ × 8′ × 7.6′	24′ × 20′ × 9.5′	40′ × 36′ × 15′	SC
Non-Display Freezer	8′ × 8′ × 7.6′	20′ × 12′ × 9.5′	40′ × 20′ × 15′	SF
Display Cooler	16′ × 8′ × 7.5′	40′ × 8′ × 7.5′	60′ × 15′ × 13.3′	DC
Display Freezer	8′ × 8′ × 7.5′	32′ × 8′ × 7.5′	40′ × 15′ × 13.3′	DF

DOE has found that walk-ins are highly customizable, particularly with regard to size, and recognizes that the size classifications proposed do not encompass all typical sizes of walk-ins. In this NOPR, the typical sizes in various size classes and use categories proposed are primarily used to relate the stocks and shipments of complete walk-in units to a reasonable representation of stocks and shipments of the refrigeration system and selected components.

9.4.1.1 Historical Stock

DOE relied on three main sources of historical stock data for walk-ins in the current analysis: the 2003 Commercial Buildings Energy Consumption Survey (CBECS),[2] the 2007 U.S. Economic Census, and manufacturer interviews. The CBECS and census data provided detailed information on the number of commercial walk-ins in total nationwide and by category of building.

DOE was unable to obtain detailed WICF unit shipment information, in part because manufacturers of envelopes typically track shipments in square feet of panel rather than number of units. Since more detailed data are available for estimation of historical stock, DOE based its shipment estimates in the preliminary analysis primarily on the historical stock. While DOE used the same historical building stock data in the NOPR to estimate the initial WICF stock, DOE revised WICF building type stock designations. CBECS 2003 data provided complete WICF unit stock for nursing care and mental health facilities, previously not included in the food service segment in the preliminary analysis. The National Restaurants Association (NRA) 2007 data[3] were used to verify that complete WICF unit stock in the restaurant market segment and values in the NOPR analysis are 50 percent higher than those in the preliminary analysis. DOE also used data provided by the National Association of Convenience Stores[4] (NACS) to estimate the stock of the WICF units in convenience stores. Another change from the preliminary analysis made in the NOPR is the exclusion of walk-ins in the dairy farm sector because further reviews indicated that the dairy industry uses milk-refrigeration equipment, which does not meet the definition of a walk-in.

In mathematical terms, this means that in equation 9.2, I_B was based on data from CBECS, whereas SF_t was based on data from the U.S. Census. Ideally, DOE would be able to base all variables in the same equation on one data source, but this is not done because of the different strengths of the two different data sets. While CBECS provides more detailed information about the nature of the walk-in stock by building type, the Census is based on a larger sample size. In addition, CBECS only considers buildings greater than 1,000 ft^2, which suggests that walk-in intensity values could be higher than presented.

Within each of the complete WICF unit categories, the shipments data must be disaggregated into detailed use categories for the shipment analysis. Since neither CBECS nor the 2007 Census distinguished between categories of walk-ins, DOE next used data inputs from manufacturers and other databases to estimate the distributions shares and apportion the share of shipments by use category.

9.4.1.2 Commercial Floor Space and Market Saturation

The amount of commercial floor space is the main driver for WICF unit stock and is appropriately one of the basic inputs into the WICF unit shipment model. For this analysis, commercial building square footage with walk-ins refers to both new and existing stock of building types.

DOE took the projected floor space construction from the National Energy Modeling System (NEMS) projection published in the the *Annual Energy Outlook 2013* (*AEO2013*).[5] These values will be updated for the final rule using the latest NEMS data. *AEO2013* gives the projections for years from 2013 through 2040. For years beyond this, DOE derived commercial floor-space data by linear extrapolation of the existing years. Beyond 2040, DOE extrapolated floor-space estimates from NEMS-projected data between 2030 and 2040. The saturation rates, which are the fractions of the building population of a given building type having at least one WICF unit, and the usage intensities, which are the average number of WICF units per building of a given type having any WICF unit, were derived using data from CBECS 2003. Table 9.4.2 gives these values for several building types as well as the walk-in stock for 2007 using the 2007 best estimate number of buildings.

Table 9.4.2 WICF Unit Saturation Rates, Usage Intensities, and 2007 Stock

CBECS Aggregated	CBECS 2003 Weighted Average Saturation Rate	CBECS 2003 Weighted Complete WICF Units per Building	2007 Best Estimate No. of Buildings/Business Units	WICF Stock Units (2007)
All Convenience Stores	0.72	1.25	146,294	133,016
All Other Lodging	0.11	1.92	33,873	7,154
College/University	0.05	4.07	37,153	7,872
Elementary/Middle/High School	0.23	1.76	266,440	105,959
Food Service	0.80	1.60	545,684	704,170
Grocery and Other Food Sales	0.76	2.58	110,907	218,131
Hospital/Inpatient Health	0.92	3.01	8,633	23,946
Hotel/Motel/Inn	0.11	4.99	96,747	51,381
Public Assembly	0.14	1.86	288,989	77,316
Florists	0.80	1.00	19,609	15,687
Nursing Care and Mental Health Facilities	0.59	1.83	48,923	52,666
Distribution Centers	0.05	1.95	166,262	14,996
Others (estimated)	--	--	--	260,000
Total WICF Stock 2007				**1,672,293**

Table 9.4.3 shows the growth rates applied to each building type. Because NEMS does not distinguish between different types of food sales building stock, DOE forecast both grocery stores and convenience stores as growing at the rate of the food sales category in NEMS. The current analysis did not revise the commercial floor space and market saturation data used in the preliminary analysis. However, the Institutional Foodservice market sector (healthcare and education affiliated) data were added. In the preliminary analysis, DOE used a shipments growth rate of approximately 2 percent, but in the NOPR analysis, DOE adjusted the rates downward to about 1 percent per year.

Table 9.4.3 Forecasted Cumulative Increase in Floorspace by Building Type Since 2007

Year	Food Sales	Foodservice	Institutional Foodservice	Other
	ft^2	ft^2	ft^2	ft^2
2015	6%	6%	13%	9%
2017	8%	9%	15%	11%
2020	12%	13%	17%	15%
2025	17%	18%	20%	22%
2030	23%	25%	23%	28%
2035	29%	32%	27%	34%
2040 (extrapolated)	36%	39%	32%	42%
2046 (extrapolated)	43%	46%	36%	49%

Following is an example of how to read Table 9.4.3: the stock of walk-ins in food services in 2035 is modeled as equal to 132 percent of the initial (2007) stock.

The share distributions used in each of the shipment models of the current analysis are based on confidential interviews with manufacturers and other parties, and DOE's own estimates. Table 9.4.4 shows the building type share distributions for each envelope use category, and Table 9.4.5 shows the overall complete WICF unit use category share distributions. Table 9.4.6 and Table 9.4.7 show DOE’s stock and shipments forecast, respectively, for complete WICF unit by use category.

Table 9.4.4 WICF Unit Use category Building Type Share Distributions

Building Type	Storage Coolers	Storage Freezers	Display Coolers	Display Freezers
Grocery	14%	7%	25%	18%
Institutional Food Service	20%	22%	0.0%	0.0%
C-Store	2%	3%	52%	82%
Restaurant	44%	46%	23%	0.0%
Other	20%	22%	0.0%	0.0%
All	100%	100%	100%	100%

Table 9.4.5 WICF Unit Use category Overall Share Distributions

Sizes	WICF Unit Use category			
	Storage Coolers	Storage Freezers	Display Coolers	Display Freezers
Small	34.4%	14.4%	1.9%	1.0%
Medium	24.4%	10.9%	4.8%	0.2%
Large	2.9%	2.3%	2.5%	0.2%
All	61.7%	27.6%	9.2%	1.4%

Table 9.4.6 Installed Stock by Year for Complete WICF unit Use category, 2017–2046

WICF Unit Application and Size Category	Forecasted number of WICF Units Installed by Year						
	2017	2020	2025	2030	2035	2040	2046
Non-Display Cooler Small	633,164	654,585	684,338	716,792	752,732	792,441	838,493
Non-Display Cooler Medium	448,265	463,431	484,496	507,472	532,917	561,030	593,633
Non-Display Cooler Large	53,888	55,711	58,243	61,005	64,064	67,444	71,363
Display Cooler Small	34,889	36,146	37,962	39,818	41,866	44,159	46,834
Display Cooler Medium	88,789	91,990	96,609	101,334	106,546	112,380	119,188
Display Cooler Large	45,901	47,555	49,943	52,386	55,081	58,096	61,616
Non-Display Freezer Small	264,881	273,831	286,304	299,691	314,615	331,227	350,473
Non-Display Freezer Medium	201,408	208,213	217,697	227,876	239,224	251,855	266,489
Non-Display Freezer Large	42,876	44,324	46,344	48,511	50,926	53,615	56,730
Display Freezer Small	19,252	19,955	21,003	21,968	23,064	24,345	25,832
Display Freezer Medium	3,795	3,934	4,140	4,330	4,547	4,799	5,092
Display Freezer Large	3,863	4,004	4,214	4,407	4,627	4,884	5,183
Total	**1,840,970**	**1,903,679**	**1,991,292**	**2,085,591**	**2,190,209**	**2,306,276**	**2,440,926**

Table 9.4.7 Forecasted Shipments of New and Replacement WICF Units, 2017–2046

WICF Unit Application and Size Category	Forecasted Number of Units Shipped by Year						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2046**
Non-Display Cooler Small	45,377	46,668	44,817	47,217	52,382	53,377	55,872
Non-Display Cooler Medium	32,126	33,040	31,729	33,429	37,085	37,789	39,556
Non-Display Cooler Large	3,862	3,972	3,814	4,019	4,458	4,543	4,755
Display Cooler Small	2,493	2,584	2,479	2,589	2,899	2,960	3,081
Display Cooler Medium	6,344	6,576	6,309	6,589	7,377	7,532	7,841
Display Cooler Large	3,280	3,400	3,262	3,407	3,814	3,894	4,054
Non-Display Freezer Small	18,982	19,544	18,754	19,725	21,926	22,358	23,375
Non-Display Freezer Medium	14,433	14,860	14,260	14,999	16,672	17,001	17,774
Non-Display Freezer Large	3,073	3,163	3,036	3,193	3,549	3,619	3,784
Display Freezer Small	1,370	1,434	1,370	1,412	1,602	1,643	1,694
Display Freezer Medium	270	283	270	278	316	324	334
Display Freezer Large	275	288	275	283	321	330	340
Total	**131,884**	**135,811**	**130,376**	**137,141**	**152,401**	**155,370**	**162,460**

DOE also compared the results of its NOPR shipment model with shipment data estimated by NAFEM (North American Association of Food Equipment Manufacturers). NAFEM's shipment estimates of WICF units are presented in Figure 9.4.1. DOE's estimates for the commercial food service segment shipments in 2010 are also shown in the plot. DOE's estimates are based on long-term growth of commercial building and population and are not specific point estimates for a given year. Further, NAFEM's estimates are based only on data from their members, who are a subset of all manufacturers. The most recent NAFEM survey covered shipments from 47 manufacturers, primarily manufacturers of walk-in panels, while DOE has identified 52 manufacturers of walk-in panels in chapter 3 of the TSD.

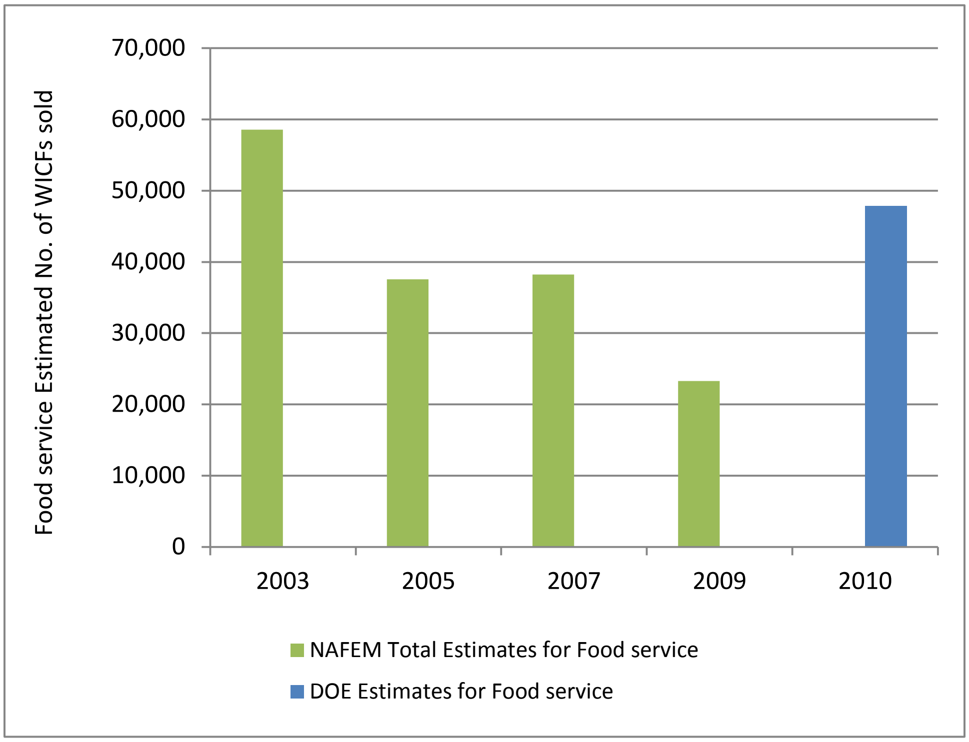

Figure 9.4.1 Estimates of WICF Shipments for the Food Service Sector

9.4.2 Refrigeration Shipment Model

As stated previously, the shipment model for complete WICF units forms the basis for estimating the initial stock and shipments for the refrigeration systems and envelope components. DOE assumed that each complete WICF unit consists of an envelope and a refrigeration system not shared with any other equipment. For the refrigeration system shipment model, DOE used the six primary walk-in refrigeration system classes, as previously discussed in the engineering analysis (chapter 5 of the TSD). These include dedicated indoor systems, dedicated outdoor systems, and unit coolers connected to multiplex systems, for both medium- and low-temperature applications. The descriptions and class codes for the refrigeration systems are presented here for convenience in Table 9.4.8.

The refrigeration shipment model produces shipments in terms of numbers of refrigeration systems of specific sizes and also in terms of aggregate capacity shipped. These were obtained by multiplying the number of complete WICF units shipped in each size and use category by the respective estimated capacity of the refrigeration system serving the unit. The aggregate refrigeration capacities derived were distributed over multiple capacity points in the refrigeration system classes for derivation of the shipment quantities of new refrigeration systems. A similar approach was also followed for estimation of the stock. Replacement quantities were estimated separately as described in section 9.3.1.2 and were added to obtain aggregate shipments.

The refrigeration capacity points that DOE chose for each refrigeration system equipment class in the refrigeration shipment model are identical to the analysis points chosen in the engineering analysis (chapter 5 of the TSD). Table 9.4.9 gives the details of these capacity points and the share of each capacity point in the respective equipment classes. The aggregate refrigeration system capacities shipped with WICF units were derived from refrigeration load estimates for each of the 12 representative WICF units (three sizes each in the four use-categories identified in section 9.1). The refrigeration loads that DOE considered are summarized in Table 9.4.10. The refrigeration loads included envelope conduction loads through walls and floor, display and non-display door infiltration, product loads, and other miscellaneous loads. In addition, the total load was inflated by 10 percent to account for uncertainties in estimation, as is typically done in the industry. Non-display door infiltration loads were calculated using an ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) table providing typical infiltration loads per day for a given envelope size and degree of usage.[6] Infiltration loads for the display doors were calculated using the Gosney and Olama[7] equation and usage data provided in an ASHRAE study report[8] on display door opening frequency and duration, and typical hours of operation for walk-in coolers. An ADM Associate report[9] also provided the minutes that a door remained open per day for coolers and freezers across several market sectors. DOE used these values to obtain a freezer-to-cooler use ratio; this determined the hours of operation for walk-in freezers. Note that these estimates of refrigeration capacities were used only for the shipments model and have no bearing on the energy use model (chapter 7 of the TSD). For detailed information on the refrigeration system capacity point specifications, refer to the engineering analysis (chapter 5 of the TSD).

Table 9.4.8 Refrigeration System Equipment Classes

Condensing Type	**Operating Temperature**	**Condenser Location**	**Class**
Multiplex	Medium	-	MC.M
	Low	-	MC.L
Dedicated	Medium	Indoor	DC.M.I
	Low		DC.L.I
	Medium	Outdoor	DC.M.O
	Low		DC.L.O

Table 9.4.9 Refrigeration System Capacity Points

Equipment Class	**Capacity *kBtu/hr***	**Percent Share**	**Capacity *kBtu/hr***	**Percent Share**
Direct Condensing Medium Temperature	Indoor (DC.M.I)		Outdoor (DC.M.O)	
	6	63%	6	15%
	18	30%	18	45%
	54	5%	54	20%
	96	2%	96	20%
Direct Condensing Medium Temperature	Indoor (DC.L.I)		Outdoor (DC.L.O)	
	6	46%	6	25%
	9	50%	9	50%
	54	4%	54	20%
			72	5%
Multiplex (Unit Coolers)	Medium (MC.M.N)		Low Temp (MC.L.N)	
	4	25%	4	20%
	9	55%	9	64%
	24	20%	18	15%
			40	1%

Furthermore, to create the refrigeration system shipment model, it was necessary to obtain refrigeration system class distributions for each of the representative WICF sizes in the different use-categories and distribution of refrigeration system sizes within each refrigeration system equipment class. Table 9.4.11 summarizes refrigeration system class shares over the complete WICF unit use and size categories. These were obtained primarily by examination and analysis of relevant data provided during confidential interviews with manufacturers and other parties. DOE obtained the total capacity of the refrigeration systems corresponding to the total shipped quantity for each of the 12 representative WICF sizes by multiplying the shipped quantities for each type by the respective estimated refrigeration capacity. Next DOE applied the distribution of refrigeration system classes over the total capacity for each WICF type (Table 9.4.11). The apportioned capacities in each refrigeration system class were further prorated based on the size distributions within the specific class (Table 9.4.8). The capacity totals obtained in this manner were divided by the respective capacity values of the capacity points to derive numbers shipped for each of the capacity points in each of the refrigeration system classes. The distributions of refrigeration system equipment classes estimated in this NOPR differ significantly from the respective distributions in the preliminary analysis. In the NOPR analysis, DOE estimated that dedicated condensing units account for approximately 70 percent of the market and multiplex condensing systems account for the remaining 30 percent. These share percentages match well with observations made by some interested parties.

Table 9.4.10 Refrigeration Capacity Estimates for Complete WICF Units

Complete WICF Unit Code	**SCS**	**SCM**	**SCL**	**DCS**	**DCM**	**DCL**	**SFS**	**SFM**	**SFL**	**DFS**	**DFM**	**DFL**
Application and size category	**Non-Display Cooler Small**	**Non-Display Cooler Medium**	**Non-Display Cooler Large**	**Display Cooler Small**	**Display Cooler Medium**	**Display Cooler Large**	**Non-Display Freezer Small**	**Non-Display Freezer Medium**	**Non-Display Freezer Large**	**Display Freezer Small**	**Display Freezer Medium**	**Display Freezer Large**
Product Load ***kBtu/day***	26	82	389	35	43	215	2	5	27	2	4	18
Transmission Load ***kBtu/day***	39	136	386	113	261	738	56	159	437	114	368	901
Non-display door infiltration ***kBtu/day***	18	42	88	21	32	63	16	31	76	16	30	53
Display Door Infiltration ***kBtu/day***	0	0	0	109	272	815	0	0	0	115	459	1,147
Estimated Capacity ***kBtu/hr****	6,288	19,477	64,725	20,783	45,585	137,348	4,943	13,051	35,968	16,439	57,371	141,265

*Based on 16 and 18 hours operation ("ON") time per day for walk-in coolers and walk-in freezers, respectively.

Table 9.4.11 Refrigeration System Equipment Class Distributions at Each WICF Unit Use category

Complete WICF Unit Code	Application and size category	Distribution of Refrigeration System Equipment Classes					
		DC.M.I	DC.M.O	DC.L.I	DC.L.O	MC.M	MC.L
SCS	Storage Cooler Small	3.6%	93.1%	0.0%	0.0%	3.2%	0.0%
SCM	Storage Cooler Medium	1.3%	84.0%	0.0%	0.0%	14.7%	0.0%
SCL	Storage Cooler Large	0.0%	50.8%	0.0%	0.0%	49.2%	0.0%
DCS	Display Cooler Small	4.6%	92.3%	0.0%	0.0%	3.1%	0.0%
DCM	Display Cooler Medium	4.0%	88.7%	0.0%	0.0%	7.3%	0.0%
DCL	Display Cooler Large	0.0%	71.8%	0.0%	0.0%	28.2%	0.0%
SFS	Storage Freezer Small	0.0%	0.0%	3.1%	95.6%	0.0%	1.3%
SFM	Storage Freezer Medium	0.0%	0.0%	2.4%	92.2%	0.0%	5.4%
SFL	Storage Freezer Large	0.0%	0.0%	0.0%	74.7%	0.0%	25.3%
DFS	Display Freezer Small	0.0%	0.0%	5.3%	89.5%	0.0%	5.3%
DFM	Display Freezer Medium	0.0%	0.0%	5.3%	85.3%	0.0%	9.5%
DFL	Display Freezer Large	0.0%	0.0%	0.0%	25.0%	0.0%	75.0%

Table 9.4.12 and Table 9.4.13 show the refrigeration system forecast for stock and shipments, respectively. As noted above, DOE forecasts that refrigeration system shipments will exceed complete WICF unit shipments because multiplex units require multiple refrigeration systems and the comparatively shorter equipment lifetime of refrigeration systems means more frequent replacements.

In the preliminary analysis, DOE assumed a higher replacement rate for refrigeration systems than for envelopes of complete WICF units. A stakeholder commented that DOE’s estimated shipment ratio of 3-to-1 between refrigeration systems and WICF units in the preliminary analysis shipment results was too high and that a more appropriate shipment ratio between refrigeration systems and envelopes would be about 1.3 to 1. In the current analysis, replacements of refrigeration systems account for about 30 to 41 percent of all refrigeration system shipments. While this estimate exceeds the suggested shipment ratio of 1.3, DOE believes that the average lifetimes of walk-in envelopes and refrigeration systems estimated through manufacturer interviews and stakeholder comments are reasonable.

Table 9.4.12 Forecasted Stock of WICF Refrigeration Systems, 2017-2046

WICF Refrigeration Systems Product Class	Capacity *kBtu/hr*	**Forecasted Number of WICF Refrigeration Systems by Year**						
		2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2046**
DC.M.I	6	47,334	48,981	51,308	53,774	56,500	59,530	63,053
DC.M.I	18	7,513	7,775	8,144	8,536	8,968	9,449	10,008
DC.M.I	54	417	432	452	474	498	525	556
DC.M.I	96	94	97	102	107	112	118	125
Total	-	**55,359**	**57,285**	**60,006**	**62,890**	**66,079**	**69,622**	**73,742**
DC.M.O	6	540,010	558,766	585,248	613,357	644,437	678,959	719,101
DC.M.O	18	540,010	558,766	585,248	613,357	644,437	678,959	719,101
DC.M.O	54	80,001	82,780	86,703	90,868	95,472	100,587	106,533
DC.M.O	96	45,001	46,564	48,771	51,113	53,703	56,580	59,925
Total	-	**1,205,022**	**1,246,876**	**1,305,970**	**1,368,696**	**1,438,049**	**1,515,084**	**1,604,660**
DC.L.I	6	10,175	10,524	11,019	11,533	12,107	12,753	13,503
DC.L.I	9	7,373	7,626	7,985	8,357	8,773	9,242	9,784
DC.L.I	54	98	102	106	111	117	123	130
Total	-	**17,646**	**18,252**	**19,111**	**20,001**	**20,997**	**22,118**	**23,418**
DC.L.O	6	226,377	234,094	244,939	256,370	269,140	283,434	299,998
DC.L.O	9	301,836	312,126	326,586	341,827	358,853	377,912	399,997
DC.L.O	54	20,122	20,808	21,772	22,788	23,924	25,194	26,666
DC.L.O	72	3,773	3,902	4,082	4,273	4,486	4,724	5,000
Total	-	**552,109**	**570,930**	**597,380**	**625,259**	**656,403**	**691,263**	**731,662**
MC.M	4	326,624	337,965	353,973	370,971	389,766	410,641	434,913
MC.M	9	319,366	330,454	346,107	362,727	381,104	401,515	425,248
MC.M	24	43,550	45,062	47,196	49,463	51,969	54,752	57,988
Total	**-**	**689,540**	**713,481**	**747,276**	**783,161**	**822,839**	**866,908**	**918,150**
MC.L	4	49,711	51,451	53,955	56,459	59,273	62,476	66,191
MC.L	9	70,700	73,175	76,737	80,297	84,300	88,854	94,138
MC.L	18	8,285	8,575	8,993	9,410	9,879	10,413	11,032
MC.L	40	249	257	270	282	296	312	331
Total	-	**128,944**	**133,458**	**139,955**	**146,448**	**153,748**	**162,055**	**171,691**
All Refrigeration Systems Total	**-**	**2,648,621**	**2,740,283**	**2,869,696**	**3,006,455**	**3,158,115**	**3,327,051**	**3,523,322**

Table 9.4.13 Forecasted Shipments of New and Replacement WICF Refrigeration Systems, Capacity Weighted, 2017-2046

WICF Refrigeration Systems	Forecasted Number of Units Shipped by Year						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2046**
Dedicated Medium Temperature Indoor	5,876	6,029	5,794	6,680	7,577	7,707	8,543
Dedicated Medium Temperature Outdoor	127,914	131,230	126,128	145,413	164,923	167,746	185,959
Dedicated Low Temperature Indoor	1,873	1,925	1,850	2,126	2,417	2,458	2,722
Dedicated Low Temperature Outdoor	58,599	60,176	57,857	66,577	75,575	76,865	85,168
Total	194,261	199,359	191,630	220,796	250,492	254,776	282,392
Multiplex system Medium Temperature	73,144	75,062	72,172	83,197	94,362	95,984	106,403
Multiplex system Low Temperature	13,670	14,084	13,530	15,495	17,691	17,983	19,880
Total	86,814	89,147	85,701	98,692	112,053	113,967	126,283
All Refrigeration Systems Total	281,076	288,506	277,331	319,488	362,545	368,743	408,675

9.4.3 Envelope Component Shipment model

To derive the initial stock of the envelope components, DOE defined specifications for each WICF unit in different use-categories and sizes. These specifications include dimensions, numbers of components, and other features that are necessary to derive initial stock and shipments for insulation panels, display doors, and non-display doors. DOE established baseline specifications for the envelope use-categories and sizes in the preliminary analysis. This process created representative walk-in units for each use category in three sizes as well as product feature specifications (*e.g.*, wall area, envelope component quantities). In the preliminary analysis, DOE proposed typical envelope sizes in various product classes, primarily to characterize the relationship between size and energy consumption within a given equipment class. In the current NOPR, the sizes are used only for enumeration of shipments and stock of complete WICF units. The sizes identified in the preliminary analysis were revised based on further information from manufacturers and stakeholder comments. Table 9.4.14 shows the envelope specifications for each of the representative walk-in units used for deriving initial stock and shipments of the refrigeration systems and envelope components. It should be noted that typical sizes for the doors, as shown in Table 9.4.14, were used to calculate the walk-in surface area, excluding doors.

Table 9.4.14 Complete WICF and Envelope Components Quantities and Sizes

Complete WICF Unit Code	**SCS**	**SCM**	**SCL**	**DCS**	**DCM**	**DCL**	**SFS**	**SFM**	**SFL**	**DFS**	**DFM**	**DFL**
Application and size category	**Non-Display Cooler Small**	**Non-Display Cooler Medium**	**Non-Display Cooler Large**	**Display Cooler Small**	**Display Cooler Medium**	**Display Cooler Large**	**Non-Display Freezer Small**	**Non-Display Freezer Medium**	**Non-Display Freezer Large**	**Display Freezer Small**	**Display Freezer Medium**	**Display Freezer Large**
Height (*ft*)	7.6	9.5	15.0	7.5	7.5	13.3	7.6	9.5	15.0	7.5	7.5	13.3
Length (*ft*)	12.0	24.0	40.0	16.0	40.0	60.0	8.0	20.0	40.0	8.0	32.0	40.0
Width (*ft*)	8.0	20.0	36.0	8.0	8.0	15.0	8.0	12.0	20.0	8.0	8.0	15.0
No. Display Doors	0.0	0.0	0.0	6.0	15.0	45.0	0.0	0.0	0.0	3.0	12.0	30.0
***Display Door Width (*ft*)**	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
***Display Door Height (*ft*)**	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
No. Passage Doors	1.0	2.0	2.0	1.0	1.0	2.0	1.0	2.0	2.0	1.0	1.0	2.0
***Passage Door Width (*ft*)**	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
***Passage Door Height (*ft*)**	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
No. Freight Doors	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
***Freight Door Width (*ft*)**	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
***Freight Door Height (*ft*)**	9.0	9.0	12.0	9.0	9.0	12.0	9.0	9.0	12.0	9.0	9.0	12.0
Total External Surface Area (ft^2)	495	1,796	5,160	616	1,360	3,788	371	1,088	3,400	368	1,112	2,658
Total Door Surface Area (ft^2)	21	42	126	115	255	745	21	42	126	68	209	511
Floor Area (ft^2)	96	480	1,440	128	320	900	64	240	800	64	256	600
Non-Floor Panel Surface Area (ft^2)	378	1,274	3,594	373	785	2,142	286	806	2,474	236	648	1,547

* Door size used only to derive initial envelope component stock and shipments, refer to the engineering analysis (chapter 5) of this TSD for door sizes and specifications used in the NOPR engineering and energy analyses.

Once the stock and shipment for the envelope components was established, it was necessary to obtain the display and non-display door stock and shipment share distributions. As presented in the engineering analysis (chapter 5 of the TSD), DOE considered three sizes for the envelope components: small, medium, and large. Manufacturer interviews and vendor catalog assessments provided the size distributions for envelope components shown in Table 9.4.15.

Table 9.4.15 WICF Envelope Component Size Share Distributions

Envelope Component	**Surface Area** ***ft^2***	**Percent Sales**	**Representative Height** ***ft***	**Representative Width** ***ft***
Panels	<20	20%	8	1.5
	21-40	60%	8	4
	>41	20%	9	5.5
Passage Doors	<18	8%	6.5	2.5
	18-25	76%	7	3
	>25	16%	7.5	4
Freight Doors	<54	47%	8	5
	55-75	38%	9	7
	>75	15%	12	7

In addition, floor panel stock and shipments were determined from manufacturer interviews and vendor catalogs. DOE assumed that 50 percent of all freezer walk-ins used insulated floor panels. DOE assumed that only 40 percent of small storage and display coolers used insulated floor panels. However, floor panels for coolers were not analyzed because floor panels in coolers have a smaller market share than freezer floor panels. The forecasted stock and shipment (rounded) of panels of different types are listed in Table 9.4.16 and Table 9.4.17, respectively, and shown in Figure 9.4.2.   Table 9.4.18 and Table 9.4.19 list the WICF display door, and passage and freight door stock and shipment forecasts, respectively. Shipments for WICF display and non-display doors are also shown in Figure 9.4.3 and Figure 9.4.4, respectively.

Table 9.4.16 Forecasted Stock of Insulation Panels for WICF, 2017–2046

Complete Walk-in Use Category	**Forecasted Stock by Year (*Millions Square Feet)***						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2046**
SCS	240	248	259	271	285	300	317
SCM	571	590	617	647	679	715	756
SCL	194	200	209	219	230	242	256
DCS	13	13	14	15	16	16	17
DCM	70	72	76	80	84	88	94
DCL	98	102	107	112	118	124	132
Cooler Panels Total	**1,185**	**1,226**	**1,282**	**1,344**	**1,411**	**1,486**	**1,573**
SFS	76	78	82	86	90	95	100
SFM	162	168	175	184	193	203	215
SFL	106	110	115	120	126	133	140
DFS	5	5	5	5	5	6	6
DFM	2	3	3	3	3	3	3
DFL	6	6	7	7	7	8	8
Freezer Panels Total	**357**	**369**	**386**	**404**	**424**	**447**	**473**
SFS	8	9	9	10	10	11	11
SFM	24	25	26	27	29	30	32
SFL	17	18	19	19	20	21	23
DFS	1	1	1	1	1	1	1
DFM	0	1	1	1	1	1	1
DFL	3	3	3	3	4	4	4
Floor Panels Total	**54**	**56**	**58**	**61**	**64**	**67**	**71**
All Panels	**1,596**	**1,651**	**1,727**	**1,809**	**1,900**	**2,000**	**2,117**

Table 9.4.17 Forecasted Shipments of New and Replacement Insulation Panels for WICF, 2017–2046

WICF Components	**Forecasted Shipments by Year (*Millions Square Feet)***						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2046**
Wall Panels Medium Temperature	85	87	84	88	98	100	105
Wall Panels Low Temperature	25	26	27	29	32	33	36
Floor Panels	26	26	25	27	30	30	32
All Panels	112	116	114	116	134	135	141

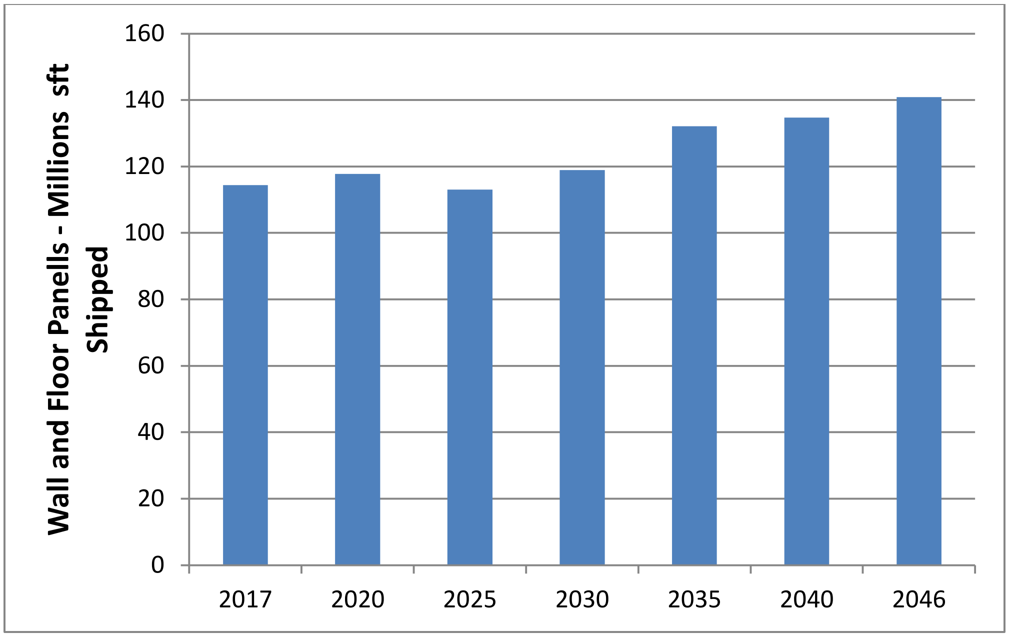

Figure 9.4.2 Total Shipments for WICF Wall and Floor Panels

Table 9.4.18 Forecasted Stock of WICF Display and Non-Display Doors, 2017–2046

WICF Components	**Year and Number of Stock Units**						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2046**
Display Door Medium Temperature	3,606,705	3,736,711	3,924,354	4,116,298	4,328,027	4,564,982	4,841,520
Display Door Low Temperature	219,172	227,173	239,100	250,086	262,571	277,149	294,084
Total	3,825,878	3,963,884	4,163,454	4,366,384	4,590,599	4,842,131	5,135,604
Passage Door Medium Temperature	1,852,950	1,916,117	2,004,274	2,099,671	2,205,269	2,322,120	2,457,739
Passage Door Low Temperature	784,220	810,800	847,954	887,578	931,780	981,081	1,038,202
Total	2,637,170	**2,726,917**	**2,852,228**	**2,987,248**	**3,137,048**	**3,303,201**	**3,495,941**
Freight Door Medium Temperature	53,888	55,711	58,243	61,005	64,064	67,444	71,363
Freight Door Low Temperature	42,876	44,324	46,344	48,511	50,926	53,615	56,730
Total	96,764	100,036	104,587	109,516	114,991	121,059	128,094
All Doors Total	**6,559,812**	**6,790,837**	**7,120,269**	**7,463,149**	**7,842,637**	**8,266,391**	**8,759,638**

Table 9.4.19 Forecasted Shipments of New and Replacement WICF Display and Non-Display Doors, 2017–2046

WICF Components	Forecasted Number of Units Shipped by Year						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2046**
Display Door Medium Temperature	396,280	403,562	391,531	446,809	519,851	532,652	587,448
Display Door Low Temperature	24,107	24,714	23,904	27,002	31,723	32,496	35,627
Total	420,387	428,276	415,436	473,810	551,573	565,148	623,075
Passage Door Medium Temperature	195,924	199,391	193,195	223,515	252,495	257,469	285,537
Passage Door Low Temperature	82,944	84,481	81,845	94,519	106,941	109,035	120,844
Total	278,868	283,872	275,041	318,034	359,436	366,504	406,381
Freight Door Medium Temperature	5,699	5,797	5,618	6,502	7,340	7,485	8,303
Freight Door Low Temperature	4,535	4,617	4,474	5,169	5,845	5,960	6,607
Total	10,234	10,414	10,092	11,672	13,185	13,445	14,910
All Doors Total	**709,489**	**722,562**	**700,569**	**803,517**	**924,194**	**945,096**	**1,044,366**

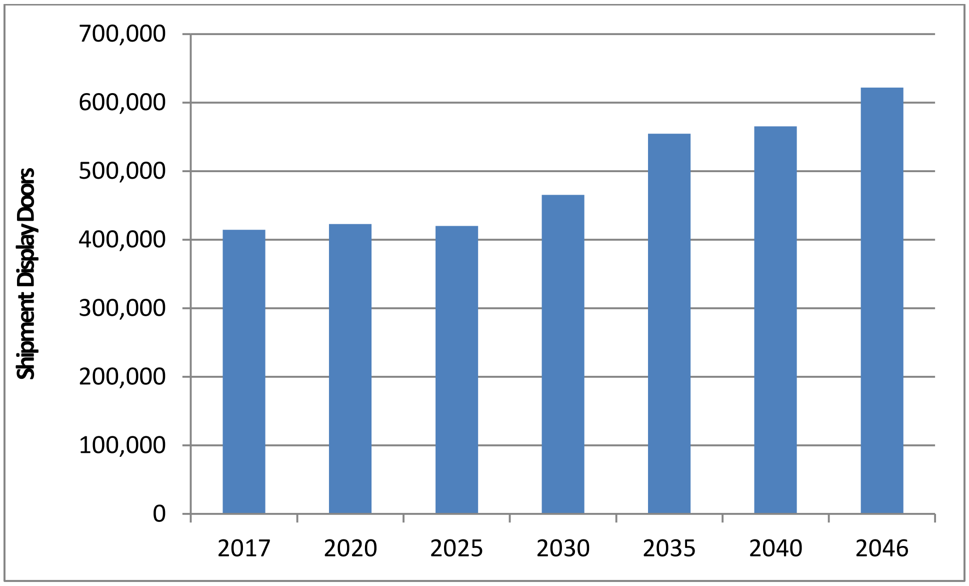

Figure 9.4.3 Total Shipments for WICF Display Doors

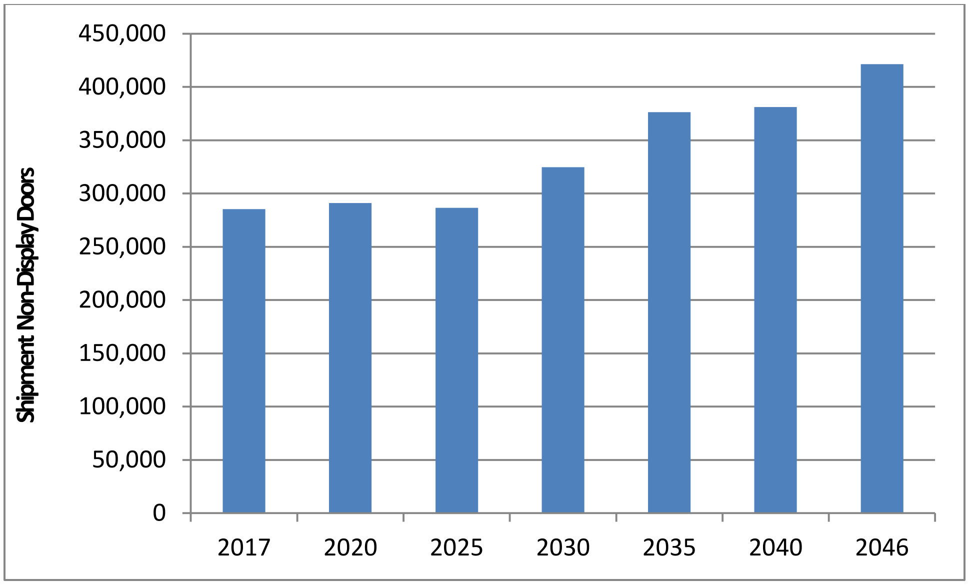

Figure 9.4.4 Total Shipments for WICF Non-Display Doors

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CHAPTER 10. NATIONAL IMPACTS ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 10. NATIONAL IMPACTS ANALYSIS

10.1 INTRODUCTION

This chapter describes the method for estimating the national impacts of trial standard levels (TSLs) for analyzed walk-in cooler and freezer equipment (walk-ins or WICF). In the national impact analysis (NIA), the U.S. Department of Energy (DOE) assesses the cumulative national energy savings (NES) and the cumulative national economic impacts of different TSLs. DOE measures energy savings as the cumulative quadrillion British thermal units (quads) of energy a TSL is expected to save the Nation. DOE measures economic impacts as the net present value (NPV) in 2012$ of total customer costs and savings expected to result from a TSL. The analysis period over which DOE calculates the NPV and NES is the lifetime of WICF equipment purchased in the 30-year period that begins in the first year of compliance with the new standards (2017–2046). Results of the NIA described in this chapter include (1) national energy savings to the Nation as a result of standards; (2) monetary value of operating cost savings (primarily from reduced energy consumption) to the Nation as a result of standards; (3) increased total installed costs to the Nation as a result of standards; and (4) the NPV of these savings (the difference between the present monetary values of operating cost savings and increased total installed costs), discounted to 2013. The main portion of this chapter summarizes the results of these estimates, and detailed results are provided in appendices 10B (for NES results) and 10C (for NPV results).

In the current engineering analysis, DOE adopted a component-level based approach addressing the WICF refrigeration system and the envelope components: panels, display doors, and non-display doors. However, a walk-in is designed to work as a single coherent unit, the characteristics of complete walk-in systems (e.g., energy consumption, installed cost) must be considered for the refrigeration system as well as all envelope components (collectively referred to as the "envelope"), to estimate the national impacts of walk-ins at any TSL. Therefore, DOE analyzes the two parts of a walk-in (envelope and refrigeration system) together for the purpose of calculating the national impacts, and uses this data to set individual standards for the envelope components and refrigeration systems, respectively. In order to analyze the national impact of the collective walk-in, DOE first created, separate NIA spreadsheets for the refrigeration system, panels, display doors, and non-display doors with the results for the each component's engineering analyses. NPV and NES results for the separate NIA spreadsheets were used to obtain WICF refrigeration system equipment class TSLs - independent of the envelope component equipment classes, and then used to obtain TSLs for combinations of refrigeration systems and envelope components. Refer to the trial standard level selection process in appendix 10D for additional information.

DOE determines both the NPV and NES for each TSL and each equipment class it selects in the engineering analysis. Chapter 5 of the TSD details the equipment classes modeled by the engineering analysis. In this rulemaking, DOE considers up to 9 efficiency levels (including baseline) for each of the envelope component equipment classes and up to 14 efficiency levels (including baseline) for each of the refrigeration system equipment classes. Tables 10D.2.4 through 10D.2.7 in appendix 10D describe the design options DOE assumed manufacturers would use to meet each TSL.

DOE performs all NIA calculations using a Microsoft Excel spreadsheet, available at http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/26. Appendix 10A provides instructions for using the spreadsheet.

The following sections describe in detail the methodology and inputs for the NIA. Section 10.2 discusses DOE's walk-in shipment forecasts by efficiency level, the installed stock of walk-ins, and the mix of efficiencies of that stock. Section 10.3 discusses DOE's calculation of national energy consumption in the base and standards cases and the resulting difference in NES between these cases. Section 10.4 discusses the NPV calculation. Section 10.5 describes the methodology for combining NES and NPV for the refrigeration and envelope components, and sections 10.5.1 and 10.5.2 present the NES and NPV results by equipment class. Several NIA inputs, including per-unit costs, per-unit energy consumption, and national shipments, are discussed in the LCC (TSD chapter 8) and shipments (TSD chapter 9) analyses. In describing the inputs to the NIA, this chapter references the LCC and shipments analyses and presents new information on installed stock. Even though two NIA spreadsheets were developed for the WICF refrigeration systems and envelope components, discussions in this chapter apply to each component's NIA analysis in the same manner. In addition, appendix 10F of the NOPR TSD presents the RISC & OIRA Consolidated Information System (ROCIS) tables with annualized benefits and costs for the TSLs considered in this rulemaking.

10.2 BASE-CASE AND STANDARDS-CASE FORECASTED WALK-IN EQUIPMENT STOCK AND EFFICIENCY DISTRIBUTIONS

Inputs to DOE's shipment forecasts (such as equipment costs and operating costs) and projected walk-in equipment stocks (such as average efficiency and energy consumption) are key parameters of DOE's NES and NPV estimates. This section describes how these key inputs to the stock and shipments for the refrigeration system, panels, display doors, and non-display doors relate to the NES and NPV.

A key factor in determining the NPV is the projected equipment efficiency distribution for current and future shipments and stock. For example, two inputs to the NPV are the per-unit total installed cost and per-unit annual operating cost. These inputs vary with the efficiency of the walk-in equipment shipped. When higher efficiency walk-in components are shipped, higher or lower installed and annual operating costs are often incurred, which then increase or decrease the NPV, respectively. The life-cycle cost analysis in chapter 8 of the TSD describes how per-unit total installed cost and per-unit annual operating cost varies as a function of efficiency for each walk-in equipment class.

Also important to determining NES and NPV is the average efficiency and total annual energy consumption of the walk-in component stock. The engineering analysis, chapter 5 of the TSD, discusses the relationships among walk-in component design, system input power, and walk-in component efficiency. The energy use characterization, chapter 7 of the TSD, describes how the per-unit energy consumption varies as a function of system input power and market sector application for each walk-in component equipment class. The results of the engineering and energy use analyses are combined to establish the average efficiency of the walk-in component stock. The total installed walk-in component stock, per equipment class, is used to determine total annual energy consumption, a key input into the NES and NPV calculations. Sections 10.3.2 and 10.4.2 discuss inputs to calculating the NES and NPV in further detail.

The following sections detail the forecasted distribution of efficiencies, installed walk-in equipment stock, and average efficiency of those stocks in the base and standards cases.

10.2.1 Installed Walk-in Equipment Stock

From the share distributions and the shipment forecasts presented in chapter 9 of the TSD, DOE establishes the installed walk-in equipment stock profile for all analyzed walk-in equipment classes. This information is an important input to the NIA because the national energy and financial impacts are directly related to the size and type of walk-in equipment stock. The following tables show the initial installed walk-in equipment stock, which DOE assumed is the same in the base case (walk-in components built without adhering to a standard) and standards case (walk-in components built with a standard in effect). Table 9.4.6 in the TSD shipments chapter 9 provides stock in 5-year increments for complete WICF unit use-categories, and for convenience is presented in this chapter in Table 10.2.1. Table 10.2.2 breaks down the stock by the envelope panel equipment class. Table 10.2.3 and Table 10.2.4 show the refrigeration system and envelope door equipment class stock, respectively.

Table 10.1 Installed Walk-in Equipment Stock by Year and Complete WICF unit Use-Category

Use-Category	Year and Stock						
	2017	2020	2025	2030	2035	2040	2046
Non-Display Cooler Small	633,164	654,585	684,338	716,792	752,732	792,441	838,493
Non-Display Cooler Medium	448,265	463,431	484,496	507,472	532,917	561,030	593,633
Non-Display Cooler Large	53,888	55,711	58,243	61,005	64,064	67,444	71,363
Display Cooler Small	34,889	36,146	37,962	39,818	41,866	44,159	46,834
Display Cooler Medium	88,789	91,990	96,609	101,334	106,546	112,380	119,188
Display Cooler Large	45,901	47,555	49,943	52,386	55,081	58,096	61,616
Non-Display Freezer Small	264,881	273,831	286,304	299,691	314,615	331,227	350,473
Non-Display Freezer Medium	201,408	208,213	217,697	227,876	239,224	251,855	266,489
Non-Display Freezer Large	42,876	44,324	46,344	48,511	50,926	53,615	56,730
Display Freezer Small	19,252	19,955	21,003	21,968	23,064	24,345	25,832
Display Freezer Medium	3,795	3,934	4,140	4,330	4,547	4,799	5,092
Display Freezer Large	3,863	4,004	4,214	4,407	4,627	4,884	5,183
Total	**1,840,970**	**1,903,679**	**1,991,292**	**2,085,591**	**2,190,209**	**2,306,276**	**2,440,926**

Table 10.2 Installed Walk-in Envelope Component Stock by Year and Panel Equipment Class

Envelope Component Equipment Class	Year and Stock						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2046**
Structural Panel Medium Temperature *ft*^{2}	1,185,335,600	1,225,839,243	1,282,450,797	1,343,561,066	1,411,196,196	1,486,075,002	1,573,000,568
Structural Panel Low Temperature *ft*^{2}	357,195,999	369,299,654	386,215,086	404,263,099	424,395,436	446,847,241	472,859,948
Floor Panel Low Temperature *ft*^{2}	53,884,470	55,716,152	58,283,525	61,005,258	64,043,635	67,438,670	71,372,617
Total	1,596,416,069	1,650,855,049	1,726,949,408	1,808,829,423	1,899,635,268	2,000,360,914	2,117,233,133

Table 10.3 Installed Walk-in Equipment Stock by Year and Refrigeration System

WICF Refrigeration Systems	**Year and Stock**						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2046**
Dedicated Medium Temperature Indoor	55,359	57,285	60,006	62,890	66,079	69,622	73,742
Dedicated Medium Temperature Outdoor	1,205,022	1,246,876	1,305,970	1,368,696	1,438,049	1,515,084	1,604,660
Dedicated Low Temperature Indoor	17,646	18,252	19,111	20,001	20,997	22,118	23,418
Dedicated Low Temperature Outdoor	552,109	570,930	597,380	625,259	656,403	691,263	731,662
Total	**1,830,136**	**1,893,343**	**1,982,466**	**2,076,846**	**2,181,528**	**2,298,088**	**2,433,482**
Multiplex System Medium Temperature	689,540	713,481	747,276	783,161	822,839	866,908	918,150
Multiplex System Low Temperature	128,944	133,458	139,955	146,448	153,748	162,055	171,691
Total	**818,485**	**846,940**	**887,230**	**929,609**	**976,587**	**1,028,964**	**1,089,841**
All Refrigeration Systems Total	**2,648,621**	**2,740,283**	**2,869,696**	**3,006,455**	**3,158,115**	**3,327,051**	**3,523,322**

Table 10.4 Installed Walk-in Equipment Stock by Year and WICF Door Equipment Class

WICF Envelope Components	Year and Stock						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2046**
Display Door Medium Temperature	3,606,705	3,736,711	3,924,354	4,116,298	4,328,027	4,564,982	4,841,520
Display Door Low Temperature	219,172	227,173	239,100	250,086	262,571	277,149	294,084
Total	**3,825,878**	**3,963,884**	**4,163,454**	**4,366,384**	**4,590,599**	**4,842,131**	**5,135,604**
Passage Door Medium Temperature	1,852,950	1,916,117	2,004,274	2,099,671	2,205,269	2,322,120	2,457,739
Passage Door Low Temperature	784,220	810,800	847,954	887,578	931,780	981,081	1,038,202
Total	**2,637,170**	**2,726,917**	**2,852,228**	**2,987,248**	**3,137,048**	**3,303,201**	**3,495,941**
Freight Door Medium Temperature	53,888	55,711	58,243	61,005	64,064	67,444	71,363
Freight Door Low Temperature	42,876	44,324	46,344	48,511	50,926	53,615	56,730
Total	**96,764**	**100,036**	**104,587**	**109,516**	**114,991**	**121,059**	**128,094**
All Doors Total	**6,559,812**	**6,790,837**	**7,120,269**	**7,463,149**	**7,842,637**	**8,266,391**	**8,759,638**

10.2.2 Efficiency Distribution of the Stock

Besides the size of the stock, the other information necessary to calculate the national energy impacts of the walk-in standard is the average energy consumption of the stock in both the base case and the standards case.

A key component of the NIA is the trend in energy efficiency forecasted for the base and standards cases. DOE developed a base-case energy efficiency distribution (which yields a shipment-weighted average efficiency) for each of the considered equipment classes for the first year (2017) of the forecast period. To project the trend in efficiency over the entire forecast period, DOE considered the current market distribution and recent trends. For refrigeration systems, DOE assumed, based on manufacturer interviews, that in the absence of new standards (the base case), shipments would be a mix of 75 percent Energy Information and Security Act (EISA)-compliant components and 25 percent higher efficiency components. For envelope components, all base-case shipments are assumed to have only a single EISA-compliant efficiency level except for cooler display doors. For cooler display doors, shipments would be a mix of 80 percent EISA-compliant equipment and 20 percent higher efficiency equipment. For both refrigeration systems and envelope components, DOE assumed no improvement of energy efficiency in the base case and held the base case energy efficiency distribution constant throughout the forecast period.

To estimate efficiency trends in the standards cases, DOE has used a “roll-up” scenario in its standards rulemakings. Under the roll-up scenario, DOE assumes: (1) product efficiencies in the base case that do not meet the standard level under consideration would “roll up” to meet the new standard level; and (2) product efficiencies above the standard level under consideration would not be affected.

Characterizing the efficiency implications of any possible standard at any given point in time, walk-in equipment will either:

- meet the baseline efficiency level (DOE assumes this for all walk-ins installed before the standard goes into effect), or
- meet the efficiency standard (DOE assumes these for all new walk-ins installed after the standard goes into effect).

DOE projects that walk-in owners will retire their walk-ins primarily in case of mechanical failure, change of business ownership, or for style reasons in the case of some display units. Since none of these reasons to retire a walk-in are affected by efficiency standards, DOE concludes that walk-in equipment will be replaced at the same rate under any efficiency standard.

10.3 NATIONAL ENERGY SAVINGS

10.3.1 National Energy Savings Definition

For each of the WICF refrigeration systems and envelope components considered in this analysis, DOE calculates annual national energy savings as the difference in annual national energy consumption (AEC) between the base case (without standards) and the standards case (with standards), adjusted by several factors. These factors are a heating, ventilation, and air conditioning (HVAC) factor, rebound factor, site-to-source conversion factor, and a discount factor. These are all described in sections 10.3.2.2 through 10.3.2.4. All together, the equation for calculating national energy savings takes this form:

$$NES_t = (AEC_{t,base} - AEC_{t,std}) \times src\_conv \times HVAC \times RF \times DF_t$$

Eq. 10.1

Where:

NES_t = national energy savings (in quads of source energy) in the year t,
AEC_t = annual national energy consumption each year (in kilowatt-hours [kWh] of electricity consumed onsite),
src_conv = conversion factor to convert from site energy (kWh) to source energy (quads, Btu/kWh),
$HVAC$ = heating, ventilation, air conditioning factor,
RF= rebound factor,

DF_t = discount factor in the year t,
t = year in the forecast (*e.g.*, 2020 or 2030),
$base$ = base case, and
std = standards case.

DOE defines the cumulative national energy savings as the sum of the national energy savings over the lifetime of the equipment shipped during the analysis period, *i.e.*, from 2017 to 2046.

DOE calculated the AEC in any given year by multiplying the annual unit energy consumption for each walk-in equipment class and efficiency level by the number of walk-ins in stock that year of that equipment class. This is shown in the following equation:

$$AEC_t = \sum_{TSL} (UEC_{PC,TSL} \times STOCK_{PC,TSL,t})$$

Eq. 10.2

Where:

UEC_{PC} = unit energy consumption (kWh per year),
$STOCK_{PC,t}$ = the number of WICF equipment class units in stock in that year, and
TSL = a specific combination of efficiency levels for both the envelope components and the refrigeration system equipment classes which meet certain economic or technical criteria.

The terms of this equation are explained in further detail in the following section.

10.3.2 National Energy Savings Inputs

Table 10.3.1 lists the inputs for determining the NES.

Table 10.5 National Energy Savings Input

Unit Energy Consumption by Walk-in Equipment Class and TSL ($UEC_{PC,TSL}$)
Walk-in Stock by Walk-in Equipment Class, TSL, and Year ($STOCK_{PC,TSL,t}$)
Site-to-Source Conversion Factor (src_conv)
Heating, Ventilation, Air Conditioning Factor (HVAC)
Rebound Factor (RF)
Discount Factor (DF)

10.3.2.1 Unit Energy Consumption and Walk-in Stock by Walk-in Type

Walk-in equipment class unit energy consumption (UEC) and stock are inputs to the NES calculation. UEC is described in the energy use characterization, chapter 7 of the TSD. Stock is described above in section 10.2.1 and in the shipments analysis in chapter 9 of the TSD.

10.3.2.2 Site-to-Source Conversion Factors

Because walk-in equipment is powered by electricity, the amount of energy it consumes indirectly at the point of electricity generation is greater than the amount of energy it uses directly. To account for this, DOE uses a site-to-source conversion factor to convert its estimates of onsite energy consumption (in the form of electricity) into primary or source energy consumption (in the form of, *e.g.*, fossil fuels). This conversion factor depends on the generation sources used to produce electricity, which can vary over time. For this NOPR, DOE derived new site-to-source conversion factors specific to each year of this analysis using the version of the Building Technologies version of the National Energy Modeling Systems (NEMS-BT) that corresponds to the 2013 version of the Energy Information Administration's *Annual Energy Outlook* (*AEO2013*).[1] Table 10.3.2 list the complete set of site-to-source conversion factors.

Table 10.6 Annual Site-to-Source Conversion Factors

Year	Conversion Factor *Btu*	Year	Conversion Factor *Btu*
2017	8,500	2046	8,559
2018	8,500	2047	8,559
2019	8,500	2048	8,559
2020	8,500	2049	8,559
2021	8,299	2050	8,559
2022	8,299	2051	8,559
2023	8,299	2052	8,559
2024	8,299	2053	8,559
2025	8,299	2054	8,559
2026	7,954	2055	8,559
2027	7,954	2056	8,559
2028	7,954	2057	8,559
2029	7,954	2058	8,559
2030	7,954	2059	8,559
2031	8,205	2060	8,559
2032	8,205	2061	8,559
2033	8,205	2062	8,559
2034	8,205	2063	8,559
2035	8,205	2064	8,559
2036	8,771	2065	8,559
2037	8,771	2066	8,559
2038	8,771	2067	8,559
2039	8,771	2068	8,559
2040	8,771	2069	8,559
2041	8,665	2070	8,559
2042	8,665	2071	8,559
2043	8,665	2072	8,559
2044	8,665	2073	8,559
2045	8,665		

10.3.2.3 Full-Fuel Cycle Energy

The full-fuel-cycle (FFC) measure includes point-of-use (site) energy, the energy losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels. DOE's traditional approach encompasses site energy and the energy losses associated with generation,

transmission, and distribution of electricity. To complete the full-fuel-cycle by encompassing the energy consumed in extracting, processing, and transporting or distributing primary fuels, which we refer to as "upstream" activities, DOE developed FFC multipliers using the data and projections generated by the National Energy Modeling System (NEMS) and published in AEO 2013. While the AEO does not provide direct calculations of full fuel cycle metrics, it does provide extensive information about the energy system, including projections of future oil, natural gas and coal supply, energy use for oil and gas field and refinery operations, and fuel consumption and emissions related to electric power production. This information can be used to define a set of parameters representing the energy intensity of energy production.
Table 10.3.3 shows the FFC energy multipliers used for SPVU for selected years. The method used to calculate a time series of FFC energy multipliers is described in appendix 10-A.

Table 10.7 Full-Fuel-Cycle Energy Multipliers (AEO 2013)

Fuel	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
Electricity (power plant energy use)	1.042	1.041	1.040	1.040	1.041	1.040

10.3.2.4 Interactions with Heating, Ventilation, and Air-Conditioning Systems

The heat output from walk-in equipment interacts with the functioning of the HVAC systems in its building. Walk-in equipment of greater efficiency may produce slightly less heat, altering that interaction. However, the models that can capture this interaction have not been developed to an adequate degree. Therefore, DOE assumed that this interaction was negligible and that estimating its precise nature and extent was not feasible. In large part, this is because most walk-ins are cooled by outdoor compressors that eject their waste heat outside the building rather than inside. Just as was done for the preliminary analysis, DOE assumed an HVAC factor of 1, or no measurable effect, for the NOPR analysis.

10.3.2.5 Rebound Factor

Under economic theory, a "rebound effect" refers to the tendency of a customer to respond to the cost savings associated with more efficient equipment in a manner that actually leads to marginally greater equipment usage, thereby diminishing some portion of anticipated benefits related to improved efficiency. This typically manifests in the tendency for customers to either make more frequent use of equipment that is highly efficient (*e.g.*, leaving efficient lights on more often) or adjusting equipment for greater thermal comfort (*e.g.*, turning the thermostat up a degree on a more efficient furnace). However, because walk-ins must cool their contents at all times, it is not possible for customers to operate WICF equipment more frequently. It is unlikely that customers would significantly decrease the operating temperature of their walk-ins simply because the units were more efficient because most walk-ins operate within a narrow thermal range that is determined by sanitary and other non-comfort reasons. For this analysis, DOE assumed there was no effect or a rebound factor of 1.

10.3.2.6 Discount Factor

DOE multiplies the value of energy savings in future years by the discount factor (DF) to calculate the present value of these energy savings. The following equation describes how to calculate the discount factor for any given year:

$$DF = 1/(1+r)^{(t-t_p)}$$

Eq. 10.3

Where:

r = discount rate,
t = year of the monetary value, and
t_p = year in which the present value is being determined.

DOE provides results calculated with both a 3-percent and a 7-percent real discount rate, in accordance with the Office of Management and Budget's (OMB's) guidance to Federal agencies on the development of regulatory analysis (OMB Circular A-4, September 17, 2003),[2] and section E, "Identifying and Measuring Benefits and Costs," therein. These discount rates are based on estimates of the average real rate of return on private investment in the U.S. economy. DOE defined the present year as 2013 (the current year) for this NOPR analysis.

10.4 NET PRESENT VALUE

10.4.1 Net Present Value Definition

Net present value is the value of a series of costs and savings over time which are discounted back to the present, or given year. The NPV presented here is the value in the present of the total change in purchase costs and operating costs that DOE forecasts WICF customers would face from energy conservation standards on walk-in equipment. Note that environmental and other potential benefits or costs are not included in the NPV calculation unless otherwise stated. The NPV is calculated as follows:

$$NPV = PVS - PVC$$

Eq. 10.4

Where:

PVS = present value of the total operating cost savings over time, and
PVC = present value of the total increase in installed costs over time.

The *PVS* and *PVC* are determined according to the following expressions:

$$PVS = \sum_{t} (OCS_t \times DF_t)$$

Eq. 10.5

$$PVC = \sum_{t} (ICS_t \times DF_t)$$

Eq. 10.6

Where:

OCS_t = total operating cost savings in year *t*,
ICS_t = total installed cost increases in year *t*,
DF_t = discount factor in year *t*, and
t = year (*PVS* and *PVC* are summed over 2017-2073).

DOE determined the contributions to PVS and PVC for each year from the effective date of the standard, 2017, to 2073, discounted for the NOPR analysis to 2013 DOE calculated costs and savings as the difference between a standards case and a base case. DOE calculated a discount factor from the discount rate and the number of years between the "present" (*i.e.*, 2013, the year to which the sum is being discounted) and the year in which the costs and savings occur. DOE calculated the NPV as the sum over time of the discounted net savings (which is equivalent to the approach shown in Eq. 10.4 through Eq. 10.6).

10.4.2 Net Present Value Inputs

Table 10.4.1 summarizes the inputs to the NPV calculation.

Table 10.8 Net Present Value Inputs

Input
Total Installed Cost Increases (ICS_t)
Total Annual Operating Cost Savings (OCS_t)
Discount Factor (DF)

10.4.2.1 Total Annual Installed Cost Increases

DOE calculates the increase in total annual installed costs as the difference between the total annual installed costs in the standards case minus those in the base case. This is shown in the following equation:

$$ICS_t = (IC_{t,base} - IC_{t,std})$$

Eq. 10.7

Where:

ICS_t = the total installed cost increases in the year *t*,
$IC_{t,base}$ = the total installed cost in the year *t* in the base case, and
$IC_{t,std}$ =the total installed cost in the year *t* in the standards case.

DOE determines the total installed cost (IC) in each year by multiplying the installed cost for each walk-in equipment class (*i.e.*, each refrigeration and envelope component class and efficiency level) by the number of walk-in equipment class shipped that year. This is shown in the following equation:

$$IC_t = \sum_{PC,TSL} (IC_{PC,TSL} \times SHIP_{PC,TSL,t})$$

Eq. 10.8

Where:

$IC_{PC,TSL}$ = the installed cost for a particular WICF equipment (WICF equipment class and TSL) of walk-in, and
$SHIP_{PC,TSL}$ = shipments of walk-in equipment class in year t.

Installed cost numbers are calculated in the life-cycle cost analysis, chapter 8 of the TSD. Shipments are calculated in the shipments analysis found in chapter 9 of the TSD.

As discussed in chapter 8, DOE assumed that the manufacturer costs and retail prices of envelope components at various efficiency levels remained fixed in real terms through the analysis period. However, DOE assumed that for refrigeration systems meeting various efficiency levels, the manufacturer cost and retail prices declined in real terms through the analysis period based on evidence in the historical data. DOE developed a default product price trend based on an experience curve derived using historical data on shipments and refrigeration equipment producer price index (also described in chapter 8). DOE used this curve to forecast the prices of refrigeration systems sold in each year in the forecast period (2017–2046). For each class of refrigeration system, DOE applied the same default product price trends to forecast the decline in real price for the refrigeration equipment. The result is a reduction in per-unit installed costs for each year of the analysis. The average annual rate of price decline in the default case is 0.25 percent. DOE performed an analysis of the sensitivity of the NPV results to high and low price trend forecasts. These sensitivity results are discussed in appendix 10E.

10.4.2.2 Total Annual Operating Cost Savings

DOE calculated the total annual operating cost savings in the same manner as the total installed cost increase, *i.e.*, as the difference between the total annual installed costs in the standards case and those in the base case. The equation takes the same form as Eq. 10.7. Similarly, DOE determines the total operating cost each year by adding up the product of annual operating cost for each of the WICF equipment classes considered in the NOPR analysis and efficiency level by the walk-in equipment class stock in that year. This equation takes the same form as Eq. 10.8, except that operating cost savings are calculated based on the size of the walk-in equipment stock in a given year rather than the number of walk-in equipment shipments in that year.

Operating cost numbers are calculated in the life-cycle cost analysis, chapter 8 of the TSD. As described in chapter 8, the major component of operating cost is electricity costs, although other costs, such as maintenance costs, are also included. Stock is calculated in the shipments analysis, as discussed in chapter 9 of the TSD.

10.4.2.3 MPC Price Trends

In prior energy conservation standards rulemakings, DOE estimated the total installed costs per unit for equipment, and then assumed that costs remain constant throughout the analysis period. This assumption is conservative because installed costs tend to decrease over time. In 2011, DOE issued a notice of data availability (NODA) titled Equipment Price Forecasting in Energy Conservation Standards Analysis. 76 FR 9696 (Feb. 22, 2011) In the NODA, DOE proposed a methodology for analyzing whether equipment prices have trended downward in real terms. The methodology examines so-called experiential learning, wherein, with ever-increasing experience with the production of a product, manufacturers are able to reduce their production costs through innovations in technology and process.

To account for increased efficiency in the WICF manufacturing process over time, DOE used a price forecast methodology based on experiential learning. In its analysis DOE assumed a reference level of learning and produced alternative high, low, and no learning scenarios. DOE also observed that impacts from including manufacturer learning were not significant enough to affect the proposed TSL levels. Please see appendix 10B for more information on experiential learning.

To project the manufacturer selling price of a unit, DOE multiplied the selling price by a coefficient specific to the year of purchase relative to the year in which prices were estimated (2012). The coefficient accounts for the effects of experiential learning.

DOE developed four learning scenarios to estimate this effect. One scenario, constant prices, is consistent with the analyses DOE historically performed. In this scenario, prices are held constant, so the learning coefficient is 1.00. DOE developed three scenarios–the high, reference, and low learning scenarios–for this rulemaking from historical WICF refrigeration system shipments and Producer Price Index data. For factor details see Appendix 10B of this TSD document which discuss the development of the price learning scenarios. For this notice, DOE used the historically derived reference scenario.

10.4.2.4 Light Technology Price Trends

As discussed in the engineering (chapter 5) and life-cycle cost (chapter 8) chapters of this TSD, DOE assumed that light-emitting diode (LED) lighting technologies are declining in price.

DOE incorporated the price projections into the NIA in the form of reductions in the cost of lighting for display doors. Table 10.9 shows the normalized LED price deflators used to reduce the price of the LED design option for display doors shipped during the analysis period.

Table 10.9 LED Price Deflators

Year	Normalized to 2017
2017	1.000
2018	0.895
2019	0.810
2020	0.740
2021	0.681

2022	0.631
2023	0.588
2024	0.550
2025	0.517
2026	0.488
2027	0.462
2028	0.438
2029	0.417
2030 - 2046	0.398

The reductions in lighting maintenance costs due to reduction in LED prices for equipment installed in 2017 to 2030 were also calculated and appropriately deducted from the lighting maintenance costs.

10.5 NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE RESULTS

The WICF refrigeration system and envelope component NIA spreadsheet models provide estimates of the NES and NPV at various TSLs. The inputs to the NIA spreadsheets are discussed in sections 10.3.2, National Energy Savings Inputs, and 10.4.2, Net Present Value Inputs.

Table 10.5.1 summarizes the inputs for both the refrigeration system and envelope component spreadsheet models that calculate the NES and NPV. A brief description of the data is given for each input. As noted above, the model is available online at http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/26.

Table 10.10 National Energy Saving and Net Present Value Inputs

Input Data	Data Description
Walk-ins Stock	The initial stock is taken from the envelope shipments model, discussed in chapter 9 of the TSD. This model is based on estimated historical shipments based on Commercial Buildings Energy Consumption Survey 2003[3] data and U.S. Census Bureau Current Industrial Reports data,[4] DOE and manufacturer estimates of walk-in lifetime, and forecasted growth rates from *AEO2013*
Shipments	Annual shipments from the envelope, refrigeration system, and envelope components in the shipments models, chapter 9 of the TSD. The stock estimates and annual shipments were determined by the same sources.
Effective Date of Standard	2017
Analysis Period	2017 to 2046 (including lifetime benefits through 2073)
Unit Energy Consumption (kWh/yr)	Established in the energy-use characterization by WICF equipment class and TSL, which is discussed in chapter 7 of the TSD.
Total Installed Cost	Established in the markups analysis (TSD chapter 6) and the life-cycle cost analysis (TSD chapter 8) by WICF equipment class and TSL.
Electricity Price Forecast	EIA-826 forecasts (to 2040) from the *AEO2013* and extrapolation for beyond 2040.
Electricity Site-to-Source Conversion	Derived factors from NEMS-BT (2012), and applied from 2017 through 2073.
Full-Fuel Cycle Conversion Factors	Conversion varies yearly and is generated by DOE's version of the EIA NEMS program (a time series conversion factor to account for the energy consumed in extracting, processing, and transporting or delivering primary fuels to electricity generation stations).
HVAC Interaction Savings	Negligible
Rebound Effect	Negligible
Discount Rate	3 and 7 percent real
Present Year	2013

10.5.1 National Energy Savings Summary Results

The following section provides summary NES results for the walk-in refrigeration system, panels, display doors, and non-display doors DOE considered in the NOPR analysis. Results are cumulative to 2073 and are shown as primary energy savings measured in quads at particular combinations of equipment classes and TSLs. More detailed NES results are provided in appendix 10-B.

Table 10.5.2 through Table 10.5.4 present DOE's forecasts of the primary NES for each TSL of the refrigeration systems, panels, display doors, non-display doors, and the combination of refrigeration systems and envelope components. Additionally, Table 10.5.4 presents the upstream NES values and aggregates both primary and upstream savings to present FFC savings. The values in these tables are shipment weighted. NES results in these tables show the maximum possible energy savings for each equipment class that would result in a net financial benefit to WICF users. In many cases, this corresponds to the highest TSL considered for the refrigeration system. This is because most of the refrigeration system TSLs analyzed in this rulemaking have positive net present values. In cases where more than one TSL provides the same energy savings at positive LCC savings, the lowest TSL providing those savings is selected.

To estimate the NES attributable to the TSLs being considered for the refrigeration systems, panels, display doors, and non-display doors, DOE compared the energy consumption of the refrigeration systems under the base case to their anticipated energy consumption under each TSL. In the results reported, DOE assumed that the aggregate energy savings for the refrigeration systems are independent of the choice of efficiency level of the components. Since all the TSLs except TSL 6 combine high efficiency refrigeration systems with components having relatively smaller efficiency increments over the baseline levels, DOE estimated that the impact of shipped capacity of refrigeration systems due to higher efficiency levels of components is not significant. Since the shipped capacity of refrigeration systems is assumed to remain unchanged, the baseline energy consumption and the energy savings for the refrigeration systems are considered to be independent of the component efficiency level at the TSLs considered.

Table 10.11 WICF Refrigeration Systems: Cumulative National Energy Savings in Quads (Primary Energy Savings 2017-2073)

Equipment Classes	Trial Standard Levels			
	1,3	2,4	5	6
DC.M.I	0.024	0.041	0.041	0.041
DC.M.O	1.825	2.446	2.524	2.524
DC.L.I	0.009	0.016	0.017	0.017
DC.L.O	0.768	1.162	1.256	1.256
MC.M	0.378	0.376	0.378	0.378
MC.L	0.099	0.084	0.099	0.099

Table 10.12 Component Equipment Classes: Cumulative National Energy Savings in Quads (Primary Energy Savings 2017-2073)

Equipment Classes	Trial Standard Levels					
	1	2	3	4	5	6
SP.M	0.259	0.000	0.324	0.221	0.273	0.553
SP.L	0.447	0.000	0.564	0.380	0.447	0.619
FP.L	0.048	0.000	0.069	0.040	0.055	0.069
DD.M	0.405	0.394	0.405	0.394	0.394	0.620
DD.L	0.021	0.020	0.029	0.020	0.020	0.095
PD.M	0.009	0.000	0.009	0.007	0.007	0.073
PD.L	0.113	0.000	0.141	0.106	0.128	0.140
FD.M	0.000	0.000	0.000	0.000	0.000	0.004
FD.L	0.010	0.000	0.013	0.007	0.012	0.013

Table 10.13 Refrigeration Systems and Components Combined: Cumulative National Energy Savings in Quads (Full-Fuel Cycle Energy Savings 2017-2073)

Application	Trial Standard Levels					
	1	2	3	4	5	6
Medium Temperature	2.900	3.257	2.965	3.486	3.617	4.193
Low Temperature	1.515	1.283	1.692	1.816	2.032	2.308

Primary Energy Savings Total	4.415	4.540	4.658	5.302	5.649	6.501
Upstream Energy Savings	0.072	0.074	0.076	0.086	0.092	0.106
FFC Total	4.487	4.614	4.734	5.388	5.741	6.607

10.5.2 Net Present Value Summary Results

Table 10.5.5 through Table 10.5.10 show the consumer NPV results for each of the TSLs DOE considered for the combination of refrigeration systems, panels, display doors, and non-display doors, using both a 7-percent and a 3-percent discount rate. Detailed NPV results are presented in appendix 10C.

DOE estimated the cumulative NPV to the Nation of the total costs and savings for customers that would result from standard levels for the WICF refrigeration systems and envelope components. In accordance with the OMB's guidelines on regulatory analysis, DOE calculated NPV using both a 7-percent and a 3-percent real discount rate. The 7-percent rate is an estimate of the average before-tax rate of return on private capital in the U.S. economy, and reflects the returns on real estate and small business capital as well as corporate capital. DOE used this discount rate to approximate the opportunity cost of capital in the private sector, since recent OMB analysis has found the average rate of return on capital to be near this rate. In addition, DOE used the 3-percent rate to capture the potential effects of standards on private consumption (*e.g.*, through higher prices for products and the purchase of reduced amounts of energy). This rate represents the rate at which society discounts future consumption flows to their present value. It can be approximated by the real rate of return on long-term government debt (*i.e.*, yield on Treasury notes minus annual rate of change in the Consumer Price Index), which has averaged about 3 percent on a pre-tax basis for the last 30 years.

In each case, the impacts cover the lifetime of products purchased in 2017–2046, and are shown in million 2012$. For a particular TSL combination, improvement of efficiency levels of the envelope components should result in reduced refrigeration load on the paired refrigeration system, and consequently the refrigeration system can be downsized. This results in additional consumer benefits. In estimating such indirect first cost benefits, DOE made several simplifying assumptions. and has included estimates of these indirect first-cost savings in the aggregate NPV tables (Table 10.5.4 and Table 10.5.7) . The direct energy savings from improving envelope components are shown in the envelope component summary tables. NPV results for the WICF refrigeration systems suggest energy conservation standards should be based on the highest TSLs because the greatest NPV is achieved at max-tech TSLs (5 and 6). In contrast, the envelope component NPV results indicate there is small benefit at high efficiency levels; therefore, energy conservation standards for envelope components should be based at levels barely above EISA-compliant baseline levels, used in the current analysis.

Table 10.14 WICF Refrigeration Systems: Net Present Value in Millions (2012$) at a 7-percent Discount Rate

Equipment Classes	Trial Standard Levels			
	1, 3	2,4	5	6
DC.M.I*	38	52	52	52
DC.M.O*	3,417	3,943	3,937	3,937
DC.L.I*	12	19	19	19
DC.L.O*	1,488	1,995	1,913	1,913
MC.M	835	843	835	835
MC.L	161	189	161	161

* For DC refrigeration systems, results include both capacity ranges

Table 10.15 Envelope Component Equipment Classes: Net Present Value in Millions (2012$) at a 7-percent Discount Rate

Equipment Classes	Trial Standard Levels					
	1	2	3	4	5	6
SP.M	289	0	121	207	11	-17,715
SP.L	662	0	269	520	21	-4,298
FP.L	63	0	52	48	22	-578
DD.M	571	545	571	545	543	-11,200
DD.L	54	51	0	51	50	-395
PD.M	4	0	4	1	1	-1,764
PD.L	106	0	38	88	6	-513
FD.M	0	0	0	0	0	-106
FD.L	10	0	5	9	2	-59

Table 10.16 Refrigeration Systems and Components Combined: Net Present Value in Millions (2012$) at a 7-percent Discount Rate

Application	Trial Standard Levels					
	1	2	3	4	5	6
Medium Temperature						
Combined NPV	5,155	5,384	4,987	5,592	5,380	-25,961
First cost benefits	6	3	18	34	45	153
Sub-Total	5,161	5,386	5,004	5,627	5,425	-25,809
Low Temperature						
Combined NPV	2,555	2,255	2,025	2,919	2,193	-3,751
First cost benefits	49	0	89	96	246	344
Sub-Total	2,604	2,255	2,114	3,015	2,438	-3,408
Total - All	7,765	7,641	7,118	8,642	7,864	-29,217

Table 10.17 WICF Refrigeration Systems: Net Present Value in Millions (2012$) at a 3-percent Discount Rate

Equipment Classes	Trial Standard Levels			
	1,3	2,4	5	6
DC.M.I	107	159	159	159
DC.M.O	9,161	11,047	11,147	11,147
DC.L.I	36	61	60	60
DC.L.O	3,951	5,483	5,455	5,455
MC.M	2,143	2,157	2,143	2,143
MC.L	450	483	450	450

Table 10.18 Envelope Component Equipment Classes: Net Present Value in Millions (2012$) at a 3-percent Discount Rate

Equipment Classes	Trial Standard Levels					
	1	2	3	4	5	6
SP.M	990	0	779	770	484	-32,834
SP.L	2,151	0	1,468	1,694	797	-7,144
FP.L	219	0	216	167	134	-985
DD.M	1,667	1,602	1,667	1,602	1,597	-20,987
DD.L	135	128	41	128	126	-640
PD.M	21	0	21	13	12	-3,329
PD.L	364	0	270	319	189	-803
FD.M	1	0	1	1	1	-200
FD.L	36	0	31	32	23	-92

Table 10.19 Refrigeration Systems and Components Combined: Net Present Value in Millions (2012$) at a 3-percent Discount Rate

Application	Trial Standard Levels					
	1	2	3	4	5	6
Medium Temperature						
Combined NPV	14,091	14,965	13,880	15,748	15,543	-43,901
First cost benefits	12	5	34	66	87	294
Subtotal	14,102	14,970	13,914	15,814	15,630	-43,607
Low Temperature						
Combined NPV	7,191	6,155	6,464	8,297	7,234	-3,700
First cost benefits	94	0	172	185	473	663
Subtotal	7,285	6,155	6,636	8,482	7,707	-3,037
Total - All	21,387	21,125	20,550	24,296	23,337	-46,644

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CHAPTER 11. LIFE-CYCLE COST SUB-GROUP ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 11. LIFE-CYCLE COST SUB-GROUP ANALYSIS

11.1 INTRODUCTION

The life-cycle cost (LCC) sub-group analysis evaluates impacts on any identifiable groups of customers of walk-in cooler and freezer (WICF) equipment who may be disproportionately affected by new energy conservation standards. The U.S. Department of Energy (DOE) accomplished this, in part, by analyzing the LCC and payback period (PBP) for WICF customers who fall into specific sub-groups.

DOE used the LCC spreadsheet model to estimate the impact on WICF sub-groups. DOE developed this LCC spreadsheet model to conduct the LCC and PBP analyses for WICF customers, as described in chapter 8 of this technical support document, Life-Cycle Cost and Payback Period Analyses. The standard LCC and PBP analyses (see chapter 8) for walk-in coolers and freezers include various types of food sales businesses that use WICF equipment. The LCC spreadsheet model allows for the identification of certain sub-groups of businesses, which can then be analyzed by sampling only that sub-group. Chapter 8 details the inputs to the LCC spreadsheet model used in determining the LCC and PBP. The LCC spreadsheet model is accessible at http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/26.

11.2 SUB-GROUPS ANALYSIS

11.2.1 WICF Customer Sub-Group

DOE identified small businesses as a sub-group that could be disproportionately affected by the new energy conservation standards for WICF equipment. DOE was concerned that increases in the purchase price of WICF equipment could have negative impacts on small businesses with low annual revenues. To identify small businesses, DOE used size standards from the Small Business Administration (SBA) to define which business entities are considered small. The SBA established size standards for types of economic activity, or industry, under the North American Industry Classification System (NAICS).[1]

The SBA defines a small business from a customer perspective by either its annual receipts (*i.e.*, revenues) or its number of employees. Assembly and food service businesses are generally defined as small if annual receipts are $6 million or less. In the case of the retail food sales business, the SBA defines as small businesses supermarkets and other grocery stores and convenience stores with less than $25 million in total annual sales. For specialty stores (*e.g.*, meat markets, bakeries, fish and seafood markets) and beer, wine, and liquor stores, this limit is less than $6.5 million in annual sales. According to Progressive Grocer, the average supermarket had sales of approximately $15.6 million in 2009,[2] so a small business could be represented as ownership of one or two average-size supermarkets or a chain of smaller grocery or convenience stores.

In examining the total WICF sales to entities that might be considered small businesses, DOE analyzed detailed statistical data from the 2007 census[3] for four business types identified in this analysis: supermarkets and grocery stores, convenience stores (including specialty food stores), convenience stores without gasoline stations, and small restaurants. These data are presented in Table 11.2.1 to Table 11.2.4 and are organized by single-unit and multi-unit firms, with specific estimates for each category of multi-unit firm.

Table 11.2.1 shows that while more than 67 percent of supermarkets and grocery stores meet the definition of a small business, these establishments are only responsible for 20 percent of the industry's total sales.

Table 11.2.1 Census Data for Supermarket and Other Grocery Business Class by Number of Establishments per Firm

Description[1]	**Number of Firms**	**Total Employment**	**Average Establishments per Firm**	**Sales per Establishment *$1000***	**Sales per Firm *$1000***
All firms	41,885	2,432,425	1.5	7,186	11,131
Single-unit firms	39,878	438,104	1.0	1,676	1,676
Multi-unit firms	2,007	1,994,321	12.5	15,974	198,998
Firms with one establishment	577	18,882	1.0	4,481	4,481
Firms with two establishments	597	49,967	2.0	5,912	11,824
Firms with 3 or 4 establishments	374	62,813	3.3	7,659	25,250
Firms with 5 to 9 establishments	235	87,447	6.4	9,939	64,030
Firms with 10 to 24 establishments	128	125,436	14.0	12,728	178,695
Firms with 25 to 49 establishments	38	88,107	33.2	12,715	422,285
Firms with 50 to 99 establishments	22	133,964	69.7	16,220	1,130,223
Firms with 100 establishments or more	36	1,427,705	441.5	18,969	8,374,159

Fraction of establishments considered small business	0.673
Fraction of firms classed as small business	0.992
Fraction of employment in small businesses	0.252
Fraction of sales in small businesses	0.200

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[1] A firm may be either a single-establishment (single-unit) firm or a multi-establishment (multi-unit) firm. A single-unit firm is a firm with only one establishment engaged in economic activities. A multi-unit firm is a firm with two or more establishments engaged in economic activities. A multi-unit firm may, however, operate only one establishment classified in the specific sector *i.e.*, Retail Trade, C-store etc. Firm size groups are based on aggregate data for all establishments operated by the same firm in a given kind-of-business classification or group for which data are presented. See the 2007 census for more details.

These same data are tabulated for convenience stores (including specialty food stores and beer, wine, and liquor stores as was done in the LCC analysis). Because the size standards are different for convenience stores compared with specialty food and beer, wine, and liquor stores, the results are first shown separately, and then aggregated in Table 11.2.2. Then, the data are tabulated for combination gasoline stations with convenience stores in Table 11.2.3 and for restaurants in Table 11.2.4.

Table 11.2.2 Census Data for Convenience Store and Specialty Food Store Business Classes, by Number of Establishments per Firm

	Description	**Number of Firms**	**Total Employment**	**Average Establishments per Firm**	**Sales per Establishment *$1000***	**Sales per Firm *$1000***
Convenience Stores	All firms	22,168	118,787	1.2	819	942
	Single-unit firms	21,529	79,302	1.0	661	661
	Multi-unit firms	639	39,485	6.2	1,671	10,408
	Firms with one establishment	300	2,458	1.0	1,087	1,087
	Firms with two establishments	183	2,804	2.0	1,159	2,318
	Firms with 3 or 4 establishments	86	2,251	3.3	1,258	4,111
	Firms with 5 to 9 establishments	25	1,014	6.0	967	5,843
	Firms with 10 to 24 establishments	19	3,369	15.9	1,487	23,634
	Firms with 25 to 49 establishments	12	3,320	36.9	1,244	45,925
	Firms with 50 to 99 establishments	10	6,365	69.4	1,682	116,707
	Firms with 100 establishments or more	4	17,904	361.0	2,239	808,383
	Fraction of establishments considered small business	0.884				
	Fraction of firms classed as small business	0.997				
	Fraction of employment in small businesses	0.735				
	Fraction of sales	0.738				
Specialty Food Stores and Beer Wine and Liquor Stores	All firms	47,320	275,950	1.2	935	1,101
	Single-unit firms	45,413	207,642	1.0	820	820
	Multi-unit firms	1,907	68,308	5.4	1,446	7,793
	Firms with one establishment	867	7,365	1.0	1,226	1,226
	Firms with two establishments	523	10,019	2.0	1,642	3,284
	Firms with 3 or 4 establishments	279	8,274	3.3	1,350	4,443
	Firms with 5 to 9 establishments	141	8,103	6.3	1,319	8,290
	Firms with 10 to 24 establishments	52	5,822	14.8	1,789	26,524
	Firms with 25 to 49 establishments	16	4,619	33.8	1,780	60,199
	Firms with 50 to 99 establishments	15	8,444	72.1	2,202	158,678
	Firms with 100 establishments or more	14	15,662	297.9	1,187	353,573

Table 11.2.3 Census Data for Convenience Store with Gasoline Station Business Class by Number of Establishments per Firm

	Description	**Number of Firms**	**Total Employment**	**Average Establishments per Firm**	**Sales per Establishment** ***$1000***	**Sales per Firm** ***$1000***
Gasoline Stations with Convenience Stores	All firms	53,375	719,108	1.8	3,449	6,300
	Single-unit firms	49,010	287,220	1.0	2,249	2,249
	Multi-unit firms	4,365	431,888	11.1	4,661	51,788
	Firms with one establishment	1,160	11,836	1.0	3,363	3,363
	Firms with two establishments	1,168	21,386	2.0	3,311	6,622
	Firms with 3 or 4 establishments	802	24,023	3.4	3,483	11,713
	Firms with 5 to 9 establishments	573	30,488	6.5	3,545	22,945
	Firms with 10 to 24 establishments	402	47,037	14.9	3,475	51,678
	Firms with 25 to 49 establishments	150	45,235	33.5	3,827	128,070
	Firms with 50 to 99 establishments	58	31,187	66.6	4,096	272,955
	Firms with 100 establishments or more	52	220,696	456.4	5,733	2,616,567
	Fraction of establishments considered small business	0.585				
	Fraction of firms classed as small business	0.982				
	Fraction of employment in small businesses	0.500				
	Fraction of sales	0.410				

Table 11.2.4 Census Data for Food Service and Drinking Places Business Class by Number of Establishments per Firm

Description	Number of Firms	Total Employment	Average Establishments per Firm	Sales per Establishment *$1000*	Sales per Firm *$1000*
All firms	111,162	2,827,162	1.3	3,691	4,851
Single-unit firms	106,820	725,048	1.0	1,108	1,108
Multi-unit firms	4,342	2,102,114	9.0	10,720	96,937
Firms with one establishment	1,495	24,725	1.0	2,264	2,264
Firms with two establishments	1,333	63,435	2.0	3,444	6,887
Firms with 3 or 4 establishments	738	72,555	3.3	4,517	14,849
Firms with 5 to 9 establishments	409	98,573	6.4	6,356	40,685
Firms with 10 establishments or more	367	1,842,826	81.9	12,666	1,037,430
Fraction of establishments considered small business	0.785				
Fraction of firms classed as small business	0.995				
Fraction of employment in small businesses	0.311				
Fraction of sales	0.278				

According to the SBA, 99 percent of all U.S. businesses fall under the SBA definition of a small business.[4] The data in Table 11.2.1 show that small businesses account for 20 percent of the sales and 25.2 percent of the employment in the supermarket/grocery business class whereas the convenience store business class has 88 percent of the sales and 83 percent of the employment occurs in small businesses, as shown in Table 11.2.2. Data for convenience stores with gasoline stations, shown in Table 11.2.3, are more mixed, with 58.5 percent of the sales and 41 percent of employment occurring in stores that fit the definition of small businesses. In the food service and drinking places business class, 33.1 percent of employment and 27.8 percent of sales are attributed to small businesses, with 99.5 percent of the firms being classed as small businesses.

In examining the five business classes considered in the LCC analysis: grocery stores, convenience stores, restaurants, food service establishments, and other establishments, DOE considered which business class would be substantially representative of small businesses that are likely to be adversely affected under this rulemaking. In consideration of the comments submitted by interested parties and the census data described previously, food service and drinking places, and small non-chain restaurants in particular, appear to best match the criteria above. For example, restaurants pay higher electricity prices[5] compared to the other business classes, but use similar amounts of electricity for the same type of equipment. Small restaurants also face somewhat higher costs of capital. For the sub-group analysis, it was assumed that small restaurants have no access to national accounts and therefore face higher wholesale and retail markups for initial equipment purchases, resulting in higher equipment prices.

Based on this assessment, DOE has used data for food service and drinking places as a representative proxy for small business WICF purchasers, but with the added assumption of no access to national account purchasing, resulting in higher equipment costs. Thus, DOE has defined small restaurants as the representative sub-group for the LCC sub-group analysis.

11.2.2 Life-Cycle Cost and Payback Period Results for Small Business Sub-Group

Table 11.2.5 to Table 11.2.8 summarize the LCC, LCC savings, and PBP results for the small business sub-group WICF refrigeration systems. Similarly, Table 11.2.9 through Table 11.2.11 provides the same data for WICF envelope components.

The baseline in all cases is the baseline efficiency level used in the LCC. Results are provided by trial standard level (TSL) for each representative WICF equipment class. The LCC and PBP results indicate that the overall benefit of potentially higher WICF refrigeration and envelope component (panel and door) efficiency level on the small business sub-group is qualitatively similar to the benefits on the full sample of business types that use WICF refrigeration systems and envelope components covered by this rulemaking.

Table 11.2.5 LCC and PBP Results for WICF Outdoor Dedicated Condensing Medium Temperature Refrigeration Systems, Small Business Sub-Group (2012$)

Trial Standard Level	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings** *2012$*				**Payback Period** *years*
	Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings**	**% of Consumers that Experience**			**Median**
					Net Cost	**No Impact**	**Net Benefit**	
Small Capacity (6 kBtu/hr)								
Baseline	$3,104	$6,678	$9,743					
TSL1	$4,326	$4,598	$8,924	$554	0	0	100	2.1
TSL2	$4,557	$4,214	$8,772	$698	0	0	100	3.3
TSL3	$4,557	$4,203	$8,765	$703	0	0	100	3.3
TSL4	$4,326	$4,610	$8,931	$550	0	0	100	2.1
TSL5	$4,890	$3,820	$8,711	$757	4	0	96	4.4
TSL6	$4,890	$3,820	$8,711	$757	4	0	96	4.4
Medium Capacity (18 kBtu/hr)								
Baseline	$5,033	$13,027	$18,008					
TSL1	$6,905	$8,898	$15,804	$1,715	0	0	100	1.0
TSL2	$7,812	$6,957	$14,770	$2,693	0	0	100	2.6
TSL3	$6,905	$8,898	$15,804	$1,715	0	0	100	1.0
TSL4	$7,812	$6,957	$14,770	$2,693	0	0	100	2.6
TSL5	$7,812	$6,957	$14,770	$2,693	0	0	100	2.6
TSL6	$7,812	$6,957	$14,770	$2,693	0	0	100	2.6
Large Capacity (54 kBtu/hr)								
Baseline	$5,033	$41,593	$46,384					
TSL1	$15,124	$18,214	$33,341	$11,787	0	0	100	1.0
TSL2	$16,746	$16,058	$32,807	$12,293	0	0	100	1.8
TSL3	$15,124	$18,214	$33,341	$11,787	0	0	100	1.0
TSL4	$16,746	$16,058	$32,807	$12,293	0	0	100	1.8
TSL5	$16,746	$16,058	$32,807	$12,293	0	0	100	1.8
TSL6	$16,746	$16,058	$32,807	$12,293	0	0	100	1.8

Table 11.2.6 LCC and PBP Results for WICF Indoor Dedicated Condensing Medium Temperature Refrigeration Systems, Small Business Sub-Group (2012$)

Trial Standard Level	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings** *2012$*				**Payback Period** *years*
	Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings**	**% of Consumers that Experience**			**Median**
					Net Cost	**No Impact**	**Net Benefit**	
Small Capacity (6 kBtu/hr)								
Baseline	$3,053	$7,389	$10,403					
TSL1	$4,097	$5,957	$10,055	$65	0	0	99	3.5
TSL2	$4,490	$5,275	$9,765	$339	5	0	95	5.0
TSL3	$4,097	$5,957	$10,055	$65	0	0	99	3.5
TSL4	$4,490	$5,275	$9,765	$339	5	0	95	5.0
TSL5	$4,490	$5,275	$9,765	$339	5	0	95	5.0
TSL6	$4,490	$5,275	$9,765	$339	5	0	95	5.0
Large Capacity (18 kBtu/hr)								
Baseline	$4,977	$16,187	$21,116					
TSL1	$6,568	$12,708	$19,276	$1,266	0	0	100	2.2
TSL2	$7,184	$11,622	$18,807	$1,724	0	0	100	2.2
TSL3	$6,568	$12,708	$19,276	$1,266	0	0	100	2.2
TSL4	$7,184	$11,622	$18,807	$1,724	0	0	100	2.2
TSL5	$7,184	$11,622	$18,807	$1,724	0	0	100	2.2
TSL6	$7,184	$11,622	$18,807	$1,724	0	0	100	2.2

Table 11.2.7 LCC and PBP Results for WICF Outdoor Dedicated Condensing Low Temperature Refrigeration Systems, Small Business Sub-Group (2012$)

Trial Standard Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period *years*
	Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
					Net Cost	No Impact	Net Benefit	
Small Capacity (6 kBtu/hr)								
Baseline	$3,504	$11,405	$14,890					
TSL1	$4,600	$8,161	$12,762	$1,724	0	0	100	2.1
TSL2	$5,031	$6,792	$11,823	$1,709	0	0	100	1.7
TSL3	$4,600	$8,161	$12,762	$1,724	0	0	100	2.1
TSL4	$5,031	$6,792	$11,823	$1,709	0	0	100	1.7
TSL5	$5,441	$6,363	$11,805	$1,726	0	0	100	2.8
TSL6	$5,441	$6,363	$11,805	$1,726	0	0	100	2.8
Medium Capacity (9 kBtu/hr)								
Baseline	$3,763	$12,573	$16,304					
TSL1	$5,116	$9,743	$14,860	$1,001	0	0	100	0.7
TSL2	$6,085	$7,549	$13,634	$2,160	0	0	100	2.9
TSL3	$5,116	$9,743	$14,860	$1,001	0	0	100	0.7
TSL4	$6,085	$7,549	$13,634	$2,160	0	0	100	2.9
TSL5	$6,170	$7,501	$13,671	$2,126	0	0	100	3.1
TSL6	$6,170	$7,501	$13,671	$2,126	0	0	100	3.1
Large Capacity (9 kBtu/hr)								
Baseline	$12,870	$62,544	$75,078					
TSL1	$22,927	$36,748	$59,680	$13,361	0	0	100	0.5
TSL2	$23,182	$36,034	$59,221	$13,795	0	0	100	0.6
TSL3	$22,927	$36,748	$59,680	$13,361	0	0	100	0.5
TSL4	$23,182	$36,034	$59,221	$13,795	0	0	100	0.6
TSL5	$29,585	$30,621	$60,213	$12,862	0	0	100	3.2
TSL6	$29,585	$30,621	$60,213	$12,862	0	0	100	3.2

Table 11.2.8 LCC and PBP Results for WICF Indoor Dedicated Condensing Low Temperature Refrigeration Systems, Small Business Sub-Group (2012$)

Trial Standard Level	**Life-Cycle Cost** *2012$*			**Life-Cycle Cost Savings** *2012$*				**Payback Period** *years*
	Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings**	**% of Consumers that Experience**			**Median**
					Net Cost	**No Impact**	**Net Benefit**	
Small Capacity (6 kBtu/hr)								
Baseline	$3,439	$12,828	$16,246					
TSL1	$4,449	$10,622	$15,071	$734	0	0	100	3.4
TSL2	$4,983	$9,965	$14,948	$1,048	0	0	100	2.7
TSL3	$4,449	$10,622	$15,071	$734	0	0	100	3.4
TSL4	$4,983	$9,965	$14,948	$1,048	0	0	100	2.7
TSL5	$5,068	$9,921	$14,989	$1,009	0	0	100	3.1
TSL6	$5,068	$9,921	$14,989	$1,009	0	0	100	3.1
Large Capacity (9 kBtu/hr)								
Baseline	$3,689	$15,981	$19,641					
TSL1	$4,993	$13,979	$18,973	$133	0	0	100	2.1
TSL2	$5,447	$12,570	$18,017	$1,037	0	0	100	2.9
TSL3	$4,993	$13,979	$18,973	$133	0	0	100	2.1
TSL4	$5,447	$12,570	$18,017	$1,037	0	0	100	2.9
TSL5	$5,532	$12,519	$18,052	$1,004	0	0	100	3.2
TSL6	$5,532	$12,519	$18,052	$1,004	0	0	100	3.2

For Table 11.2.9 through Table 11.2.11, envelope components were analyzed at their individual size options, and the results were aggregated by their market share contributions. This method provides the following estimates by TSL and allows for high level comparisons of LCC savings.

Table 11.2.9 LCC and PBP Results for WICF Envelope Components, Standard and Floor Panels, Small Business Sub-Group (2012$)

Trial Standard Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period *years*
	Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
					Net Cost	No Impact	Net Benefit	
Medium Temperature Standard Panel								
Baseline	$1,008	$93	$1,100					
TSL1	$1,008	$93	$1,100	$13	14	0	86	3.8
TSL2	$977	$114	$1,093	$0	0	100	0	0.0
TSL3	$1,044	$82	$1,126	-$8	83	0	24	6.8
TSL4	$1,008	$77	$1,086	$6	36	0	64	4.5
TSL5	$1,044	$63	$1,107	-$16	97	0	7	8.9
TSL6	$3,206	$19	$3,225	-$2,141	100	0	0	146.1
Low Temperature Standard Panel								
Baseline	$1,123	$269	$1,385					
TSL1	$1,123	$269	$1,385	$110	3	0	97	2.8
TSL2	$1,011	$383	$1,401	$0	0	100	0	0.0
TSL3	$1,373	$208	$1,581	-$76	82	0	18	7.3
TSL4	$1,123	$207	$1,328	$68	7	0	93	3.6
TSL5	$1,374	$154	$1,527	-$92	95	0	5	9.9
TSL6	$3,208	$73	$3,281	-$1,902	100	0	0	42.6
Low Temperature Floor Panel								
Baseline	$1,203	$235	$1,432					
TSL1	$1,203	$235	$1,432	$58	7	0	93	3.5
TSL2	$1,103	$306	$1,413	$0	0	100	0	0.0
TSL3	$1,349	$161	$1,510	-$13	83	0	24	5.9
TSL4	$1,203	$181	$1,383	$27	36	0	64	4.4
TSL5	$1,349	$119	$1,466	-$52	93	0	7	7.9
TSL6	$2,982	$76	$3,058	-$1,661	100	0	0	48.3

Table 11.2.10 LCC and PBP Results for WICF Envelope Components, Opaque Doors, Small Business Sub-Group (2012$)

Trial Standard Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period *years*
	Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
					Net Cost	No Impact	Net Benefit	
Medium Temperature Passage Door								
Baseline	$692	$85	$777					
TSL1	$692	$85	$777	$2	30	0	70	4.5
TSL2	$684	$88	$771	$0	0	100	0	0.0
TSL3	$692	$85	$777	$2	30	0	70	4.5
TSL4	$692	$79	$771	$0	57	0	43	5.5
TSL5	$692	$77	$769	-$1	69	0	31	6.0
TSL6	$1,637	$18	$1,655	-$886	100	0	0	78.8
Low Temperature Passage Door								
Baseline	$1,070	$2,117	$3,187					
TSL1	$1,070	$2,117	$3,187	$64	18	0	82	4.3
TSL2	$881	$2,166	$3,047	$0	0	100	0	0.0
TSL3	$1,226	$2,053	$3,278	-$37	70	0	30	6.2
TSL4	$1,070	$1,935	$3,005	$43	33	0	67	4.7
TSL5	$1,226	$1,855	$3,081	-$65	76	0	24	7.0
TSL6	$1,864	$1,832	$3,695	-$677	100	0	0	18.3
Medium Temp Freight Doors								
Baseline	$1,278	$141	$1,419					
TSL1	$1,278	$138	$1,416	$3	28	0	72	4.4
TSL2	$1,266	$138	$1,404	$0	0	100	0	0.0
TSL3	$1,278	$138	$1,416	$3	28	0	72	4.4
TSL4	$1,278	$126	$1,404	$0	55	0	45	5.4
TSL5	$1,278	$121	$1,399	-$6	66	0	34	5.9
TSL6	$2,512	$47	$2,559	-$1,160	100	0	0	81.6
Low Temperature Freight Door								
Baseline	$1,671	$3,288	$4,959					
TSL1	$1,671	$3,288	$4,959	$138	8	0	92	3.8
TSL2	$1,427	$3,344	$4,771	$0	0	100	0	0.0
TSL3	$1,915	$3,173	$5,087	$13	60	0	40	5.8
TSL4	$1,544	$3,101	$4,644	$126	2	0	98	2.9
TSL5	$1,915	$2,860	$4,774	-$58	72	0	28	6.5
TSL6	$3,274	$2,808	$6,081	-$1,357	100	0	0	21.6

Table 11.2.11 LCC and PBP Results for WICF Envelope Components, Display Doors, Small Business Sub-Group (2012$)

Trial Standard Level	Life-Cycle Cost *2012$*			Life-Cycle Cost Savings *2012$*				Payback Period *years*
	Installed Cost	Discounted Operating Cost	LCC	Average Savings	% of Consumers that Experience			Median
					Net Cost	No Impact	Net Benefit	
Medium Temperature Display Door								
Baseline	$1,100	$506	$1,605					
TSL1	$1,201	$180	$1,380	$225	0	0	100	2.1
TSL2	$1,201	$174	$1,375	$215	0	0	100	2.2
TSL3	$1,201	$180	$1,380	$225	0	0	100	2.1
TSL4	$1,201	$174	$1,375	$215	0	0	100	2.2
TSL5	$1,201	$172	$1,372	$210	0	0	100	2.2
TSL6	$4,171	$71	$4,242	-$2,660	100	0	0	37.3
Low Temperature Display Door								
Baseline	$1,594	$1,369	$2,964					
TSL1	$1,750	$1,004	$2,753	$210	0	0	100	N/A
TSL2	$1,750	$925	$2,674	$193	0	0	100	N/A
TSL3	$2,039	$944	$2,980	-$12	64	0	36	6.2
TSL4	$1,750	$925	$2,674	$193	0	0	100	N/A
TSL5	$1,750	$914	$2,663	$191	0	0	100	N/A
TSL6	$4,229	$365	$4,594	-$1,740	99	0	1	18.9

At the recommended TSL4, LCC savings and PBPs for the small business subgroup remain positive, although somewhat less positive than other business types. Based on this analysis, as a recognizable sub-group, small businesses would expect no significant additional negative impact from increased WICF efficiency levels compared with the full sample of WICF customers considered in the rulemaking.

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 amended energy conservation standards on manufacturers of walk-in coolers and freezers, 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 walk-in cooler and freezer industry, including data on sales volumes, 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 manufacturers. The GRIM included analysis of walk-in panel, door, and refrigeration manufacturers. DOE also developed interview guides to gather information on the potential impacts on these manufacturers. In Phase III, "Subgroup Impact Analysis," DOE interviewed manufacturers representing a broad cross-section of the walk-ins industry. Using information from phase II, DOE refined its analysis in the GRIM, developed additional analyses for sub-groups that required special consideration, and incorporated qualitative data from interviews into its analysis.

12.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the walk-in cooler and freezer industry that built upon the market and technology assessment prepared for this rulemaking (refer to chapter 3 of the TSD). Before initiating the detailed impact studies, DOE collected information on the present and past structure and market characteristics of the walk-ins industry. This information included 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 walk-in manufacturers that DOE used to derive the preliminary financial inputs for the GRIM (*e.g.*, revenues, depreciation, SG&A, and research and development (R&D) expenses).

DOE also used public information to further calibrate its initial characterization of the industry, including Securities and Exchange Commission (SEC) 10–K reports,[1] Standard & Poor's (S&P) stock reports,[2] Dun and Bradstreet (D&B) company profiles,[3] corporate annual reports, and the U.S. Census Bureau's 2011 Annual Survey of Manufacturers (2011 ASM).[4] DOE also characterized these industries using information from its engineering analysis and the life-cycle cost analysis.

12.2.2 Phase II: Industry Cash-Flow Analysis and Interview Guide

Phase II focused on the financial impacts of potential amended energy conservation standards on manufacturers of walk-in components. More stringent energy conservation standards can affect manufacturer cash flows in three distinct ways: (1) create a need for increased investment, (2) raise production costs per unit, and (3) alter revenue due to higher per-unit prices and/or possible changes in sales volumes. To quantify these impacts, DOE used the GRIM to perform cash-flow analyses for walk-in panel, door, and refrigeration manufacturers. In performing these analyses, DOE used the financial values derived during Phase I and the shipment scenarios used in the NIA.

In Phase II, DOE grouped the cash flow results for key walk-in components to allow DOE to better assess the impacts of amended energy conservation standards on manufacturers. DOE presented the MIA cash flow results for this rulemaking in three groupings: walk-in panel, door, and refrigeration manufacturers. There is some overlap across these three groups. For example, a number of panel manufacturers also manufacturer solid doors for walk-ins. However, in general, manufacturers of refrigeration, panels, and doors operate distinct businesses and will have differentiated impacts as a result of an amended energy conservation standard.

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 thirty years after the standards' compliance date. These factors include annual expected revenues, costs of goods sold, SG&A, taxes, and capital expenditures related to the amended standards. Inputs to the GRIM include manufacturing production costs, markup assumptions, 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 9 of the

TSD, provided the basis for the shipment projections in the GRIM. The financial parameters were developed using publicly available manufacturer data and were revised with information submitted confidentially during manufacturer interviews. The GRIM results are compared to base case projections for the industry. The financial impact of amended energy conservation standards is the difference between the discounted annual cash flows in the base case and standards case at each TSL.

12.2.2.2 Interview Guides

During Phase II of the MIA, DOE interviewed manufacturers to gather information on the effects of an energy conservation standard on revenues and finances, direct employment, capital assets, and industry competitiveness. Before the interviews, DOE distributed an interview guide to interviewees. The interview guide provided a starting point for identifying relevant issues and impacts of amended energy conservation standards on individual manufacturers or subgroups of manufacturers. Most of the information received from these meetings is protected by non-disclosure agreements and resides with DOE's contractors. The MIA interview topics included (1) key issues to this rulemaking; (2) a company overview and organizational characteristics; (3) engineering and life cycle cost analysis follow-up; (4) manufacturer markups and profitability; (5) shipment projections and market shares; (6) financial parameters; (7) conversion costs; (8) cumulative regulatory burden; (9) direct employment impact assessment; (10) exports, foreign competition, and outsourcing; (11) consolidation; and (12) impacts on small businesses.

12.2.3 Phase III: Subgroup Analysis

In Phase III, "Subgroup Impact Analysis," DOE interviewed walk-in refrigeration, walk-in panel, and walk-in door manufacturers. DOE interviewed a representative cross-section of manufacturers, including small and large companies, subsidiaries and independent firms, and public and private companies. The interviews provided DOE with valuable information for evaluating the impacts of amended energy conservation standards on manufacturer cash flows, investment requirements, and employment. Using information from phase II and from the interviews, DOE refined its analysis for the equipment classes included in the GRIM.

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 sought to obtain feedback from industry on the approaches used in the GRIMs and to isolate key issues and concerns.

DOE used these interviews to tailor the GRIM to reflect unique financial characteristics of each product group. Interviews were scheduled well in advance to provide every opportunity for key individuals to be available for comment. Although a written response to the questionnaire was acceptable, DOE sought interactive interviews, which help clarify responses and identify additional issues. The resulting information provides valuable inputs to the GRIM developed for the equipment 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 model based on this feedback. Section 12.4.3 provides more information on how DOE calculated the parameters.

12.2.3.3 Manufacturer Subgroup Analysis

Using average cost assumptions to develop an industry-cash-flow estimate may not adequately assess differential impacts of amended energy conservation standards among manufacturer subgroups. For example, small manufacturers, niche players, or manufacturers exhibiting a cost structure that largely differs from the industry average could be more negatively affected. To address this possible impact, DOE used the results of the industry characterization analysis in Phase I to group manufacturers that exhibit similar characteristics.

For this rulemaking, DOE presents the industry impacts by grouping panel, door, and refrigeration manufacturers separately. By segmenting the results, DOE is able to discuss how these different groups of manufacturers will be impacted by amended energy conservation standards. Grouping these product categories reduced the need for a subgroup analysis because the impacts of each group are characterized by the MIA separately.

Small-Business Manufacturer Subgroup

DOE investigated whether small business manufacturers should be analyzed as a manufacturer subgroup. DOE used the Small Business Administration (SBA) small business size standards effective on November 5, 2010, 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.[5] For the equipment 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.

Table 12.2.1 SBA and NAICS Classification of Small Businesses Potentially Affected by This Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Air−conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing	N/A	750	333415

DOE used publicly available and proprietary information to identify potential small manufacturers. DOE's research involved industry trade association membership directories (including AHRI), product databases (e.g., AHRI Directory[a], NFS International listings[b], the SBA Database), individual company websites, and market research tools (e.g., Hoovers.com) to create a list of every company that manufactures or sells products covered by this rulemaking. DOE also asked stakeholders and industry representatives if they were aware of any other small manufacturers during manufacturer interviews and at previous DOE public meetings. 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.

Based on this analysis DOE identified two companies that manufacture refrigeration, forty-two companies that primarily produce walk-in panels, and five companies that primarily produce doors in the WICF industry that are small businesses. DOE attempted to contact small businesses to solicit feedback on the potential impacts of energy conservation standards. The businesses replied with varying amounts of information in written responses and/or interviews. In addition to posing a subset of modified MIA interview questions, DOE solicited data on differential impacts these companies might experience from amended energy conservation standards. Based on these interviews and industry research, DOE reports the potential impacts of this rulemaking on small manufacturers in section 12.6.

12.2.3.4 Manufacturing Capacity Impact

One significant outcome of amended energy conservation standards could be the obsolescence of existing manufacturing assets. 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 GRIM. These estimates can be found in section 12.4.8. DOE's discussion of the capacity impact can be found in section 12.7.2.

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[a] See www.ahridirectory.org/ahriDirectory/pages/home.aspx.

[b] See http://www.nsf.org/Certified/Food/

12.2.3.5 Employment Impact

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. To assess how domestic direct employment patterns might be affected, the interviews explored current employment trends in the walk-ins industry. The interviews also solicited manufacturer views on changes in employment patterns that may result from more stringent standards. The employment impacts section of the interview guide focused on current employment levels associated with manufacturers at each production facility, expected future employment levels with and without amended energy conservation standards, and differences in workforce skills and issues related to the retraining of employees. The employment impacts are reported in section 12.7.1.

12.2.3.6 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects 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 walk-in cooler and freezer products, 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 sections describe the most significant issues identified by manufacturers. These summaries are provided in aggregate to protect manufacturer confidentiality.

12.3.1 Cost of Testing

All door, panel, and refrigeration manufacturers expressed strong concern regarding the cost of compliance testing. The majority of walk-ins sold are not standard combinations of box sizes, refrigeration components, and doors. Almost every walk-in unit is tailored to meet customer specifications. According to manufacturers, DOE-mandated testing of every configuration sold is not realistic and could become a financial burden that would negatively impact manufacturers' profitability.

The cost of compliance testing includes the engineering support necessary to design and run tests, the cost of the units tested, and the cost of third-party testing support. Some manufacturers indicated that it may be necessary to set up new test labs to deal with compliance requirements. Beyond DOE compliance testing, energy conservation standards may lead to product redesigns that require new industry certifications, such as UL fire safety, NSF 2 food service, and NSF 7 commercial refrigerator and freezer standards compliance.

Multiple door, panel, and refrigeration manufacturers expressed concern that these compliance and certification testing costs may lead to less customization in the industry. As an example, one door manufacturer was concerned that walk-in manufacturers would offer fewer door choices and partner with fewer door companies in order to reduce testing burden. As another example, a manufacturer that only produces unit coolers indicated the need to certify the complete refrigeration system would force them to leave to WICF market. As the unit cooler supplier, the manufacturer does not have the ability to certify the entire system because they do not supply the condensing unit portion of the system. Today, the unit cooler manufacturer's customers pair the unit coolers with condensing units from other manufacturers to assemble a walk-in refrigeration system. The manufacturer speculated that, in a regulated environment, their customers would switch from buying refrigeration components from manufacturers like themselves to buying complete systems with matched unit coolers and condensing units from larger competitors that build complete systems rather than components. Their customers would make this change in order to avoid the test burden on refrigeration systems. Other manufacturers mentioned that the cost of testing could ultimately lead to conditions in which small panel manufacturers would be forced out of the market.

Finally, there was some concern from walk-in manufacturers regarding pricing and availability of third-party testing. Several walk-in manufacturers noted that it is unclear whether a sufficient number of qualified third parties exist to carry out the performance testing mandated by DOE for the entire industry. One manufacturer was concerned that an insufficient number of test facilities would leading to higher testing costs and delays in achieving compliance.

12.3.2 Unclear enforcement plan and ambiguity in compliance responsibility

All of the interviewed manufacturers expressed concern that an energy conservation standard rulemaking could result in unfair competition if the standard is not properly enforced. Interviewed manufacturers claimed that numerous manufacturers, particularly small one-to-two person operations, are not currently complying with the existing walk-in regulations in EPCA, which took effect January 1, 2009. The manufacturers explained that smaller operations often have an incentive to be non-compliant. By using designs that do not comply with existing regulations, the non-compliant manufacturers maintain a price advantage over compliant industry players.

Manufacturers emphasized the need to have well-defined compliance responsibilities. WICF units can be manufactured and delivered as per standard by the manufacturer, but the end user may decide to remove some of the efficiency features, such as strip curtains. Additionally, the quality of installation at the client site is often a factor that manufacturers cannot control because field assembly is managed by contractors. Manufacturers also noted that, for some installations, the contractors purchase the walk-in envelope and refrigeration equipment from separate suppliers, making it impossible for the equipment manufacturers to determine the efficiency of the installed product. Multiple manufacturers requested clarification to better understand which party bears responsibility for ensuring field-assembled walk-ins meet federal standards.

12.3.3 Profitability impacts

Walk-in manufacturers discussed how new energy conservation standards could affect profit levels. Manufacturers considered the walk-in industry to be a low margin-business. Price competition can be very aggressive, particularly for large orders and for name-brand client accounts. Manufacturers stated that low margins leave little room for the added costs that energy conservation standards could impose. Manufacturers noted that they will have to absorb the additional costs or pass the costs onto the customer.

Specifically, manufacturers emphasized their concern about the impact of thicker panels, thicker doors, and more efficient refrigeration on profitability. Thicker panels require more material and longer processing times. The end result could be a reduction in factory throughput coupled with increased cost. Additionally, manufacturers noted that thicker panels are heavier, which leads to higher shipping costs. Similar concerns exist for solid doors. To achieve higher refrigeration efficiencies, manufacturers would have to purchase larger coils, more efficient compressors, and more expensive control systems. All these components increase the cost of goods sold for the completed walk-in.

Manufacturers speculated that passing all these costs onto their customers would lead to lower volume orders, as customers with set budgets would not be able to purchase as many walk-ins (in the case of chain stores) or as much walk-in (in the case of individual operations) for the same dollar amount. Alternatively, absorbing these costs would significantly reduce profit margins.

12.3.4 Excessive conversion cost

According to panel manufacturers, a new energy conservation standard that requires increased levels of thickness could result in high conversion costs. Much of the existing production equipment is designed to produce panels 3.5 inches to 5 inches thick. Panels that are 6 inches thick or greater are less common in the industry. Any standard that results in the market moving to 5-inch thick panels would require some conversion cost as factories that use foam-in-place technology must accommodate increased curing times. Manufacturers indicated that the conversion costs could range from $100,000 to $500,000, depending on the manufacturer’s existing equipment. Any standard that requires 6-inch thick panels would involve significant additional investment by most manufacturers. At this level of thickness, manufacturers estimate conversion costs ranging from $200,000 to $1 million per company. Any standard that requires 7-inch thick panels would require all manufacturers to reevaluate their manufacturing process. Conversion costs would range from $1.5 million to $4 million. Based on manufacturer statements, any standard that moved the industry to 6-inch thick panels would likely put even some of the top ten panel manufacturers out of business.

12.3.5 Disproportionate impact on small business

Most interviewed manufacturers noted new energy conservation standards could have a disproportionate impact on small businesses, as compared to larger businesses. The cost of testing, the potential increase in materials, and the potential need to obtain financing are the factors that could more severely affect small business manufacturers producing refrigeration, panels, and doors.

Manufacturers voiced concerns regarding the cost of both compliance testing and industry certification testing (e.g. UL and NSF certifications) on small businesses. According to manufacturers, the price tag for testing is likely to be similar for both small and large companies due to the high level of product customization in the industry. For small businesses, the cost will spread across smaller sales volumes, making recuperation of the testing investment more difficult. Some manufacturers thought that compliance testing costs alone could force small manufacturers to exit the industry.

Additionally, small manufacturers indicated that they face a significant price disadvantage for foaming agents (used for insulation) and components due to their small purchasing quantities when compared to large manufacturers. Any standard that requires small manufacturers to use more foam or more expensive components will exacerbate the pricing gap. Given the price-sensitive nature and low margin of the industry, the small envelope manufacturers were concerned that requiring thicker panels provided a competitive advantage to large manufacturers that could obtain foaming agents at a lower price based on order quantities that are of larger magnitude.

Several interviewed manufacturers are concerned that current tightness in financial markets and reduced economic activity could negatively impact their ability to obtain financing necessary to cover compliance costs. This is particularly true for small business operations, which have greater difficulty obtaining financing

12.3.6 Refrigerant phase-out

Interviewed manufacturers are concerned about the impacts of mandated changes in blowing agent and refrigerants. Currently, walk-in manufacturers use HFC-404 and HFC-134a refrigerants. While HFC-404 is exclusively used as a refrigerant, HFC-134a is used as both a refrigerant and a blowing agent in the walk-in manufacturing industry.

Several manufacturers expressed concern about the impact of a potential phase-down or phase-out of HFCs. The concern is acute because there is not a clear alternative or substitute to HFCs for the industry. Without a clear replacement, any phase-out would create a period of uncertainty as the industry identifies suitable alternatives and then redesigns both products and processes around the replacement. In general, past phase-outs have led to more expensive and less efficient refrigerant replacements.

For panel manufacturers, conversion to a new blowing agent would be costly as they would have to go through a transition period in which foam would need to be reformulated. Production processes and facilities would need to adapt to the new foam blend. In the past, replacement blowing agents have been more expensive and have presented challenges to the production process as they create flow characteristics different from the agents they replace. Finally, previous blowing agent substitutes have led to foam blends with lower R-value, providing less insulation. Lower insulation effectiveness results in thicker panels needed to meet a standard, which leads to increased production cost and therefore lower profit margins.

For refrigeration manufacturers, a HFC phase-out would be costly as it would require redesign of all products. Some manufacturers stated that a HFC phase-out would force them to use flammable refrigerants. Manufacturers noted that some alternative refrigerants may require substantially larger systems to achieve the same levels of performance.

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, 2013, and continuing to 2046. The model calculates the INPV by summing the stream of annual discounted cash flows during this period and adding a discounted terminal value.[6]

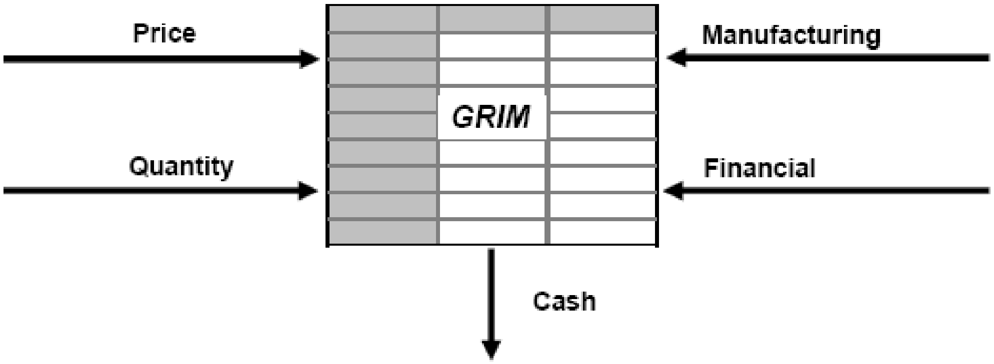

Figure 12.4.1 Using the GRIM to Calculate Cash Flow

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.

12.4.2 Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, Census data, credit ratings, the shipments model, the engineering analysis, and the manufacturer interviews.

12.4.2.1 Corporate Annual Reports

Corporate annual reports to the SEC (SEC 10-Ks) provided many of the initial financial inputs to the GRIM. These reports exist for publicly held companies and are freely available to the general public. DOE developed initial financial inputs to the GRIM by examining the annual SEC 10-K reports filed by publicly-traded manufacturers that manufacture walk-in refrigeration, panels, and doors. 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 the GRIM analysis. These figures were later revised using feedback from interviews to be representative of manufacturing for each product grouping. 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). Chapter 9 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 MPC estimates. The analysis provided the labor, materials, overhead, and total production costs for different design option for refrigeration, panels, and doors. The engineering analysis also estimated a manufacturer markup and a shipping cost to provide the manufacturer selling price (MSP) for design option.

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 equipment 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;
- MPCs estimated in the engineering analysis; and
- Possible profitability impacts.

12.4.3 Financial Parameters

Table 12.4.1 provides financial parameters for seven large companies engaged in manufacturing and selling walk-in coolers and freezers. The values listed are averages over a 5-year period (2004 to 2008).

Table 12.4.1 GRIM Financial Parameters Based on 2004–2008 Weighted Company Financial Data

Parameter	Industry-weighted Average	Manufacturers						
		A	B	C	D	E	F	G
Tax Rate (% of Taxable Income)	25.7%	27.2%	23.6%	33.3%	17.5%	32.0%	0.0%	26.6%
Working Capital (% of Revenue)	13.6%	7.2%	30.8%	10.2%	15.3%	16.4%	4.7%	11.3%
SG&A (% of Revenue)	16.1%	11.7%	9.1%	23.3%	12.9%	22.9%	12.7%	22.4%
R&D (% of Revenues)	1.9%	3.2%	0.5%	1.2%	1.4%	0.4%	3.1%	2.7%
Depreciation (% of Revenues)	2.4%	2.3%	1.6%	1.3%	1.6%	2.2%	7.4%	3.2%

Capital Expenditures (% of Revenues)	2.1%	2.1%	1.2%	1.8%	1.7%	1.9%	5.5%	2.4%

While most of these companies also manufacturer products not covered by this rulemaking, DOE used these parameters as initial estimates. During interviews, manufacturers were asked to provide their own figures for the parameters listed in Table 12.4.4. Where applicable, DOE adjusted the parameters in the GRIM using manufacturer feedback and market share information. Additionally, based on manufacturer feedback, DOE analyzed walk-in panel, door, and refrigeration manufacturer financials separately. Table 12.4.2, Table 12.4.3, and Table 12.4.4 presents the revised financial parameters for walk-in panels, doors, and refrigeration equipment, respectively.

Table 12.4.2 GRIM Revised Walk-ins Panel Financial Parameters

Parameter	**Revised Estimate**
Tax Rate (% of Taxable Income)	32.7%
Working Capital (% of Revenue)	11.7%
Net Property, Plant, and Equipment (% of Revenues)	24.8%
SG&A (% of Revenue)	16.1%
R&D (% of Revenues)	1.6%
Depreciation (% of Revenues)	1.5%
Capital Expenditures (% of Revenues)	2.1%

Table 12.4.3 GRIM Revised Walk-ins Door Financial Parameters

Parameter	**Revised Estimate**
Tax Rate (% of Taxable Income)	25.7%
Working Capital (% of Revenue)	17.2%
Net Property, Plant, and Equipment (% of Revenues)	24.8%
SG&A (% of Revenue)	22.4%
R&D (% of Revenues)	2.0%
Depreciation (% of Revenues)	1.5%
Capital Expenditures (% of Revenues)	1.8%

Table 12.4.4 GRIM Revised Walk-ins Refrigeration Financial Parameters

Parameter	**Revised Estimate**
Tax Rate (% of Taxable Income)	30.1%
Working Capital (% of Revenue)	20.0%
Net Property, Plant, and Equipment (% of Revenues)	24.8%
SG&A (% of Revenue)	18.9%
R&D (% of Revenues)	1.1%
Depreciation (% of Revenues)	1.3%
Capital Expenditures (% of Revenues)	1.0%

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 walk-ins industry based on several representative companies, using the following formula:

WACC = After-Tax Cost of Debt x (Debt Ratio) + Cost of Equity x (Equity Ratio)

The cost of equity is the rate of return that equity investors (including, potentially, the company) expect to earn on a company's stock. These expectations are reflected in the market price of the company's stock. The capital asset pricing model (CAPM) provides one widely used means to estimate the cost of equity. According to the CAPM, the cost of equity (expected return) is:

Cost of Equity = Riskless Rate of Return + β x Risk Premium

Where:

Riskless rate of return 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 calculated that the industry average cost of equity for the walk-in cooler and freezer industry is 14.9 percent (Table 12.4.5).

Table 12.4.5 Cost of Equity Calculation

Parameter	Industry Weighted Average	A	B	C	D	E	F	G
(1) Average Beta	1.2	1.1	2.6	0.9	2.0	1.0	1.9	1.24
(2) Yield on 10-Year (1928-2010)	4.33							
(3) Market Risk Premium	6.09							
Cost of Equity (2)+[(1)*(3)]	14.9							
Equity/Total Capital	0.65	0.63	0.48	0.53	0.71	0.68	1.00	0.67

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 five public manufacturers by using S&P ratings and adding the relevant spread to the risk-free rate.

In practice, investors use a variety of different maturity Treasury bonds to estimate the risk-free rate. DOE used the 10-year Treasury bond return because it captures long-term inflation expectations and is less volatile than short-term rates. The risk free rate is estimated to be approximately 5.2 percent, which is the average 10-year Treasury bond return between 1928 and 2010.

For the cost of debt, S&P's Credit Services provided the average spread of corporate bonds for the five manufacturers for which data was available between 2004 and 2010. 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 12.4.6 presents the derivation of the cost of debt and the capital structure of the industry (*i.e.* the debt ratio (debt/total capital)).

Table 12.4.6 Cost of Debt Calculation

Parameter	**Industry Weighted Average**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
S&P Bond Rating		A	BB-	BB+	BBB+	-	-	A
(2) Yield on 10-Year (1928-2010)	5.23							
(2) Gross Cost of Debt	7.5	5.83	8.83	7.53	6.83	-	-	5.83
(3) Tax Rate	25.7	27.2	23.6	33.3	17.5	32	-	26.6
Net Cost of Debt (2) x [1-(3)]	7.5							
Debt/Total Capital	0.35	0.37	0.52	0.47	0.29	0.32	0.00	0.33

Using public information for these seven companies, the initial estimate for the industry's WACC was approximately 11.5 percent. Subtracting an inflation rate of 3.19 percent over the analysis period used in the initial estimate, the inflation-adjusted WACC and the initial estimate of the discount rate used in the straw-man GRIM is 8.3 percent. DOE also asked for feedback on the discount rate during manufacturer interviews. Based on this feedback, DOE used a discount rate of 10.5 for the walk-in panels analysis, 9.4 for the walk-in doors analysis, and 10.2 for the walk-in refrigeration analysis.

12.4.5 Trial Standard Levels

DOE developed a number of efficiency levels for each type of equipment class. TSLs were then developed by selecting likely groupings of efficiency levels for all equipment types. Each TSL includes combinations of efficiency levels for walk-in cooler and freezer panels, doors, and refrigeration. Table 12.4.7 presents the TSLs used for energy efficiency analysis in the GRIM.

Table 12.4.7 Trial Standard Levels for Energy Efficiency Analysis of Walk-in Coolers & Freezers

Equipment Class	Baseline	TSL1	TSL2	TSL3	TSL4	TSL5	TSL6
DC.M.I, < 9,000	Baseline	EL 1	EL 6	EL 1	EL 6	EL 6	EL 6
DC.M.I, ≥ 9,000	Baseline	EL 3	EL 6	EL 3	EL 6	EL 6	EL 6
DC.M.O, < 9,000	Baseline	EL 6	EL 8	EL 6	EL 8	EL 9	EL 9
DC.M.O, ≥ 9,000	Baseline	EL 3	EL 10	EL 3	EL 10	EL 10	EL 10
DC.L.I, < 9,000	Baseline	EL 6	EL 6	EL 6	EL 6	EL 7	EL 7
DC.L.I, ≥ 9,000	Baseline	EL 1	EL 6	EL 1	EL 6	EL 7	EL 7
DC.L.O, < 9,000	Baseline	EL 9	EL 7	EL 9	EL 7	EL 10	EL 10
DC.L.O, ≥ 9,000	Baseline	EL 2	EL 10	EL 2	EL 10	EL 11	EL 11
MC.M	Baseline	EL 3	EL 2	EL 3	EL 2	EL 3	EL 3
MC.L	Baseline	EL 5	EL 2	EL 5	EL 2	EL 5	EL 5
SP.M	Baseline	EL 1	Baseline	EL 2	EL 1	EL 2	EL 6
SP.L	Baseline	EL 2	Baseline	EL 4	EL 2	EL 4	EL 5
FP.L	Baseline	EL 2	Baseline	EL 4	EL 2	EL 4	EL 5
DD.M	Baseline	EL 2	EL 2	EL 2	EL 2	EL 2	EL 6
DD.L	Baseline	EL 1	EL 1	EL 2	EL 1	EL 1	EL 5
PD.M	Baseline	EL 1	Baseline	EL 1	EL 1	EL 1	EL 8
PD.L	Baseline	EL 3	Baseline	EL 6	EL 3	EL 6	EL 8
FD.M	Baseline	EL 1	Baseline	EL 1	EL 1	EL 1	EL 9
FD.L	Baseline	EL 3	Baseline	EL 6	EL 2	EL 6	EL 8

12.4.6 NIA Shipments

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 applied the NIA shipments forecasts. For dedicated condensing systems, the representative capacities reported by the NIA were distributed into size-based classes as shown in the following table.

Table 12.4.8 Refrigeration System Equipment Class Definitions

Equipment Class	Equipment Class Code	Capacities Analyzed (kBtu/hr)
Dedicated Condensing, Medium Temperature, Indoor, < 9,000 Btu/h Capacity	DC.M.I, < 9,000	6
Dedicated Condensing, Medium Temperature, Indoor, ≥ 9,000 Btu/h Capacity	DC.M.I, ≥ 9,000	18, 54, 96
Dedicated Condensing, Medium Temperature, Outdoor, < 9,000 Btu/h Capacity	DC.M.O, < 9,000	6
Dedicated Condensing, Medium Temperature, Outdoor , ≥ 9,000 Btu/h Capacity	DC.M.O, ≥ 9,000	18, 54, 96
Dedicated Condensing, Low Temperature, Indoor, < 9,000 Btu/h Capacity	DC.L.I, < 9,000	6
Dedicated Condensing, Low Temperature, Indoor, ≥ 9,000 Btu/h Capacity	DC.L.I, ≥ 9,000	9, 54
Dedicated Condensing, Low Temperature, Outdoor, < 9,000Btu/h Capacity	DC.L.O, < 9,000	6
Dedicated Condensing, Low Temperature, Outdoor, ≥ 9,000 Btu/h Capacity	DC.L.O, ≥ 9,000	9, 54, 72
Multiplex Condensing, Medium Temperature	MC.M	4, 9, 24
Multiplex Condensing, Low Temperature	MC.L	4, 9, 18, 40

Chapter 9 of the TSD explains DOE’s calculations of total shipments in detail. Table 12.4.9 and Table 12.4.10 show base case shipments forecasted in the shipment analysis for the walk-in cooler and freezer rulemaking.

Table 12.4.9 Total Base Case NIA Shipments for Walk-in Envelope (in Units Shipped)

Year	SP.M	SP.L	FP.L	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
2013	2,358,987	715,614	107,981	369,276	22,810	181,711	77,221	5,287	4,220
2014	2,468,870	743,421	112,121	380,062	23,140	187,045	79,118	5,441	4,325
2015	2,579,993	779,562	117,473	387,679	23,489	192,513	81,599	5,605	4,464
2016	2,639,692	791,602	119,392	414,780	25,414	194,219	81,986	5,640	4,478
2017	2,653,449	799,704	120,606	396,280	24,107	195,924	82,944	5,699	4,535
2018	2,719,456	819,474	123,613	402,686	24,534	199,065	84,280	5,789	4,607
2019	2,744,194	827,242	124,822	405,125	24,763	200,141	84,772	5,819	4,633
2020	2,732,230	823,868	124,330	403,562	24,714	199,391	84,481	5,797	4,617
2021	2,707,590	816,673	123,265	400,808	24,596	198,038	83,932	5,756	4,586
2022	2,675,395	807,057	121,824	397,125	24,395	196,292	83,236	5,706	4,548
2023	2,645,338	797,883	120,433	393,471	24,156	194,833	82,602	5,664	4,514
2024	2,628,921	792,549	119,608	391,395	23,970	193,481	82,018	5,625	4,483
2025	2,623,447	790,483	119,273	391,531	23,904	193,195	81,845	5,618	4,474
2026	2,626,024	790,872	119,301	394,376	23,991	193,917	82,111	5,641	4,490
2027	2,641,567	795,295	119,940	401,321	24,337	195,518	82,724	5,687	4,524
2028	2,670,912	803,939	121,221	412,871	24,977	204,126	86,332	5,938	4,721
2029	2,711,816	816,179	123,055	428,551	25,897	213,829	90,420	6,221	4,945

2030	2,760,308	830,799	125,256	446,809	27,002	223,515	94,519	6,502	5,169
2031	2,818,067	848,386	127,917	466,125	28,207	232,406	98,304	6,760	5,376
2032	2,883,342	868,396	130,966	484,755	29,420	239,917	101,526	6,977	5,551
2033	2,947,392	888,014	133,951	500,020	30,422	245,549	103,953	7,140	5,683
2034	3,007,837	906,378	136,743	511,435	31,170	249,539	105,670	7,255	5,776
2035	3,066,489	924,156	139,443	519,851	31,723	252,495	106,941	7,340	5,845
2036	3,120,855	940,576	141,939	526,269	32,143	254,860	107,948	7,408	5,900
2037	3,148,794	948,953	143,207	529,351	32,323	255,929	108,392	7,439	5,924
2038	3,156,866	951,440	143,585	530,884	32,403	256,247	108,516	7,448	5,931
2039	3,147,875	948,921	143,208	531,752	32,445	256,661	108,686	7,461	5,941
2040	3,125,668	942,595	142,257	532,652	32,496	257,469	109,035	7,485	5,960
2041	3,132,104	944,190	142,459	537,229	32,664	260,685	110,348	7,580	6,033
2042	3,144,071	947,645	142,969	544,364	33,055	264,875	112,100	7,703	6,129
2043	3,163,445	953,337	143,817	553,374	33,568	269,793	114,168	7,846	6,242
2044	3,191,014	961,525	145,043	563,923	34,189	275,077	116,401	8,000	6,365
2045	3,226,553	972,160	146,640	575,486	34,888	280,398	118,658	8,154	6,488
2046	3,269,056	984,946	148,567	587,448	35,627	285,537	120,844	8,303	6,607

Table 12.4.10 Total Base Case NIA Shipments for Walk-in Refrigeration (in Units Shipped)

Year	DC.M.I < 9,000	DC.M.I ≥ 9,000	DC.M.O < 9,000	DC.M.O ≥ 9,000	DC.L.I < 9,000	DC.L.I ≥ 9,000	DC.L.O < 9,000	DC.L.O ≥ 9,000	MC.M	MC.L
2013	4,675	915	53,338	69,141	1,010	791	22,464	32,447	57,290	10,983
2014	4,812	942	54,900	71,166	1,033	809	22,987	33,204	58,974	11,208
2015	4,937	966	56,332	73,023	1,062	831	23,668	34,187	60,522	11,484
2016	5,018	982	57,243	74,204	1,074	840	23,891	34,509	61,504	11,650
2017	5,024	984	57,322	74,307	1,080	845	24,027	34,705	61,595	11,712
2018	5,105	999	58,239	75,496	1,097	859	24,408	35,256	62,586	11,912
2019	5,133	1,005	58,557	75,907	1,104	864	24,548	35,458	62,932	12,001
2020	5,155	1,009	58,808	76,233	1,110	869	24,673	35,639	63,210	12,066
2021	5,122	1,003	58,428	75,740	1,103	864	24,520	35,417	62,808	12,012
2022	5,071	993	57,844	74,982	1,093	856	24,294	35,091	62,186	11,901
2023	5,023	983	57,304	74,283	1,083	847	24,064	34,760	61,610	11,785
2024	4,975	974	56,755	73,572	1,072	839	23,835	34,428	61,024	11,662
2025	4,954	970	56,522	73,270	1,067	835	23,723	34,266	60,776	11,591
2026	4,960	971	56,591	73,359	1,067	835	23,745	34,298	60,852	11,577
2027	4,996	978	57,006	73,896	1,073	840	23,899	34,521	61,299	11,635
2028	5,214	1,021	59,492	77,119	1,119	876	24,931	36,011	63,968	12,124
2029	5,462	1,069	62,324	80,791	1,172	917	26,111	37,716	67,010	12,694
2030	5,711	1,118	65,164	84,472	1,226	959	27,298	39,431	70,060	13,275
2031	5,945	1,164	67,825	87,921	1,276	999	28,417	41,047	72,919	13,830
2032	6,145	1,203	70,105	90,877	1,320	1,033	29,379	42,436	75,370	14,323
2033	6,295	1,232	71,817	93,097	1,353	1,059	30,105	43,485	77,212	14,698
2034	6,402	1,253	73,027	94,665	1,377	1,077	30,616	44,223	78,514	14,963
2035	6,479	1,268	73,907	95,806	1,394	1,091	30,987	44,760	79,462	15,156
2036	6,539	1,280	74,592	96,693	1,407	1,101	31,272	45,171	80,200	15,305
2037	6,563	1,285	74,863	97,044	1,412	1,105	31,383	45,331	80,494	15,357
2038	6,566	1,286	74,906	97,100	1,412	1,105	31,399	45,354	80,541	15,360
2039	6,573	1,287	74,978	97,194	1,414	1,106	31,430	45,399	80,620	15,369
2040	6,590	1,290	75,172	97,446	1,417	1,109	31,516	45,524	80,829	15,406
2041	6,666	1,305	76,049	98,582	1,433	1,121	31,876	46,044	81,771	15,554
2042	6,772	1,326	77,255	100,145	1,455	1,139	32,376	46,766	83,067	15,789
2043	6,897	1,350	78,689	102,004	1,482	1,160	32,974	47,628	84,608	16,075
2044	7,033	1,377	80,241	104,016	1,511	1,182	33,623	48,566	86,277	16,390
2045	7,171	1,404	81,812	106,053	1,540	1,206	34,282	49,518	87,966	16,714
2046	7,305	1,430	83,334	108,026	1,569	1,228	34,921	50,441	89,603	17,032

12.4.6.1 Shipments Forecast

As part of the shipments analysis, DOE estimated the base-case shipment distribution by efficiency level for walk-in panels, doors, and refrigeration. In the base case, 25% of refrigeration units are assumed to ship at EL 1, 75% of medium temperature display doors are assumed to ship at either EL 1 or EL 2, and 25% of low temperature display doors are assumed to ship at EL 1. All other equipment classes are assumed to ship at the baseline level in the base case.

In the standards case, the shipments analysis assumes a roll-up scenario, where all shipments in the base case that do not meet the standard would instead ship at the new standard level. The key assumptions and methodology used to forecast shipments can be found in chapter 9 of the TSD.

12.4.7 Production Costs

Changes in production costs affect revenues and gross profits. Products that are more efficient typically cost more to produce than baseline products (as shown in chapter 5 of the TSD). For the MIA, DOE used the manufacturer production costs (MPCs) derived in the engineering analysis.

For walk-ins refrigeration equipment, the engineering analysis included MPCs for units from 6 kBtu/hr to 720 kBtu/hr. The NIA shipments estimated the number of units at various representative capacity points. The GRIM used the manufacturing production costs from the engineering analysis and the NIA Shipments to calculate shipment-weighted average MPC for each equipment class. Additionally, the GRIM relied on the engineering analysis to determine labor, materials, overhead, and depreciation percentages that constitute the full MPC.

For walk-in panels, the engineering analysis included MPCs for small, medium, and large panels. The GRIM used medium panels, which are 8 feet by 4 feet, as a representative size for calculations. Thickness was dependent on the application and equipment class.

Similarly, for walk-in doors, the GRIM used medium sized doors from the engineering analysis as representative. All MPC calculations were based on a 7 foot by 3 foot passage doors, 9 foot by 7 foot freight doors, and 6.25 foot by 2.5 foot display door.

To calculate baseline manufacturer selling prices (MSP), DOE followed a three step process. First, DOE derived MPCs from the engineering and tear down analyses. Second, DOE applied a manufacturer markup, which varies with the markup scenario (which is discussed in detail in section 12.4.9). Finally, an estimate shipping cost is added to the marked up costs to arrive at the MSP.

Table 12.4.11 through Table 12.4.29 show the production cost estimates used in the GRIM for each analyzed equipment class. A flat markup of 1.35 was applied to refrigeration, of 1.33 to panels, of 1.5 to solid doors, and of 1.62 to display doors.

Table 12.4.11 Manufacturer Production Cost Breakdown ($2012) for Dedicated Condensing, Medium Temperature, Indoor System, < 9,000 Btu/h Capacity

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$47.92	$1,158.61	$142.38	$17.77	$1,366.68	$103.29	1.35	$1,948.31
EL 1	$48.85	$1,181.01	$145.13	$18.11	$1,393.11	$103.29	1.35	$1,983.99
EL 2	$49.78	$1,203.41	$147.88	$18.45	$1,419.53	$103.29	1.35	$2,019.66
EL 3	$50.58	$1,222.87	$150.28	$18.75	$1,442.49	$103.29	1.35	$2,050.65
EL 4	$52.69	$1,273.87	$156.54	$19.53	$1,502.65	$141.15	1.35	$2,169.73
EL 5	$52.82	$1,276.92	$156.92	$19.58	$1,506.24	$141.15	1.35	$2,174.58
EL 6	$53.02	$1,281.83	$157.52	$19.66	$1,512.04	$141.15	1.35	$2,182.40
EL 7	$56.27	$1,360.43	$167.18	$20.86	$1,604.76	$141.15	1.35	$2,307.57
EL 8	$63.41	$1,533.05	$188.39	$23.51	$1,808.37	$141.15	1.35	$2,582.45

Table 12.4.12 Manufacturer Production Cost Breakdown ($2012) for Dedicated Condensing, Medium Temperature, Indoor System, ≥ 9,000 Btu/h Capacity

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$62.88	$1,982.39	$192.52	$29.47	$2,267.28	$113.93	1.35	$3,174.76
EL 1	$64.35	$2,028.60	$197.01	$30.16	$2,320.13	$113.93	1.35	$3,246.10
EL 2	$65.82	$2,074.81	$201.50	$30.85	$2,372.98	$113.93	1.35	$3,317.45
EL 3	$67.51	$2,128.34	$206.69	$31.64	$2,434.20	$139.25	1.35	$3,425.42
EL 4	$68.22	$2,150.67	$208.86	$31.98	$2,459.74	$139.25	1.35	$3,459.90
EL 5	$68.42	$2,156.95	$209.47	$32.07	$2,466.92	$139.25	1.35	$3,469.59
EL 6	$69.06	$2,177.21	$211.44	$32.37	$2,490.09	$139.25	1.35	$3,500.87
EL 7	$74.21	$2,339.35	$227.19	$34.78	$2,675.53	$139.25	1.35	$3,751.21
EL 8	$80.58	$2,540.34	$246.71	$37.77	$2,905.41	$139.25	1.35	$4,061.55

Table 12.4.13 Manufacturer Production Cost Breakdown ($2012) for Dedicated Condensing, Medium Temperature, Outdoor System, < 9,000 Btu/h Capacity

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$49.14	$1,180.37	$143.27	$18.08	$1,390.86	$103.29	1.35	$1,980.95
EL 1	$50.07	$1,202.80	$145.99	$18.42	$1,417.29	$103.29	1.35	$2,016.62
EL 2	$52.41	$1,258.97	$152.81	$19.29	$1,483.48	$141.15	1.35	$2,143.84
EL 3	$53.35	$1,281.40	$155.53	$19.63	$1,509.90	$141.15	1.35	$2,179.52
EL 4	$54.47	$1,308.31	$158.80	$20.04	$1,541.61	$141.15	1.35	$2,222.33
EL 5	$54.59	$1,311.35	$159.17	$20.09	$1,545.20	$141.15	1.35	$2,227.17
EL 6	$55.40	$1,330.69	$161.51	$20.38	$1,567.98	$141.15	1.35	$2,257.93
EL 7	$55.60	$1,335.60	$162.11	$20.46	$1,573.78	$141.15	1.35	$2,265.75
EL 8	$58.39	$1,402.52	$170.23	$21.48	$1,652.63	$153.54	1.35	$2,384.59
EL 9	$65.63	$1,576.53	$191.35	$24.15	$1,857.67	$153.54	1.35	$2,661.39
EL 10	$69.37	$1,666.23	$202.24	$25.52	$1,963.37	$153.54	1.35	$2,804.08
EL 11	$71.10	$1,707.94	$207.30	$26.16	$2,012.51	$153.54	1.35	$2,870.43

Table 12.4.14 Manufacturer Production Cost Breakdown for Dedicated Condensing, Medium Temperature, Outdoor System, ≥ 9,000 Btu/h Capacity

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$63.32	$2,009.84	$191.25	$29.83	$2,294.24	$113.93	1.35	$3,211.16
EL 1	$64.78	$2,056.14	$195.65	$30.51	$2,347.09	$113.93	1.35	$3,282.51
EL 2	$66.24	$2,102.44	$200.06	$31.20	$2,399.94	$113.93	1.35	$3,353.85
EL 3	$67.12	$2,130.22	$202.70	$31.61	$2,431.65	$113.93	1.35	$3,396.66
EL 4	$67.86	$2,153.85	$204.95	$31.96	$2,458.63	$113.93	1.35	$3,433.08
EL 5	$69.65	$2,210.52	$210.34	$32.80	$2,523.31	$139.25	1.35	$3,545.73
EL 6	$71.77	$2,277.83	$216.75	$33.80	$2,600.15	$147.86	1.35	$3,658.07
EL 7	$78.22	$2,482.61	$236.23	$36.84	$2,833.91	$147.86	1.35	$3,973.63
EL 8	$78.86	$2,502.91	$238.17	$37.14	$2,857.08	$147.86	1.35	$4,004.91
EL 9	$79.06	$2,509.20	$238.76	$37.24	$2,864.26	$147.86	1.35	$4,014.60
EL 10	$81.97	$2,601.79	$247.57	$38.61	$2,969.96	$147.86	1.35	$4,157.30
EL 11	$86.14	$2,734.19	$260.17	$40.57	$3,121.09	$147.86	1.35	$4,361.33
EL 12	$86.14	$2,734.19	$260.17	$40.57	$3,121.09	$147.86	1.35	$4,361.33

Table 12.4.15 Manufacturer Production Cost Breakdown ($2012) for Dedicated Condensing, Low Temperature, Indoor System, < 9,000 Btu/h Capacity

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$49.76	$1,345.24	$146.18	$20.30	$1,561.48	$88.06	1.35	$2,196.06
EL 1	$50.61	$1,368.00	$148.65	$20.64	$1,587.91	$88.06	1.35	$2,231.74
EL 2	$51.45	$1,390.77	$151.13	$20.99	$1,614.33	$88.06	1.35	$2,267.41
EL 3	$52.37	$1,415.69	$153.83	$21.36	$1,643.26	$88.06	1.35	$2,306.46
EL 4	$54.09	$1,462.27	$158.90	$22.07	$1,697.33	$113.38	1.35	$2,404.77
EL 5	$54.32	$1,468.45	$159.57	$22.16	$1,704.51	$113.38	1.35	$2,414.46
EL 6	$54.69	$1,478.43	$160.65	$22.31	$1,716.09	$113.38	1.35	$2,430.10
EL 7	$60.60	$1,638.19	$178.01	$24.72	$1,901.53	$113.38	1.35	$2,680.45
EL 8	$62.29	$1,683.72	$182.96	$25.41	$1,954.38	$113.38	1.35	$2,751.79
EL 9	$70.13	$1,895.75	$206.00	$28.61	$2,200.49	$113.38	1.35	$3,084.04

Table 12.4.16 Manufacturer Production Cost Breakdown for Dedicated Condensing, Low Temperature, Indoor System, ≥ 9,000 Btu/h Capacity

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$50.01	$1,440.82	$146.84	$21.57	$1,659.24	$103.30	1.35	$2,343.27
EL 1	$51.63	$1,487.55	$151.60	$22.27	$1,713.06	$134.61	1.35	$2,447.23
EL 2	$52.43	$1,510.50	$153.94	$22.61	$1,739.48	$134.61	1.35	$2,482.91
EL 3	$53.35	$1,537.22	$156.67	$23.01	$1,770.25	$134.61	1.35	$2,524.45
EL 4	$54.15	$1,560.17	$159.01	$23.36	$1,796.68	$134.61	1.35	$2,560.12
EL 5	$54.37	$1,566.40	$159.64	$23.45	$1,803.86	$134.61	1.35	$2,569.81
EL 6	$54.71	$1,576.46	$160.67	$23.60	$1,815.44	$134.61	1.35	$2,585.45
EL 7	$60.30	$1,737.49	$177.08	$26.01	$2,000.88	$134.61	1.35	$2,835.80
EL 8	$68.65	$1,977.97	$201.59	$29.61	$2,277.82	$134.61	1.35	$3,209.67
EL 9	$70.24	$2,023.87	$206.26	$30.30	$2,330.67	$134.61	1.35	$3,281.02

Table 12.4.17 Manufacturer Production Cost Breakdown ($2012) for Dedicated Condensing, Low Temperature, Outdoor System, < 9,000 Btu/h Capacity

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$54.21	$1,461.30	$156.30	$22.02	$1,693.84	$88.06	1.35	$2,374.74
EL 1	$50.74	$1,367.66	$146.29	$20.61	$1,585.29	$88.06	1.35	$2,228.20
EL 2	$51.56	$1,389.98	$148.67	$20.95	$1,611.16	$88.06	1.35	$2,263.14
EL 3	$52.56	$1,416.77	$151.54	$21.35	$1,642.21	$88.06	1.35	$2,305.05
EL 4	$54.82	$1,477.66	$158.05	$22.27	$1,712.80	$94.14	1.35	$2,406.42
EL 5	$55.75	$1,502.92	$160.76	$22.65	$1,742.08	$94.14	1.35	$2,445.95
EL 6	$57.71	$1,555.65	$166.39	$23.44	$1,803.19	$121.99	1.35	$2,556.30
EL 7	$58.07	$1,565.43	$167.44	$23.59	$1,814.54	$121.99	1.35	$2,571.62
EL 8	$65.99	$1,778.94	$190.28	$26.81	$2,062.02	$121.99	1.35	$2,905.72
EL 9	$66.22	$1,785.01	$190.93	$26.90	$2,069.05	$121.99	1.35	$2,915.21
EL 10	$69.53	$1,874.30	$200.48	$28.24	$2,172.55	$121.99	1.35	$3,054.93
EL 11	$71.19	$1,918.94	$205.25	$28.92	$2,224.30	$121.99	1.35	$3,124.80
EL 12	$75.92	$2,046.61	$218.91	$30.84	$2,372.29	$121.99	1.35	$3,324.58

Table 12.4.18 Manufacturer Production Cost Breakdown ($2012) for Dedicated Condensing, Low Temperature, Outdoor System, ≥ 9,000 Btu/h Capacity

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$51.21	$1,473.05	$147.55	$22.02	$1,693.84	$103.30	1.35	$2,389.98
EL 1	$52.92	$1,522.05	$152.46	$22.75	$1,750.18	$134.61	1.35	$2,497.35
EL 2	$53.71	$1,545.03	$154.76	$23.10	$1,776.61	$134.61	1.35	$2,533.03
EL 3	$54.51	$1,568.01	$157.07	$23.44	$1,803.03	$134.61	1.35	$2,568.70
EL 4	$55.47	$1,595.59	$159.83	$23.85	$1,834.74	$134.61	1.35	$2,611.51
EL 5	$56.43	$1,623.22	$162.60	$24.26	$1,866.51	$134.61	1.35	$2,654.40
EL 6	$58.95	$1,695.61	$169.85	$25.35	$1,949.76	$144.85	1.35	$2,777.02
EL 7	$67.59	$1,944.28	$194.76	$29.06	$2,235.70	$144.85	1.35	$3,163.05
EL 8	$67.94	$1,954.36	$195.77	$29.21	$2,247.29	$144.85	1.35	$3,178.69
EL 9	$68.16	$1,960.60	$196.39	$29.31	$2,254.47	$144.85	1.35	$3,188.38
EL 10	$71.36	$2,052.52	$205.60	$30.68	$2,360.17	$144.85	1.35	$3,331.08
EL 11	$72.96	$2,098.49	$210.20	$31.37	$2,413.02	$144.85	1.35	$3,402.42
EL 12	$77.52	$2,229.92	$223.37	$33.33	$2,564.15	$144.85	1.35	$3,606.46
EL 13	$77.52	$2,229.92	$223.37	$33.33	$2,564.15	$144.85	1.35	$3,606.46

Table 12.4.19 Manufacturer Production Cost Breakdown ($2012) for Multiplex, Medium Temperature, Indoor Walk-in (MC.M)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$20.00	$459.62	$68.57	$7.22	$555.39	$26.59	1.35	$776.36
EL 1	$20.95	$481.48	$71.83	$7.56	$581.81	$26.59	1.35	$812.04
EL 2	$21.90	$503.35	$75.09	$7.91	$608.24	$26.59	1.35	$847.71
EL 3	$22.32	$512.94	$76.52	$8.06	$619.82	$26.59	1.35	$863.35

Table 12.4.20 Manufacturer Production Cost Breakdown ($2012) for Multiplex, Low Temperature, Indoor Walk-in (MC.L)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$20.00	$459.62	$68.57	$7.22	$555.39	$26.59	1.35	$776.36
EL 1	$20.95	$481.48	$71.83	$7.56	$581.81	$26.59	1.35	$812.04
EL 2	$21.90	$503.35	$75.09	$7.91	$608.24	$26.59	1.35	$847.71
EL 3	$23.80	$547.09	$81.62	$8.59	$661.09	$26.59	1.35	$919.06
EL 4	$24.22	$556.67	$83.05	$8.74	$672.67	$26.59	1.35	$934.70
EL 5	$34.91	$802.40	$119.70	$12.60	$969.60	$26.59	1.35	$1,335.55

Table 12.4.21 Manufacturer Production Cost Breakdown ($2012) for Medium Temperature Side Panels (SP.M)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$34.43	$114.68	$1.46	$2.71	$153.28	$25.43	1.32	$227.76
EL 1	$36.24	$118.30	$1.47	$2.72	$158.72	$25.43	1.32	$234.94
EL 2	$38.59	$122.04	$1.56	$2.88	$165.08	$26.65	1.32	$244.55
EL 3	$39.31	$134.90	$1.59	$2.87	$178.68	$29.10	1.32	$264.96
EL 4	$39.97	$147.37	$1.62	$2.88	$191.83	$31.55	1.32	$284.77
EL 5	$47.74	$176.35	$1.77	$3.14	$229.01	$31.55	1.32	$333.84
EL 6	$69.55	$535.65	$4.11	$5.75	$615.07	$26.65	1.32	$838.54

Table 12.4.22 Manufacturer Production Cost Breakdown ($2012) for Low Temperature Side Panels (SP.L)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$37.07	$117.33	$1.56	$2.90	$158.86	$26.65	1.32	$236.34
EL 1	$38.51	$122.14	$1.55	$2.87	$165.08	$26.65	1.32	$244.55
EL 2	$39.31	$134.90	$1.59	$2.88	$178.68	$29.10	1.32	$264.96
EL 3	$39.96	$147.37	$1.62	$2.88	$191.83	$31.55	1.32	$284.77
EL 4	$47.74	$176.35	$1.77	$3.15	$229.01	$31.55	1.32	$333.84
EL 5	$69.55	$535.67	$4.11	$5.74	$615.07	$26.65	1.32	$838.54

Table 12.4.23 Manufacturer Production Cost Breakdown ($2012) for Low Temperature Floor Panels (FP.L)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$41.07	$130.03	$1.59	$2.93	$175.61	$25.43	1.32	$257.24
EL 1	$46.13	$138.76	$1.62	$3.02	$189.53	$25.43	1.32	$275.60
EL 2	$48.35	$142.18	$1.68	$3.09	$195.30	$26.65	1.32	$284.45
EL 3	$48.85	$155.25	$1.70	$3.07	$208.88	$29.10	1.32	$304.82
EL 4	$49.32	$167.92	$1.73	$3.06	$222.03	$31.55	1.32	$324.63
EL 5	$66.18	$490.69	$3.81	$5.33	$566.01	$26.65	1.32	$773.78

Table 12.4.24 Manufacturer Production Cost Breakdown ($2012) for Medium Temperature Display Door (DD.M)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$58.02	$251.92	$20.37	$26.63	$356.95	$16.89	1.62	$595.15
EL 1	$64.44	$243.17	$20.22	$26.43	$354.27	$16.89	1.62	$590.81
EL 2	$76.87	$297.07	$20.03	$26.19	$420.17	$16.89	1.62	$697.57
EL 3	$87.38	$397.42	$19.59	$25.62	$530.00	$16.89	1.62	$875.50
EL 4	$97.09	$503.62	$21.71	$28.39	$650.82	$16.89	1.62	$1,071.22
EL 5	$119.28	$689.91	$26.56	$34.74	$870.49	$16.89	1.62	$1,427.08
EL 6	$209.01	$1,435.36	$46.20	$60.46	$1,751.03	$16.89	1.62	$2,853.55

Table 12.4.25 Manufacturer Production Cost Breakdown ($2012) for Low Temperature Display Door (DD.L)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$104.32	$453.92	$36.52	$47.76	$642.52	$16.89	1.62	$1,057.77
EL 1	$131.29	$413.73	$41.09	$53.73	$639.84	$16.89	1.62	$1,053.43
EL 2	$138.30	$539.36	$35.97	$47.03	$760.65	$16.89	1.62	$1,249.15
EL 3	$149.04	$742.39	$38.51	$50.38	$980.32	$16.89	1.62	$1,605.01
EL 4	$158.83	$961.42	$35.36	$46.25	$1,201.86	$16.89	1.62	$1,963.90
EL 5	$222.35	$1,414.42	$49.50	$64.75	$1,751.03	$16.89	1.62	$2,853.55

Table 12.4.26 Manufacturer Production Cost Breakdown ($2012) for Medium Temperature Passage Door (PD.M)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$42.11	$147.25	$14.73	$5.45	$209.54	$16.45	1.50	$330.76
EL 1	$42.92	$150.95	$14.75	$5.46	$214.08	$16.45	1.50	$337.57
EL 2	$48.02	$171.31	$14.87	$5.50	$239.70	$16.45	1.50	$376.00
EL 3	$49.03	$175.02	$15.12	$5.59	$244.75	$17.27	1.50	$384.39
EL 4	$51.01	$182.42	$15.60	$5.77	$254.80	$18.90	1.50	$401.11
EL 5	$61.24	$223.34	$15.68	$5.80	$306.05	$18.90	1.50	$477.97
EL 6	$63.25	$230.91	$16.08	$5.95	$316.18	$20.53	1.50	$494.81
EL 7	$104.33	$395.24	$16.08	$5.95	$521.60	$20.53	1.50	$802.93
EL 8	$150.44	$566.26	$17.94	$6.63	$741.28	$15.64	1.50	$1,127.55

Table 12.4.27 Manufacturer Production Cost Breakdown ($2012) for Low Temperature Passage Door (PD.L)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$54.25	$195.58	$11.21	$4.14	$265.18	$17.27	1.50	$415.04
EL 1	$55.17	$199.77	$11.26	$4.16	$270.37	$17.27	1.50	$422.82
EL 2	$65.22	$240.25	$11.78	$4.36	$321.61	$17.27	1.50	$499.69
EL 3	$75.40	$281.18	$12.20	$4.51	$373.29	$17.27	1.50	$577.21
EL 4	$77.48	$288.75	$12.50	$4.62	$383.35	$18.90	1.50	$593.93
EL 5	$79.57	$296.41	$12.78	$4.73	$393.49	$20.53	1.50	$610.76
EL 6	$92.60	$348.78	$13.14	$4.86	$459.39	$20.53	1.50	$709.61
EL 7	$113.86	$456.95	$11.87	$4.82	$587.50	$17.27	1.50	$898.51
EL 8	$138.25	$658.62	$12.57	$5.03	$814.46	$17.27	1.50	$1,238.96

Table 12.4.28 Manufacturer Production Cost Breakdown ($2012) for Medium Temperature Freight Door (FD.M)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$97.43	$444.43	$23.23	$8.95	$574.04	$43.35	1.50	$904.42
EL 1	$98.81	$450.23	$23.32	$9.02	$581.37	$43.35	1.50	$915.42
EL 2	$106.47	$508.34	$23.41	$9.06	$647.27	$43.35	1.50	$1,014.27
EL 3	$109.06	$520.29	$23.93	$9.11	$662.39	$45.51	1.50	$1,039.10
EL 4	$114.42	$543.61	$25.17	$9.27	$692.47	$47.95	1.50	$1,086.66
EL 5	$121.58	$583.64	$23.95	$8.85	$738.02	$49.81	1.50	$1,156.84
EL 6	$136.80	$599.60	$22.87	$9.15	$768.42	$52.65	1.50	$1,205.28
EL 7	$147.20	$682.09	$22.24	$7.99	$859.52	$54.11	1.50	$1,343.40
EL 8	$211.30	$969.83	$32.81	$10.76	$1,224.70	$49.72	1.50	$1,886.78
EL 9	$353.19	$1,503.65	$33.72	$8.33	$1,898.89	$51.33	1.50	$2,899.66

Table 12.4.29 Manufacturer Production Cost Breakdown ($2012) for Low Temperature Freight Door (FD.L)

	Labor	Material	Overhead	Depreciation	MPC	Shipping	Markup	MSP
Baseline	$136.28	$511.56	$23.10	$8.27	$679.21	$51.80	1.50	$1,070.63
EL 1	$135.68	$515.13	$27.09	$9.70	$687.59	$51.80	1.50	$1,083.20
EL 2	$149.36	$568.62	$26.15	$9.37	$753.50	$51.80	1.50	$1,182.05
EL 3	$169.69	$644.80	$22.17	$7.94	$844.60	$51.80	1.50	$1,318.70
EL 4	$177.79	$665.73	$22.94	$8.22	$874.67	$56.70	1.50	$1,368.71
EL 5	$183.31	$690.04	$23.36	$8.37	$905.07	$61.60	1.50	$1,419.21
EL 6	$201.91	$763.97	$22.88	$8.19	$996.95	$61.60	1.50	$1,557.02
EL 7	$263.25	$929.68	$23.40	$8.38	$1,224.70	$51.80	1.50	$1,888.86
EL 8	$315.13	$1,572.50	$16.98	$6.08	$1,910.69	$51.80	1.50	$2,917.84

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 plant, property, and equipment to adapt or change existing production facilities in order to fabricate and assemble new product design that comply with amended energy conservation standards. 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. DOE based its estimates of the conversion costs for each efficiency level on information obtained from manufacturer interviews and the design pathways analyzed in the engineering analysis.

12.4.8.1 Walk-in Panel Conversion Costs

Capital conversion costs are small relative to industry size at levels below EL 2, which translates to 4-inch side panels for medium temperature applications and 5-inch side panels for low temperature applications. At EL 3, DOE anticipates manufacturers would use six-inch side panels for low temperature applications to comply with a standard. Manufactures with jigs and presses that cannot accommodate six inches of foam would need to make capital expenditures to upgrade their tooling. Conversion costs could run as high as $16 million for the industry. At EL 4, six-inch panels are needed for compliance for all walls and floors. Based on information collected during manufacturer interview, some manufacturers of panels would need to retool. In addition to jigs, molds, and presses that accommodate thicker panels, manufacturers may need to reformulate their foams to have the appropriate flow and curing characteristics. Some manufacturers indicated that larger holding tanks and new foaming systems may be necessary. Manufacturers that can produce six-inch panels today may need to add capacity, including additional presses, in order to maintain existing level of throughput since six-inch panels have longer curing times than four-inch and five-inch panels. Conversion costs would increase to $49 million for the industry. At EL 5, manufacturers would need to integrate vacuum insulated panels (VIPs) into their designs. This would require significant investments, as no manufacturer uses VIP technology today. The inclusion of VIPs could require dramatic changes to product design and production processes, increasing industry capital conversion costs to level above $110 million if all manufacturers were to convert.

In panel manufacturing facilities that the DOE visited, all three panel equipment classes (SP.M, SP.L, FP.L) were produced on the same lines. The same foaming equipment and presses were used for all equipment classes. To reflect this, the department did not sum the conversion costs for the three equipment classes. Rather, the DOE used the highest conversion cost of the three equipment classes to represent the conversion costs for the industry.

The product conversion costs for panels primarily consist of industry standard certifications. Third party certifications are demanded by end-users and are a necessity to sell into key markets. These certifications include UL testing and NSF testing, as well as structural and seismic testing. At max tech (EL 6), product conversion costs ramp up dramatically due to the R&D expense necessary to incorporate vacuum insulated panel (VIPs) technology.

Table 12.4.30 Panel Industry Capital Conversion Costs by Equipment class and Trial Standard Level ($2012 Millions)

Efficiency Level	SP.M	SP.L	FP.L
Baseline	-	-	-
EL 1	$10.98	$10.98	$10.98
EL 2	$10.98	$16.48	$10.98
EL 3	$16.48	$49.43	$16.48
EL 4+	$49.43	$49.43	$49.43
EL 5	$49.43	$159.26	$126.31
EL 6	$109.83		

Table 12.4.31 Panel Industry Product Conversion Costs by Equipment class and Trial Standard Level ($2012 Millions)

Efficiency Level	SP.M	SP.L	FP.L
Baseline	-	-	-
EL 1	$2.75	$2.75	$2.75
EL 2	$4.39	$4.39	$4.39
EL 3	$6.04	$6.04	$6.04
EL 4	$8.24	$6.04	$8.24
EL 5	$8.24	$33.50	$33.50
EL 6	$35.70		

12.4.8.2 Walk-in Door Conversion Costs

To estimate conversion costs for display and solid doors, DOE relied substantially on information obtained from manufacturer interviews and from the engineering analysis.

For medium temperature display doors, the DOE determined that there are few conversion costs from EL 1 to EL 2. The design options considered at these levels require component substitutions and/or additions that can be accommodated by current production lines. At EL3, some capital expenditure would be needed to improve factory conveyor systems for handling soft coats. EL 4 can be met with lighting sensors, which do not require additional investments in plant or property. EL 5 and EL 6 incorporate multiple panes, additional coatings and higher performing gas fill corresponding to more efficient glass packs found on the market. Some capital expenditures are required, but the majority of conversion costs come in the form of product conversion costs.

For low temperature display doors, manufacturers will likely move to LED lighting and incorporate lighting sensors to meet EL 1 and EL 2. Manufacturers incur conversion costs for conveyor systems to handle soft coats at EL 3. EL 4 requires the use of krypton, a more exotic fill gas, to improve efficiency. No manufacturer interviewed uses krypton gas today. They would likely need to make some capital investment to add krypton gas in their production lines. EL 4 can be met with lighting sensors, which do not require additional investments in plant or property. For EL 5, industry feedback indicated that the required changes to the glass pack would be implemented by glass suppliers. Such changes would not require new production equipment on the part of door manufacturers.

For passage and freight doors, capital conversion costs are directly related to changes in door thickness. As panels get thicker, manufacturer may need new jigs and presses. Of the fifty-five solid door manufactures identified by DOE, fifty-two also produce panels for walk-ins. It is assumed that these manufacturers would use the foaming systems from the panel business to produce doors and incur no additional capital conversion costs. The conversion costs associated with foaming thicker insulation for these manufacturers are accounted for in the panel analysis. Solid door manufacturers that do not produce panels would need to upgrade their facility and have their conversion costs accounted for in the doors analysis. Since all solid doors designs are typically produced on the same line, DOE used the highest conversion cost of the four solid door equipment classes to represent the solid door conversion costs for the industry.

Though not all display and solid door efficiency levels require additional capital conversion costs, it is likely that any standard above baseline would require product conversion costs. All design options would require an investment to specify new components, test functionality, and apply for 3rd party industry certifications.

Table 12.4.32 Door Industry Capital Conversion Costs by Equipment class and Trial Standard Level (2012$ Millions)

Efficiency Level	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
Baseline	-	-	-	-	-	-
EL 1	-	-	$3.02	$3.02	$3.02	$3.02
EL 2	-	-	$3.02	$3.02	$3.02	$3.02
EL 3	$0.07	$0.07	$4.67	$3.02	$7.69	$3.02
EL 4	$0.07	$0.16	$9.01	$7.69	$10.88	$7.69
EL 5	$0.07	$1.81	$12.03	$12.03	$12.03	$12.03
EL 6	$1.71		$15.05	$12.03	$13.63	$12.03
EL 7			$75.46	$72.44	$15.05	$72.44
EL 8			$78.48	$72.44	$43.44	$72.44
EL 9					$75.46	

Table 12.4.33 Door Industry Product Costs by Equipment class and Trial Standard Level (2012$ Millions)

Efficiency Level	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
Baseline	-	-	-	-	-	-
EL 1	$0.07	-	$3.02	$3.02	$3.02	$3.02
EL 2	$0.07	$0.07	$3.02	$3.02	$3.02	$3.02
EL 3	$0.13	$0.13	$3.02	$3.02	$3.02	$3.02
EL 4	$0.20	$0.20	$3.02	$3.02	$3.02	$3.02
EL 5	$0.20	$0.26	$3.02	$3.02	$3.02	$3.02
EL 6	$0.33		$3.02	$3.02	$3.02	$3.02
EL 7			$3.02	$9.06	$3.02	$9.06
EL 8			$9.06	$9.06	$5.86	$9.06
EL 9					$9.06	

12.4.8.1 Walk-in Refrigeration Conversion Costs

DOE analysis indicated most design options for walk-in refrigeration equipment could be implemented with component swaps that require no new production machinery, no new conveyor equipment, and no additional floor space. As a result capital conversion costs are limited for the walk-in refrigeration manufacturers. However, for manufacturers that produce condenser coils in-house, there could be significant re-tooling expenses. These capital conversion costs are included in the model and in Table 12.4.34. The different equipment classes of walk-in refrigeration are typically built on the same production lines. In order to avoid double counting capital conversion costs, DOE did not sum the conversion costs for each equipment class. Rather, DOE applied the largest capital conversion cost of the 10 refrigeration equipment classes to represent the capital conversion cost of the industry.

The product conversion costs for walk-ins are also limited. The product conversion costs primarily consist of R&D costs, UL and NSF costs, and marketing expenses. The product conversion costs for walk-ins cooler and freezer refrigeration can be found in Table 12.4.34 and Table 12.4.35. The DOE did sum the conversion costs for the various equipment classes since each equipment class would have its own set of one-time R&D, industry certification, and marketing expenses.

Table 12.4.34 Refrigeration Industry Capital Conversion Costs by Equipment class and Efficiency Level ($2012 Millions)

Eff Level	DC.M.I, < 9k	DC.M.I, ≥ 9k	DC.M.O, < 9k	DC.M.O, ≥ 9k	DC.L.I, < 9k	DC.L.I, ≥ 9k	DC.L.O, < 9k	DC.L.O, ≥ 9k	MC.M.I	MC.L.I
Baseline	-	-	-	-	-	-	-	-	-	-
EL 1	-	-	-	-	-	-	-	-	-	-
EL 2	-	-	-	-	-	-	-	-	-	-
EL 3	-	$4.39	-	-	-	-	-	-		-
EL 4	-	$4.39	-	$0.44	-	-	$0.44	$0.44		-
EL 5	-	$4.39	-	$0.44	-	$4.39	$0.44	$0.44		
EL 6	$4.39	$4.39	-	$0.44	$4.39	$4.39	$0.44	$0.44		
EL 7			$0.44	$4.83	$4.39	$4.39	$0.44	$0.44		
EL 8			$0.44	$4.83			$0.44	$0.44		
EL 9			$4.83	$4.83			$0.44	$4.50		
EL 10				$4.83			$4.83	$4.50		
EL 11				$4.83				$4.50		

Table 12.4.35 Refrigeration Industry Product Conversion Costs by Equipment class and Efficiency Level ($2012 Millions)

Eff Level	DC.M.I, < 9k	DC.M.I, ≥ 9k	DC.M.O, < 9k	DC.M.O, ≥ 9k	DC.L.I, < 9k	DC.L.I, ≥ 9k	DC.L.O, < 9k	DC.L.O, ≥ 9k	MC. M.I	MC.L .I
Baseline	-	-	-	-	-	-	-	-	-	-
EL 1	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22
EL 2	$0.44	$0.44	$0.44	$0.44	$0.44	$0.44	$0.44	$0.44	$0.44	$0.44
EL 3	$0.66	$1.54	$0.66	$0.66	$0.66	$0.66	$0.66	$0.66	$0.66	$0.66
EL 4	$0.88	$1.76	$0.88	$0.88	$0.88	$0.88	$0.88	$0.88		$0.88
EL 5	$1.10	$1.98	$1.10	$1.10	$1.10	$1.98	$1.10	$1.10		$1.10
EL 6	$2.20	$2.20	$1.32	$1.32	$2.20	$2.20	$1.32	$1.32		
EL 7			$1.54	$2.42	$2.42	$2.42	$1.54	$1.54		
EL 8			$1.76	$2.64			$1.76	$1.76		
EL 9			$2.86	$2.86			$1.98	$2.79		
EL 10				$3.08			$3.08	$3.01		
EL 11								$3.23		

12.4.9 Markup Scenarios

DOE used several standards case markup scenarios to represent the uncertainty about the impacts of energy conservation standards on prices and profitability. In the base case, DOE used the same markups applied in the engineering analysis. In the standards case, DOE modeled two markup scenarios to represent the uncertainty about the potential impacts on prices and profitability following the implementation of amended energy conservation standards: (1) a preservation of gross margin percentage scenario and (2) a preservation of earnings before interest and tax (EBIT) 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 Preservation of Gross Margin Percentage Scenario

Under the preservation-of-gross-margin-percentage scenario, DOE applied a single uniform “gross margin percentage” markup across all efficiency levels. As production costs increase with efficiency, this scenario implies that the absolute dollar markup will increase as well. DOE assumed the non-production cost markup—which includes SG&A expenses,; research and development expenses,; interest,; and profit— to be 1.32 for panels, 1.50 for solid doors, 1.62 for display doors, and 1.35 for refrigeration. These markups are consistent with the ones DOE assumed in the engineering analysis. Manufacturers indicated that it is optimistic to assume that, as their manufacturer production costs increase in response to an energy conservation standard, they would be able to maintain the same gross margin percentage markup. Therefore, DOE assumes that this scenario represents a high bound to industry profitability under an energy conservation standard.

12.4.9.2 Preservation of Operating Profit Scenario

During interviews, multiple manufacturers expressed concern that the higher production costs could harm profitability. Because of market characteristics, several manufacturers suggested that the additional costs of higher minimum efficiency products could not be fully passed through to customers. Incorporating this feedback, DOE modeled the preservation of operating profit scenario.

In the preservation of operating profit scenario, manufacturer markups are set so that operating profit one year after the compliance date of the new energy conservation standards is the same as in the base case. Under this scenario, as the cost of production and the cost of sales go up, manufacturers are generally required to reduce their markups to a level that maintains base case operating profit. The implicit assumption behind this markup scenario is that the industry can only maintain only its operating profit in absolute dollars after the standard. Operating margin in percentage terms is squeezed (reduced) between the base case and standards case.

12.4.10 Experience Curve Rates

For this rulemaking, DOE applied experience curve multipliers to both the base case and standards case MSP forecasts in the GRIM. The experience curve applied to the GRIM is identical to the experience curve applied to the NIA for this rule. Refer to section IV.F.1 for a description of how DOE derived the experience curve multipliers. A detailed discussion of the experience curve modeling is provided in Appendix 8-J of the TSD.

12.4.11 Light Emitting Diode (LED) Price Projections

In an effort to capture the anticipated cost reduction of LED components in the rulemaking analyses, DOE incorporated price projections from its Solid State Lighting program into its MPC values for the primary equipment classes. As discussed in chapter 5 of the TSD, the price projections for LED case lighting were based on projections in the DOE's Solid State Lighting Program's 2012 report, Energy Savings Potential of Solid-State Lighting in General Illumination Applications 2010 to 2030[c] ("the energy savings report"). The price projection results in the component cost of LEDs decreasing over the analysis period for both the base case and standards case analysis in the GRIM.

12.5 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, the GRIM estimated indicators of financial impacts on the walk-in cooler and freezer industry. The following sections detail additional inputs and assumptions for the analysis of walk-in

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[c] Navigant Consulting. "Energy Savings Potential of Solid-State Lighting in General Illumination Applications 2010 to 2030." Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Feb. 2010. Web. Apr. 2013.

panels, doors, and refrigeration. 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 GRIM for this rulemaking estimates cash flows from 2013 to 2046, the same analysis period used in the NIA (chapter 10 of the TSD). This timeframe models both the short-term impacts on the industry from the announcement of the standard until the compliance date (2013 until 2017) and a long-term assessment over the 30 year analysis period used in the NIA (2017 – 2046).

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. The markup scenarios are described in greater detail in section 12.4.9 above.

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 1 or 2 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 12.4.1 through Figure 12.5.6 below present the annual net cash flows over the analysis period.

Annual cash flows are discounted to the base year, 2013. After the standards 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. Cash flows between the announcement date and the compliance date are driven by the level of conversion costs and the proportion of these investments spent every year. 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.

12.5.2 Walk-in Cooler & Freezer Industry Financial Impacts

Table 12.5.1 and Table 12.5.2 provide the INPV estimates for walk-in panel products for the two scenarios. Figure 12.5.1 and Figure 12.5.2 present the net annual cash flows for the two scenarios.

Table 12.5.1 Preservation of Gross Margin Percentage Scenario Changes in INPV for Walk-in Cooler & Freezer Panels

	Units	**Base Case**	**Trial Standard Level**					
			1	**2**	**3**	**4**	**5**	**6**
INPV	$2012 M	207.3	195.8	207.3	177.0	195.8	177.0	441.9
Change in INPV	$2012 M	-	-11.5	0.0	-30.2	-11.5	-30.2	234.7
	(%)	-	-5.6	0.0	-14.6	-5.6	-14.6	113.2

Table 12.5.2 Preservation of Operating Profit Scenario Changes in INPV for Walk-in Cooler & Freezer Panels

	Units	**Base Case**	**Trial Standard Level**					
			1	**2**	**3**	**4**	**5**	**6**
INPV	$2012 M	207.3	182.2	207.3	144.1	182.2	144.1	-212.9
Change in INPV	$2012 M	-	-25.0	0.0	-63.1	-25.0	-63.1	-420.2
	(%)	-	-12.1	0.0	-30.5	-12.1	-30.5	-202.7

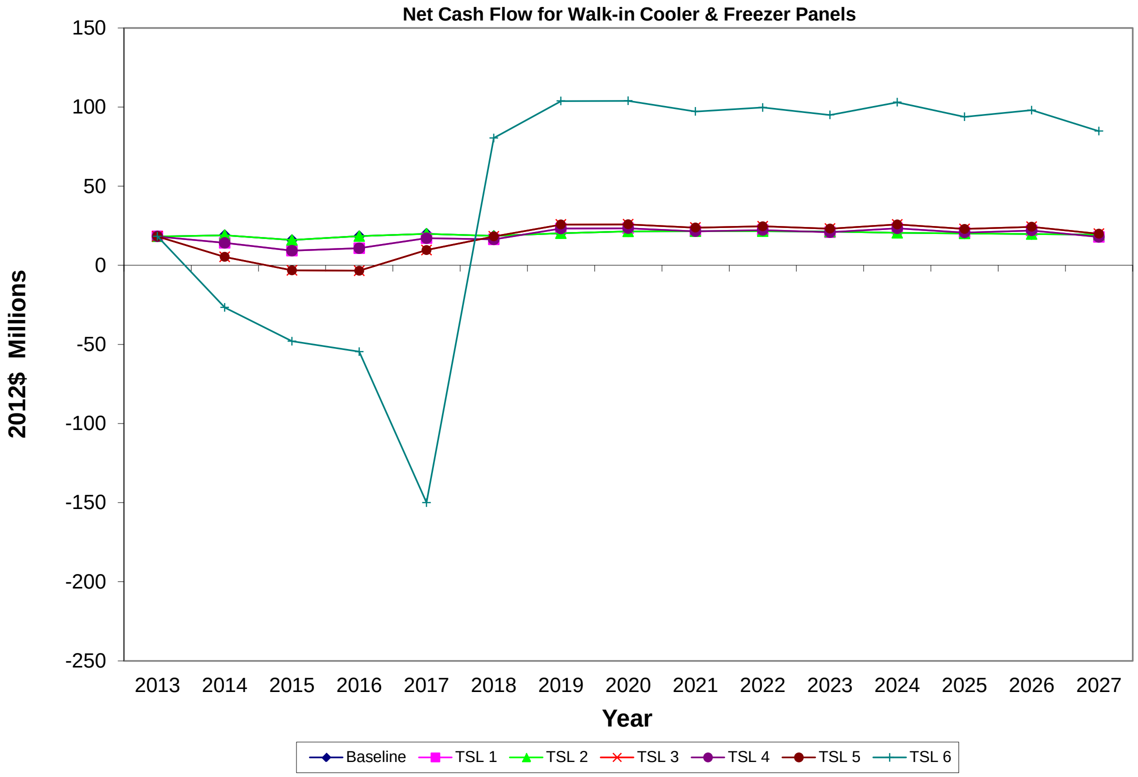

Figure 12.5.1 Annual Industry Net Cash Flows for Walk-ins Panels (Preservation of Gross Margin Percentage Markup Scenario)

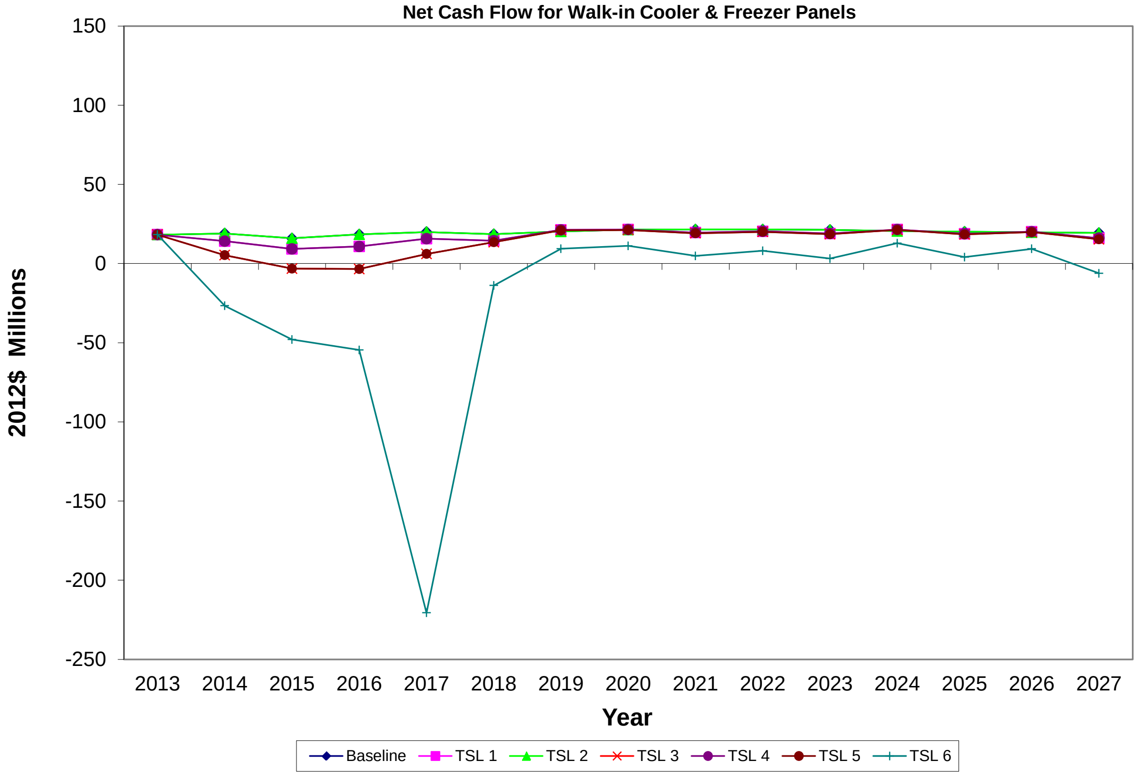

Figure 12.5.2 Annual Industry Net Cash Flows for Walk-ins Panels (Preservation of Operating Profit Markup Scenario)

Table 12.5.3 and Table 12.5.4 provide the INPV estimates for walk-in door products for the two scenarios. Figure 12.5.3 and Figure 12.5.4 represent the net annual cash flows for the two scenarios.

Table 12.5.3 Preservation of Gross Margin Percentage Scenario Changes in INPV for Walk-in Cooler & Freezer Doors

	Units	**Base Case**	**Trial Standard Level**					
			1	**2**	**3**	**4**	**5**	**6**
INPV	$2012 M	454.6	470.7	470.2	467.8	470.6	466.4	1145.1
Change in INPV	$2012 M	-	16.1	15.6	13.2	16.0	11.8	690.5
	(%)	-	3.5	3.4	2.9	3.5	2.6	151.9

Table 12.5.4 Preservation of Operating Profit Scenario Changes in INPV for Walk-in Cooler & Freezer Doors

	Units	**Base Case**	**Trial Standard Level**					
			1	**2**	**3**	**4**	**5**	**6**
INPV	$2012 M	454.6	437.6	446.2	428.2	437.8	427.3	260.8
Change in INPV	$2012 M	-	-17.0	-8.4	-26.4	-16.8	-27.3	-193.8
	(%)	-	-3.7	-1.8	-5.8	-3.7	-6.0	-42.6

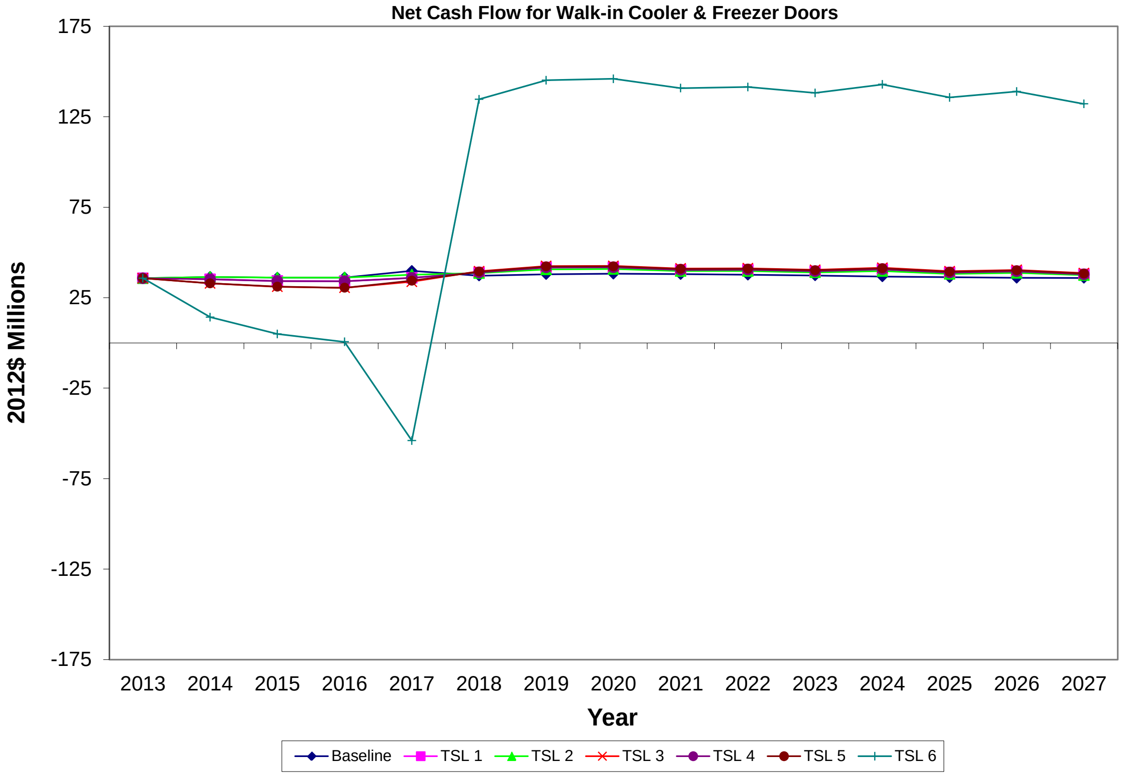

Figure 12.5.3 Annual Industry Net Cash Flows for Walk-ins Doors (Preservation of Gross Margin Percentage Markup Scenario)

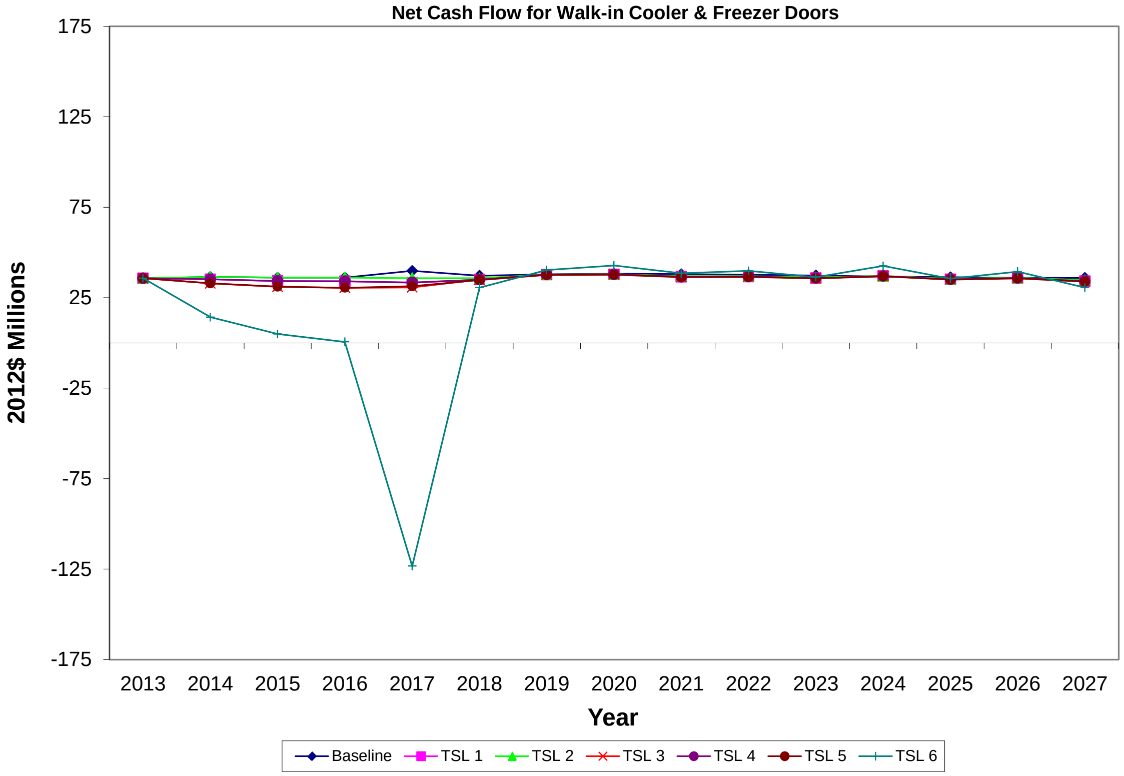

Figure 12.5.4 Annual Industry Net Cash Flows for Walk-ins Doors (Preservation of Operating Profit Markup Scenario)

Table 12.5.5 and Table 12.5.6 provide the INPV estimates for walk-in refrigeration products for the two scenarios. Figure 12.5.5 and Figure 12.5.6 represent the net annual cash flows for the two scenarios.

Table 12.5.5 Preservation of Gross Margin Percentage Scenario Changes in INPV for Walk-in Cooler & Freezer Refrigeration

	Units	Base Case	Trial Standard Level					
			1	2	3	4	5	6
INPV	$2012 M	189.1	183.3	184.8	183.3	184.8	188.3	188.3
Change in INPV	$2012 M	-	-5.9	-4.4	-5.9	-4.4	-0.8	-0.8
	(%)	-	-3.1	-2.3	-3.1	-2.3	-0.4	-0.4

Table 12.5.6 Preservation of Operating Profit Scenario Changes in INPV for Walk-in Cooler & Freezer Refrigeration

	Units	Base Case	Trial Standard Level					
			1	2	3	4	5	6
INPV	$2012 M	189.1	170.9	153.6	170.9	153.6	145.8	145.8
Change in INPV	$2012 M	-	-18.3	-35.5	-18.3	-35.5	-43.3	-43.3
	(%)	-	-9.67	-18.8	-9.7	-18.8	-22.9	-22.9

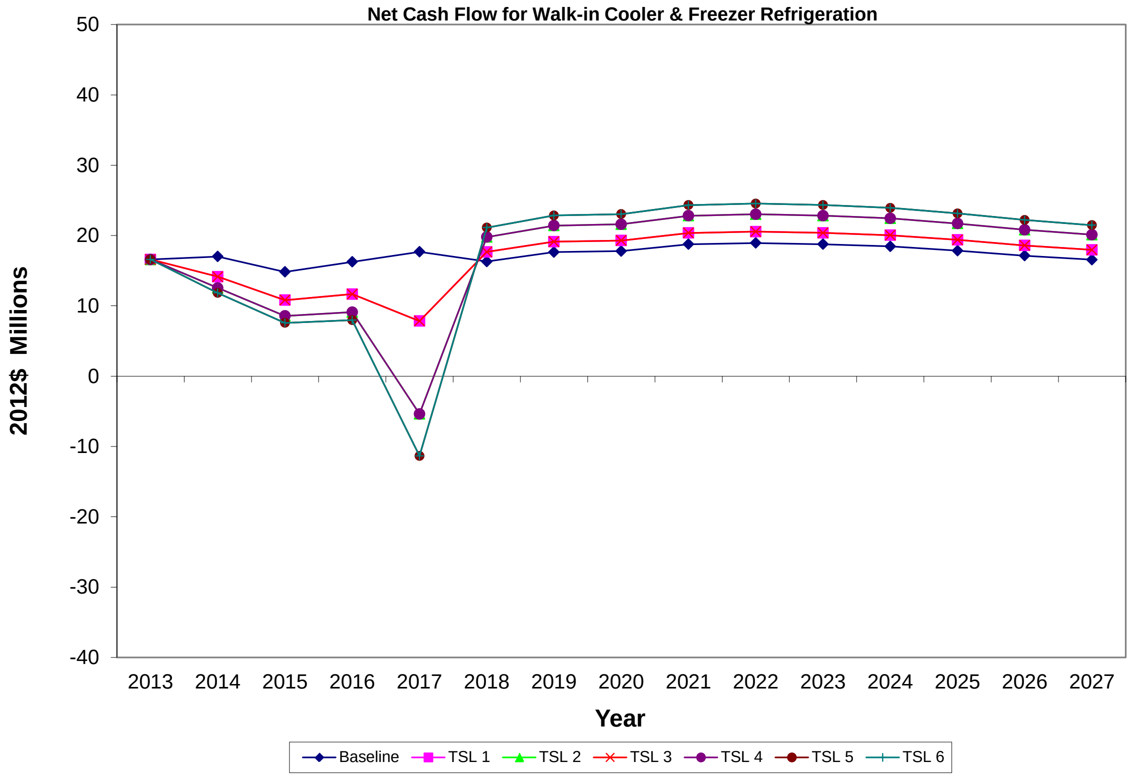

Figure 12.5.5 Annual Industry Net Cash Flows for Walk-ins Refrigeration (Preservation of Gross Margin Percentage Markup Scenario)

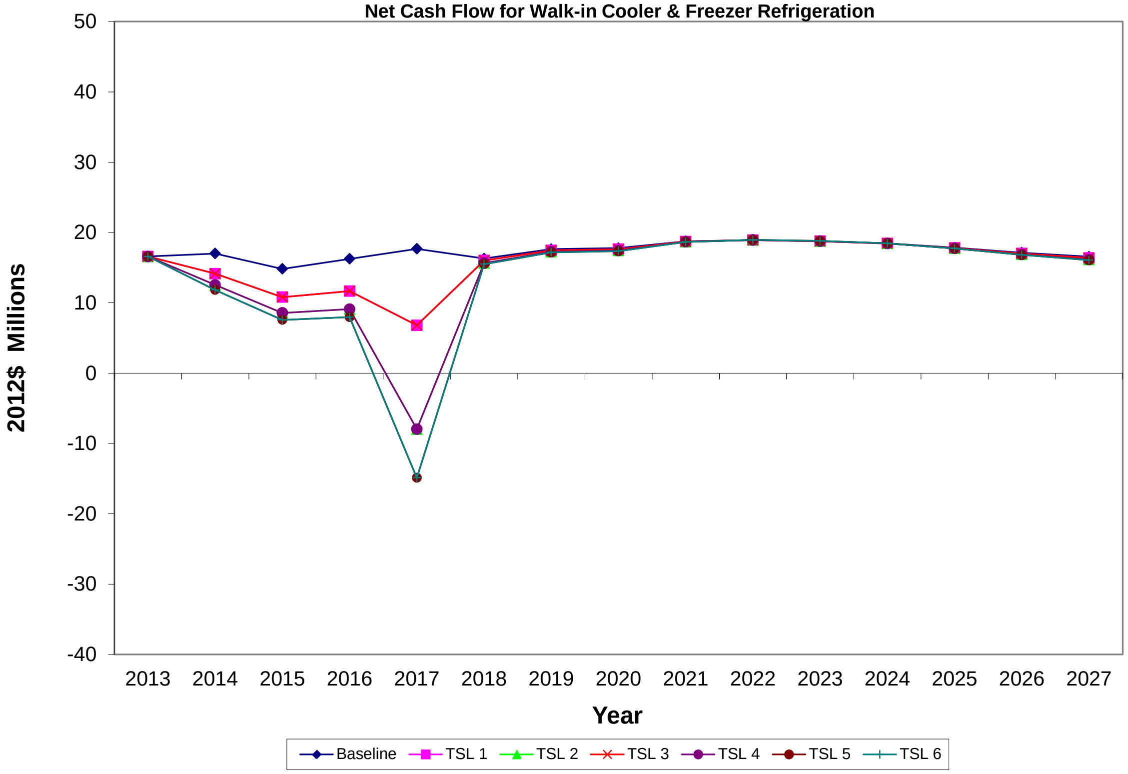

Figure 12.5.6 Annual Industry Net Cash Flows for Walk-ins Refrigeration (Preservation of Operating Profit Markup Scenario)

12.6 IMPACTS ON SMALL BUSINESS MANUFACTURERS

DOE conducted a more focused inquiry of the companies that could be small business manufacturers of products covered by this rulemaking. For "Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing," the Small Business Administration (SBA) has set a size threshold of 750 employees or less for an entity to be considered as a small business for this category. During its market survey, DOE used all available public information to identify potential small manufacturers. DOE's research involved industry trade association membership directories (including AHRI and NAFEM), product databases (e.g., FTC, The Thomas Register, CEC, and ENERGY STAR databases), individual company websites, and market research tools (e.g., Dunn and Bradstreet reports) to create a comprehensive list of companies that manufacture or sell products covered by this rulemaking. DOE also asked stakeholders and industry representatives if they were aware of any other small manufacturers during manufacturer interviews and at previous DOE public meetings. DOE reviewed publicly-available data and contacted select companies on its list, as necessary, to determine whether they met the SBA's definition of a small business manufacturer of covered walk-in products. 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 identified 51 panel manufacturers in the WICF industry. Based on publicly available information, 42 of the identified panel manufacturers are believed to be small businesses. The Department notes that there may be more than the 51 panel manufacturers identified as part of its review. As part of the MIA interviews, the Department interviewed nine panel manufacturers, including three small business operations. During MIA interviews, multiple manufacturers claimed that there are "hundreds of two-man garage-based operations" that produce WICF panels in small quantities. They asserted that these small manufacturers do not typically comply with EISA 2007 standards and do not obtain UL or NSF certifications for their equipment. DOE was not able to identify these small businesses and did not consider them in its analysis. Based on the large number of small panel manufacturers and the potential scope of the impact, DOE could not certify that the proposed standards would not have a significant impact on a significant number of small businesses with respect to the panel industry.

DOE identified 58 walk-in door manufacturers, 54 of which produce solid doors. The remaining four produce display doors. However, 51 of the 54 solid door manufacturers produce panels as their primary business and are considered in the category of panel manufacturers above. The remaining three solid door manufacturers are all considered to be small businesses. Two of the display door manufacturers are considered small businesses. Therefore, of the seven manufacturers that exclusively produce WICF doors (three producing solid doors and four producing display doors), DOE determined that five are small businesses. As part of the MIA interviews, the Department interviewed six door manufacturers, including four small business operations. Based on the large proportion of small door manufacturers in the door market, DOE could not certify that the proposed standards would not have a significant impact on a significant number of small businesses with respect to the door industry.

DOE identified nine refrigeration system manufacturers in the WICF industry. Based on publicly available information, two of the manufacturers are small businesses. One small business focuses on large warehouse refrigeration systems, which are outside the scope of this rulemaking. However, at its smallest capacity, this company's units are sold to the walk-in market. The other small business specializes in building evaporators and unit coolers for a range of refrigeration applications, including the walk-in market. As part of the MIA interviews, the Department interviewed five refrigeration manufacturers, including the two small business operations. Both small businesses expressed concern that the rulemaking would negatively impact their businesses and one small business indicated it they would exit the walk-ins industry as a result of any standard that would directly impact walk-in refrigeration system energy efficiency. However, due to the small number of small businesses that manufacture WICF refrigeration systems and the fact that only one of them focuses on WICF refrigeration as a key market segment and constitutes a very small share of the overall walk-in market, DOE certifies that the proposed standards would not have a significant impact on a significant number of small businesses with respect to the refrigeration equipment industry.

In summary, DOE recognizes that amended energy conservation standards can potentially disproportionately impact on small businesses. Larger manufacturers could have a competitive advantage due to their size and ability to access capital that may not be available to small businesses. Larger businesses also have larger production volumes over which to spread costs. DOE provides additional analysis in section VI.B, Review Under the Regulatory Flexibility Act, in the NOPR Notice.

12.7 OTHER IMPACTS

12.7.1 Employment

12.7.1.1 Methodology

To quantitatively assess the impacts of energy conservation standards on employment, DOE used the GRIM to estimate the domestic labor expenditures and number of employees in the base case and at each TSL from 2013 through 2046. DOE used statistical data from the U.S. Census Bureau’s 2011 Annual Survey of Manufacturers (ASM), the results of the engineering analysis, and interviews with manufacturers to determine the inputs necessary to calculate industry-wide labor expenditures and domestic employment levels. Labor expenditures related to manufacturing of the product are a function of the labor intensity of the product, the sales volume, and an assumption that wages remain fixed in real terms over time. The total labor expenditures in each year are calculated by multiplying the MPCs by the labor percentage of MPCs.

The total labor expenditures in the GRIM were then converted to domestic production employment levels by dividing production labor expenditures by the annual payment per production worker (production worker hours times the labor rate found in the U.S. Census Bureau’s 2011 ASM). The estimates of production workers in this section cover workers, including line-supervisors who are directly involved in fabricating and assembling a product within the original equipment manufacturer (OEM) facility. Workers performing services that are closely associated with production operations, such as materials handling tasks using forklifts, are also included as production labor. DOE’s estimates only account for production workers who manufacture the specific products covered by this rulemaking.

In evaluating the impact of energy efficiency standards on employment, DOE performed separate analyses on all three walk-in component manufacturer industries: panels, doors and refrigeration systems.

12.7.1.2 Direct Employment Impacts

Using the GRIM, DOE estimates in the absence of new energy conservation standard, there would be 3,482 domestic production workers for walk-in panels, 1,187 domestic production workers for walk-in doors, and 346 domestic production workers for walk-in refrigeration systems in 2017. DOE also estimates that, for every one production worker, there will be 0.354 non-production workers, resulting in 4,715 total employees for panels, 1,607 total employees for doors, and 468 total employees for refrigeration systems in the walk-ins industry.

Table 12.7.1, Table 12.7.2, and Table 12.7.3 show the range of the impacts of potential new energy conservation standards on U.S. production workers in the walk-in panel, door, and refrigeration markets, respectively.

Table 12.7.1 Potential Changes in the Total Number of Production Workers for Walk-in Cooler and Freezer Panels in 2017

TSL	1	2	3	4	5	6
Potential Changes in Domestic Production Workers 2017*	-435 to 134	0 to 0	-871 to 490	-435 to 134	-871 to 490	-1741 to 3,243

*DOE presents a range of potential employment impacts.

Table 12.7.2 Potential Changes in the Total Number of Production Workers for Walk-in Cooler and Freezer Doors in 2017

TSL	1	2	3	4	5	6
Potential Changes in Domestic Production Workers 2017*	-60 to 149	0 to 97	-120 to 196	-60 to 146	-120 to 192	-349 to 2,409

*DOE presents a range of potential employment impacts.

Table 12.7.3 Potential Changes in the Total Number of Production Workers for Walk-in Cooler and Freezer Refrigeration in 2017

TSL	1	2	3	4	5	6
Potential Changes in Domestic Production Workers 2017*	0 to 31	-88 to 74	0 to 31	-88 to 74	-116 to 99	-116 to 99

*DOE presents a range of potential employment impacts.

The employment impacts shown in Table 12.7.1, Table 12.7.2, and Table 12.7.3 represent the potential production employment changes that could result following the compliance date of new energy conservation standards. The upper end of the results in the table estimates the maximum increase in the number of production workers after the implementation of new energy conservation standards and it assumes that manufacturers would continue to produce the same scope of covered products within the United States.

The lower end of the range represents the maximum decrease to the total number of U.S. production workers in the industry due to manufacturers leaving the industry. However, in the long-run, DOE would expect the manufacturers that do not leave the industry to add employees to cover lost capacity and to meet market demand.

For WICF panels, the standard goes to max tech at TSL 6. As a lower bound to the employment analysis, DOE assumes all manufacturers with less than $50M in sales would leave the industry rather than make the investments necessary to produce compliant envelopes. These manufacturers account for 50% of shipments.

At TSL 5 and TSL 3, manufacturers producing panels with extruded polystyrene foam (XPS) boards would likely need to invest in new foaming technologies. It is DOE's understanding that most high volume manufacturers are not producing XPS envelopes Based on interview feedback, it is mostly manufacturers with less than $1M in sales are using XPS technology today. As a result, the lower bound in the employment analysis, DOE assumes all these very small market share players would leave the industry rather than make the necessary investments to rebuild their business around a new technology. These manufacturers represent 30% of the shipments.

At TSL 4 and TSL 1, manufacturers would be able to continue to compete with multiple foam technologies, including XPS. However, the more efficient envelopes would require redesign, adjustments to existing equipment, and new industry certifications. As a lower bound, DOE assumes half of manufacturers with less than $1M in sales, or 15% of shipments, would choose to leave the industry.

At TSL 1, the lower bound is zero since the standard is set at the baseline for WICF panels.

Table 12.7.4 Lower Bound Employment Factors for Walk-in Cooler and Freezer Envelopes

TSL	1	2	3	4	5	6
Lower Bound Employment Factor for WICF Envelopes	0.125	0	0.25	0.125	0.25	0.5

For WICF doors, DOE incorporated employment changes for both solid doors and display doors. For solid doors, 95% of WICF door manufacturers identified by DOE produce WICF panels as their primary business. Therefore, DOE applied the same lower bounds it used for WICF panel to WICF solid doors. For display doors, the design options at TSL 1 to TSL 5 require relatively minor changes on the part of manufacturers. It is only at TSL 6, max tech, that DOE anticipates a potential loss in employment due to small manufacturers leaving the industry.

Table 12.7.5 Lower Bound Employment Factors for Walk-in Cooler and Freezer Doors

TSL	1	2	3	4	5	6
Lower Bound Employment Factor for WICF Doors	0.05	0	0.1	0.05	0.1	0.29

For WICF refrigeration, DOE based the lower bound employment factors on the complexity of design options, conversion costs, and interview information. It was determined that one-third of manufacturers may leave the industry or move production overseas if products become overly commoditized. DOE assumed max tech at TSL 5 and TSL 6 would represent a high level of commoditization while TSL 4 and TSL 2 would represent a moderate level of commoditization.

Table 12.7.6 Lower Bound Employment Factors for Walk-in Cooler and Freezer Doors

TSL	1	2	3	4	5	6
Lower Bound Employment Factor for WICF Refrigeration	0	.25	0	.25	.33	.33

The employment impacts shown are independent of the employment impacts from the broader U.S. economy, which are documented in the Employment Impact Analysis, chapter 13 of the TSD.

12.7.2 Production Capacity

Most manufacturers currently have excess production capacity. In interviews, manufacturers indicated that they are currently running below peak capacity due to current economic conditions. A slow-down in domestic expansion by supermarkets, big box stores, fast food chains, and convenience stores has resulted in reduced overall demand for walk-in coolers and freezers as compared to 2005 through 2007.

12.7.2.1 Walk-in Cooler & Freezer Panels

Manufacturers indicated that design options that necessitate thicker panels could lead to longer production times for panels. In general, every additional inch of foam increases panel cure times by roughly 20 minutes. DOE understands from manufacturer interviews, however, that the industry is not currently operating at full capacity. Given this fact, and the number of players able to produce panels above the baseline today, an increase in thickness at lower panel standards is not likely to lead to product shortages in the industry – that is, standards that are based on 4-inch or 5-inch panels. However, a standard that necessitates 6-inch panels for any of the panel equipment classes would require manufactures to add equipment to maintain throughput due longer curing times, or purchase all new tooling to enable production if the manufacturer's current equipment cannot accommodate 6-inch panels. These conversion costs are discussed in section 12.4.8 above.

12.7.2.2 Walk-in Cooler and Freezer Doors

Display door manufacturers did not identify any design options which would lead to capacity constraints. However, manufacturers commented on differences between the two types of low-emittance coating analyzed: hard low emittance coating ("hard-coat"), the baseline option, and soft low emittance coating ("soft-coat"), the corresponding design option. Hard-coat is applied to the glass pane at high temperatures during the formation of the pane, and is extremely durable, while soft-coat is applied in a separate step after the glass pane is formed and is less durable than hard low emittance coating but has better performance characteristics. Manufacturers indicated that soft-coat is significantly more difficult to work with and may require new conveyor equipment. As manufacturers adjust to working with soft-coat, high scrap rates and longer lead times may occur.

The production of solid doors is very similar to the production of panels and faces the same capacity challenges as panels. As indicated in the panel discussion above, DOE does not anticipate capacity constraints at a standard that moves manufacturers to 5-inches of thickness or less.

12.7.2.3 Walk-in Cooler & Freezer Refrigeration

DOE did not identify any significant capacity constraints for the design options being evaluated for this rulemaking. For most refrigeration manufacturers, the walk-in market makes up a relatively small percentage of their overall revenues. Additionally, most of the design options being evaluated are available as product options today. As a result, the industry should not experience capacity constraints directly resulting from an energy conservation standard.

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 walk-in manufacturers that will take effect 3 years before or after the compliance date of amended energy conservation standards for these products. In addition to the amended energy conservation regulations, 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 regulations from entities other than the Federal government that may impact manufacturers of 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.

12.7.3.1 DOE Regulations for Other Products Produced by Affected Manufacturers

In addition to the new energy conservation standards for walk-in cooler and freezer products, several other Federal 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 strain manufacturers' profits and possibly cause an exit from the market. DOE is conducting an energy conservation standard rulemaking for commercial refrigeration equipment but does not include the costs of this rulemaking in its cumulative analysis because the costs of that rulemaking are speculative at this time.

12.7.3.2 Federal Regulations

Unites States Clean Air Act

The Clean Air Act defines the EPA's responsibilities for protecting and improving the nation's air quality and the stratospheric ozone layer. The most significant of these additional regulations are the EPA mandated phase-out of hydro chlorofluorocarbons (HCFCs). The Act demands on a quarterly basis that any person who produced, imported, or exported certain substances, including HCFC refrigerants, must report the amount produced, imported and exported. Additionally, effective January 1, 2015, selling, manufacturing, and using any such substance is banned unless such substance has been used, recovered, and recycled; is used and entirely consumed in the production of other chemicals; or is used as a refrigerant in appliances manufactured prior to January 1, 2020. Finally, production phase-outs will continue until January 1, 2030 when such production will be illegal. These bans could trigger design changes to natural or low global warming potential refrigerants and could impact the insulation used in products covered by this rulemaking.

Energy Independence and Security Act of 2007

The Energy Independence and Security Act (EISA) of 2007, Pub. L. 110-14, 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. EPCA, as amended by EISA, contains prescriptive standards for the WICF industry to meet (starting in 2009) that affect the thermal enclosure, motors, and lights. (42 U.S.C. 6313(f)(1)) Some manufacturers noted that compliance with those new Congressionally-mandated requirements has forced them to incur significant product re-design costs, affecting their production process and ultimately their bottom line.

Potential Climate Change and Greenhouse Gas Legislation

Many manufacturers expressed concern about potential climate change legislation. The main concern revolves around legislation that would initiate a phase-down of hydrofluorocarbons (HFCs) and would make the new energy conservation standard levels considered in this rulemaking more difficult to achieve. There is particular concern because without a clear alternative or substitute to HFCs, any phase-out would create a period of uncertainty as the industry identifies suitable alternatives and then redesigns both products and processes around the replacement. In general, past phase-outs have led to more expensive and less efficient refrigerant replacements. Manufacturers noted that alternative refrigerants may require substantially larger systems to achieve the same levels of performance or increase the risk associated with the use of flammable substances.

DOE notes that it does not consider proposed legislation in its cumulative regulatory burden analysis because the impacts of such legislation are speculative.

State Conservation Standards

Since 2004, the State of California has established energy standards for walk-in coolers and freezers. California's Code of Regulations (Title 20, Section 1605) prescribe requirements for insulation levels, motor types, and use of automatic door-closers used for WICF applications. However, based on regulations effective January 2011, the requirements for walk-ins manufactured on or after January 1, 2009, are identical to the ones that are contained in EPCA. Therefore, California's Title 20 standards do not pose an additional regulatory burden above that which has already been established in EPCA. The states of Connecticut, Maryland and Oregon have recently established energy efficiency standards for walk-ins that are also identical to the ones contained in EPCA, so these standards also do not pose an additional regulatory burden above that which has already been established in EPCA.

Food Safety Standards

Manufacturers expressed concern regarding Federal, State and local food safety regulations. A walk-in must perform to the standards set by NSF, state, country and city health regulations. There is general concern among manufacturers about conflicting regulation scenarios as new energy conservation standards may potentially prevent or make it more difficult for them to comply with food safety regulations.

12.8 CONCLUSION

The following sections summarize the impacts for the scenarios DOE believes are most likely to capture the range of impacts on walk-in cooler and freezer panel, door, and refrigeration manufacturers as a result of amended energy conservation standards. DOE also notes that while these scenarios bound the range of most plausible impacts on manufacturers, there potentially could be circumstances which cause manufacturers to experience impacts outside of this range.

For this rulemaking, increasing TSL numbers do not necessarily correspond to more higher efficiency standards for all equipment classes. The TSLs are ordered from lowest to highest national based on the combined national energy savings of the walk-in panel, door, and refrigeration equipment classes. The TSLs are defined as follows:

Equipment Class	**Baseline**	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
DC.M.I, < 9,000	Baseline	EL 1	EL 6	EL 1	EL 6	EL 6	EL 6

DC.M.I, ≥ 9,000	Baseline	EL 3	EL 6	EL 3	EL 6	EL 6	EL 6
DC.M.O, < 9,000	Baseline	EL 6	EL 8	EL 6	EL 8	EL 9	EL 9
DC.M.O, ≥ 9,000	Baseline	EL 3	EL 10	EL 3	EL 10	EL 10	EL 10
DC.L.I, < 9,000	Baseline	EL 6	EL 6	EL 6	EL 6	EL 7	EL 7
DC.L.I, ≥ 9,000	Baseline	EL 1	EL 6	EL 1	EL 6	EL 7	EL 7
DC.L.O, < 9,000	Baseline	EL 9	EL 7	EL 9	EL 7	EL 10	EL 10
DC.L.O, ≥ 9,000	Baseline	EL 2	EL 10	EL 2	EL 10	EL 11	EL 11
MC.M	Baseline	EL 3	EL 2	EL 3	EL 2	EL 3	EL 3
MC.L	Baseline	EL 5	EL 2	EL 5	EL 2	EL 5	EL 5
SP.M	Baseline	EL 1	Baseline	EL 2	EL 1	EL 2	EL 6
SP.L	Baseline	EL 2	Baseline	EL 4	EL 2	EL 4	EL 5
FP.L	Baseline	EL 2	Baseline	EL 4	EL 2	EL 4	EL 5
DD.M	Baseline	EL 2	EL 2	EL 2	EL 2	EL 2	EL 6
DD.L	Baseline	EL 1	EL 1	EL 2	EL 1	EL 1	EL 5
PD.M	Baseline	EL 1	Baseline	EL 1	EL 1	EL 1	EL 8
PD.L	Baseline	EL 3	Baseline	EL 6	EL 3	EL 6	EL 8
FD.M	Baseline	EL 1	Baseline	EL 1	EL 1	EL 1	EL 9
FD.L	Baseline	EL 3	Baseline	EL 6	EL 2	EL 6	EL 8

TSL 1 represents the set of refrigeration system efficiency levels that returns the highest NPV at a level that can be met by all compressors types (scroll, semi-hermetic, and hermetic). The refrigeration system is combined with the panel and door design options that return the highest total NPV.

TSL 2 sets the efficiency standard for panels and solid doors at the baseline efficiency and sets standards for refrigeration and display doors at levels that maximize NPV.

TSL 3 represents the set of refrigeration system efficiency levels that returns the highest energy savings under the conditions that NPV is greater than zero and that the level can be met by all compressor types (scroll, semi-hermetic, hermetic). The refrigeration system is combined with the panel and door design options that return the highest total national energy savings with positive NPV results.

TSL 4 represents the set of refrigeration system efficiency levels that provide the maximum consumer net benefits paired with the envelope component efficiency levels that maximize consumer net benefits.

TSL 5 represents the combination of panel, door, and refrigeration efficiency levels that maximize national energy savings and provide a positive consumer net benefits.

TSL 6 is the max-tech level for each equipment class for all components.

12.8.1 Conclusions for Walk-in Cooler and Freezer Panel MIA

Table 12.8.1 Manufacturer Impact Analysis Results for WICF Panels

	Units	Base Case	Trial Standard Level					
			1	**2**	**3**	**4**	**5**	**6**
INPV	2012 $M	207.3	182.2 to 195.8	207.3 to 207.3	144.1 to 177.0	182.2 to 195.8	144.1 to 177.0	-212.9 to 441.9
Change in INPV	2012 $M	-	-25.0 to -11.5	0.0 to 0.0	-63.1 to -30.2	-25.0 to -11.5	-63.1 to -30.2	-420.2 to 234.7
	%	-	-12.1 to -5.6	0.0 to 0.0	-30.5 to -14.6	-12.1 to -5.6	-30.5 to -14.6	-202.7 to 113.2
FCF (2014)	2012 $M	18.4	10.7	18.4	-3.4	10.7	-3.4	-54.6
Change in FCF (2014)	2012 $M	-	-7.7	0.0	-21.8	-7.7	-21.8	-73.0
	%	-	-41.6	0.0	-118.7	-41.6	-118.7	-396.9
Conversion Costs	2012 $M	-	21	0	58	21	58	195

At TSL 1, DOE models the impacts on panel INPV to be negative under both mark-up scenarios. The change in panel INPV ranges from -$25.0 million to -$11.5 million, or a change in INPV of -12.1 percent to -5.6 percent. At this level, panel industry free cash flow[d] is estimated to decrease by as much as $7.7 million, or 41.6 percent compared to the base-case value of $18.4 million in 2016, the year before the compliance date. The primary driver of the drop in INPV is the standard for low-temperature side panels, which goes up to EL 2. At EL 2, manufacturers would likely use 5-inch thick side panels for low-temperature applications to meet the panel standard. At this level, DOE estimates conversion costs to be $21 million for the industry.

At TSL 2, the standard for all panel equipment classes are set to the baseline efficiency. As a result, there are no changes to INPV, no changes in industry free cash flow, and no conversion costs.

At TSL 3, DOE estimates impacts on panel INPV to range from -$63.1 million to -$30.2 million, or a change in INPV of -30.5 percent to -14.6 percent. At this level, panel industry free cash flow is estimated to decrease by as much as $21.8 million, or 118.7% compared to the base-case value of $18.4 million in the year before the compliance date. The large percentage drop in cash flow in the GRIM indicates that conversion costs are high relative to the size of the industry and relative to annual operating

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[d] Free cash flow (FCF) is a metric commonly used in financial valuation. DOE calculates this value by adding back depreciation to net operating profit after tax and subtracting increases in working capital and capital expenditures.

profits. Conversion costs are expected to total $58 million. The conversion costs are driven by the need for 6-inch panels for both low temperature floor and side panels, as described in section 12.4.8 of the TSD. During manufacturer interviews, some panel manufacturers stated they would evaluate leaving the industry rather than make the required investments to meet the standard.

At TSL 4, the standard for all panel equipment classes are identical to those at TSL 1.

DOE estimates TSL 5 impacts on panel INPV to be range from -$63.1 million to -$30.2 million, or a change in INPV of -30.5 percent to -14.6 percent. At this level, panel industry free cash flow is estimated to decrease by as much as $21.8 million, or 118.7 percent compared to the base-case value of $18.4 million in the year before the compliance date. At this TSL, conversion costs total $58 million for the industry. These conversion costs are based on DOE's analysis indicating that industry would likely adopt 6-inch side floor panels to meet the standard. As in TSL 3, some panel manufacturers would likely leave the industry at this level of burden.

TSL 6 represents the use of max-tech design options for all equipment classes. DOE estimates impacts on panel INPV to be range from -$420.2 million to $234.7 million, or a change in INPV of -202.7 percent to 113.2 percent. At this level, panel industry free cash flow is estimated to decrease by as much as $73.0 million, or 396.9 percent compared to the base-case value of $18.4 million in the year before the compliance date. Impacts at the most negative end of the range would likely force many manufacturers out of the industry.

12.8.2 Conclusions for Walk-in Cooler and Freezer Door MIA

Table 12.8.2 Manufacturer Impact Analysis Results for WICF Doors

	Units	Base Case	Trial Standard Level					
			1	**2**	**3**	**4**	**5**	**6**
INPV	2012 $M	454.6	437.6 to 470.7	446.2 to 470.2	428.2 to 467.8	437.8 to 470.6	427.3 to 466.4	260.8 to 1145.1
Change in INPV	2012 $M	-	-17.0 to 16.1	-8.4 to 15.6	-26.4 to 13.2	-16.8 to 16.0	-27.3 to 11.8	-193.8 to 690.5
	%	-	-3.7 to 3.5	-1.8 to 3.4	-5.8 to 2.9	-3.7 to 3.5	-6.0 to 2.6	-42.6 to 151.9
FCF (2014)	2012 $M	36.1	34.1	36.1	30.4	34.1	30.5	0.6
Change in FCF (2014)	2012 $M	-	-2.07	0.00	-5.7	-2.1	-5.7	-35.6
	%	-	-5.7	0.0	-15.8	-5.7	-15.7	-98.5
Conversion Costs	2012 $M	-	6	0.0	15	6	15	92

For TSL 1, DOE models the change in INPV for doors to range from -$17.0 million to $16.1 million, or a change in INPV of -3.7 percent to 3.5 percent. At this standard level, door industry free cash flow is estimated to decrease by as much as $2.1 million, or 5.7 percent compared to the base case value of $36.1 million in the year before the compliance date. DOE expects solid door manufacturers to pursue design options that reduce the loss of heat through door frames and through embedded windows. Changes to door frame design may require new tooling. Total conversion costs for the door industry are expected to reach $6 million.

At TSL 2, DOE estimates the impacts on door INPV to range from -$8.4 million to $15.6 million, or a change in INPV of -1.8 percent to 3.4 percent. At this level, door industry free cash flow is estimated to decrease by a negligible amount in the year before the compliance year. Furthermore, there are minimal conversion costs. To meet the standard, display door manufacturers would need to replace existing lighting with LEDs and reduce anti-sweat wire energy consumption. For solid door manufacturers, the standard is set at the baseline. Total conversion costs are expected to total $0.1 million for the industry. These costs are primarily product conversion costs associated incorporating heater wire controls and updating marketing literature.

For TSL 3, DOE estimates the change in door INPV to range from -$26.4 million to $13.2 million, or a change in INPV of -5.8 percent to 2.9 percent. At this level, door industry free cash flow is estimated to decrease by as much as $5.7 million, or 15.8 percent compared to the base-case value of $36.1 million in the year before the compliance date. At this level, display doors would need to incorporate lighting sensors. Solid doors for low temperature walk-ins would likely need to be redesigned to 6-inches of thickness. The additional production equipment and the cost of product redesigns drive conversion costs up to $15 million, more than double the conversion costs at TSL 1 and TSL 2. This conversion cost number assumes that manufacturers that produce both panels and solid doors would use the same foaming equipment and presses to produce both products since DOE models panel manufacturers also going to 6-inch side panels for low temperature applications at TSL 3. Manufacturers that exclusively produce freight doors and passage doors will not be able to spread their investment over as many equipment classes.

For TSL 4, DOE estimates impacts on door INPV to range from -$16.8 million to $16.0 million, or a change in INPV of -3.7 percent to 3.5 percent. At this considered level, door industry free cash flow is estimated to decrease by as much as $2.1 million, or 5.7 percent compared to the base-case value of $36.1 million in the year before the compliance date. The standard levels for doors at TSL 4 are nearly identical to the standard levels at TSL 2, except that the standard is one efficiency level lower for the low temperature freight door equipment class. As mentioned above, DOE expects display door manufacturers to pursue design changes that do not require new manufacturing equipment. Manufacturers are expected to use LEDs in display doors and reduce anti-sweat wire energy consumption for medium temperature applications. DOE expects solid door manufacturers to pursue design options that reduce the loss of heat through door frames and through embedded windows. Changes to door frame design may require new tooling. Total conversion costs are expected to reach $6 million for the industry.

For TSL 5, DOE estimates impacts on door INPV to range from -$27.3 million to $11.8 million, or a change in INPV of -6.0 percent to 2.6 percent, at TSL 5. At this level, door industry free cash flow is estimated to decrease by as much as $5.7 million, or 15.7 percent compared to the base-case value of $36.1 million in the year before the compliance date. This standard level for doors at TSL 5 is nearly identical to the standard levels at TSL 3. Total conversion costs are expected to reach $15 million.

For TSL 6, DOE estimates impacts on door INPV to range from -$193.8 million to $690.5 million, or a change in INPV of -42.6 percent to 151.9 percent. At this level, door industry free cash flow is estimated to decrease by as much $35.6 million, or 98.5 percent compared to the base-case value of $36.1 million in the year before the compliance date. Conversion costs would total $92 million. At this level, some door manufacturers would likely choose to leave the industry rather than make the necessary investments to comply with standards.

12.8.3 Conclusions for Walk-in Cooler and Freezer Refrigeration MIA

Table 12.8.3 Manufacturer Impact Analysis Results for WICF Refrigeration

	Units	Base Case	Trial Standard Level					
			1	2	3	4	5	6
INPV	2012 $M	189.1	170.9 to 183.3	153.6 to 184.8	170.9 to 183.3	153.6 to 184.8	145.8 to 188.3	145.8 to 188.3
Change in INPV	2012 $M	-	-18.3 to -5.9	-35.5 to -4.4	-18.3 to -5.9	-35.5 to -4.4	-43.3 to -0.8	-43.3 to -0.8
	%	-	-9.7 to -3.1	-18.8 to -2.3	-9.7 to -3.1	-18.8 to -2.3	-22.9 to -0.4	-22.9 to -0.4
FCF (2014)	2012 $M	16.3	11.7	9.1	11.7	9.1	8.0	8.0
Change in FCF (2014)	2012 $M	-	-4.6	-7.2	-4.6	-7.2	-8.3	-8.3
	%	-	-28.2	-44.0	-28.2	-44.0	-51.0	-51.0
Conversion Costs	2012 $M	-	15	24	15	24	28	28

At TSL 1, DOE estimates impacts on refrigeration INPV to range from -$18.3 million to -$5.9 million, or a change in INPV of -9.7 percent to -3.1 percent. At this level, refrigeration industry free cash flow is estimated to decrease by as much as $4.6 million, or 28.2 percent compared to the base-case value of $16.3 million in 2016, the year before the compliance year. For dedicated condensing, medium temperature, indoor refrigeration systems, DOE's engineering analysis indicates that manufacturers would need to incorporate multiple design options to achieve this standard. The design options would likely include variable speed evaporator fan motors and larger condensing coils. For dedicated condensing, low temperature, indoor refrigeration systems, manufacturers may need to further include improved condenser fan, improved evaporator fan blades, and electronically commutated motors. For dedicated condensing, medium temperature, outdoor refrigeration systems, design options necessary to meet TSL 1 would include variable speed evaporator fan motors, improved condenser fan blades, electronically commutated condenser fan motors, and improved evaporator fan blades. For dedicated condensing, low temperature, outdoor refrigeration systems, additional design options required to meet the trial standard level include ambient sub-cooling, variable speed condenser fans, and defrost control strategies. For multiplex refrigeration, manufacturers would need to evaluate design improvements, such as variable speed evaporator fan motors, improved fan blade designs, defrost control, and hot gas defrost. Integration of these design options across equipment classes will require extensive engineering investments. As a result, conversion costs total $15 million for the industry.

At TSL 2, DOE estimates impacts on refrigeration INPV to range from -$35.5 million to -$4.4 million, or a change in INPV of -18.8 percent to -2.3 percent. At this level, refrigeration industry free cash flow is estimated to decrease by as much as $7.2 million, or 44.0 percent compared to the base-case value of $16.3 million in the year before the compliance date. From TSL 1 to TSL 2, standards increase for most equipment classes. For dedicated condensing, medium temperature, indoor systems, a manufacturer would need to consider including electronically commutated condenser fan motors, improved condenser fan blades, and improved evaporator fan blades. For dedicated condensing, medium temperature, outdoor systems, the most cost effective options include using ambient subcooling, variable speed condenser fan motors, and floating head pressure with electronic expansion valves. For dedicated condensing, low temperature, outdoor systems, manufacturers will need to consider incorporating improved evaporator fan blades, larger condenser coils, and floating head pressure with electronic expansion valves. The range of changes do not require significant amounts of new production equipment, but could require substantial development and engineering time. DOE estimates the WICF refrigeration industry's conversion costs to increase to $24 million.

At TSL 3, the standards and the impacts on the walk-in refrigeration industry are identical to those at TSL 1.

At TSL 4, the standards and the impacts on the walk-in refrigeration industry are identical to those at TSL 2.

TSL 5 and TSL 6 represent max-tech for WICF refrigeration systems. DOE estimates impacts on refrigeration INPV to range from -$43.3 million to -$0.8 million, or a change in INPV of -22.9 percent to -0.4 percent. At this level, refrigeration industry free cash flow is estimated to decrease by as much as $8.3 million, or 51.0 percent compared to the base-case value of $16.3 million in the year before the compliance year. DOE's engineering analysis indicates that manufacturers would need to incorporate design changes beyond those for TSL 4 and TSL 3 to achieve this standard. Additional design changes for dedicated condensing, low temperature, indoor and outdoor refrigeration would include defrost controls. For multiplex units, the standard levels at

TSL 5 and 6 are identical to those at TSL 1. Total conversion costs are expected to reach $28 million for the industry.

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CHAPTER 13. EMPLOYMENT IMPACT ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 13. EMPLOYMENT IMPACT ANALYSIS

13.1 INTRODUCTION

The imposition of 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 equipment, along with the affiliated distribution and service companies, resulting from the imposition of standards. The U.S. Department of Energy (DOE) evaluates direct employment impacts in its manufacturer impact analysis, as described in chapter 12 of the technical support document. However, indirect employment impacts may result from the imposition of standards such as expenditures shifting between goods (the substitution effect) and changes in income and overall expenditure levels (the income effect).

DOE intends the employment impact analysis to estimate indirect national job creation or job elimination resulting from possible new standards, due to reallocation of the associated expenditures for purchasing and operating equipment. DOE conducts this analysis for the notice of proposed rulemaking (NOPR) for walk-in cooler and freezer (WICF) refrigeration systems and envelope components (panels, display doors, and non-display doors). DOE will estimate national impacts on major sectors of the U.S. economy, using publicly available data and incorporating different energy price scenarios that it will carry out as part of the analysis for the NOPR. DOE will make all methods and documentation available for review.

13.2 ASSUMPTIONS

DOE expects new equipment standards to decrease energy consumption, and therefore to reduce expenditures for energy. The standards may increase the purchase price of equipment, including the retail price plus sales tax, and increase installation costs. However, the net savings may be reallocated toward new investments or even to other sectors of the economy.

Using an input/output econometric model of the U.S. economy, this analysis estimated the short-term effect of these expenditure impacts on net economic output and employment. DOE intends this analysis to quantify the indirect employment impacts of these expenditure changes. It evaluated direct employment impacts at manufacturers' facilities in the manufacturer impact analysis (see chapter 12).

DOE notes that the Impact of Sector Energy Technologies (ImSET) model is not a general equilibrium forecasting model, and understands the uncertainties involved in projecting employment impacts, especially changes in the later years of the analysis.[1] Because ImSET does not incorporate price changes, the employment effects predicted by ImSET would over-estimate the magnitude of actual job impacts over the long run for this rule. Because input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. We therefore include a qualitative discussion of how labor markets are likely to respond in the longer term. In future rulemakings, DOE may consider the use of other modeling approaches for examining long run employment impacts.

13.3 METHODOLOGY

The Department based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 3.1.1[2] as a successor to ImBuild[3], a special-purpose version of the IMPLAN[4] national input/output model. ImSET estimates the employment and income effects of building energy technologies. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy efficiency investments in buildings.

In an input/output model, the level of employment in an economy is determined by the 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 equipment. The increased cost of equipment leads to higher employment in the manufacturing sectors and lower employment in other economic sectors. Second, commercial firm and residential spending are redirected from utilities toward firms that supply production inputs. Third, electric utility sector investment funds are released for use in other sectors of the economy. When consumers use less energy, electric utilities experience relative reductions in demand, which leads to reductions in utility sector investment and employment.

DOE also notes that the employment impacts estimated with ImSET for the entire economy differ from the employment impacts in the WICF manufacturing sector estimated in chapter 12 using the Government Regulatory Impact Model (GRIM). The methodologies used and the sectors analyzed in the ImSET and GRIM models are different.

13.4 SHORT-TERM RESULTS

The results in this section refer to impacts of WICF equipment standards relative to the base case. DOE disaggregated the impact of standards on employment into three component effects: increased capital investment costs, decreased energy costs, and changes in operations and maintenance costs. DOE anticipates no change in operations and maintenance costs for WICF equipment.

Using the ImSET model, DOE considers the impact of the proposed rule in its first five years on three aggregate sectors: the WICF equipment production sector, the energy generation sector, and the general consumer goods sector (as mentioned previously, ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the rule increases the purchase price of WICF equipment; this increase in expenditures causes an increase in employment in this sector. At the same time, the improvements in energy efficiency reduce expenditures on electricity. The reduction in electricity demand causes a reduction in employment in that sector. Finally, based on the net impact of increased expenditures on WICF equipment and reduced expenditures on electricity, expenditures on everything else are either positively or negatively affected, increasing or reducing jobs in that sector accordingly. The model also captures any indirect jobs created or lost by changes in consumption due to changes in employment (as more workers are hired they consume more goods, which generates more employment, the converse is true for workers laid off).

Table 13.4.1 shows the net national short-term change in employment in 2017, the first year after standards will have gone into effect; and in 2021, five years into the analysis period. These results show a small but positive impact on employment throughout the analysis period.

Table 13.4.1 Net National Short-Term Change in Employment Under WICF Trial Standard Levels*

Year	Trial Standard Level	Net National Change in Jobs *Thousands*
2017	1	0.7
	2	0.8
	3	0.7
	4	0.9
	5	1.0
	6	1.1
2021	1	3.4
	2	3.7
	3	3.5
	4	4.2
	5	4.4
	6	5.0

* Compliance date of standard is 2017.

13.5 LONG-TERM RESULTS

Due to the short payback period of energy efficiency improvements mandated by this rule, over the long term we expect the energy savings to consumers to increasingly dominate the increase in equipment costs, resulting in increased aggregate savings to consumers. As a result, we expect demand for electricity to decline over time and demand for other goods to increase. Since the electricity generation sector is relatively capital intensive compared to the consumer goods sector, the net effect will be an increase in labor demand. In equilibrium, this should lead to upward pressure on wages and a shift in employment away from electricity generation towards consumer goods. Note that in long-run equilibrium there is no net effect on total employment since wages adjust to bring the labor market into equilibrium. Nonetheless, even to the extent that markets are slow to adjust, we anticipate that net labor market impacts will be minor over time due to the small magnitude of the short-term effects presented in Table 13.4.1. The ImSET model projections, assuming no price or wage effects until 2021, are included in Table 13.4.1.

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CHAPTER 14. UTILITY IMPACT ANALYSIS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 14. UTILITY IMPACT ANALYSIS

14.1 INTRODUCTION

In the utility impact analysis, the U.S. Department of Energy (DOE) analyzes the changes in electric installed capacity and generation that result for each trial standard level (TSL).

The utility impact analysis uses 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*). DOE uses a variant of this model, referred to as NEMS-BT,[b] to account for selected utility impacts of energy conservation standards. DOE's analysis consists of a comparison between model results for the most recent AEO reference case and for cases in which energy use is decremented to reflect the impact of standards. For the analysis of standards on WICF, DOE used the version of NEMS based on the *Annual Energy Outlook 2013* (*AEO 2013)*[1].

NEMS-BT has a number of advantages that have led to its use 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.
- NEMS-BT is updated each year, with each edition of the AEO, to reflect changes in energy prices, supply trends, regulations, etc.
- The comprehensiveness of NEMS-BT permits the modeling of interactions among the various energy supply and demand sectors.

14.2 METHODOLOGY

DOE uses NEMS-BT to estimate the marginal impacts of reduction in energy demand on the energy supply sector. In principle, marginal values should provide a better estimate of the actual impact of energy conservation standards. In practice, the numerical differences between marginal and average values may turn out to be smaller than the intrinsic uncertainties in the AEO.

NEMS uses predicted growth in demand for each end use to build up a projection of the total electric system load growth. The system load shapes are converted internally to load duration curves, which are then used to estimate the most cost-effective additions to capacity. When electricity demand deviates from the AEO reference case, in general there are three inter-related effects: the annual generation (TWh) from the stock of electric generating capacity changes, the total generation capacity itself (GW) may change, and the mix of capacity by fuel type may change. Each of these effects can vary for different types of end use. The change in

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[a] For more information on NEMS, refer to the DOE/EIA 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).

total generating capacity is sensitive to the degree to which the end use is peak coincident, while the capacity mix is sensitive to the hourly load shape associated with the end use.

To model the impact of a standard, DOE inputs a reduction to annual energy demand for the corresponding end use in the appropriate start year. The NEMS-BT model is run with the decremented energy demand to determine the modified build-out of capacity and total generation. Regional effects of a standard can be accounted for by defining the energy demand decrement as a function of census division.

The output of the NEMS-BT analysis includes the effective marginal heat rate (ratio of the change in fuel consumption in quads to the change in generation in TWh), and the capacity reduction by fuel type for a given reduction in total generation. DOE uses the site energy savings multiplied by a transmission and distribution (T&D) loss factor to estimate the reduction in generation for each TSL. The relationship between a reduction[c] in electricity generation (TWh) and the reduction in capacity (GW) is estimated based on the output of NEMS-BT model runs using the end-use specific energy demand decrement. Details on the approach used may be found in Coughlin (2013).[2]

NEMS-BT provides output for the following capacity types: coal, nuclear, combined cycle (natural gas), renewable sources, oil and natural gas steam, combustion turbine/diesel, pumped storage, fuel cells, and distributed generation (natural gas). DOE grouped oil and natural gas steam and combustion turbine/diesel into a peaking category, and grouped pumped storage, fuel cells, and distributed generation (natural gas) into an “other” category.

In general, energy conservation standards impact primarily fossil combustion (coal, natural gas, and diesel) and renewables. Pumped storage and nuclear power are very insensitive to small changes in demand, while fuel cells and distributed generation make up a very small fraction (less than 1%) of the generation capacity base.

14.3 UTILITY IMPACT RESULTS

This section presents results of the analysis for all of the capacity types except “Other”, for which the impacts are very small.

14.3.1 Installed Capacity

The figures in this section show the changes in U.S. electricity installed capacity that result for each TSL by major plant type for selected years. Note that a negative number means an increase in capacity under a TSL.

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[c] These reductions are defined relative to the AEO Reference case.

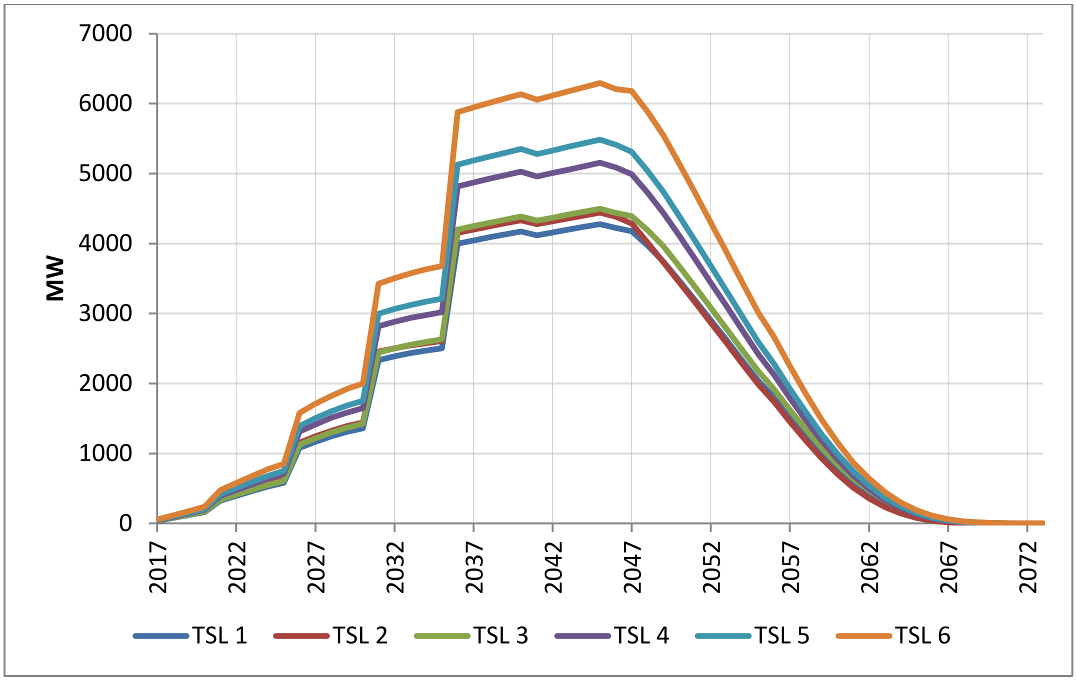

Figure 14.3.1 WICF Total Capacity Reduction

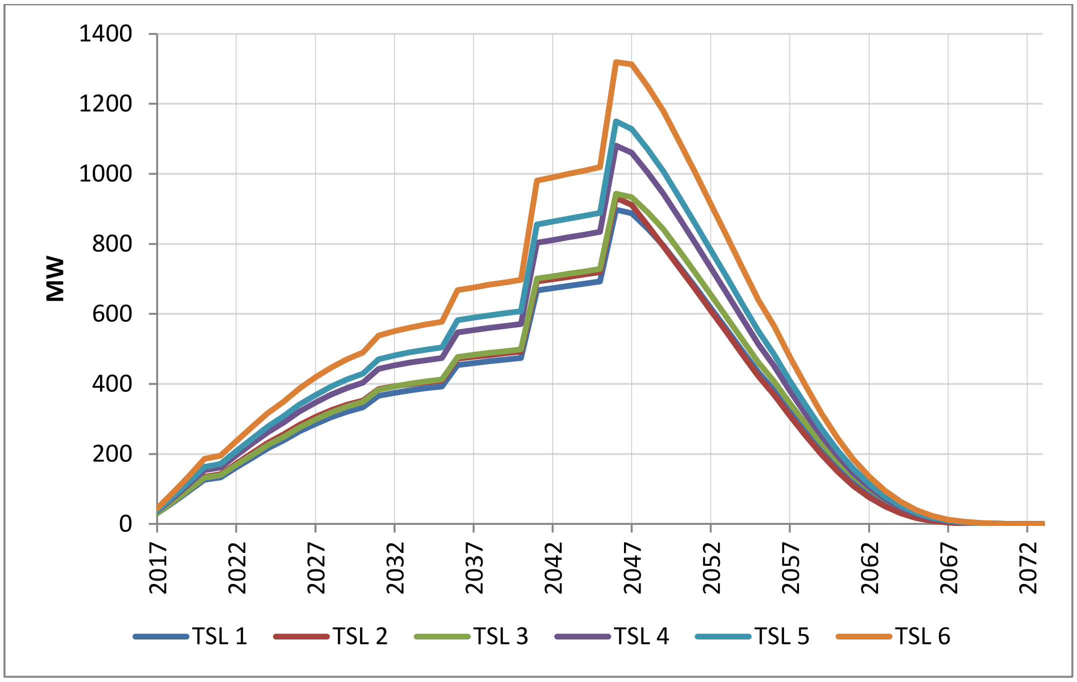

Figure 14.3.2 WICF Coal Capacity Reduction

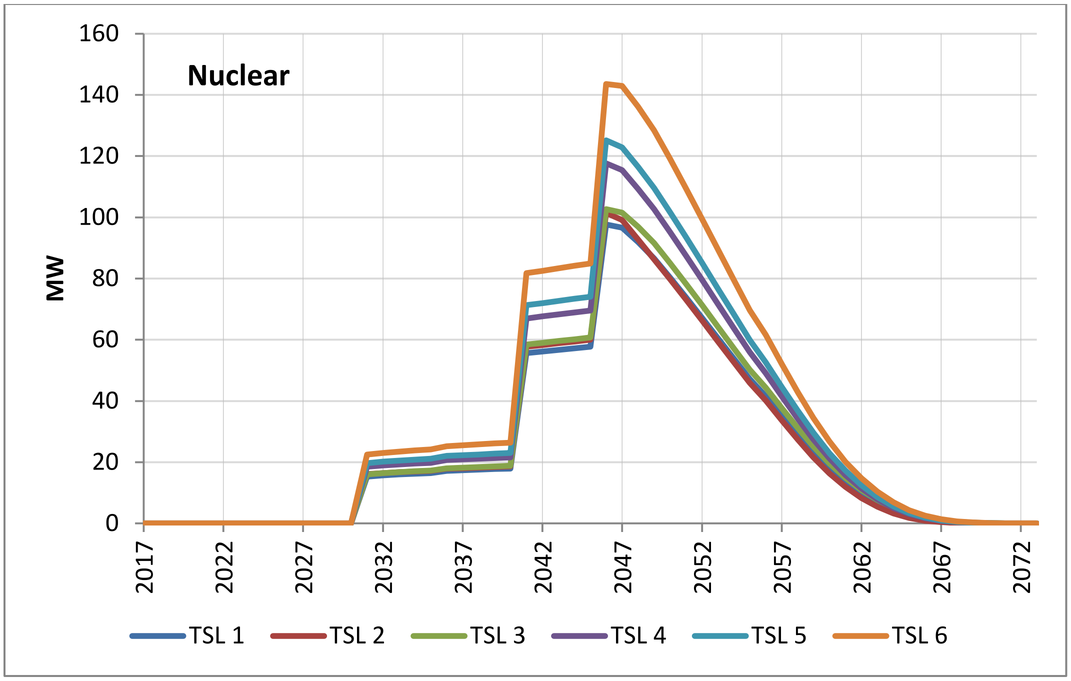

Figure 14.3.3 WICF Nuclear Capacity Reduction

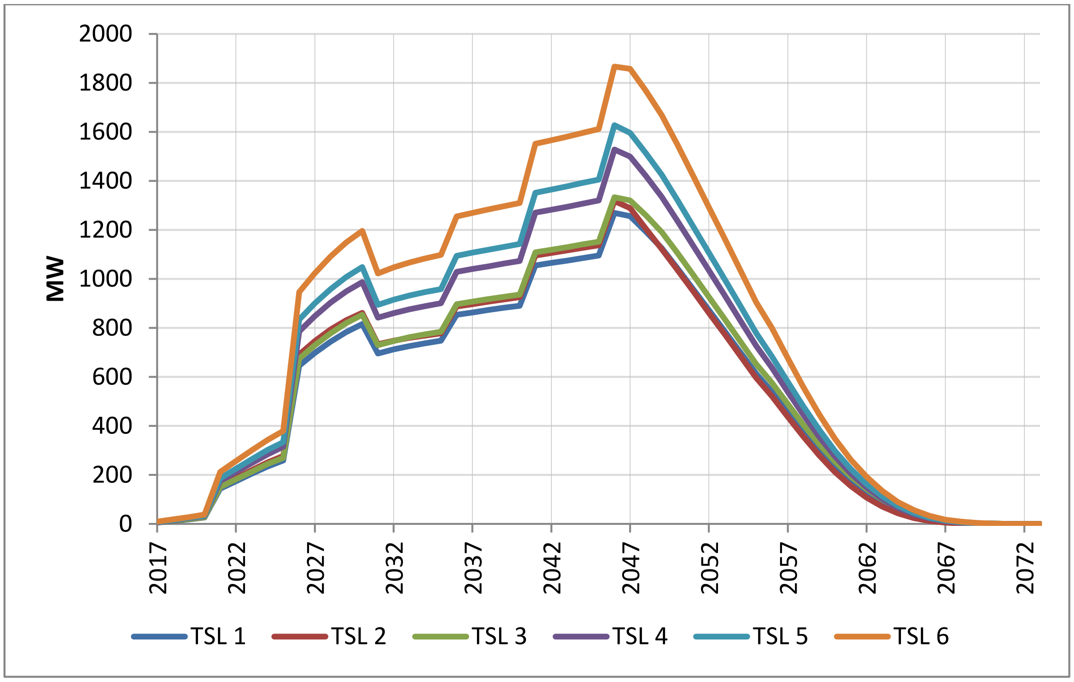

Figure 14.3.4 WICF Gas Combined Cycle Capacity Reduction

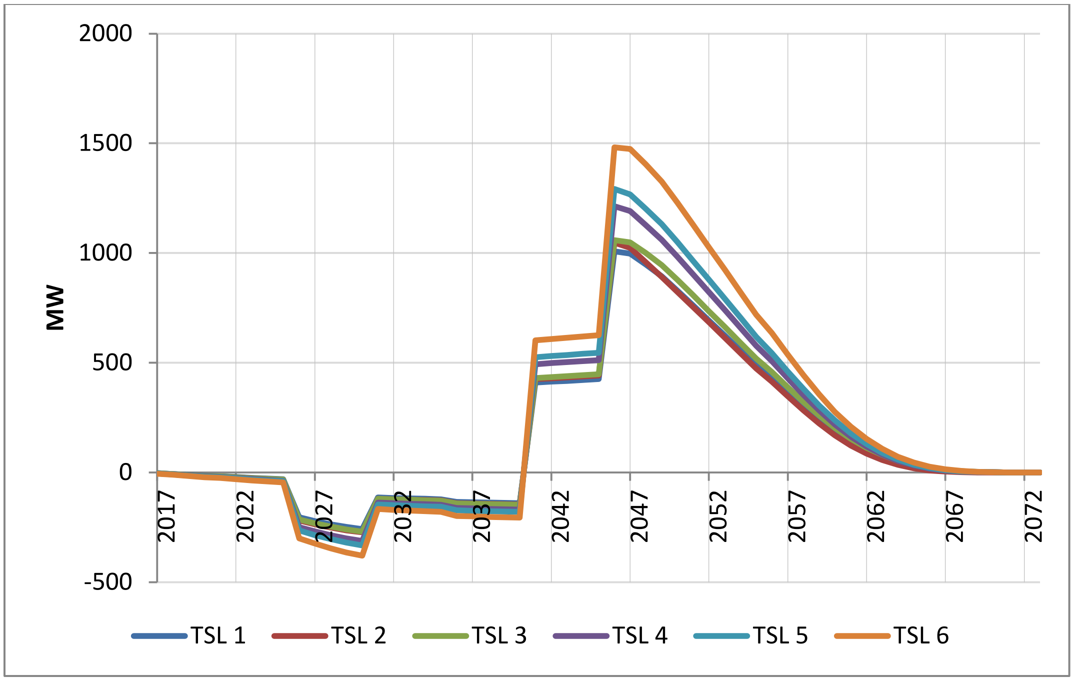

Figure 14.3.5 WICF Peaking Capacity Reduction

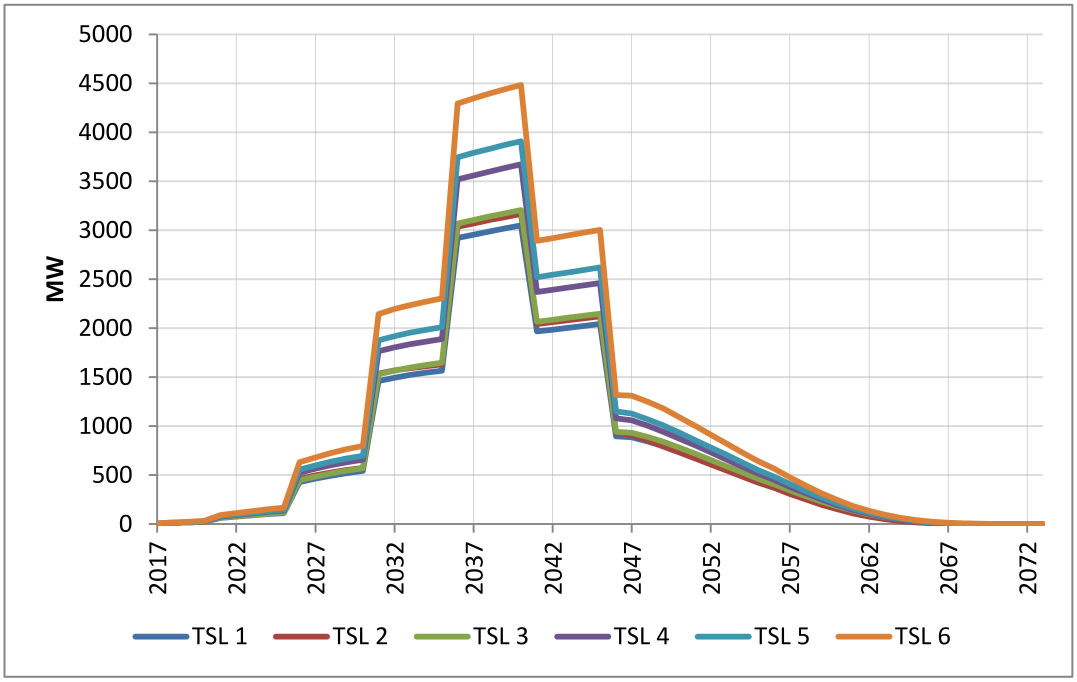

Figure 14.3.6 WICF Renewables Capacity Reduction

14.3.2 Electricity Generation

The figures in this section show the annual change in electricity generation that result for each TSL by plant type. Coal-fired power plants account for most of the generation reduction. Note that a negative number means an increase in generation under a TSL.

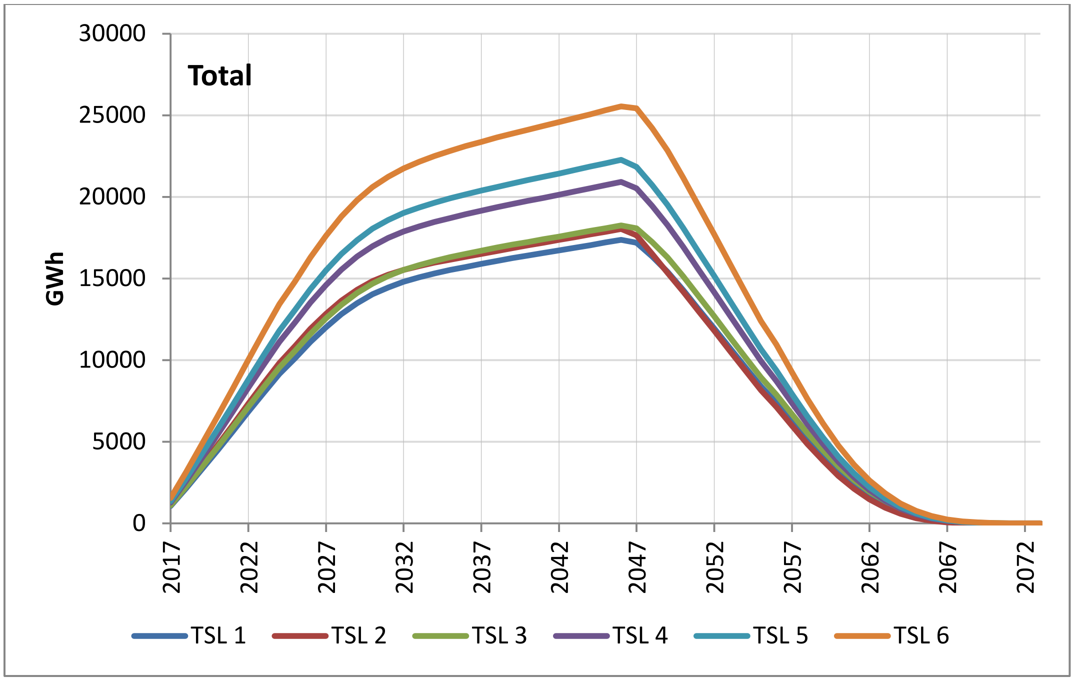

Figure 14.3.7 WICF Total Generation Reduction

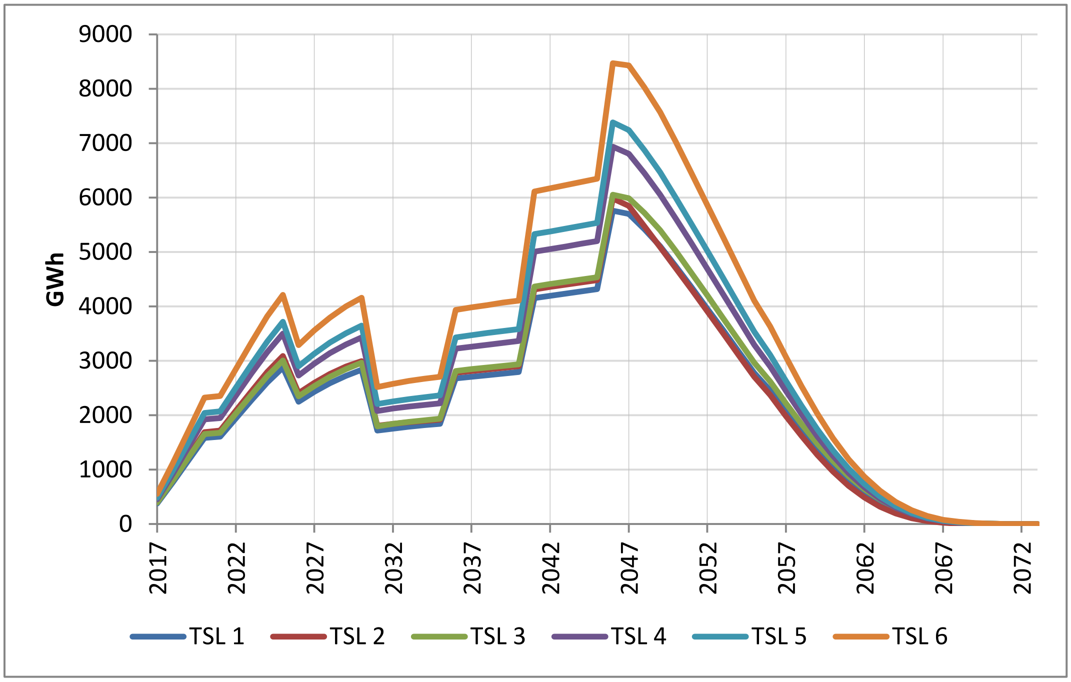

Figure 14.3.8 WICF Coal Generation Reduction

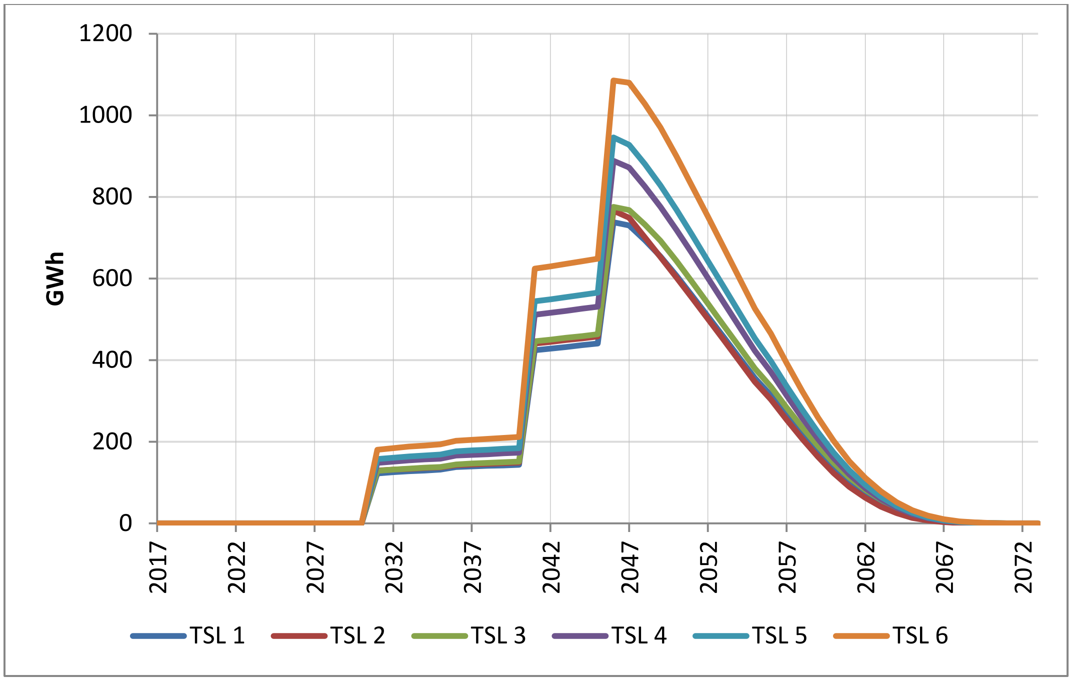

Figure 14.3.9 WICF Nuclear Generation Reduction

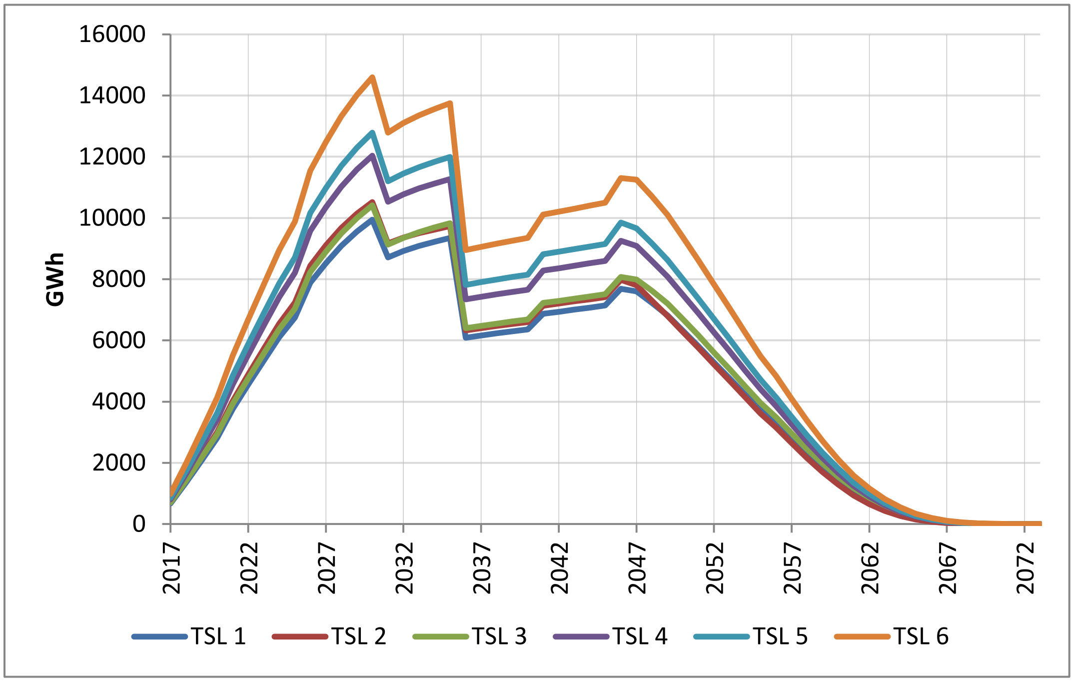

Figure 14.3.10 WICF Gas Combined Cycle Generation Reduction

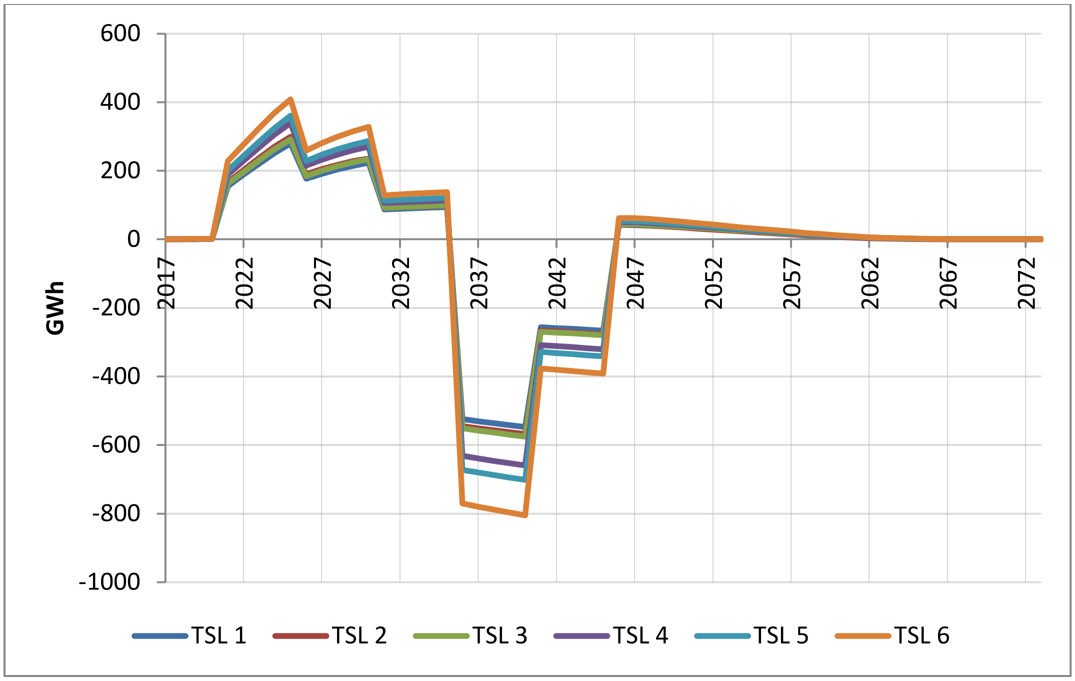

Figure 14.3.11 WICF Peaking Generation Reduction

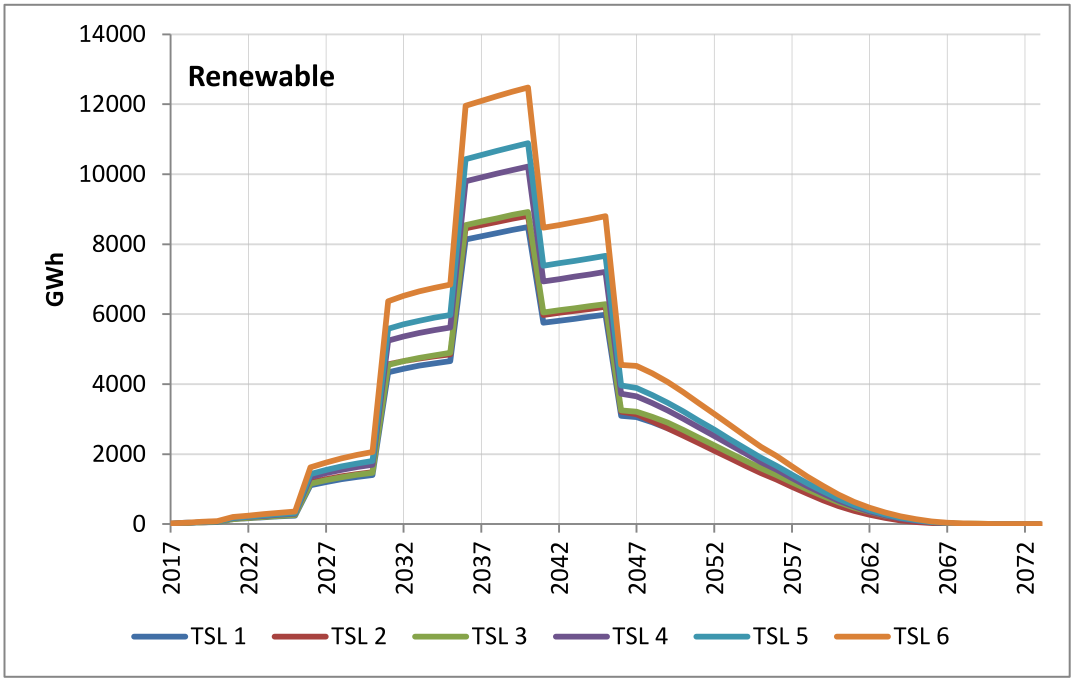

Figure 14.3.12 WICF Renewables Generation Reduction

14.3.3 Results Summary

Table 14.3.1 presents a summary of the utility impact results for WICF.

Table 14.3.1 WICF Summary of Utility Impact Results

	TSL					
	1	**2**	**3**	**4**	**5**	**6**
Installed Capacity Reduction (MW)						
2020	161.9	172.8	169.1	196.6	208.7	237.3
2025	583.1	625.6	608.8	709.6	753.1	853.8
2030	1,361.5	1,439.7	1,425.2	1,647.6	1,750.6	1,998.6
2035	2,503.2	2,605.6	2,629.7	3,017.0	3,211.1	3,680.0
2040	4,172.2	4,332.2	4,385.2	5,024.9	5,349.3	6,135.3
Electricity Generation Reduction (TWh)						
2020	4.46	4.76	4.66	5.41	5.75	6.54
2025	10.12	10.86	10.57	12.32	13.07	14.82
2030	14.03	14.84	14.69	16.99	18.05	20.60
2035	15.52	16.16	16.30	18.71	19.91	22.82
2040	16.40	17.03	17.24	19.75	21.03	24.12

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1. U.S. Department of Energy–Energy Information Administration, *Annual Energy Outlook 2013*. 2013. Washington, DC. DOE/EIA-0383(2013). http://www.eia.gov/forecasts/aeo/

2. Coughlin, K. *Modeling the Capacity and Emissions Impact of Reduced Electricity Demand*. Lawrence Berkeley National Laboratory. Berkeley, CA. LBNL-6092E. Feb 2013.

CHAPTER 15. EMISSIONS IMPACT ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 15. EMISSIONS IMPACT ANALYSIS

15.1 INTRODUCTION

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2) and mercury (Hg). The second component estimates the impacts of a potential standard on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the reductions to emissions of all species due to “upstream” activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Together, these emissions account for the full-fuel-cycle (FFC), in accordance with DOE’s FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011), as amended at 77 FR 49701 (Aug. 17, 2012).

The analysis of power sector emissions uses marginal emissions intensity factors derived from runs of DOE’s National Energy Modeling System – Building Technologies (NEMS-BT) model, described in Chapter 15. DOE used the version of NEMS based on the *Annual Energy Outlook 2013 (AEO 2013).*[1] Each annual version of NEMS incorporates the projected impacts of existing air quality regulations on emissions. *AEO 2013* generally represents current Federal and State legislation and final implementation regulations in place as of the end of December 2012.

Combustion emissions of CH_4 and N_2O are estimated using emissions intensity factors published by the EPA, GHG Emissions Factors Hub.[a] The FFC upstream emissions are estimated based on the methodology developed by Coughlin (2013).[2] The upstream emissions include both emissions from fuel combustion during extraction, processing and transportation of fuel, and “fugitive” emissions (direct leakage to the atmosphere) of CH_4 and CO_2. DOE also reports CO_2 equivalents for methane and nitrous oxide, based on global warming potential over a 100 year time horizon[b].

The emissions intensity factors are expressed in terms of physical units per MWh or MMBtu of site energy savings. Total emissions reductions are estimated using the energy savings calculated in the national impact analysis (chapter 10).

15.2 AIR QUALITY REGULATIONS AND EMISSIONS IMPACTS

SO_2 emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap and trading programs. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for affected EGUs in the 48 contiguous states and the District of Columbia (D.C.). SO_2 emissions from 28 eastern states and D.C. were also limited under the Clean Air

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[a] http://www.epa.gov/climateleadership/guidance/ghg-emissions.html

[b] Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn,G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. *In: Climate Change 2007:The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Page 212.

Interstate Rule (CAIR), which created an allowance-based trading program that that operates along with the Title IV program in those States and D.C. 70 FR 25162 (May 12, 2005). CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) but parts of it remained in effect. See *North Carolina v. EPA*, 550 F.3d 1176 (D.C. Cir. 2008); *North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir. 2008). On July 6, 2011, EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule (CSAPR). 76 FR 48208 (Aug. 8, 2011). On August 21, 2012, the D.C. Circuit issued a decision to vacate CSAPR. See *EME Homer City Generation, LP v. EPA*, 696 F.3d 7, 38 (D.C. Cir. 2012). The court ordered EPA to continue administering CAIR. The *AEO2013* emissions factors used for today's notice of proposed rulemaking assume that CAIR remains a binding regulation through 2040.

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

Beginning in 2015, however, SO_2 emissions will fall as a result of the Mercury and Air Toxics Standards (MATS) for power plants, which were announced by EPA on December 21, 2011. 77 FR 9304 (Feb. 16, 2012).[c] In the final MATS rule, EPA established a standard for hydrogen chloride as a surrogate for acid gas hazardous air pollutants (HAP), and also established a standard for SO_2 (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, SO_2 emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO 2013* assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2015. Both technologies, which are used to reduce acid gas emissions, also reduce SO_2 emissions. Under the MATS, NEMS shows a reduction in SO_2 emissions when electricity demand decreases (e.g., as a result of energy efficiency standards). Emissions will be far below the cap that would be established by CAIR, so it is unlikely that excess SO_2 emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in SO_2 emissions by any regulated EGU. Therefore, DOE believes that efficiency standards will reduce SO_2 emissions in 2015 and beyond.

CAIR established a cap on NO_x emissions in 28 eastern States and the District of Columbia. Energy conservation standards are expected to have little effect on NO_x emissions in those States covered by CAIR because excess NO_x emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in NO_x emissions.

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[c] On July 20, 2012, EPA announced a partial stay, for a limited duration, of the effectiveness of national new source emission standards for hazardous air pollutants from coal- and oil-fired electric utility steam generating units. <www.epa.gov/airquality/powerplanttoxics/pdfs/20120727staynotice.pdf>

However, standards would be expected to reduce NO_x emissions in the States not affected by CSAPR , so DOE estimated NOx emissions reductions from potential standards for those States.

The MATS limit mercury emissions from power plants, but they do not include emissions caps and, as such, DOE's energy conservation standards would likely reduce Hg emissions. DOE estimated mercury emissions reductions using the NEMS-BT based on *AEO 2013*, which incorporates the MATS.

15.3 POWER SECTOR EMISSIONS FACTORS

The analysis of power sector emissions uses marginal emissions intensity factors derived from runs of DOE's NEMS-BT model, using the version updated to the *Annual Energy Outlook 2013 (AEO 2013),* To model the impact of a standard, DOE inputs a reduction to annual energy demand for the corresponding end use in the appropriate start year. The NEMS-BT model is run with the decremented energy demand to determine the modified build-out of capacity, fuel use and power sector emissions. A marginal emissions intensity factor is defined by dividing the reduction in the total emissions of a given pollutant by the reduction in total generation (in billion kWh). DOE uses the site energy savings multiplied by a T&D loss factor to estimate the reduction in generation for each TSL. Details on the approach used may be found in Coughlin (2012).[2]

Table 15.3.1 presents the average power plant emissions factors for selected years. These power plant emissions factors are derived from the emissions factors of the plant types used to supply electricity to homes. DOE did not have data on the load shape of furnace fans, so it used a load shape that has constant energy use and is used when the building is occupied. The average factors for each year take into account the projected shares of each of the sources in total electricity generation.

The power plant emissions factor for NOx is an average for the entire U.S. The marginal calculation based on the NEMS-BT model accounts for the fact that NOx emissions are capped in some States.

Table 15.3.1 Power Plant Emissions Factors

	Unit*	**2017**	**2020**	**2025**	**2030**	**2035**	**2040**
CO_2	kg/MWh	598	598	563	514	452	305
SO_2	g/MWh	572	572	704	708	364	461
NOx	g/MWh	394	394	394	303	215	191
Hg	g/MWh	0.0014	0.0014	0.0005	0.0009	0.0005	0.0007
N_2O	g/MWh	7.0	7.2	7.2	7.1	7.1	6.9
CH_4	g/MWh	49	50	50	50	49	48

* Refers to site electricity savings.

15.4 UPSTREAM AND GHG EMISSIONS FACTORS

The upstream emissions accounting uses the same approach as the upstream energy accounting described in appendix 10-B. See also Coughlin (2012).[2] When demand for a particular fuel is reduced, there is a corresponding reduction in the emissions from combustion of that fuel at either the building site or the power plant. The associated reduction in energy use for upstream activities leads to further reductions in emissions. These upstream emissions are defined to include the combustion emissions from the fuel used upstream, the fugitive emissions associated with the fuel used upstream, and the fugitive emissions associated with the fuel used on site.

Fugitive emissions of CO_2 occur during oil and gas production, but are small relative to combustion emissions. They comprise about 2.5% of total CO_2 emissions for natural gas and 1.7% for petroleum fuels. Fugitive emissions of methane occur during oil, gas and coal production. Combustion emissions of CH_4 are very small, while fugitive emissions (particularly for gas production) may be relatively large. Hence, fugitive emissions make up over 99% of total methane emissions for natural gas, about 95% for coal, and 93% for petroleum fuels.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. For ease of application in its analysis, DOE developed all of the emissions factors using site (point of use) energy savings in the denominator. presents the electricity upstream emissions factors for selected years. The caps that apply to power sector NO_x emissions do not apply to upstream combustion sources.

Table 15.4.1 Electricity Upstream Emissions Factors

	Unit	2015	2020	2025	2030	2035	2040
CO_2	kg/MWh	28.1	27.3	26.9	26.8	26.9	26.3
SO_2	g/MWh	10.2	5.3	5.3	5.2	5.2	5.1
NOx	g/MWh	355	340	334	333	336	329
Hg	g/MWh	0.00006	0.00001	0.00001	0.00001	0.00001	0.00001
N_2O	g/MWh	0.26	0.25	0.25	0.25	0.24	0.24
CH_4	g/MWh	2083	2025	2008	2025	2057	1999

15.5 EMISSIONS IMPACT RESULTS

Table 15.5.1 presents the estimated cumulative emissions reductions for the lifetime of equipment sold in 2017-2046 for each TSL.

Table 15.5.1 Cumulative Emissions Reduction for Potential Standards for Walk-in Coolers and Freezers

	TSL					
	1	**2**	**3**	**4**	**5**	**6**
Power Sector and Site Emissions						
CO_2 (million metric tons)	234.32	240.95	246.75	281.35	299.79	345.05
NO_X (thousand tons)	178.96	183.22	188.62	214.60	228.76	263.66
Hg (tons)	0.52	0.53	0.54	0.62	0.66	0.76
N_2O (thousand tons)	5.22	5.33	5.51	6.26	6.67	7.70
CH_4 (thousand tons)	29.18	29.98	30.74	35.03	37.33	42.98
SO_2 (thousand tons)	313.03	322.01	329.61	375.89	400.52	460.93
Upstream Emissions						
CO_2 (million metric tons)	13.87	14.27	14.61	16.66	17.75	20.43
NO_X (thousand tons)	190.90	196.36	201.02	229.24	244.26	281.10
Hg (tons)	0.01	0.01	0.01	0.01	0.01	0.01
N_2O (thousand tons)	0.14	0.14	0.15	0.17	0.18	0.21
CH_4 (thousand tons)	1,159.66	1,192.72	1,221.16	1,392.52	1,483.77	1,707.59
SO_2 (thousand tons)	2.97	3.06	3.13	3.57	3.80	4.38
Total Emissions						

CO_2 (million metric tons)	248.19	255.22	261.36	298.01	317.54	365.48
NO_X (thousand tons)	369.85	379.58	389.64	443.84	473.02	544.76
Hg (tons)	0.52	0.54	0.55	0.63	0.67	0.77
N_2O (thousand tons)	5.36	5.48	5.65	6.43	6.85	7.90
CH_4 (thousand tons)	1,188.84	1,222.70	1,251.90	1,427.56	1,521.10	1,750.57
SO_2 (thousand tons)	316.00	325.06	332.74	379.46	404.32	465.31

Figure 15.5.1 through Figure 15.5.6 show the annual reductions for total emissions for each type of emission from each TSL. The reductions reflect the lifetime impacts of equipment sold in 2017-2046.

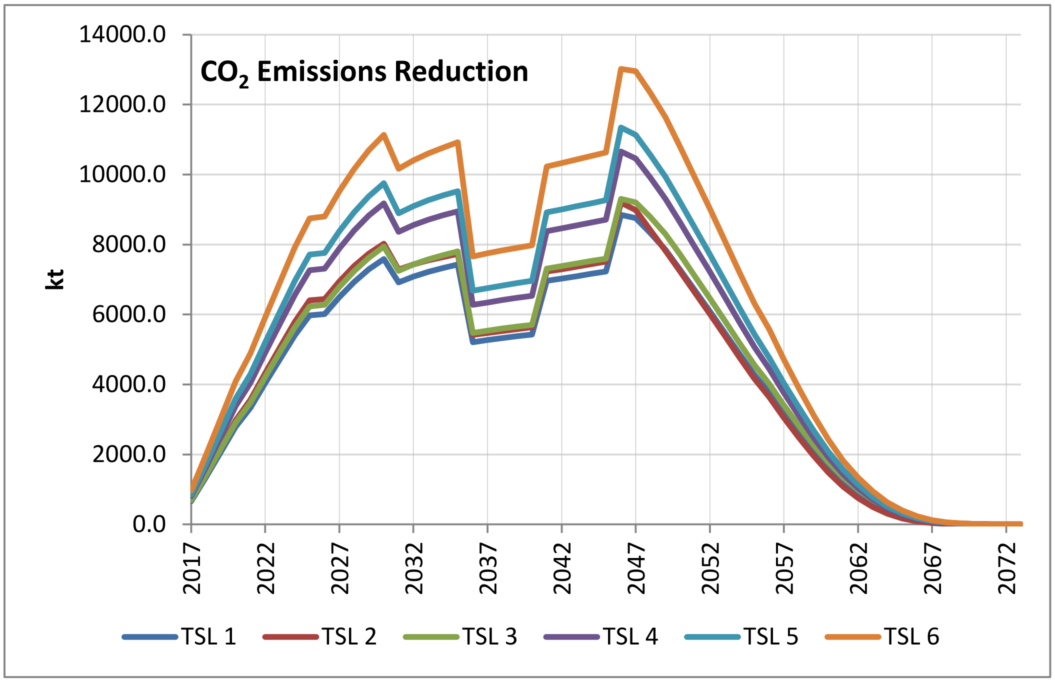

Figure 15.5.1 Walk-in Cooler and Freezer Equipment: CO2 Emissions Reduction

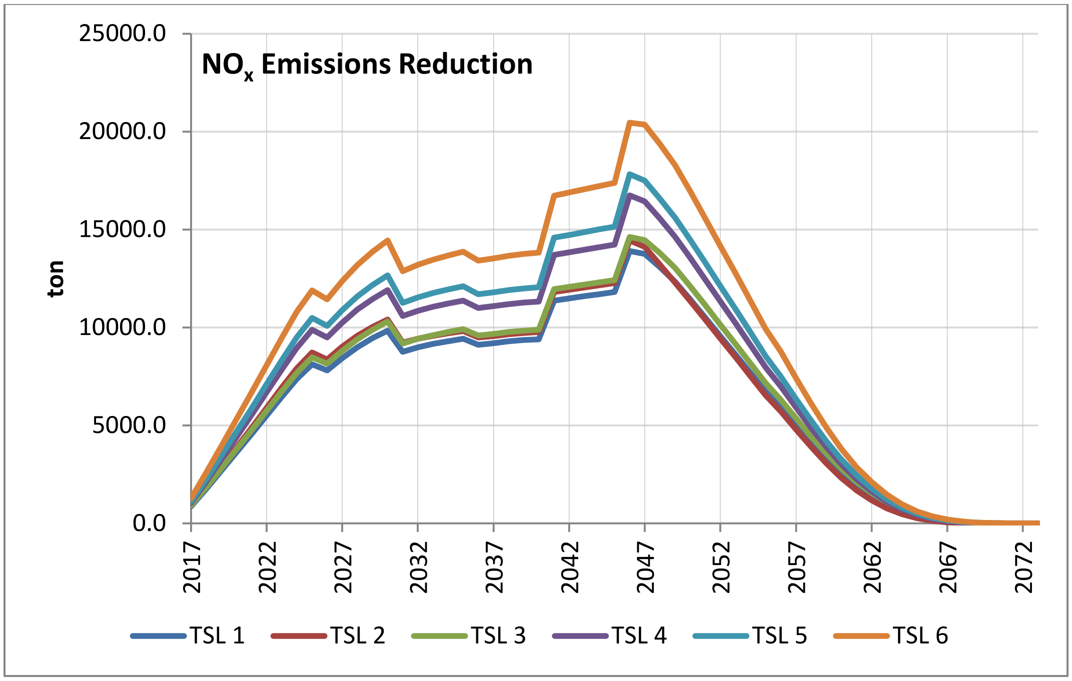

Figure 15.5.2 Walk-in Cooler and Freezer Equipment: NOx Emissions Reduction

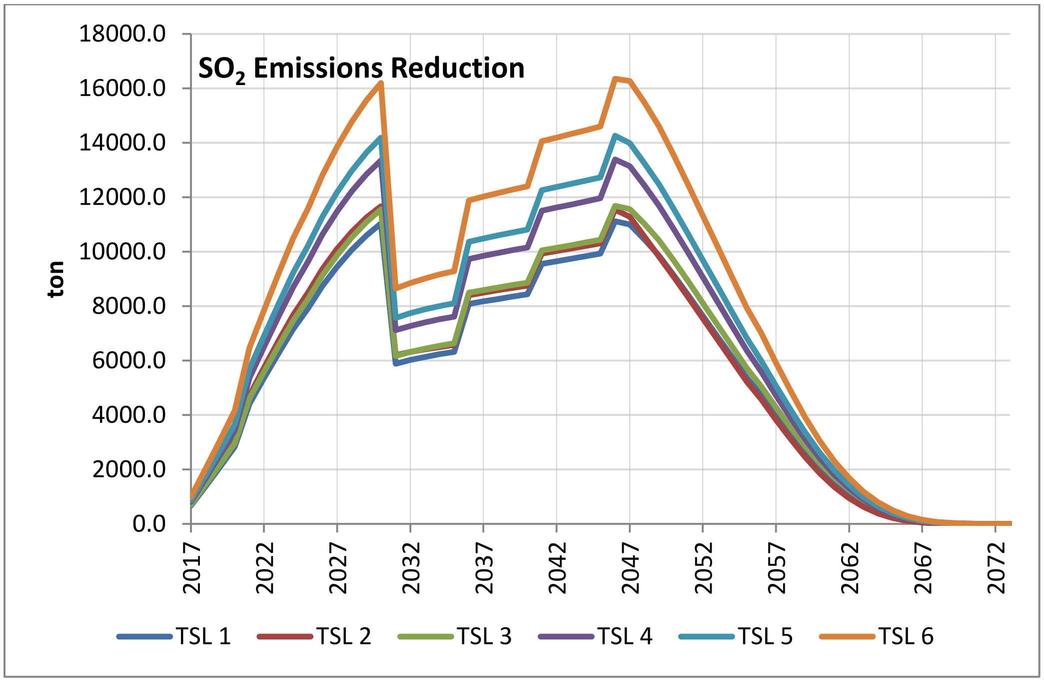

Figure 15.5.3 Walk-in Cooler and Freezer Equipment: SO2 Emissions Reduction

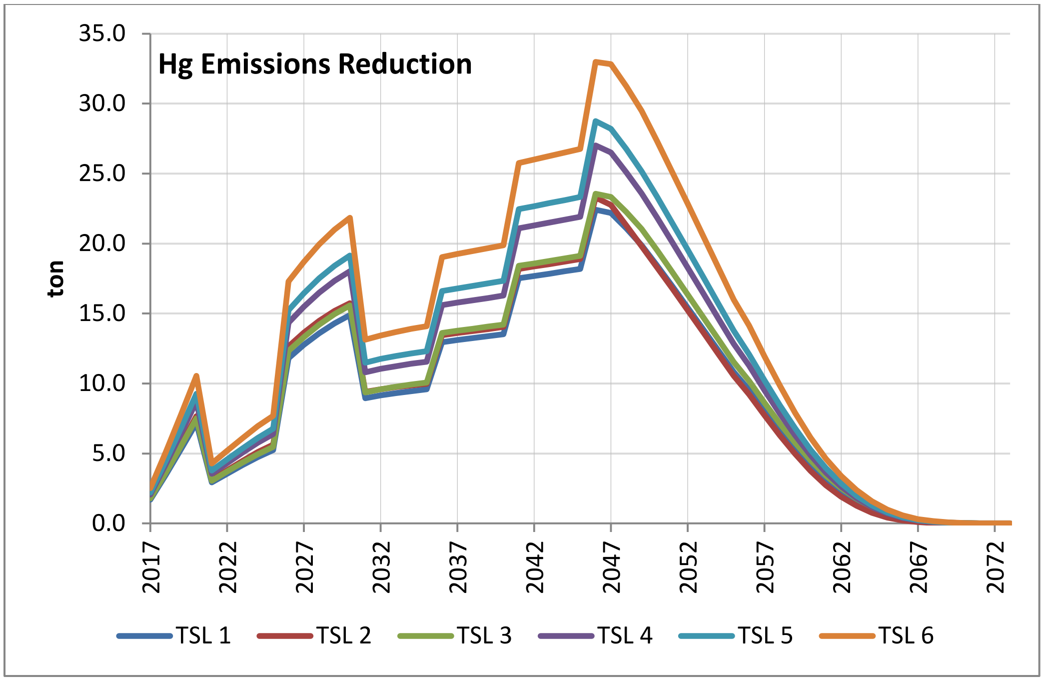

Figure 15.5.4 Walk-in Cooler and Freezer Equipment: Hg Emissions Reduction

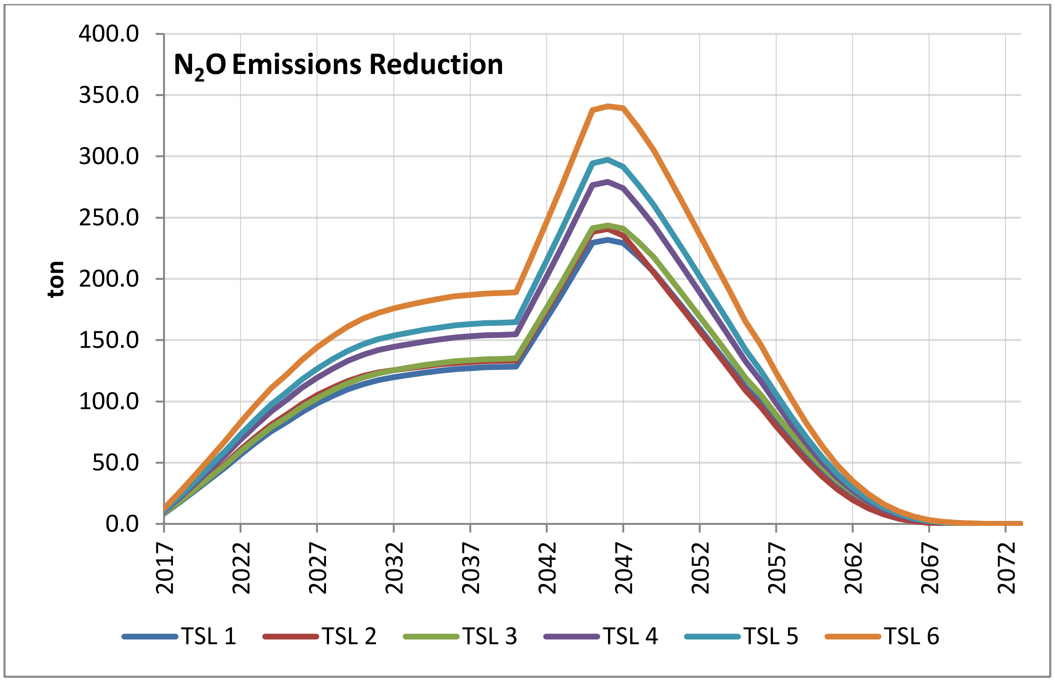

Figure 15.5.5 Walk-in Cooler and Freezer Equipment: N2O Emissions Reduction

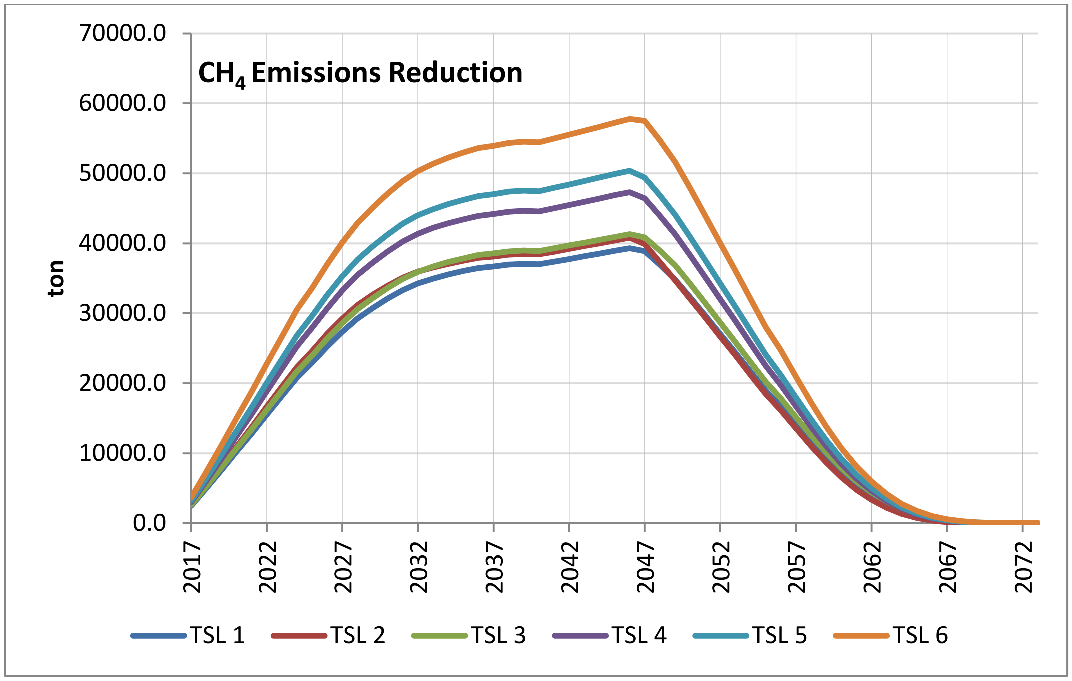

Figure 15.5.6 Walk-in Cooler and Freezer Equipment: CH4 Emissions Reduction

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CHAPTER 16. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 16. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

INTRODUCTION

As part of its assessment of energy conservation standards for walk-in coolers and freezers (WICF), DOE estimated the monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_X) that are expected to result from each of the TSLs considered. This chapter summarizes the basis for the monetary values used for each of these emissions and presents the benefits estimates considered.

MONETIZING CARBON DIOXIDE EMISSIONS

Social Cost of Carbon

The social cost of carbon (SCC) is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. Estimates of the SCC are provided in dollars per metric ton of carbon dioxide. 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.

Under section 1(b)(6) 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 SCC estimates presented here is to allow agencies to incorporate the monetized social benefits of reducing CO_2 emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

As part of the interagency process that developed these SCC estimates, technical experts from numerous agencies met on a regular basis to explore the technical literature in relevant fields, discuss key model inputs and assumptions, and consider public comments. 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.

Monetizing Carbon Dioxide Emissions

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A report from the National Research Council[1] 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. 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.

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.[2] These interim values represented the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules.

Current Approach and Key Assumptions

After 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.[a] 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 quantifying damages taken by the key modelers in the field. An extensive review of the literature

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[a] The models are described in appendix 16-A of the TSD.

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. The values grow in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although preference is given to consideration of the global benefits of reducing CO_2 emissions. Table 16.2.1 presents the values in the 2010 interagency group report,[b] which is reproduced in appendix 16-A of the TSD.

The SCC values used for this analysis were generated using the most recent versions of the three integrated assessment models that have been published in the peer-reviewed literature.[c] Table 16.2.2 shows the updated sets of SCC estimates in five year increments from 2010 to 2050. The full set of annual SCC estimates between 2010 and 2050 is reported in appendix 16-B of the TSD. The central value that emerges is the average SCC across models at the 3 percent discount rate. However, for purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance of including all four sets of SCC values.

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[b] *Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Interagency Working Group on Social Cost of Carbon, United States Government, February 2010. http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf.

[c] *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. Interagency Working Group on Social Cost of Carbon, United States Government*. May 2013. http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf

Table 16.2.1 Annual SCC Values from 2010 Interagency Report, 2010 – 2050 (in 2007 dollars per metric ton)

Year	**Discount Rate %**			
	5	3	2.5	3
	Average	Average	Average	95th Percentile
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

Table 16.2.2 Annual SCC Values from 2013 Interagency Update, 2010–2050 (in 2007 dollars per metric ton CO_2)

Year	**Discount Rate %**			
	5	3	2.5	3
	Average	Average	Average	95th Percentile
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Research Council report mentioned above points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. There are a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC. The interagency group 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 summary, in considering the potential global benefits resulting from reduced CO_2 emissions, DOE used the values from the 2013 interagency report, escalated to 2012$ using the GDP price deflator. For each of the four cases specified, the values used for emissions in 2015 were $12.9, $40.8, $62.2, and $117.0 per metric ton avoided.

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

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 13, new or amended energy conservation standards would reduce NO_X emissions in those States that are not affected by caps. DOE estimated the monetized value of NO_X emissions reductions resulting from each of the TSLs considered based on environmental damage estimates found in the relevant scientific literature. Available estimates suggest a very wide range of monetary values, ranging from \$468 to \$4,809 per ton in 2012\$).[4] In accordance with OMB guidance, DOE calculated a range of monetary benefits using each of the economic values for NO_X and real discount rates of 3 percent and 7 percent.[5]

DOE is still evaluating appropriate values to use to monetize avoided SO_2 and Hg emissions. It did not monetize these emissions for this analysis.

RESULTS

Table 16.4.1presents the global values of CO_2 emissions reductions for each considered TSL. DOE calculated domestic values as a range from 7 percent to 23 percent of the global values, and these results are presented in Table 16.4.2.

Table 16.4.1 Estimates of Global Present Value of CO_2 Emissions Reduction under WICF Standard Levels

TSL	SCC Case*			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
	Million 2012$			
Primary Energy Emissions				
1	1,477	7,032	11,276	21,608
2	1,532	7,270	11,648	22,334
3	1,553	7,396	11,863	22,730
4	1,778	8,456	13,557	25,982
5	1,893	9,005	14,438	27,671
6	2,173	10,349	16,597	31,803
Upstream Emissions				
1	87	415	666	1,277
2	90	429	688	1,320
3	91	437	701	1,343
4	104	499	801	1,535
5	111	532	853	1,635
6	128	611	980	1,879
Total Emissions				
1	1,564	7,447	11,942	22,885
2	1,622	7,699	12,336	23,654
3	1,644	7,833	12,564	24,074
4	1,882	8,955	14,357	27,518
5	2,004	9,536	15,291	29,306
6	2,301	10,959	17,577	33,682

* For each of the four cases, the corresponding SCC value for emissions in 2015 is $12.9, $40.8, $62.2, and $117.0 per metric ton (2012$).

Table 16.4.2 Estimates of Domestic Present Value of CO_2 Emissions Reduction under WICF Trial Standard Levels

TSL	SCC Case*			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
	Million 2012$			
Primary Energy Emissions				
1	103.4 to 339.7	492.2 to 1,617.3	789.3 to 2,593.6	1,512.6 to 4,969.9
2	107.3 to 352.5	508.9 to 1,672.1	815.4 to 2,679.1	1,563.4 to 5,136.9
3	108.7 to 357.1	517.7 to 1,701.1	830.4 to 2,728.6	1,591.1 to 5,228.0
4	124.5 to 408.9	591.9 to 1,944.8	949.0 to 3,118.0	1,818.8 to 5,975.9
5	132.5 to 435.3	630.3 to 2,071.1	1,010.7 to 3,320.8	1,936.9 to 6,364.2
6	152.1 to 499.8	724.4 to 2,380.2	1,161.8 to 3,817.4	2,226.2 to 7,314.6
Upstream Emissions				
1	6.1 to 20.0	29.1 to 95.5	46.6 to 153.2	89.4 to 293.7
2	6.3 to 20.7	30.0 to 98.7	48.1 to 158.2	92.4 to 303.5
3	6.4 to 21.0	30.6 to 100.4	49.0 to 161.1	94.0 to 309.0
4	7.3 to 24.0	34.9 to 114.8	56.0 to 184.1	107.5 to 353.1
5	7.8 to 25.6	37.2 to 122.3	59.7 to 196.1	114.5 to 376.1
6	8.9 to 29.4	42.8 to 140.5	68.6 to 225.4	131.6 to 432.3
Total Emissions				
1	109.5 to 359.7	521.3 to 1,712.7	836.0 to 2,746.7	1,602.0 to 5,263.6
2	113.6 to 373.2	538.9 to 1,770.8	863.5 to 2,837.3	1,655.8 to 5,440.4
3	115.1 to 378.1	548.3 to 1,801.6	879.5 to 2,889.7	1,685.1 to 5,536.9
4	131.8 to 432.9	626.8 to 2,059.6	1,005.0 to 3,302.2	1,926.2 to 6,329.1
5	140.3 to 460.9	667.5 to 2,193.4	1,070.4 to 3,517.0	2,051.4 to 6,740.3
6	161.0 to 529.2	767.2 to 2,520.7	1,230.4 to 4,042.8	2,357.7 to 7,746.9

* For each of the four cases, the corresponding SCC value for emissions in 2015 is $12.9, $40.8, $62.2, and $117.0 per metric ton (2012$).

Table 16.4.3 presents the present value of cumulative NO_X emissions reductions for each TSL, calculated using the average dollar-per-ton value of $2,639 at seven-percent and three-percent discount rates.

Table 16.4.3 Estimates of Present Value of NO_X Emissions Reduction under WICF Standard Levels

TSL	3% discount rate	7% discount rate
	Million 2012$	
Power Sector Emissions		
1	219.7	96.3
2	227.7	101.0
3	231.0	100.9
4	264.4	116.2
5	281.5	123.6
6	323.3	141.4
Upstream Emissions		
1	240.1	105.4
2	249.4	110.5
3	252.3	110.5
4	289.1	127.2
5	307.7	135.3
6	353.1	154.8
Total Emissions		
1	459.8	201.6
2	477.1	211.4
3	483.3	211.4
4	553.5	243.5
5	589.2	258.9
6	676.5	296.3

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CHAPTER 17. REGULATORY IMPACT ANALYSIS FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR WALK-IN COOLERS AND FREEZERS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 17. REGULATORY IMPACT ANALYSIS FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR WALK-IN COOLERS AND FREEZERS

17.1 INTRODUCTION

Under the Process Rule (*Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products*, 61 FR 36974 (July 15, 1996)), the U.S. Department of Energy (DOE) is committed to continually explore non-regulatory alternatives to standards. DOE will prepare a draft regulatory impact analysis pursuant to E.O. 12866, *Regulatory Planning and Review*, which will be subject to review under the Executive Order by the Office of Management and Budget's Office of Information and Regulatory Affairs. 58 FR 51735 (Oct. 4, 1993). DOE has identified five major alternatives to standards as representing feasible policy options to reduce walk-in cooler and freezer (WICF or walk-in) energy consumption. DOE has evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compares the effectiveness of each one to the effectiveness of the proposed standards rule.

The non-regulatory means of achieving energy savings that DOE proposes to analyze are listed in Table 17.1.1. In support of DOE's notice of proposed rulemaking, DOE includes a quantitative analysis of each alternative, the methodology for which is discussed briefly below in this technical support document (TSD).

Table 17.1.1 Non-Regulatory Alternatives to Standards

No new regulatory action
Consumer tax credits
Customer rebates
Voluntary energy efficiency targets
Early replacement

17.2 METHODOLOGY

DOE will use the national impact analysis (NIA) spreadsheet models to calculate the national energy savings (NES) and the net present value (NPV) corresponding to each alternative to the proposed standards. The NIA model is discussed in chapter 10 of this TSD. To compare each alternative quantitatively to the proposed energy conservation standards, DOE quantifies the effect of each alternative on the purchase and use of energy efficient walk-in coolers and freezers. Once it has quantified each alternative, DOE will make the appropriate revisions to the inputs in the NIA models to estimate energy savings compared with the base case scenario. Key inputs that DOE may revise in these models are:

- energy prices and escalation factors;
- implicit market discount rates for trading off purchase price against operating expense when choosing product efficiency;
- business purchase prices and operating costs;
- purchase price-versus-efficiency relationships; and

- product stock data.

The key measures of the impact of each alternative will be:

- Energy use: Cumulative energy use of the equipment shipped from the effective date of the new standard to the year 2073.
- National energy savings: Cumulative national energy use from the base case projection minus the alternative policy case projection, given in quadrillion British thermal units (quads).
- Net present value: Represents the value in 2012$ (discounted to 2013) of net monetary savings from products bought during the period from the effective date of the policy (2017) through the end of the life of all purchased equipment during the analysis period (2073).

17.3 NON-REGULATORY POLICIES

17.3.1 No New Regulatory Action

The base case is the one in which no new regulatory action is taken with regard to the energy efficiency of walk-ins, as described in the NIA (chapter 10 of this TSD). 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

Consumer rebates cover a portion of the difference in incremental product price between products meeting baseline efficacy levels and those meeting higher efficacy levels, resulting in a higher percentage of consumers purchasing more efficacious models and decreased aggregated energy use compared to the base case. Because DOE does not have demand elasticity data specific to walk-ins, DOE assumed a rebate that paid 100 percent of the incremental product price.

DOE's previous research[1] showed that for the rebate amount that was equal to the full incremental cost, consumer response rate was about 25 percent. However, this research describes the response rates for residential customers. Because WICF equipment is purchased by commercial customers, DOE assumed that responses rates would be twice as high because such incentives directly influence a firm's accounting profits. Therefore, for a rebate worth 100 percent of the incremental cost, DOE assumed a response rate of 50 percent and estimated a corresponding shift of 50 percent in market shares to the proposed trial standard level's (TSL's) efficient products, with no change in total shipments. DOE estimated NPV and NES values under these assumptions and the results are presented in Table 17.3.1 and Table 17.3.2.

Although the rebate program reduces the total installed cost to the customer, it is financed by tax revenues. Therefore, from a societal perspective, the installed cost at any efficiency level does *not* change with the rebate program; rather, part of the cost is transferred from the consumer to taxpayers as a whole. Consequently, DOE assumed that equipment costs in the rebates scenario were identical to the NIA base case.

DOE assumed that rebates would remain in effect for the duration of the analysis period.

Table 17.3.1 Consumer Rebate Energy Savings and NPV for Refrigeration Systems

Policy Alternatives	**Primary Energy Savings*** **2017–2073** ***quads***	**Net Present Value** 2017-2073** ***billion 2012$***	
		7% Discount Rate	**3% Discount Rate**
No new regulatory action	0	0	0
Consumer rebates (100% scenario)	2.06	2.62	8.54
Today's standards at TSL 4	4.13	8.48	23.31

[*] Energy savings are in source quads.

[**] Net present value is the value in the present of a time series of costs and savings.

Table 17.3.2 Consumer Rebate Energy Savings and NPV for Envelope Components (Panels and Doors)

Policy Alternatives	**Primary Energy Savings*** **2017–2073** ***quads***	**Net Present Value** 2017-2073** ***billion 2012$***	
		7% Discount Rate	**3% Discount Rate**
No new regulatory action	0	0	0
Consumer rebates (100% scenario)	0.59	0.39	1.19
Today's standards at TSL 4	1.18	1.47	4.66

[*] Energy savings are in source quads.

[**] Net present value is the value in the present of a time series of costs and savings.

17.3.3 Consumer Tax Credits

Consumer tax credits are considered a viable non-regulatory market transformation program, as shown by the inclusion of Federal consumer tax credits in the Energy Policy Act of 2005 (EPACT 2005; Pub L. 109-58, 119 Stat 1026 (2005)) for various residential appliances. From a consumer perspective, the most important difference between rebate and tax credit programs is that a rebate can be obtained relatively quickly, whereas receipt of tax credits is delayed until income taxes are filed or a tax refund is provided by the Internal Revenue Service (IRS).

As with consumer rebates, DOE assumed that consumer tax credits paid 100 percent of the incremental product price, but estimated a different response rate. The delay in reimbursement makes tax credits less attractive than rebates; consequently, DOE estimated a response rate that is 80 percent of that for rebate programs, or 40 percent, and therefore estimated a corresponding shift of 40 percent in market shares to the proposed TSL's efficient products, with no change in total shipments. DOE estimated NPV and NES values under these assumptions and the results are presented in Table 17.3.3 and Table 17.3.4.

From a societal perspective, tax credits (like rebates) do not change the installed cost of the equipment, but rather transfer a portion of the cost from the consumer to taxpayers as a whole. DOE, therefore, assumed that equipment costs in the consumer tax credits scenario were identical to the NIA base case.

DOE assumed that tax credits would remain in effect for the duration of the analysis period.

Table 17.3.3 Tax Credit Energy Savings and NPV for Refrigeration Systems

Policy Alternatives	Primary Energy Savings[*] 2017–2073 *quads*	Net Present Value** 2017-2073 *billion 2012$*	
		7% Discount Rate	**3% Discount Rate**
No new regulatory action	0	0	0
Consumer tax credits (100% incremental price scenario)	1.65	1.45	5.59
Today's standards at TSL 4	4.13	8.48	23.31

[*] Energy savings are in source quads.

[**] Net present value is the value in the present of a time series of costs and savings.

Table 17.3.4 Tax Credit Energy Savings and NPV for Envelope Components (Panels and Doors)

Policy Alternatives	Primary Energy Savings[*] 2017–2073 *quads*	Net Present Value** 2017-2073 *billion 2012$*	
		7% Discount Rate	**3% Discount Rate**
No new regulatory action	0	0	0
Consumer tax credits (100% incremental price scenario)	0.47	0.32	0.50
Today's standards at TSL 4	1.18	1.47	4.66

[*] Energy savings are in source quads.

[**] Net present value is the value in the present of a time series of costs and savings.

17.3.4 Voluntary Energy Efficiency Programs

While it is possible that voluntary programs for equipment would be effective, DOE lacks a quantitative basis to determine how effective such a program might be. As noted previously, broader economic and social considerations are in play than simple economic return to the equipment purchaser. DOE lacks the data necessary to quantitatively project the degree to which such voluntary programs for more expensive, higher efficiency equipment like walk-in coolers and freezers would modify the market.

17.3.5 Early Replacement

Early replacement refers to the replacement of walk-ins before the end of their useful lives. The purpose of this policy is to retrofit or replace old, inefficient equipment with high efficiency units. DOE studied the feasibility of a Federal program to promote early replacement of appliances and equipment under EPACT 1992. In this study, DOE identified Federal policy options for early replacement that include a direct national program, replacement of federally owned equipment, promotion through equipment manufacturers, customer incentives, incentives to utilities, market behavior research, and building regulations.

While cost-effective opportunities to install units that are more efficient exist, DOE determined that a Federal early replacement program is not economically justified because the market for walk-ins is relatively small, especially for federally owned equipment, and distributed across a broad set of customers; thus, the savings are not expected to be significant.

17.4 SUMMARY OF RESULTS FOR NON-REGULATORY ALTERNATIVES

Table 17.4.1 and Table 17.4.2 show the NES and NPV for the non-regulatory alternatives analyzed. The case in which no regulatory action is taken with regard to walk-ins constitutes the base case (or “No Action”) scenario. Since this is the base case, NES and NPV are zero by definition. For comparison, the table includes the results of the NES and NPV for TSL 4 associated with the proposed energy conservation standard. Energy savings are expressed in quads in terms of primary or source energy, which includes generation and transmission losses from electricity utility sector.

Table 17.4.1 Cumulative NES of Non-Regulatory Alternatives Compared to the Proposed Standards for Walk-Ins

Policy Alternatives	**Primary NES** ***quads***
No new regulatory action	0
Consumer tax credits	2.12
Customer rebates	2.65
Voluntary energy efficiency targets	0
Early replacement	0
Proposed standards (TSL 4)	5.30

Table 17.4.2 Cumulative NPV of Non-Regulatory Alternatives Compared to the Proposed Standards for Walk-Ins

Policy Alternatives	**Cumulative Net Present Value** ***billion 2012$***	
	7% Discount	**3% Discount**
No new regulatory action	0	0
Consumer tax credits	1.78	6.09
Customer rebates	3.01	9.74
Voluntary energy efficiency targets	0	0
Early replacement	0	0
Proposed standards (TSL 4)	9.95	27.97

As shown above, none of the policy alternatives DOE examined would achieve close to the amount of energy or monetary savings that could be realized under the proposed rule. Also, implementing either tax credits or customer rebates would incur initial and/or administrative costs that were not considered in this analysis.

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APPENDIX 5A. DETAILED DATA FOR ENGINEERING COST-EFFICIENCY CURVES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX 5A. DETAILED DATA FOR ENGINEERING COST-EFFICIENCY CURVES

5A.1 INTRODUCTION

This appendix provides further details on information presented in the Engineering analysis (TSD chapter 5).

5A.2 PANEL COST-EFFICIENCY CURVES

Table 5.A.2.1 Cost-Efficiency Data for SP.M.SML

Efficiency Level	Daily Energy Use [Btu/h-ft^2-F]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.08	$54	$81	Baseline
L1	0.05	$58	$87	L0 + SOFTNOSE
L2	0.04	$61	$91	L1 + TCK2
L3	0.03	$67	$100	L2 + TCK3
L4	0.03	$73	$108	L3 + TCK4
L5	0.02	$86	$125	L4 + NONE
L6	0.01	$231	$315	L5 + HYB

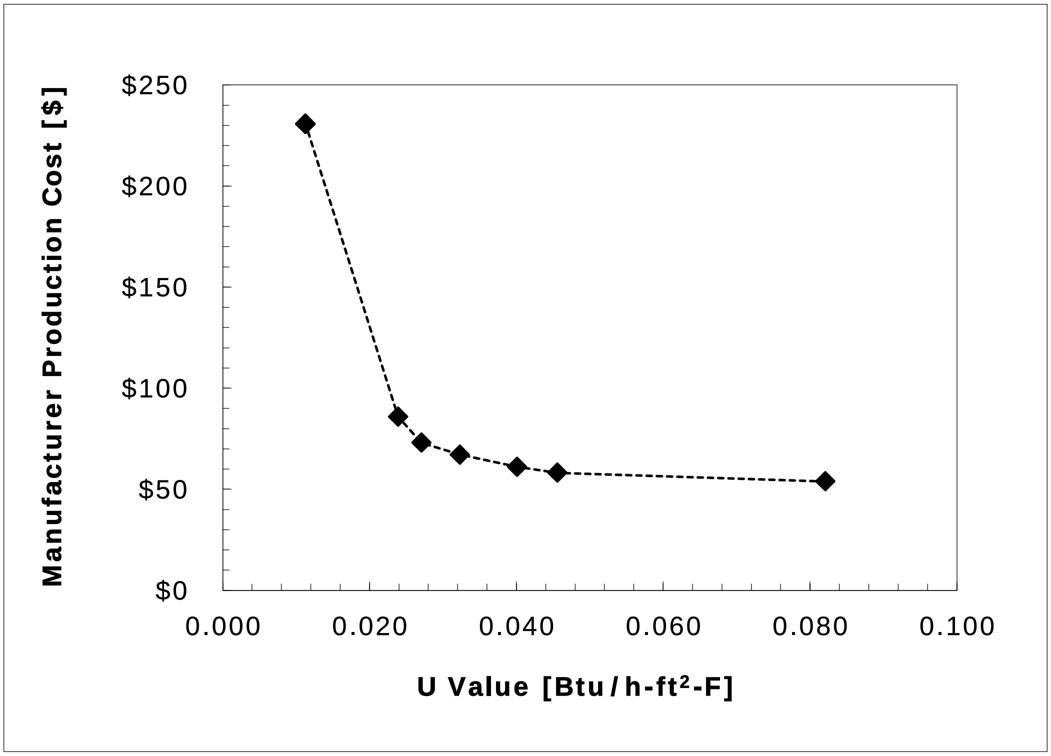


Figure 5A.2.1 Cost-Efficiency Curve for Small Cooler Structural Panel

Table 5A.2.2 Cost-Efficiency Data for SP.M.MED

Efficiency Level	Daily Energy Use [Btu/h-ft^2-F]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.06	$153	$228	Baseline
L1	0.04	$159	$235	L0 + SOFTNOSE
L2	0.04	$165	$245	L1 + TCK2
L3	0.03	$179	$266	L2 + TCK3
L4	0.03	$192	$285	L3 + TCK4
L5	0.02	$229	$335	L4 + NONE
L6	0.01	$615	$839	L5 + HYB

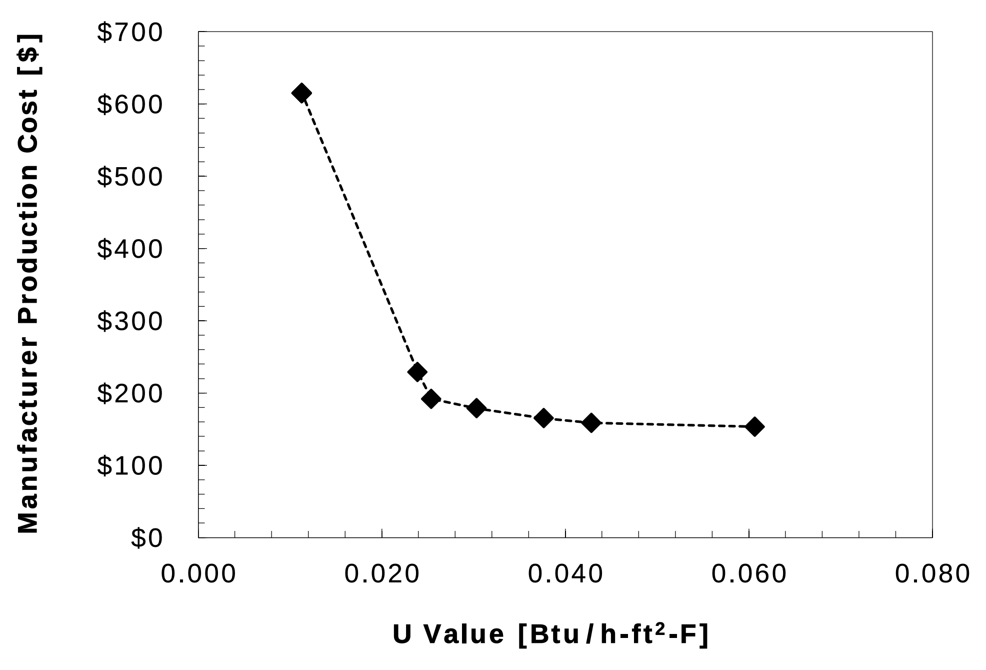


Figure 5A.2.2 Cost-Efficiency Curve for Medium Cooler Structural Panel

Table 5.A.2.3 Cost-Efficiency Data for SP.M.LRG

Efficiency Level	Daily Energy Use (Btu/h-ft^2-F)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.06	$240	$357	Baseline
L1	0.04	$247	$366	L0 + SOFTNOSE
L2	0.04	$256	$380	L1 + TCK2
L3	0.03	$276	$411	L2 + TCK3
L4	0.03	$296	$440	L3 + TCK4
L5	0.02	$354	$517	L4 + NONE
L6	0.01	$951	$1,298	L5 + HYB

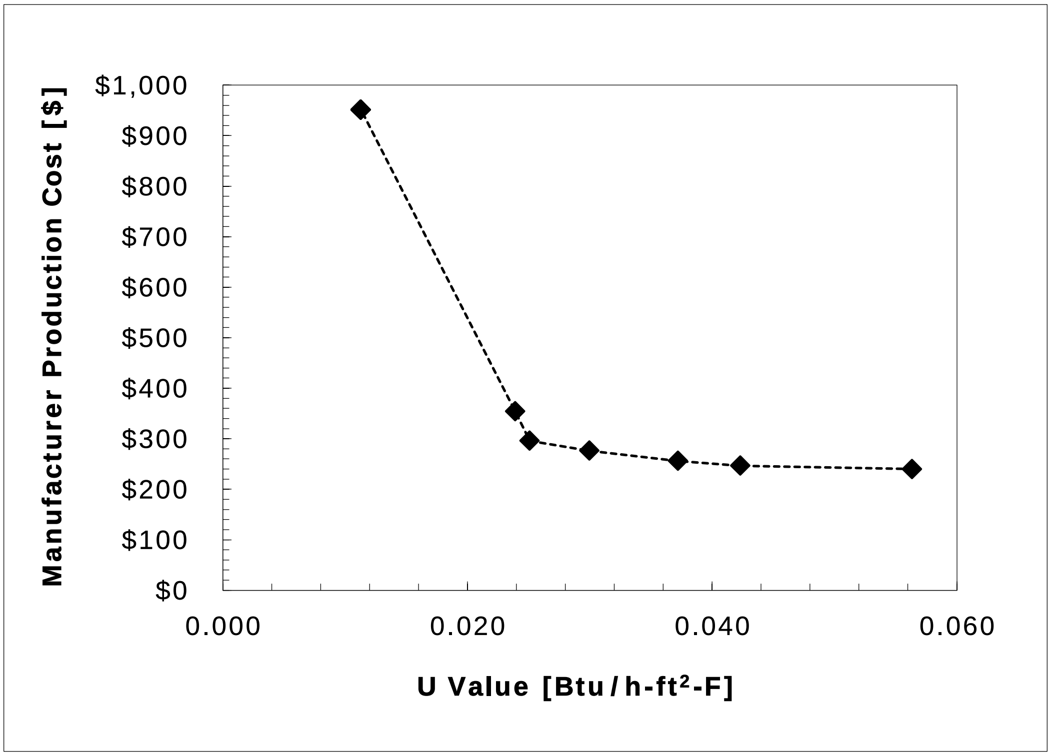


Figure 5A.2.3 Cost-Efficiency Curve for Large Cooler Structural Panel

Table 5A.2.4 Cost-Efficiency Data for SP.L.SML

Efficiency Level	Daily Energy Use (Btu/h-ft^2-F)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.07	$56	$84	Baseline
L1	0.04	$61	$91	L0 + SOFTNOSE
L2	0.03	$67	$100	L1 + TCK2
L3	0.03	$73	$108	L2 + TCK3
L4	0.02	$86	$125	L3 + NONE
L5	0.01	$231	$315	L4 + HYB

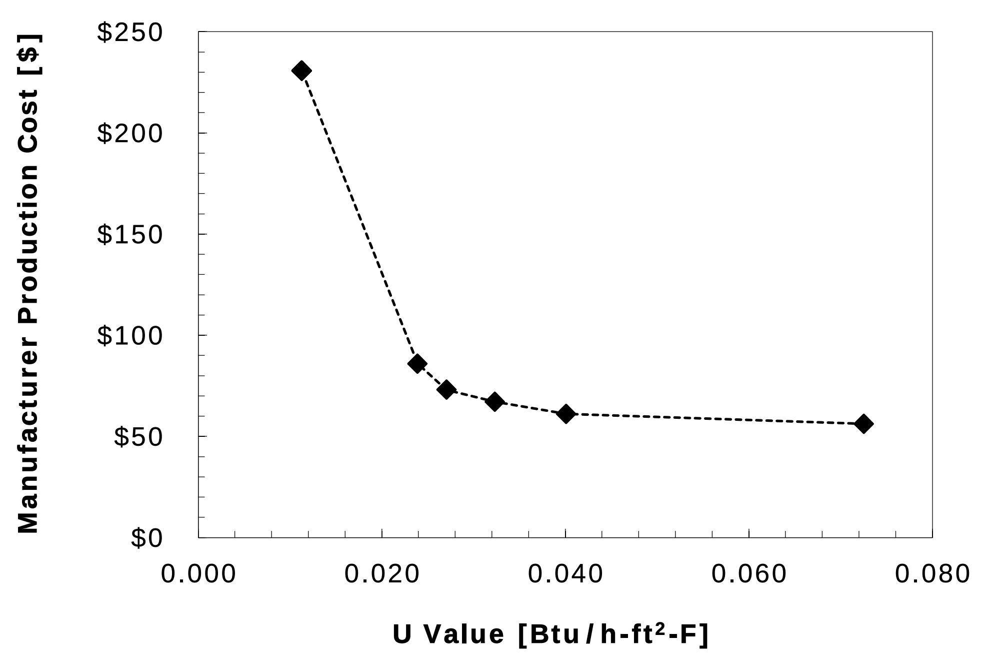


Figure 5A.2.4 Cost-Efficiency Curve for Small Freezer Structural Panel

Table 5A.2.5 Cost-Efficiency Data for SP.L.MED

Efficiency Level	Daily Energy Use (Btu/h-ft^2-F)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.05	$159	$237	Baseline
L1	0.04	$165	$245	L0 + SOFTNOSE
L2	0.03	$179	$266	L1 + TCK2
L3	0.03	$192	$285	L2 + TCK3
L4	0.02	$229	$335	L3 + NONE
L5	0.01	$615	$839	L4 + HYB

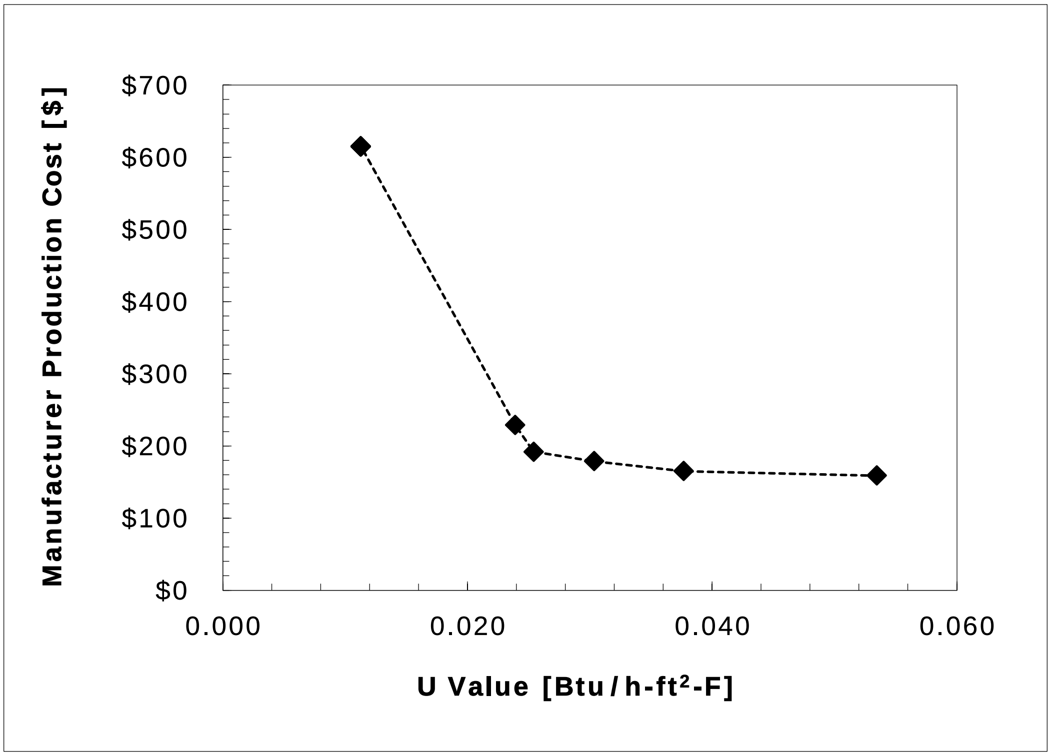


Figure 5A.2.5 Cost-Efficiency Curve for Medium Freezer Structural Panel

Table 5A.2.6 Cost-Efficiency Data for SP.L.LRG

Efficiency Level	Daily Energy Use (Btu/h-ft^2-F)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.05	$249	$370	Baseline
L1	0.04	$256	$380	L0 + SOFTNOSE
L2	0.03	$276	$411	L1 + TCK2
L3	0.03	$296	$440	L2 + TCK3
L4	0.02	$354	$517	L3 + NONE
L5	0.01	$951	$1,298	L4 + HYB

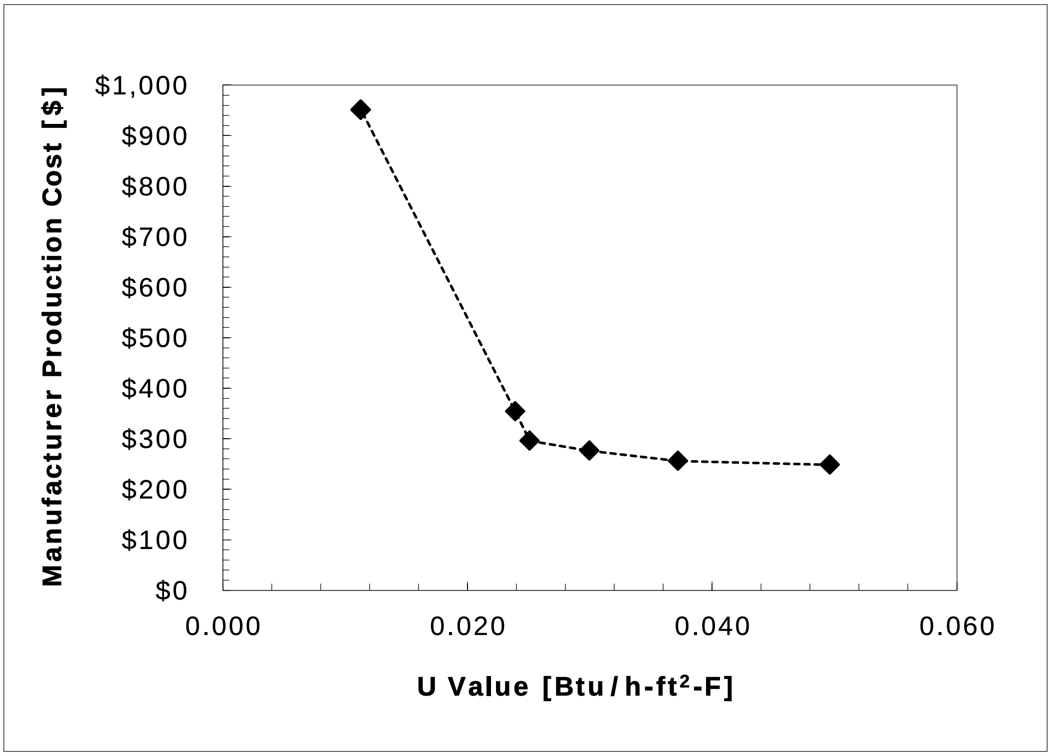


Figure 5A.2.6 Cost-Efficiency Curve for Large Freezer Structural Panel

Table 5A.2.7 Cost-Efficiency Data for FP.L.SML

Efficiency Level	Daily Energy Use (Btu/h-ft^2-F)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.07	$85	$125	Baseline
L1	0.04	$93	$136	L0 + SOFTNOSE
L2	0.04	$97	$141	L1 + TCK2
L3	0.03	$104	$152	L2 + TCK3
L4	0.03	$111	$163	L3 + TCK4
L5	0.02	$270	$369	L4 + HYB

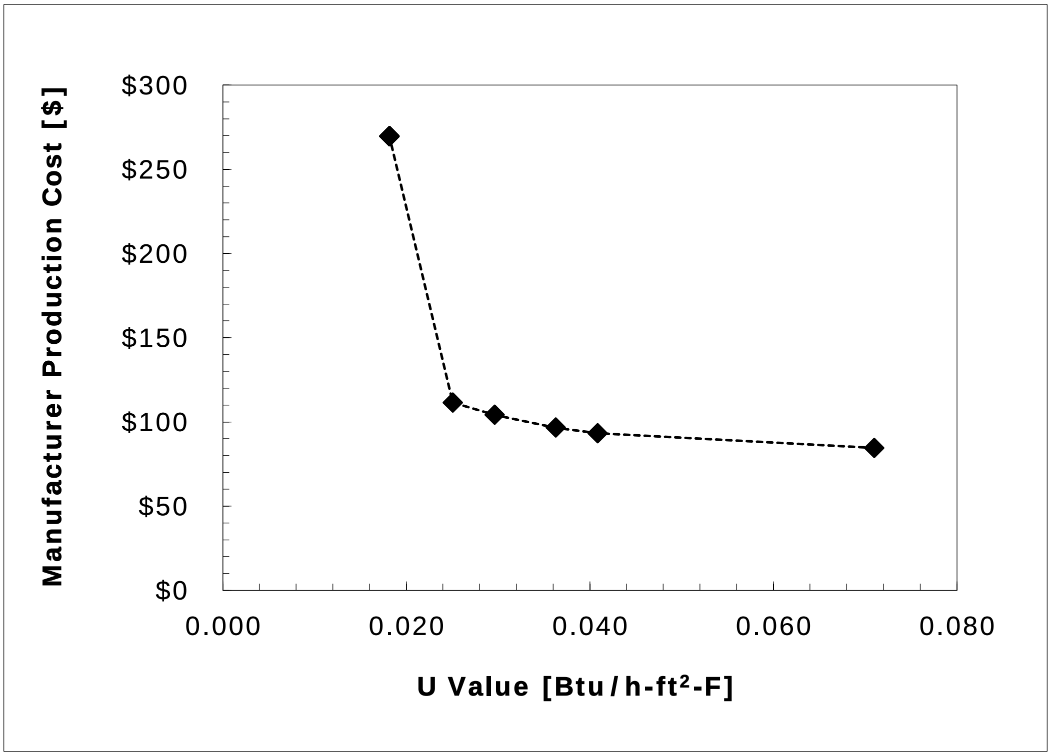


Figure 5A.2.7 Cost-Efficiency Curve for Small Freezer Floor Panel

Table 5A.2.8 Cost-Efficiency Data for FP.F.MED

Efficiency Level	Daily Energy Use (Btu/h-ft^2-F)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.06	$176	$258	Baseline
L1	0.04	$190	$276	L0 + SOFTNOSE
L2	0.04	$195	$285	L1 + TCK2
L3	0.03	$209	$305	L2 + TCK3
L4	0.02	$222	$325	L3 + TCK4
L5	0.02	$566	$774	L4 + HYB

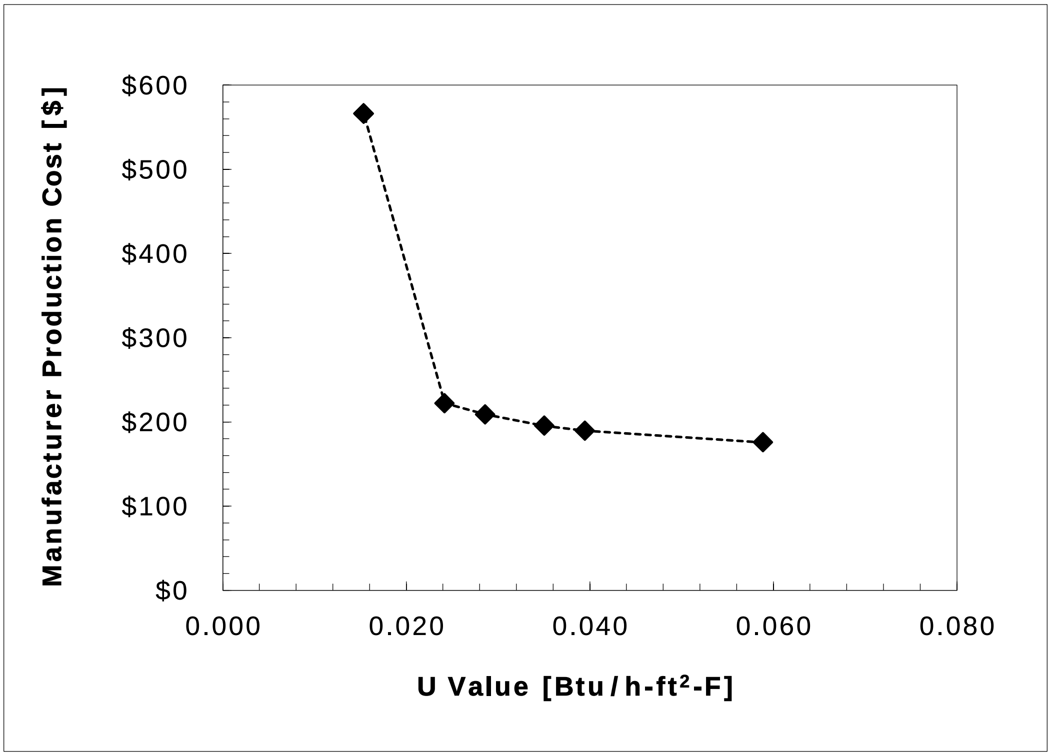


Figure 5A.2.8 Cost-Efficiency Curve for Medium Freezer Floor Panel

Table 5A.2.9 Cost-Efficiency Data for FP.L.LRG

Efficiency Level	Daily Energy Use (Btu/h-ft^2-F)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.05	$301	$441	Baseline
L1	0.04	$322	$468	L0 + SOFTNOSE
L2	0.03	$331	$483	L1 + TCK2
L3	0.03	$353	$516	L2 + TCK3
L4	0.02	$374	$548	L3 + TCK4
L5	0.01	$973	$1,330	L4 + HYB

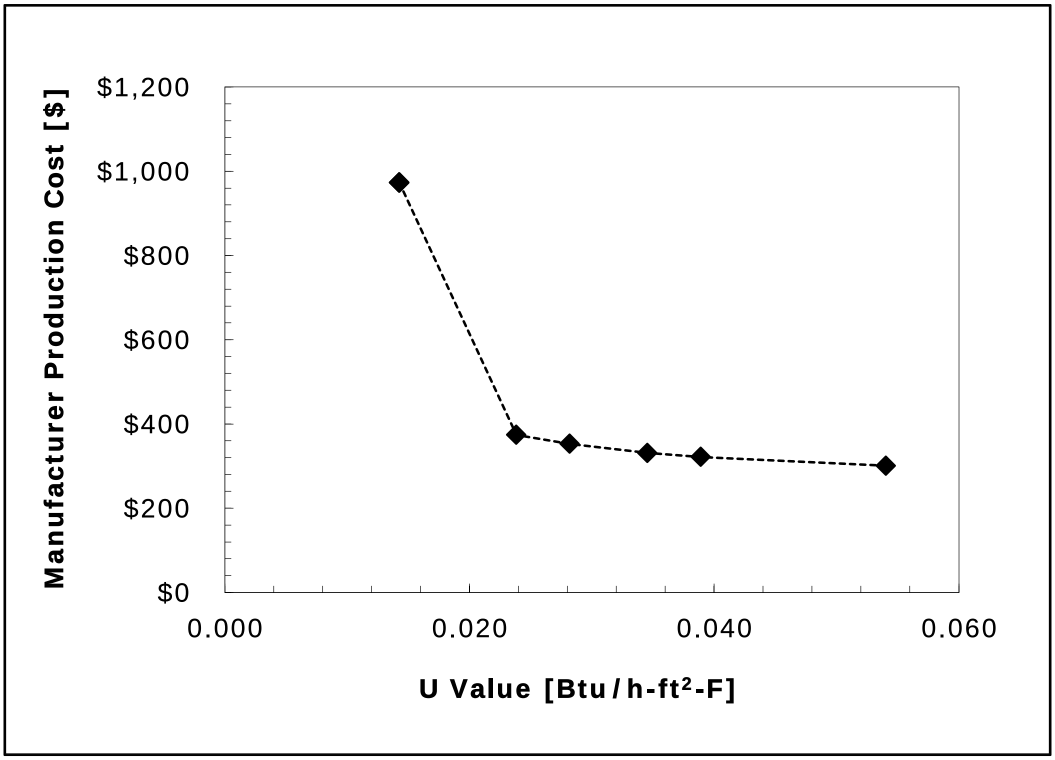


Figure 5A.2.9 Cost-Efficiency Curve for Large Freezer Floor Panel

5A.3 DISPLAY DOOR COST-EFFICIENCY CURVES

Table 5A.3.1 Cost-Efficiency Data for DD.M.SML

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.5	$277	$498	Baseline
L1	1.7	$274	$493	L0 + LT2
L2	1.0	$340	$600	L1 + ASCTRL
L3	0.8	$423	$735	L2 + DR2
L4	0.7	$544	$930	L3 + CS2-L
L5	0.6	$710	$1,199	L4 + DR3
L6	0.4	$1,375	$2,278	L5 + DR4

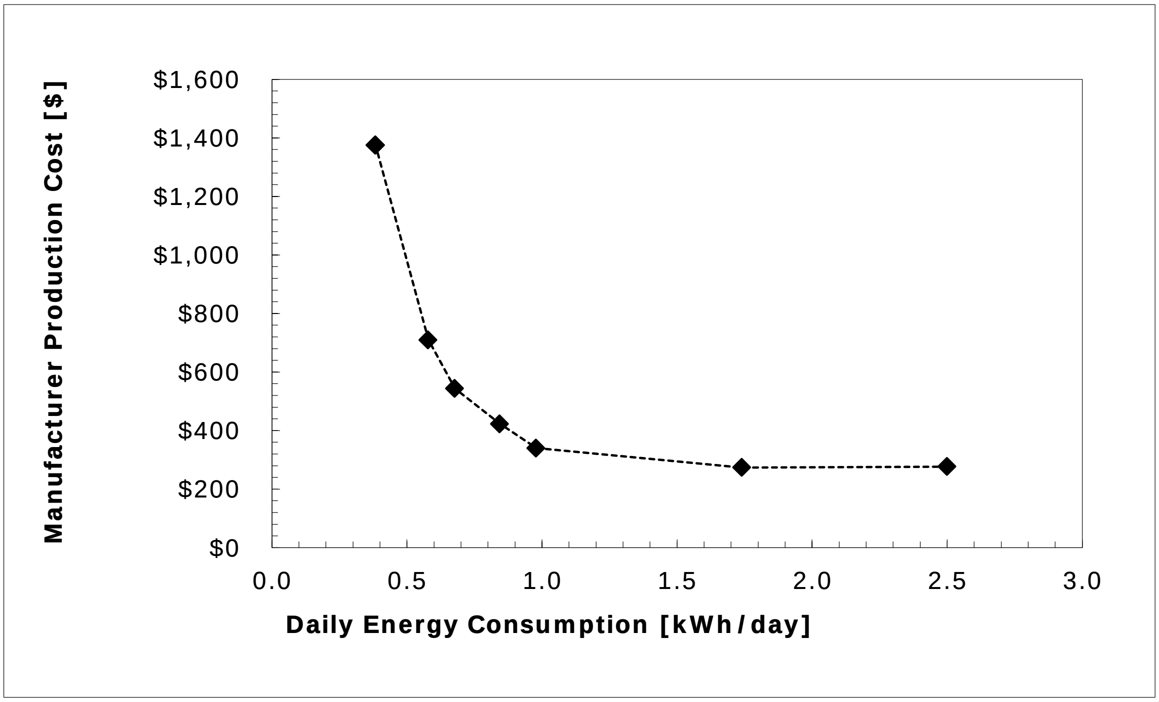


Figure 5A.3.1 Cost-Efficiency Curve for Small Cooler Display Doors

Table 5A.3.2 Cost-Efficiency Data for DD.M.MED

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.9	$357	$644	Baseline
L1	2.2	$354	$639	L0 + LT2
L2	1.1	$420	$746	L1 + ASCTRL
L3	1.0	$530	$924	L2 + DR2
L4	0.8	$651	$1,120	L3 + CS2-L
L5	0.7	$870	$1,476	L4 + DR3
L6	0.4	$1,751	$2,902	L5 + DR4

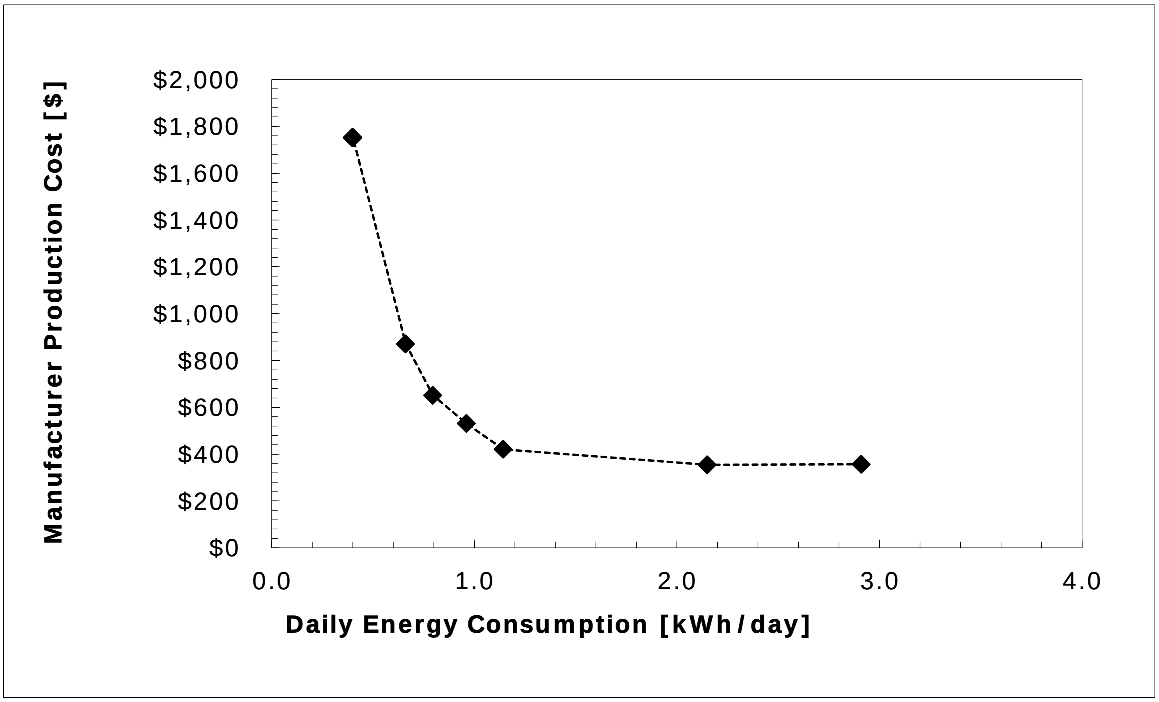


Figure 5A.3.2 Cost-Efficiency Curve for Medium Cooler Display Doors

Table 5A.3.3 Cost-Efficiency Data for DD.M.LRG

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	3.8	$470	$850	Baseline
L1	2.8	$478	$863	L0 + LT2
L2	1.4	$544	$970	L1 + ASCTRL
L3	1.2	$692	$1,209	L2 + DR2
L4	1.0	$813	$1,404	L3 + CS2-L
L5	0.8	$1,108	$1,883	L4 + DR3
L6	0.5	$2,291	$3,800	L5 + DR4

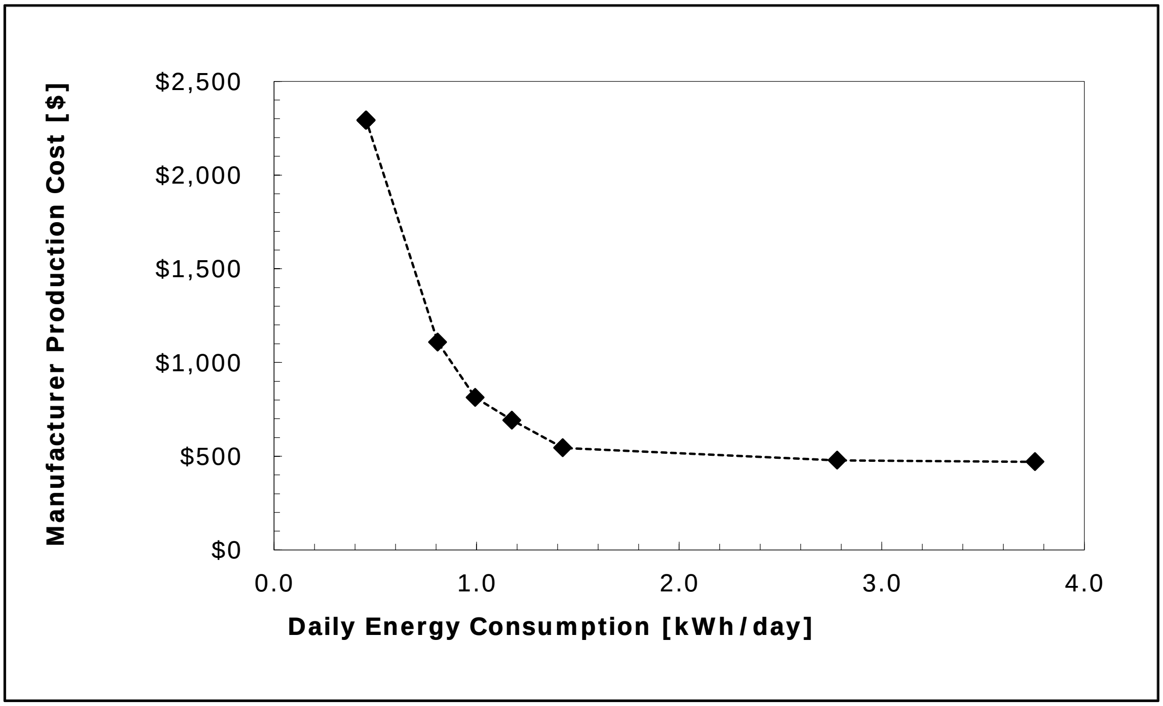


Figure 5A.3.3 Cost-Efficiency Curve for Large Cooler Display Doors

Table 5A.3.4 Cost-Efficiency Data for DD.L.SML

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	5.2	$509	$873	Baseline
L1	4.3	$506	$869	L0 + LT2
L2	4.1	$627	$1,065	L1 + CS2-L
L3	2.7	$793	$1,334	L2 + DR2
L4	2.0	$960	$1,605	L3 + DR3
L5	1.7	$1,375	$2,278	L4 + DR4

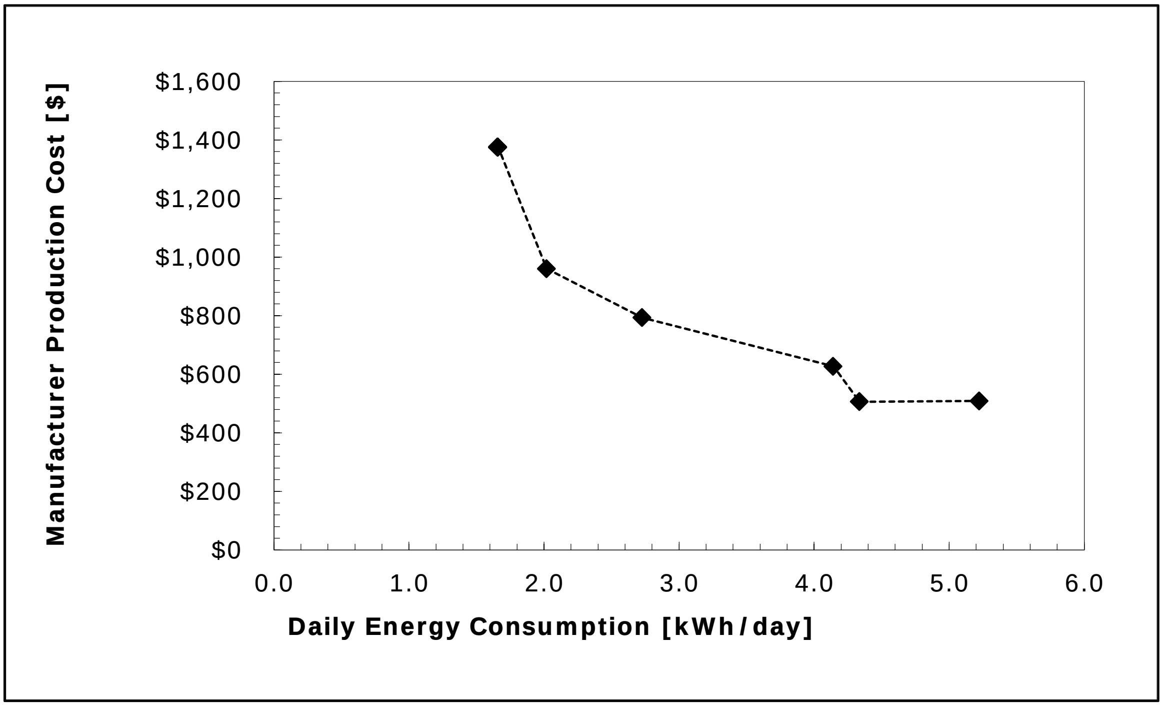


Figure 5A.3.4 Cost-Efficiency Curve for Small Freezer Display Doors

Table 5A.3.5 Cost-Efficiency Data for DD.L.MED

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	6.5	$643	$1,106	Baseline
L1	5.6	$640	$1,102	L0 + LT2
L2	5.4	$761	$1,298	L1 + CS2-L
L3	3.5	$980	$1,654	L2 + DR2
L4	2.6	$1,202	$2,013	L3 + DR3
L5	2.1	$1,751	$2,902	L4 + DR4

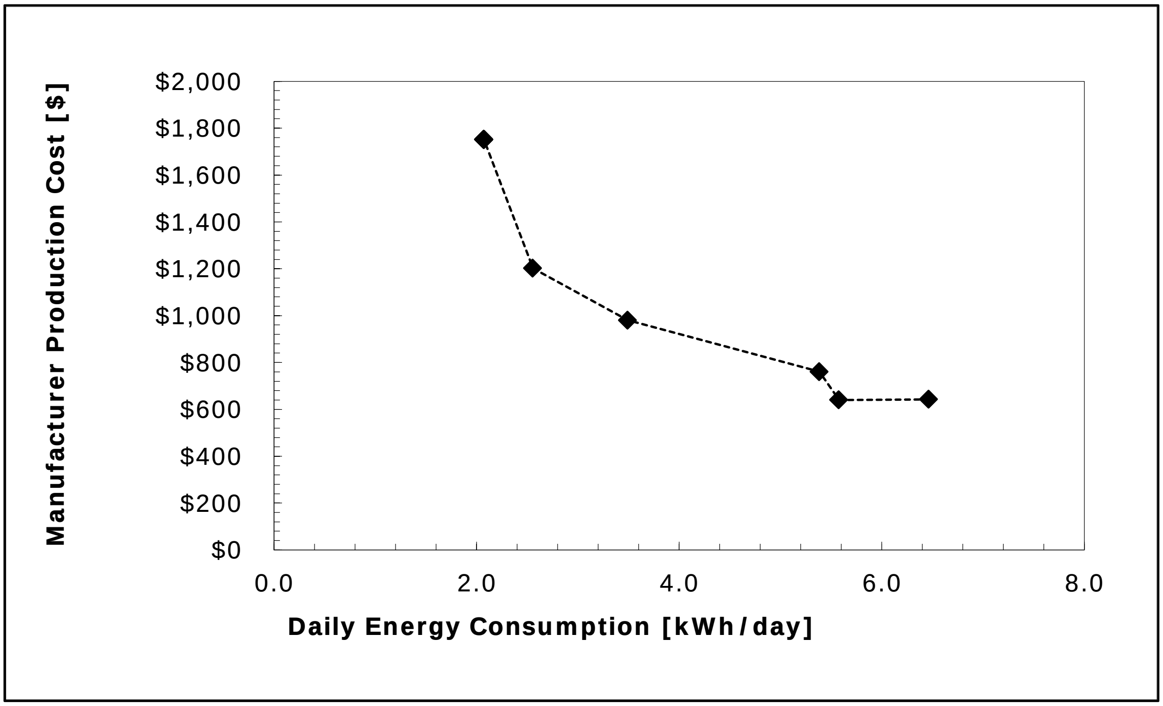


Figure 5A.3.5 Cost-Efficiency Curve for Medium Freezer Display Doors

Table 5A.3.6 Cost-Efficiency Data for DD.L.LRG

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	8.5	$831	$1,435	Baseline
L1	7.4	$839	$1,448	L0 + LT2
L2	4.8	$1,135	$1,926	L1 + DR2
L3	3.6	$1,432	$2,409	L2 + DR3
L4	3.4	$1,553	$2,604	L3 + CS2-L
L5	2.7	$2,291	$3,800	L4 + DR4

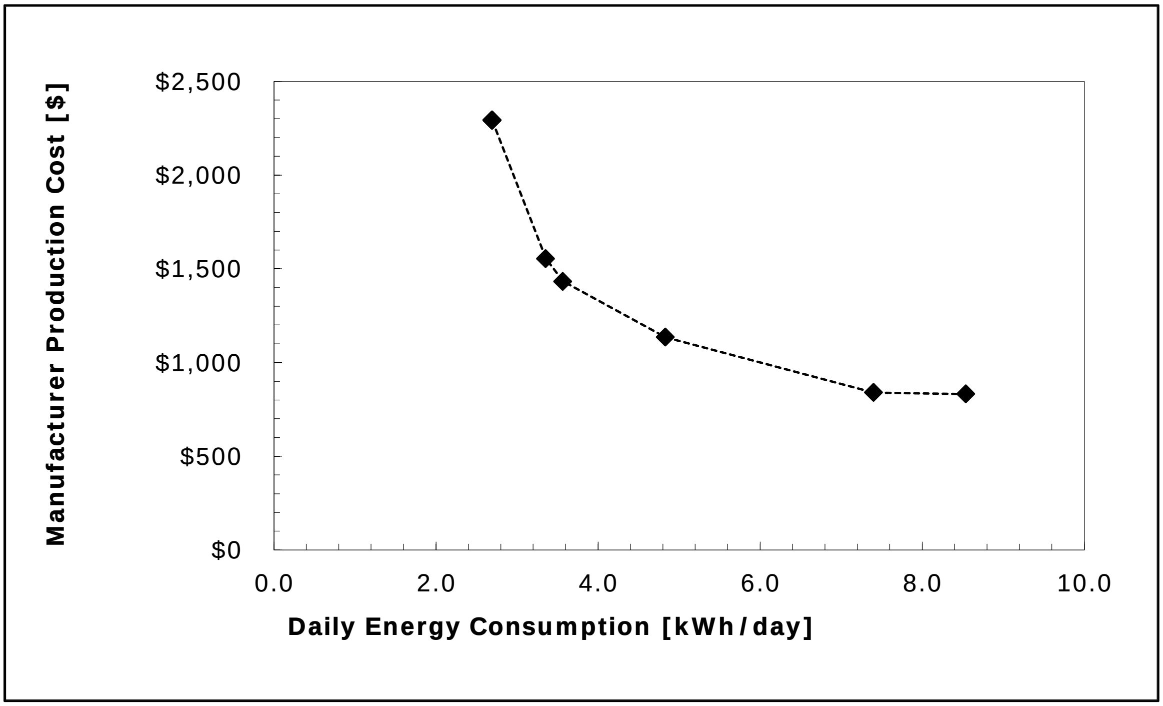


Figure 5A.3.6 Cost-Efficiency Curve for Large Freezer Display Doors

5A.4 NON-DISPLAY DOOR COST-EFFICIENCY CURVES

Table 5A.4.1 Cost-Efficiency Data for PD.M.SML

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.30	$180	$283	Baseline
L1	0.27	$184	$289	L0 + SOFT
L2	0.22	$210	$328	L1 + DR2
L3	0.22	$214	$335	L2 + TCK2
L4	0.21	$222	$348	L3 + TCK3
L5	0.17	$273	$425	L4 + DR3
L6	0.16	$281	$439	L5 + TCK4
L7	0.04	$487	$747	L6 + DR4
L8	0.02	$655	$997	L7 + HYB

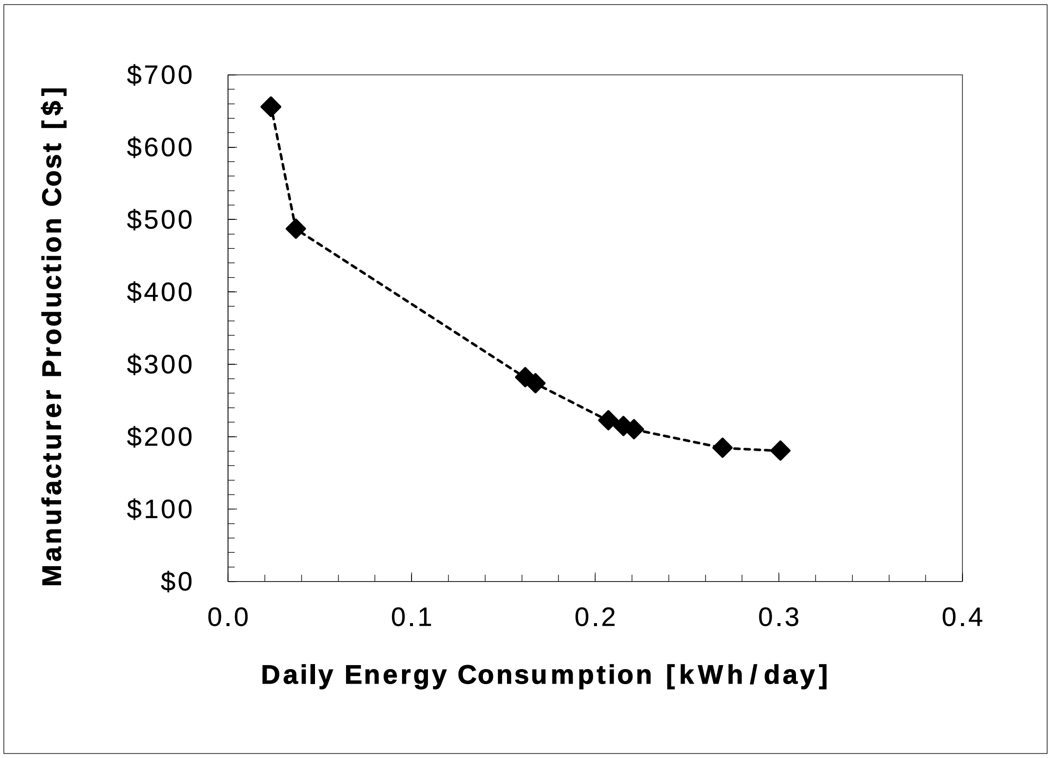


Figure 5A.4.1 Cost-Efficiency Curve for Small Non-Display Cooler Passage Doors

Table 5A.4.2 Cost-Efficiency Data for PD.M.MED

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.32	$210	$331	Baseline
L1	0.28	$214	$338	L0 + SOFT
L2	0.24	$240	$377	L1 + DR2
L3	0.23	$245	$385	L2 + TCK2
L4	0.22	$255	$402	L3 + TCK3
L5	0.18	$306	$479	L4 + DR3
L6	0.17	$316	$495	L5 + TCK4
L7	0.05	$522	$804	L6 + DR4
L8	0.03	$741	$1,130	L7 + HYB

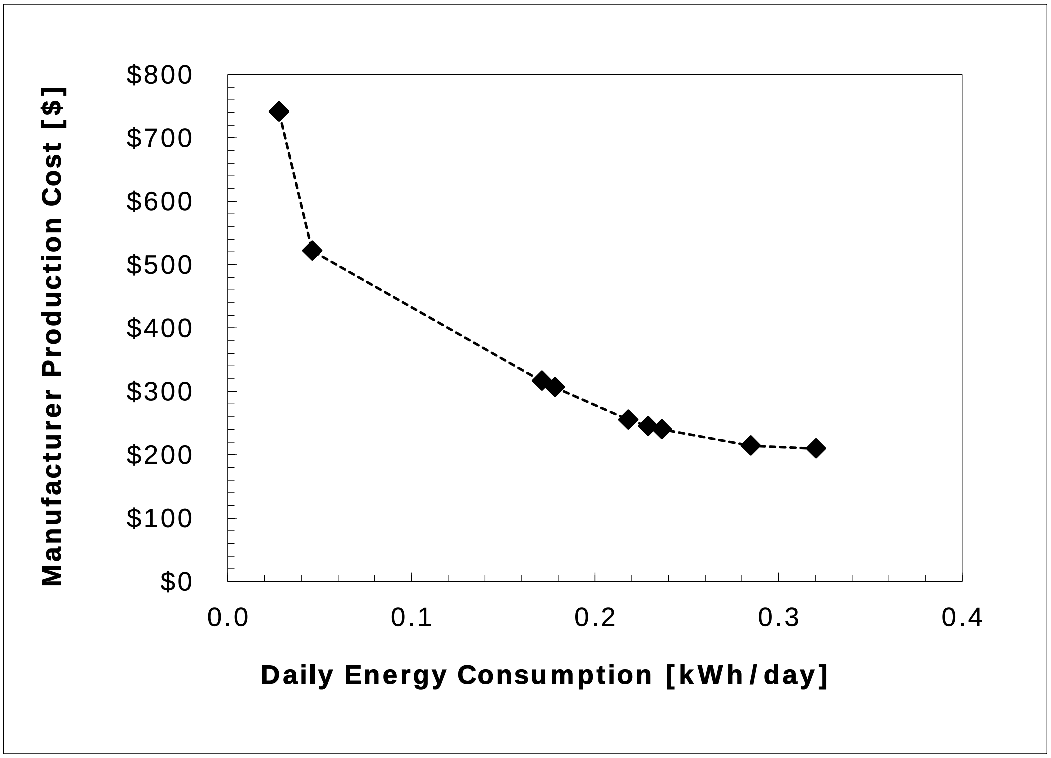


Figure 5A.4.2 Cost-Efficiency Curve for Medium Non-Display Cooler Passage Doors

Table 5A.4.3 Cost-Efficiency Data for PD.M.LRG

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.36	$265	$422	Baseline
L1	0.31	$270	$430	L0 + SOFT
L2	0.27	$296	$468	L1 + DR2
L3	0.25	$303	$479	L2 + TCK2
L4	0.24	$316	$502	L3 + TCK3
L5	0.20	$368	$579	L4 + DR3
L6	0.19	$381	$602	L5 + TCK4
L7	0.06	$587	$910	L6 + DR4
L8	0.04	$904	$1,381	L7 + HYB

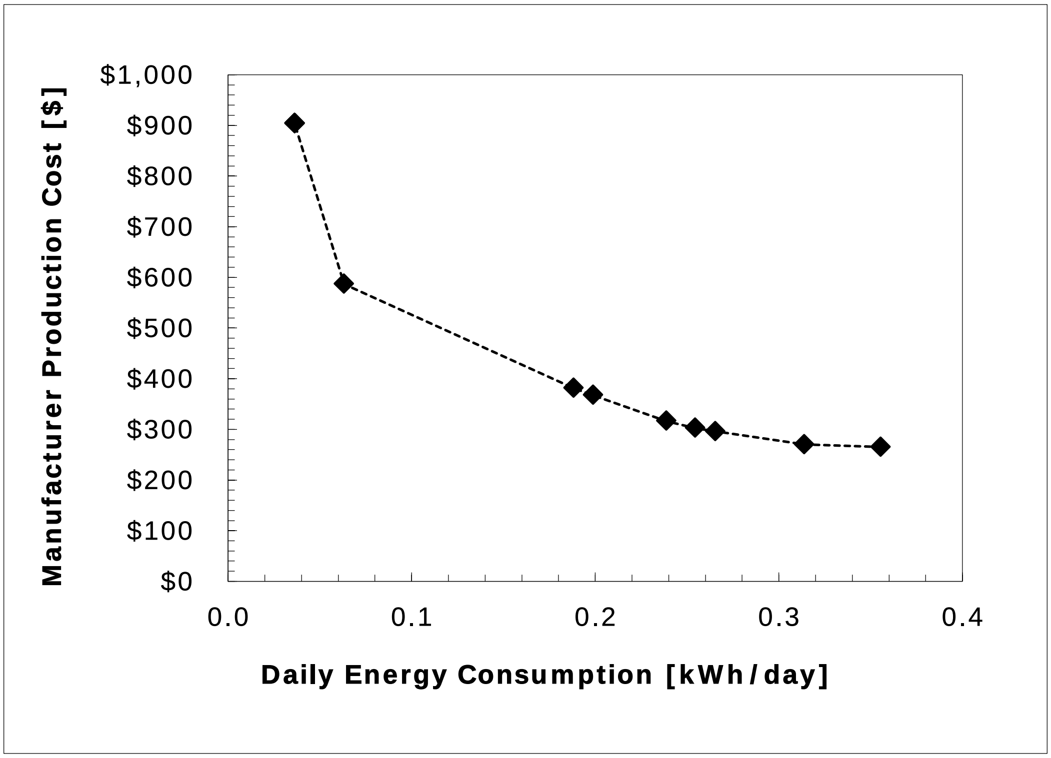


Figure 5A.4.3 Cost-Efficiency Curve for Large Non-Display Cooler Passage Doors

Table 5A.4.4 Cost-Efficiency Data for PD.L.SML

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	7.08	$235	$366	Baseline
L1	6.96	$240	$373	L0 + SOFT
L2	6.52	$291	$450	L1 + DR2
L3	6.26	$342	$528	L2 + DR3
L4	6.23	$351	$541	L3 + TCK2
L5	6.20	$359	$555	L4 + TCK3
L6	6.07	$425	$653	L5 + ASCTRL
L7	6.01	$553	$846	L6 + DR4
L8	5.98	$728	$1,105	L7 + HYB

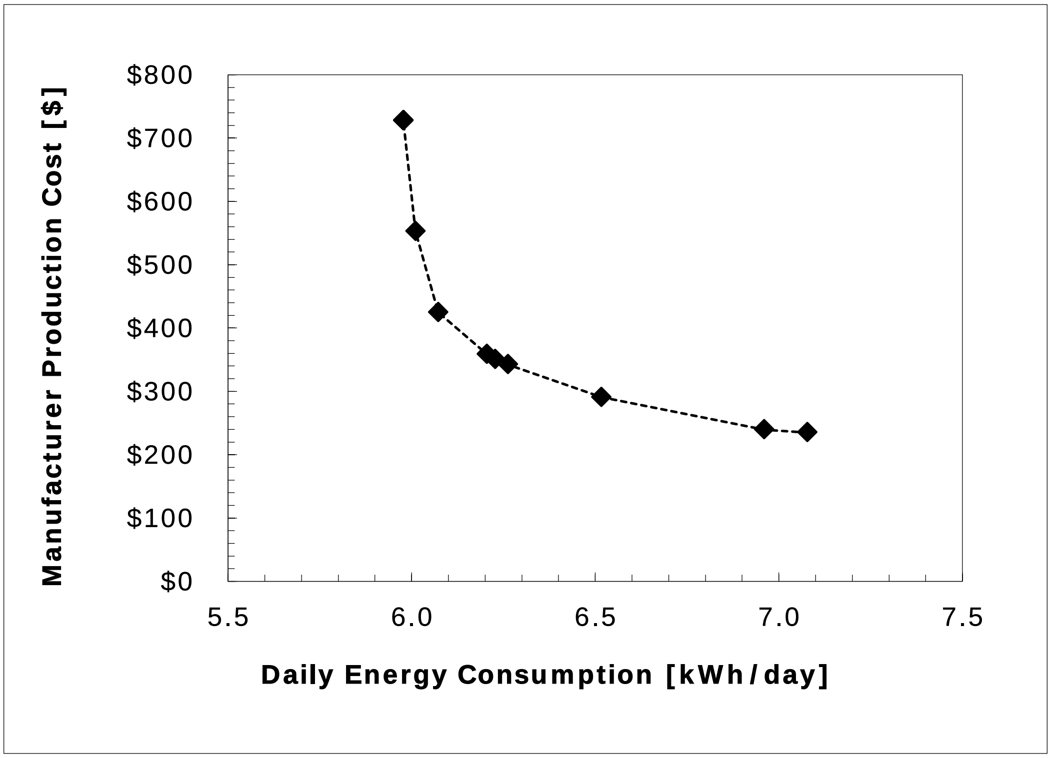


Figure 5A.4.4 Cost-Efficiency Curve for Small Non-Display Freezer Passage Doors

Table 5A.4.5 Cost-Efficiency Data for PD.L.MED

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	7.82	$265	$416	Baseline
L1	7.69	$270	$423	L0 + SOFT
L2	7.25	$322	$500	L1 + DR2
L3	6.99	$373	$578	L2 + DR3
L4	6.95	$383	$595	L3 + TCK2
L5	6.92	$393	$611	L4 + TCK3
L6	6.79	$459	$710	L5 + ASCTRL
L7	6.72	$587	$902	L6 + DR4
L8	6.67	$814	$1,240	L7 + HYB

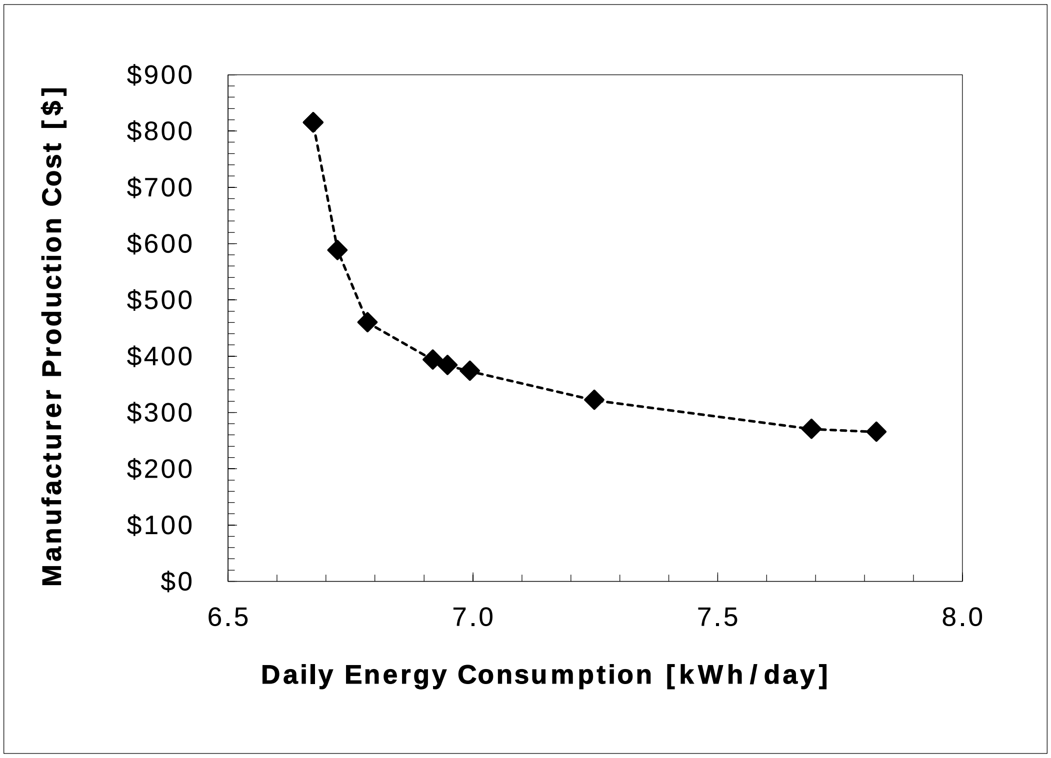


Figure 5A.4.5 Cost-Efficiency Curve for Medium Non-Display Freezer Passage Doors

Table 5A.4.6 Cost-Efficiency Data for PD.L.LRG

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	9.03	$322	$509	Baseline
L1	8.88	$328	$518	L0 + SOFT
L2	8.43	$380	$595	L1 + DR2
L3	8.18	$431	$672	L2 + DR3
L4	8.11	$445	$695	L3 + TCK2
L5	8.07	$459	$718	L4 + TCK3
L6	7.94	$524	$817	L5 + ASCTRL
L7	7.88	$653	$1,009	L6 + DR4
L8	7.79	$978	$1,493	L7 + HYB

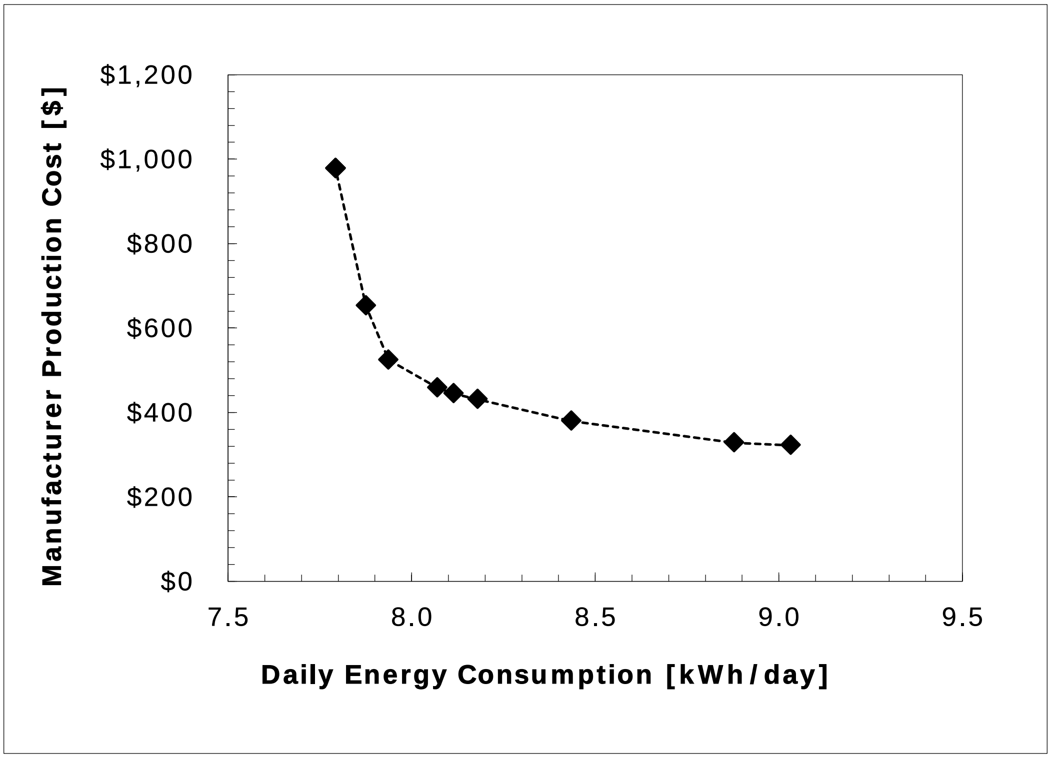


Figure 5A.4.6 Cost-Efficiency Curve for Large Non-Display Freezer Passage Doors

Table 5A.4.7 Cost-Efficiency Data for FD.M.SML

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.39	$356	$566	Baseline
L1	0.35	$362	$575	L0 + SOFT
L2	0.30	$388	$614	L1 + DR2
L3	0.28	$398	$630	L2 + TCK2
L4	0.26	$417	$663	L3 + TCK3
L5	0.22	$469	$740	L4 + DR3
L6	0.21	$489	$773	L5 + TCK4
L7	0.08	$694	$1,082	L6 + DR4
L8	0.05	$1,119	$1,712	L7 + HYB

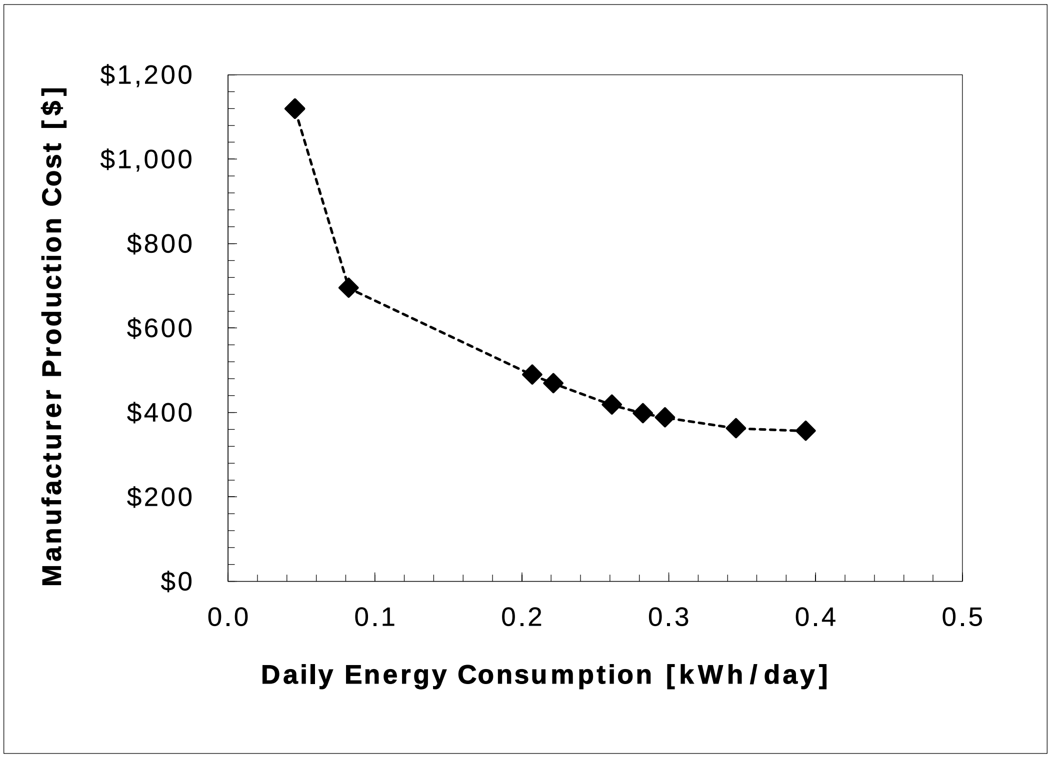


Figure 5A.4.7 Cost-Efficiency Curve for Small Non-Display Cooler Freight Doors

Table 5A.4.8 Cost-Efficiency Data for FD.M.MED

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.65	$574	$912	Baseline
L1	0.60	$581	$923	L0 + SOFT
L2	0.46	$647	$1,022	L1 + ASCTRL
L3	0.44	$662	$1,047	L2 + TCK2
L4	0.40	$692	$1,097	L3 + TCK3
L5	0.36	$738	$1,165	L4 + DR2
L6	0.34	$768	$1,216	L5 + TCK4
L7	0.31	$860	$1,353	L6 + DR3
L8	0.25	$1,225	$1,900	L7 + DR4
L9	0.19	$1,898.89	$2,901.80	L8 + HYB

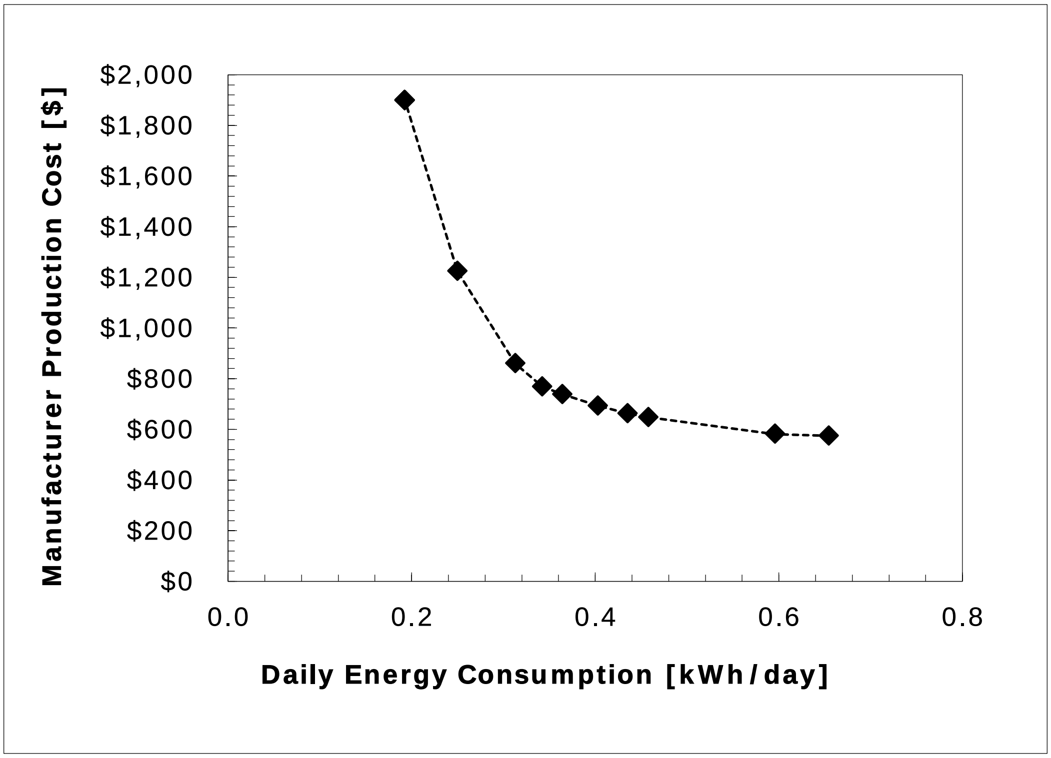


Figure 5A.4.8 Cost-Efficiency Curve for Medium Non-Display Cooler Freight Doors

Table 5A.4.9 Cost-Efficiency Data for FD.M.LRG

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	0.73	$719	$1,146	Baseline
L1	0.66	$727	$1,159	L0 + SOFT
L2	0.53	$793	$1,258	L1 + ASCTRL
L3	0.49	$813	$1,291	L2 + TCK2
L4	0.45	$853	$1,357	L3 + TCK3
L5	0.41	$898	$1,425	L4 + DR2
L6	0.38	$938	$1,492	L5 + TCK4
L7	0.35	$1,029	$1,628	L6 + DR3
L8	0.29	$1,394	$2,176	L7 + DR4
L9	0.21	$2,296.19	$3,515.57	L8 + HYB

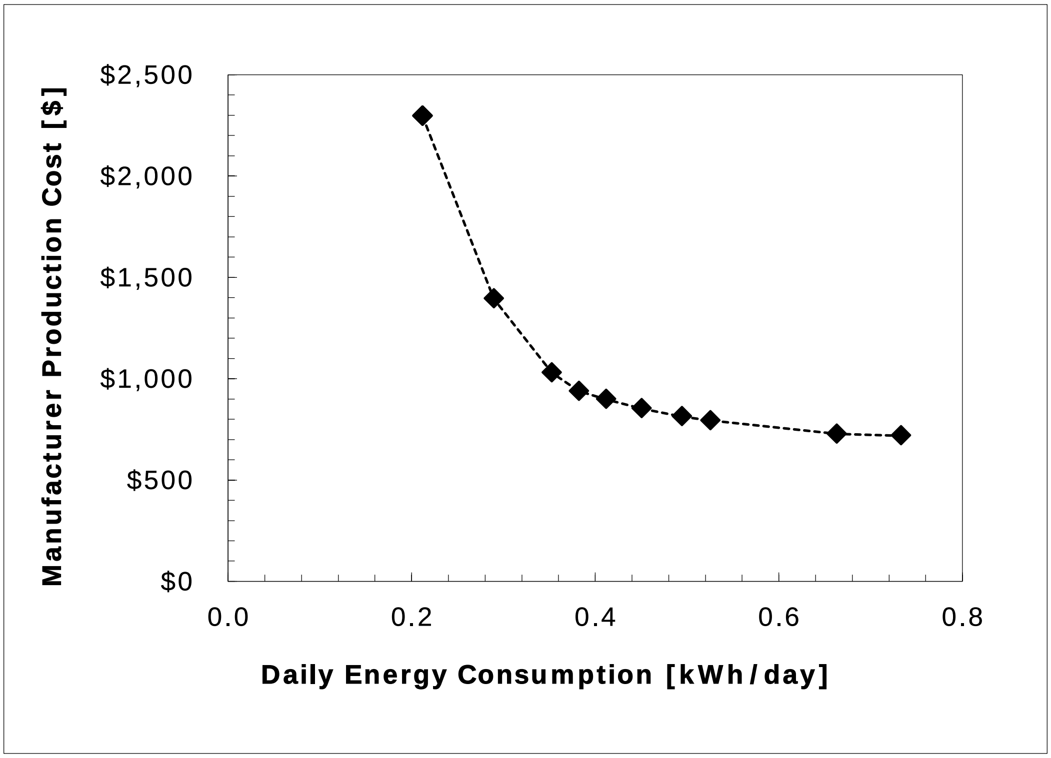


Figure 5A.4.9 Cost-Efficiency Curve for Large Non-Display Cooler Freight Doors

Table 5A.4.10 Cost-Efficiency Data for FD.L.SML

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	10.25	$416	$659	Baseline
L1	10.08	$423	$669	L0 + SOFT
L2	9.63	$474	$746	L1 + DR2
L3	9.38	$526	$823	L2 + DR3
L4	9.29	$546	$856	L3 + TCK2
L5	9.23	$566	$889	L4 + TCK3
L6	9.10	$632	$988	L5 + ASCTRL
L7	9.03	$760	$1,180	L6 + DR4
L8	8.92	$1,194	$1,825	L7 + HYB

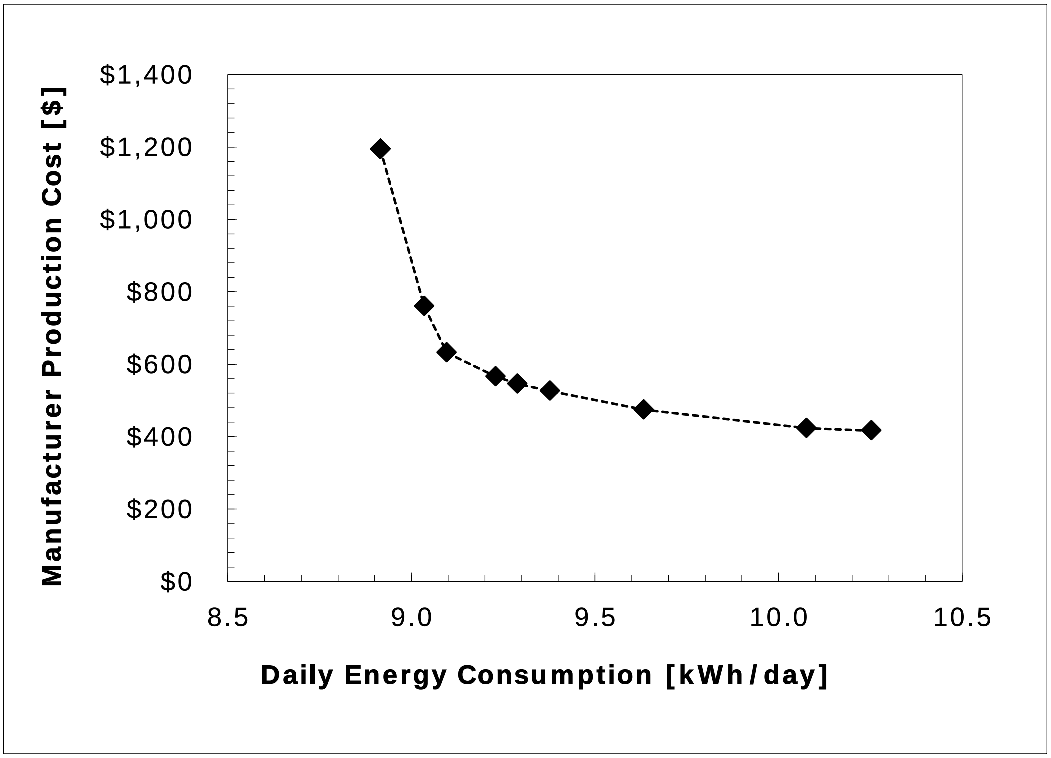


Figure 5A.4.10 Cost-Efficiency Curve for Small Non-Display Freezer Freight Doors

Table 5A.4.11 Cost-Efficiency Data for FD.L.MED

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	13.71	$679	$1,072	Baseline
L1	13.49	$688	$1,085	L0 + SOFT
L2	12.58	$753	$1,184	L1 + ASCTRL
L3	12.13	$845	$1,320	L2 + DR2
L4	11.99	$875	$1,370	L3 + TCK2
L5	11.90	$905	$1,421	L4 + TCK3
L6	11.67	$997	$1,559	L5 + DR3
L7	11.55	$1,225	$1,900	L6 + DR4
L8	11.35	$1,911	$2,920	L7 + HYB

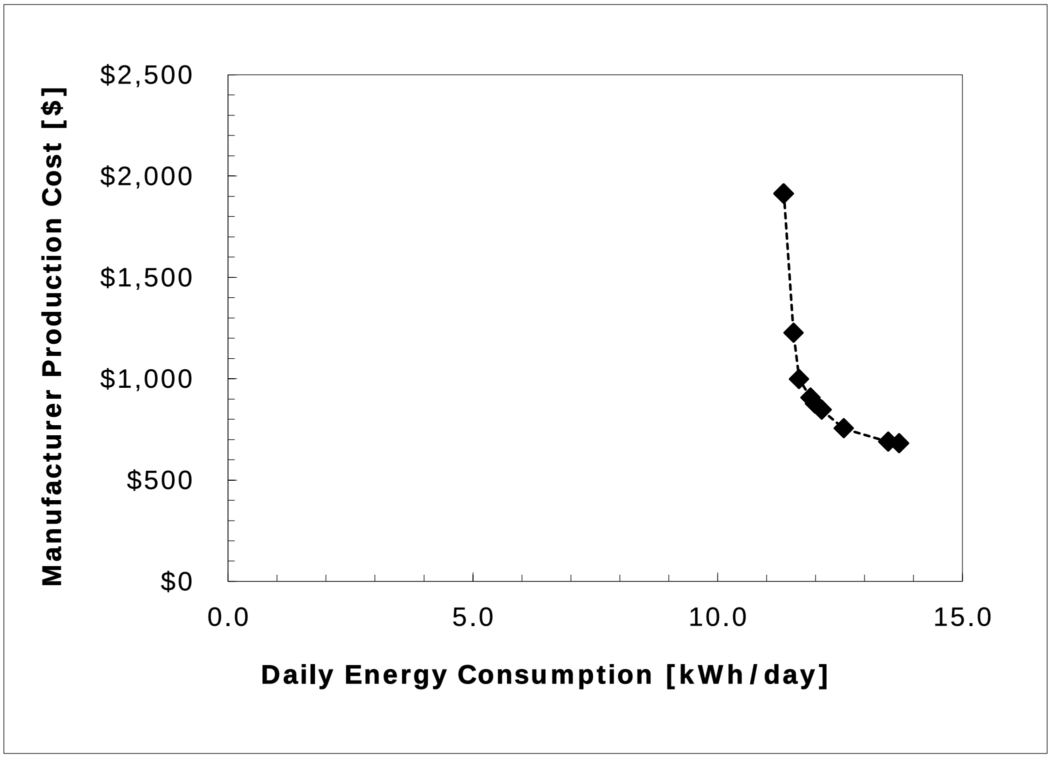


Figure 5A.4.11 Cost-Efficiency Curve for Medium Non-Display Freezer Freight Doors

Table 5A.4.12 Cost-Efficiency Data for FD.L.LRG

Efficiency Level	Daily Energy Use (kWh/day)	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	15.62	$828	$1,314	Baseline
L1	15.36	$838	$1,329	L0 + SOFT
L2	14.45	$904	$1,428	L1 + ASCTRL
L3	14.00	$995	$1,564	L2 + DR2
L4	13.81	$1,035	$1,630	L3 + TCK2
L5	13.69	$1,075	$1,697	L4 + TCK3
L6	13.45	$1,167	$1,834	L5 + DR3
L7	13.34	$1,394	$2,176	L6 + DR4
L8	13.06	$2,310	$3,537	L7 + HYB

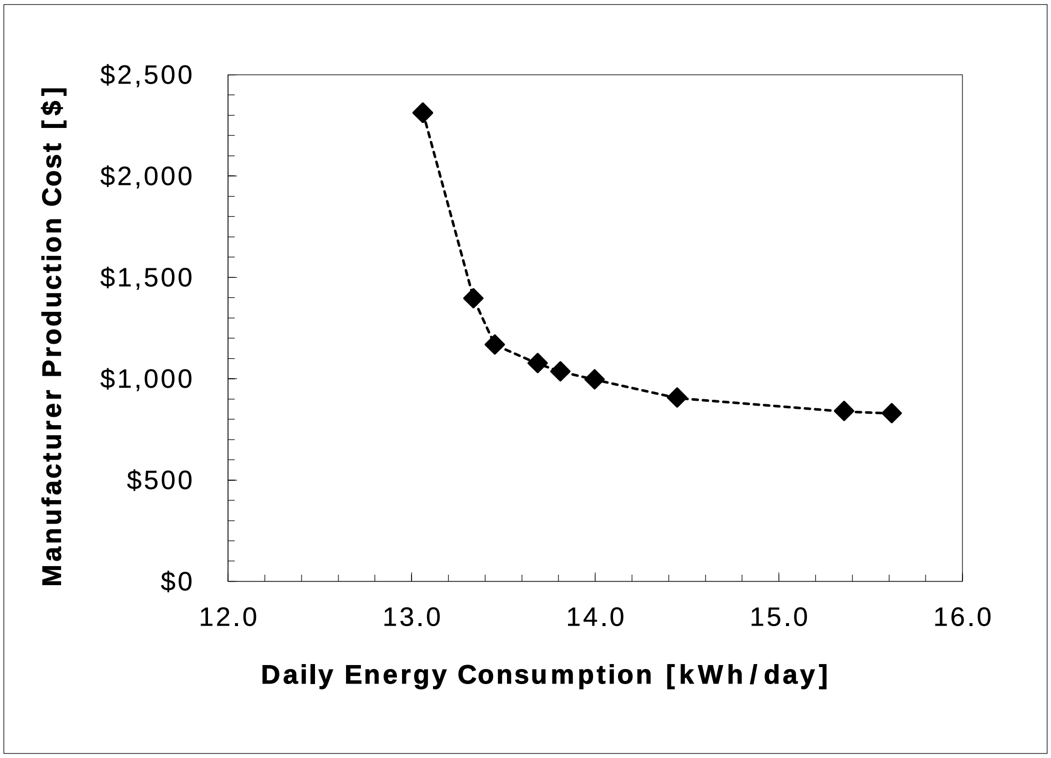


Figure 5A.4.12 Cost-Efficiency Curve for Large Non-Display Freezer Freight Doors

5A.5 REFRIGERATION COST-EFFICIENCY CURVES

Table 5A.5.13 Cost-Efficiency Data for DC.M.I.HER.006.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	3.78	$1,453	$2,090	Baseline
L1	4.12	$1,478	$2,123	L0 + MEF
L2	4.42	$1,503	$2,157	L1 + VEF
L3	4.53	$1,520	$2,180	L2 + EC
L4	4.54	$1,522	$2,184	L3 + CB2
L5	4.57	$1,528	$2,191	L4 + EB2
L6	5.07	$1,689	$2,456	L5 + CD2

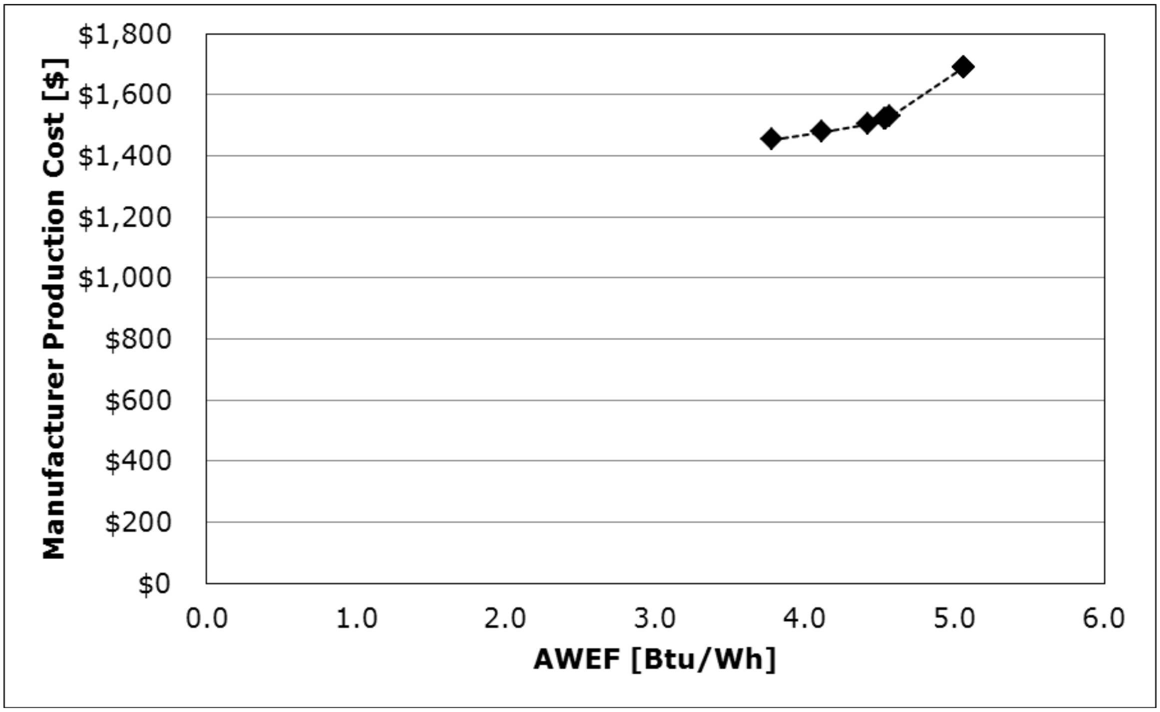


Figure 5A.5.13 Cost-Efficiency Curve for DC.M.I.HER.006.H

Table 5A.5.14 Cost-Efficiency Data for DC.M.I.HER.018.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.52	$2,162	$3,061	Baseline
L1	5.12	$2,212	$3,128	L0 + MEF
L2	5.70	$2,262	$3,196	L1 + VEF
L3	6.19	$2,391	$3,400	L2 + CD2
L4	6.42	$2,442	$3,470	L3 + EC
L5	6.44	$2,449	$3,479	L4 + CB2
L6	6.51	$2,471	$3,509	L5 + EB2

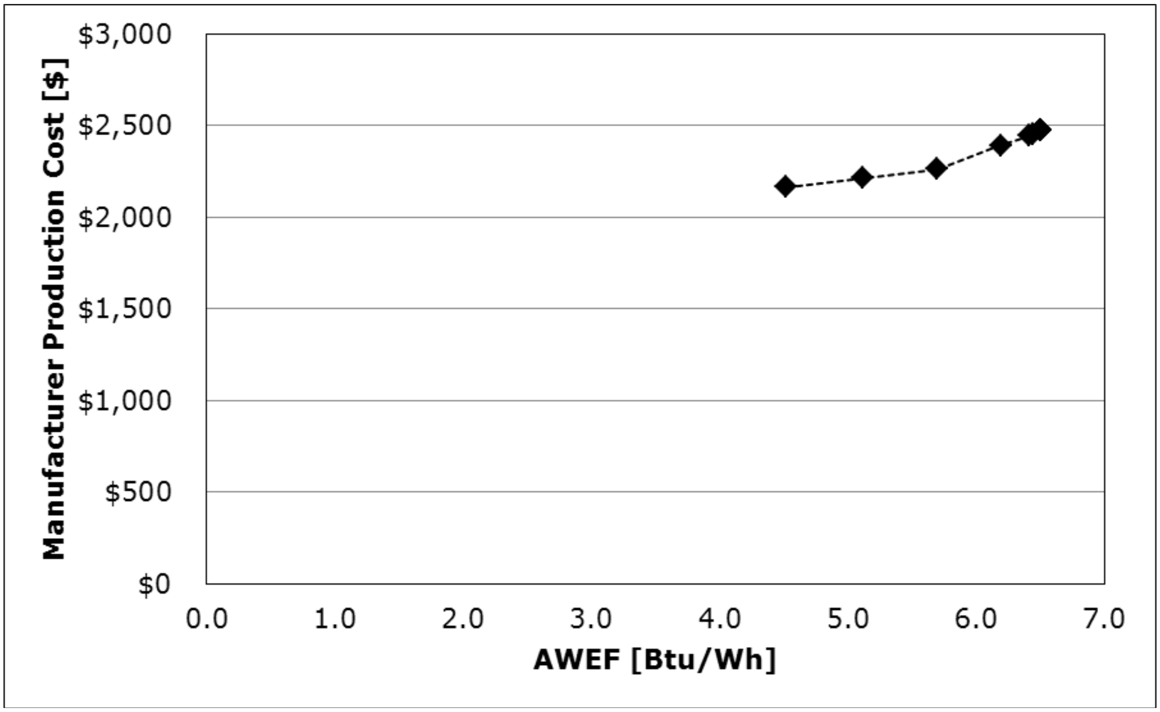


Figure 5A.5.14 Cost-Efficiency Curve for DC.M.I.HER.018.H

Table 5A.5.15 Cost-Efficiency Data for DC.M.I.SCR.018.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.68	$2,381	$3,356	Baseline
L1	5.31	$2,431	$3,424	L0 + MEF
L2	5.93	$2,481	$3,491	L1 + VEF
L3	6.55	$2,614	$3,702	L2 + CD2
L4	6.81	$2,666	$3,772	L3 + EC
L5	6.83	$2,672	$3,781	L4 + CB2
L6	6.90	$2,694	$3,811	L5 + EB2

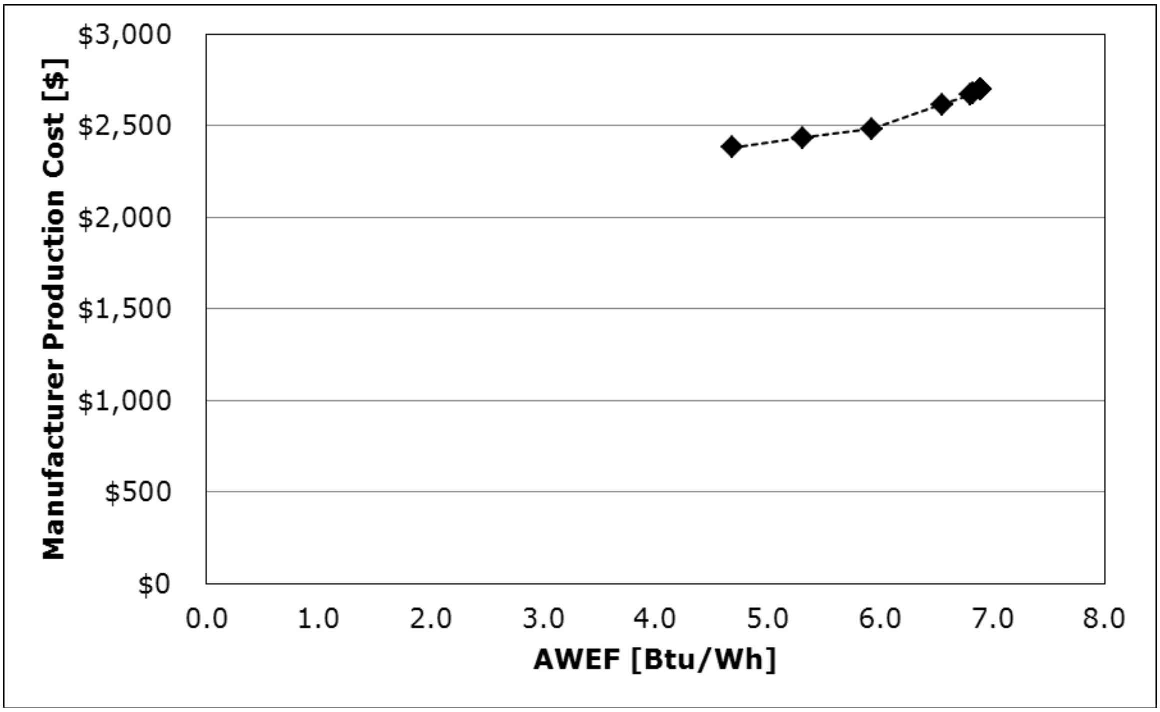


Figure 5A.5.15 Cost-Efficiency Curve for DC.M.I.SCR.018.H

Table 5A.5.16 Cost-Efficiency Data for DC.M.I.SCR.054.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.49	$3,592	$5,320	Baseline
L1	5.22	$3,642	$5,387	L0 + MEF
L2	5.99	$3,692	$5,455	L1 + VEF
L3	6.11	$3,725	$5,500	L2 + EC
L4	6.95	$3,991	$5,939	L3 + CD2
L5	6.97	$4,008	$5,962	L4 + CB2
L6	7.06	$4,091	$6,073	L5 + EB2

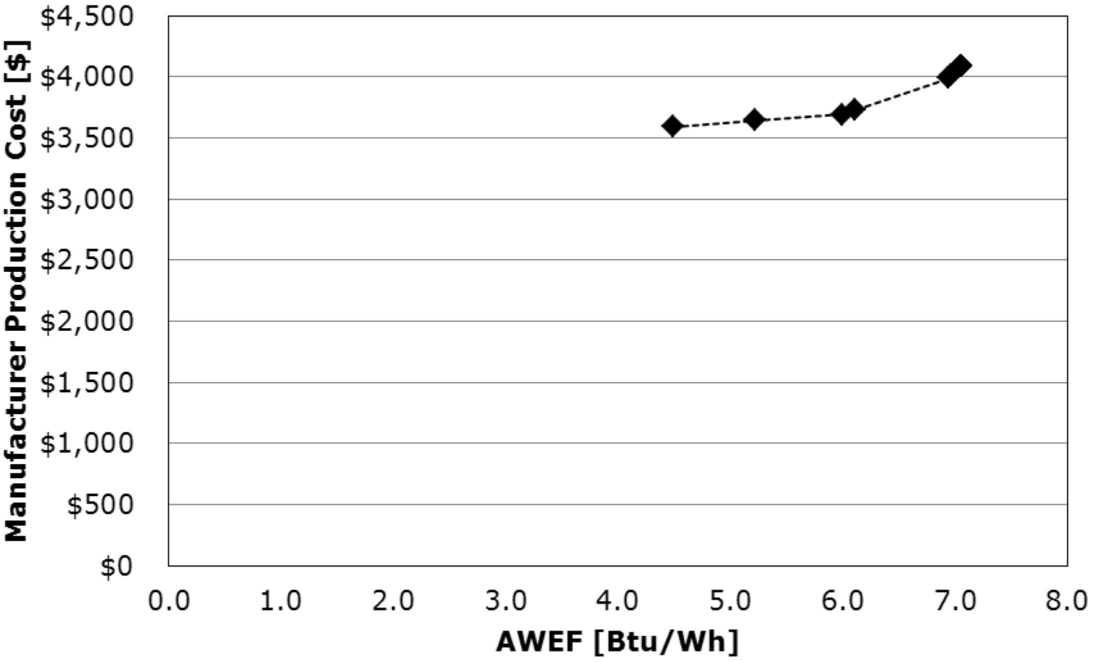


Figure 5A.5.16 Cost-Efficiency Curve for DC.M.I.SCR.054.H

Table 5A.5.17 Cost-Efficiency Data for DC.M.I.SCR.096.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.08	$6,264	$9,407	Baseline
L1	4.78	$6,364	$9,542	L0 + MEF
L2	5.54	$6,464	$9,677	L1 + VEF
L3	5.65	$6,531	$9,767	L2 + EC
L4	6.43	$7,061	$10,646	L3 + CD2
L5	6.46	$7,095	$10,692	L4 + CB2
L6	6.55	$7,259	$10,914	L5 + EB2

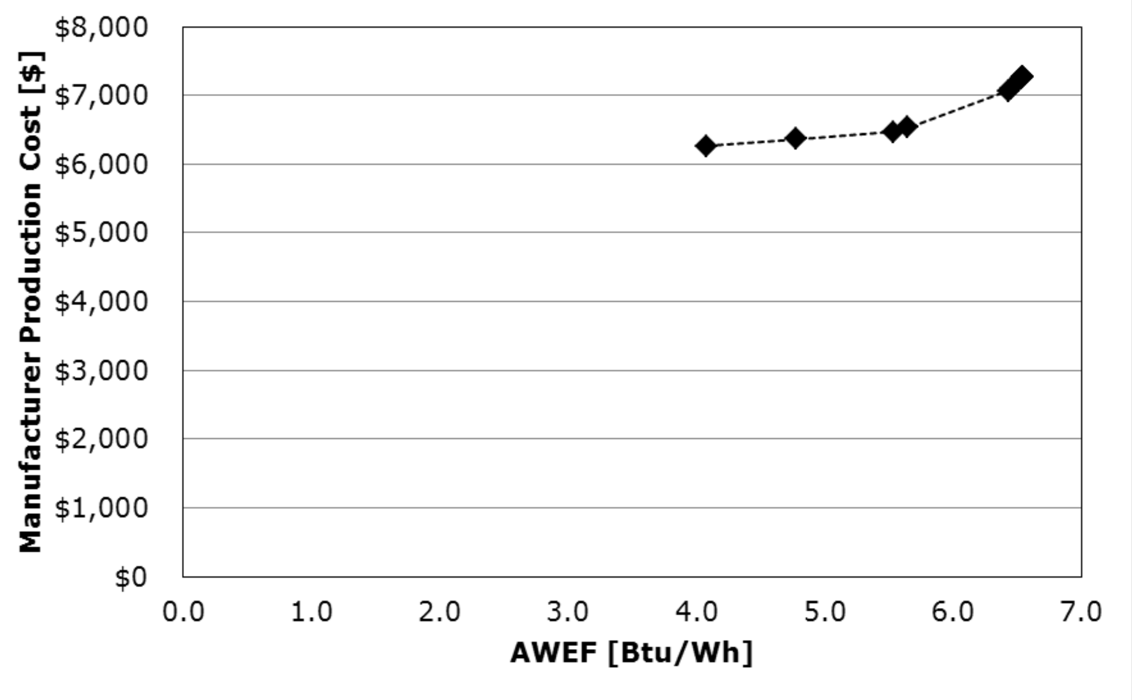


Figure 5A.5.17 Cost-Efficiency Curve for DC.M.I.SCR.096.H

Table 5A.5.18 Cost-Efficiency Data for DC.M.I.SEM.006.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.44	$1,570	$2,248	Baseline
L1	4.88	$1,595	$2,282	L0 + MEF
L2	5.27	$1,620	$2,316	L1 + VEF
L3	5.43	$1,637	$2,339	L2 + EC
L4	5.45	$1,640	$2,342	L3 + CB2
L5	5.49	$1,645	$2,349	L4 + EB2
L6	6.11	$1,792	$2,595	L5 + CD2

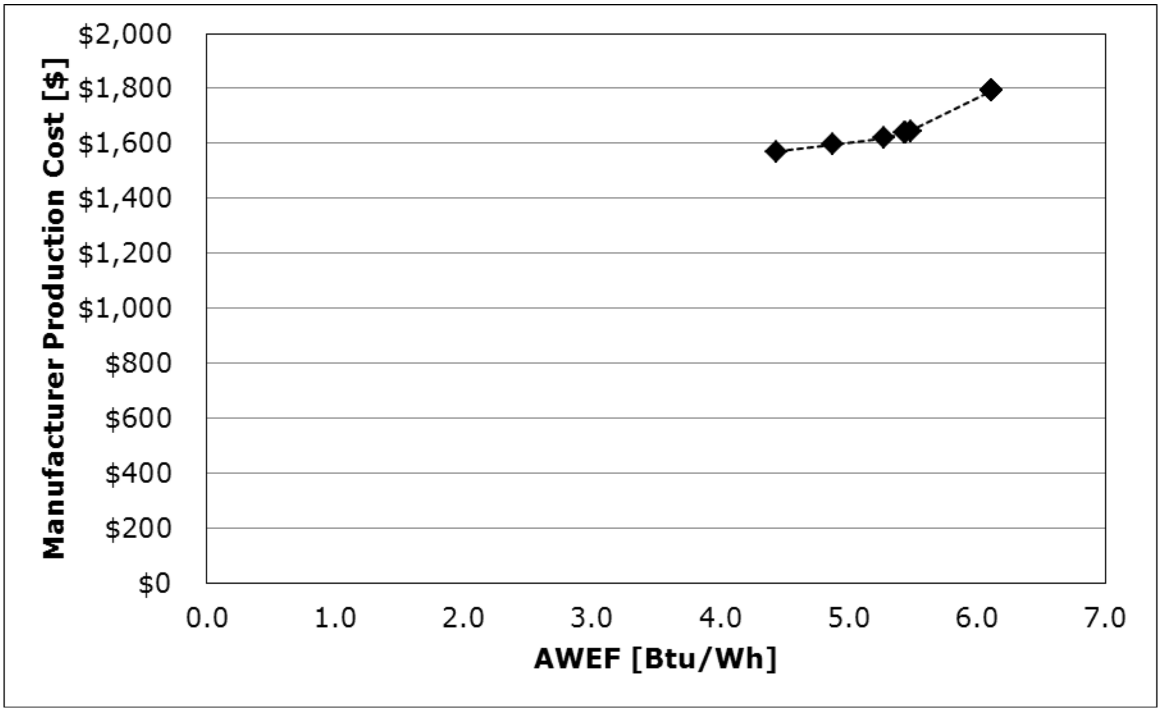


Figure 5A.5.18 Cost-Efficiency Curve for DC.M.I.SEM.006.H

Table 5A.5.19 Cost-Efficiency Data for DC.M.I.SEM.018.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.36	$2,622	$3,681	Baseline
L1	4.91	$2,672	$3,748	L0 + MEF
L2	5.46	$2,722	$3,816	L1 + VEF
L3	5.94	$2,831	$3,995	L2 + CD2
L4	6.15	$2,883	$4,065	L3 + EC
L5	6.17	$2,889	$4,074	L4 + CB2
L6	6.22	$2,911	$4,104	L5 + EB2

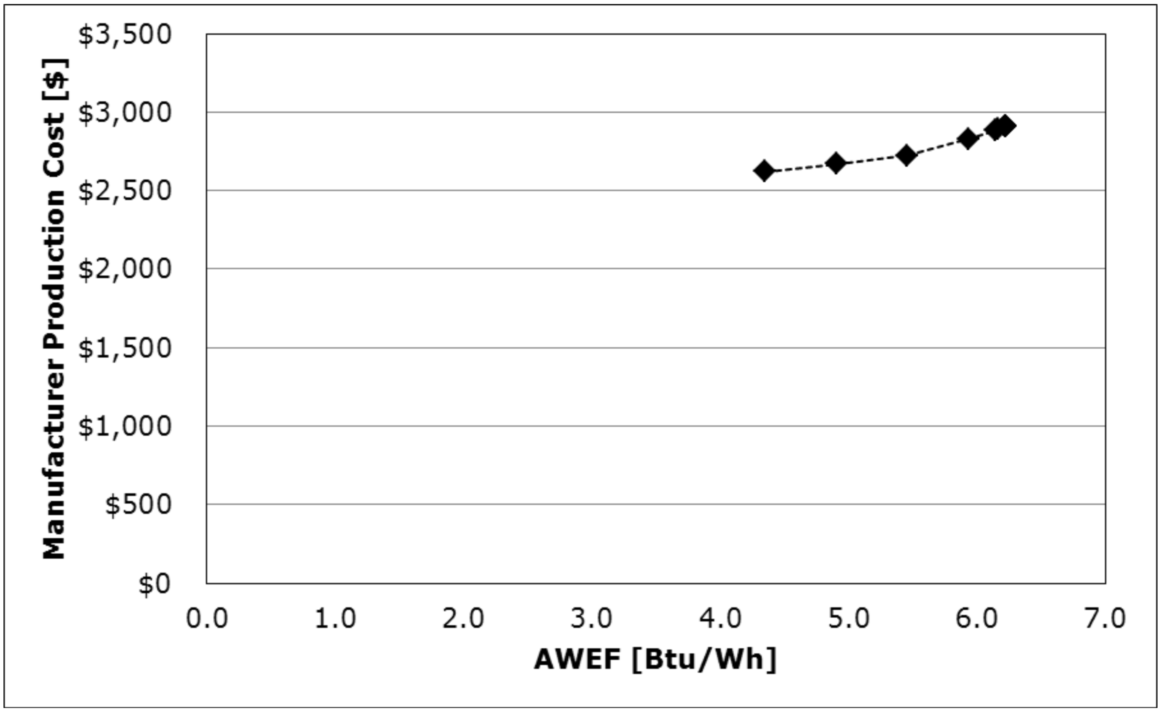


Figure 5A.5.19 Cost-Efficiency Curve for DC.M.I.SEM.018.H

Table 5A.5.20 Cost-Efficiency Data for DC.M.I.SEM.054.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.70	$4,158	$6,084	Baseline
L1	5.49	$4,208	$6,151	L0 + MEF
L2	6.33	$4,258	$6,219	L1 + VEF
L3	6.46	$4,291	$6,264	L2 + EC
L4	7.15	$4,533	$6,671	L3 + CD2
L5	7.18	$4,550	$6,694	L4 + CB2
L6	7.27	$4,632	$6,805	L5 + EB2

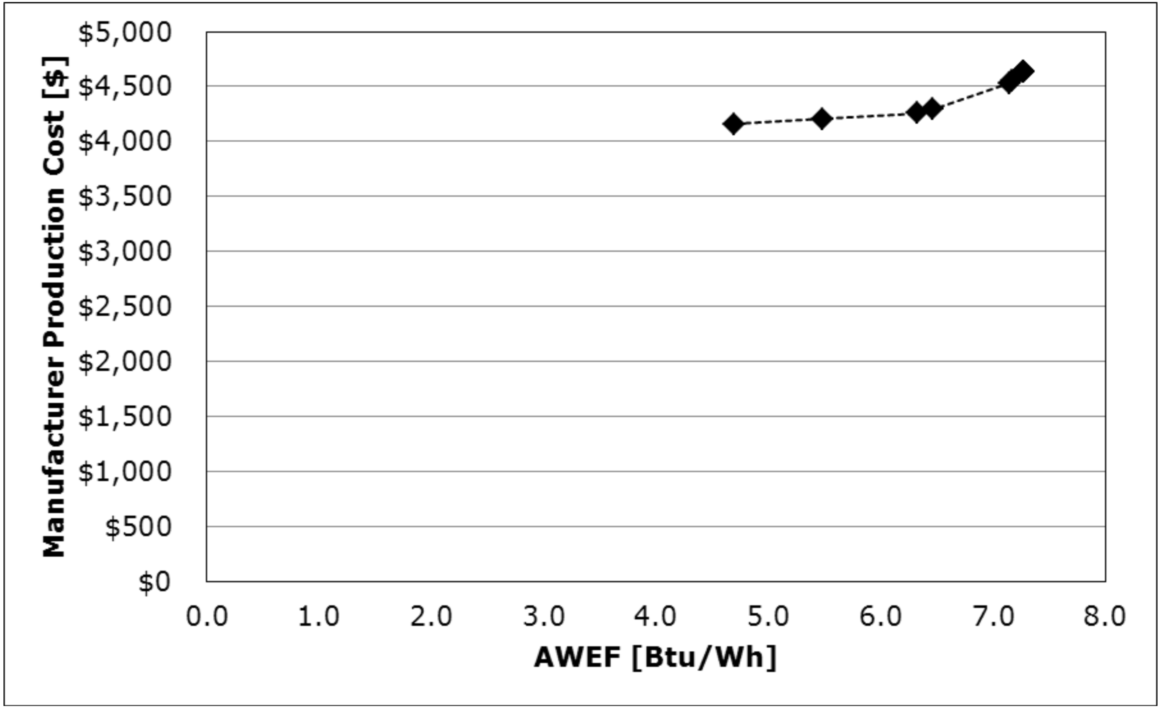


Figure 5A.5.20 Cost-Efficiency Curve for DC.M.I.SEM.054.H

Table 5A.5.21 Cost-Efficiency Data for DC.M.I.SEM.096.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.33	$6,975	$10,366	Baseline
L1	5.10	$7,075	$10,501	L0 + MEF
L2	5.95	$7,175	$10,636	L1 + VEF
L3	6.08	$7,241	$10,726	L2 + EC
L4	6.70	$7,710	$11,523	L3 + CD2
L5	6.73	$7,744	$11,569	L4 + CB2
L6	6.82	$7,909	$11,790	L5 + EB2

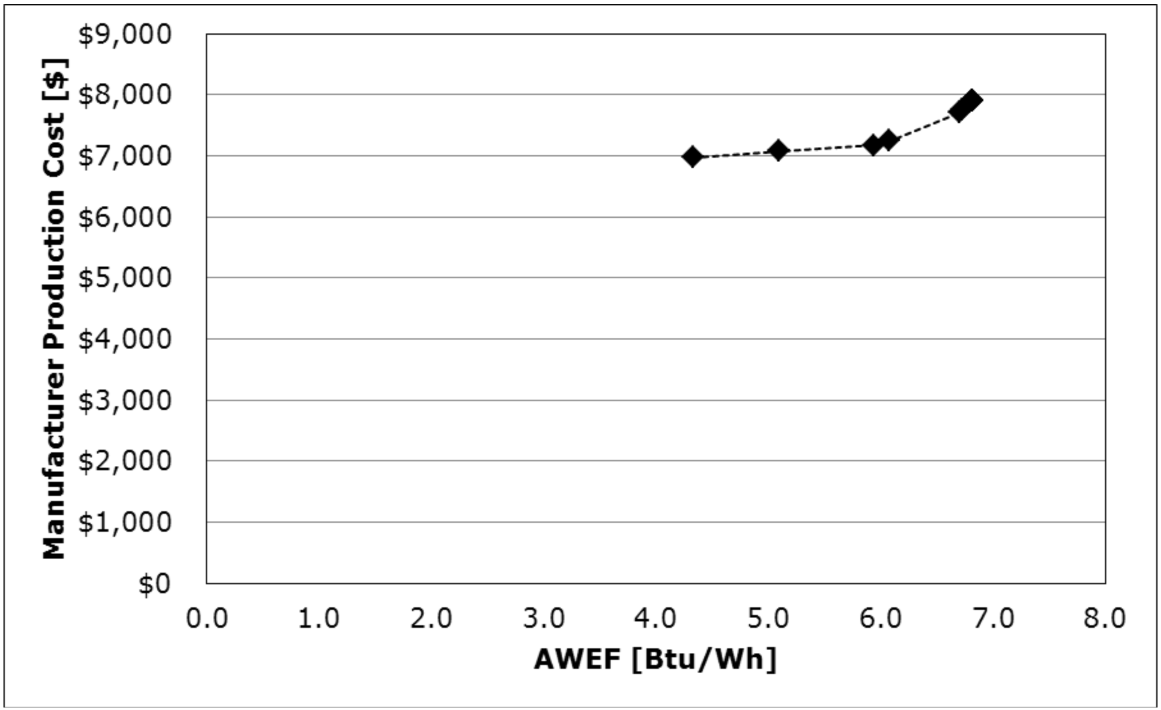


Figure 5A.5.21 Cost-Efficiency Curve for DC.M.I.SEM.096.H

Table 5A.5.22 Cost-Efficiency Data for DC.M.O.HER.006.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.16	$1,486	$2,134	Baseline
L1	4.70	$1,511	$2,168	L0 + MEF
L2	5.23	$1,536	$2,202	L1 + VEF
L3	5.72	$1,566	$2,242	L2 + FHP
L4	5.74	$1,568	$2,245	L3 + CB2
L5	5.88	$1,585	$2,269	L4 + EC
L6	5.91	$1,591	$2,276	L5 + EB2
L7	6.44	$1,669	$2,392	L6 + ASC
L8	6.65	$1,719	$2,460	L7 + VSCF
L9	7.47	$1,893	$2,747	L8 + CD2

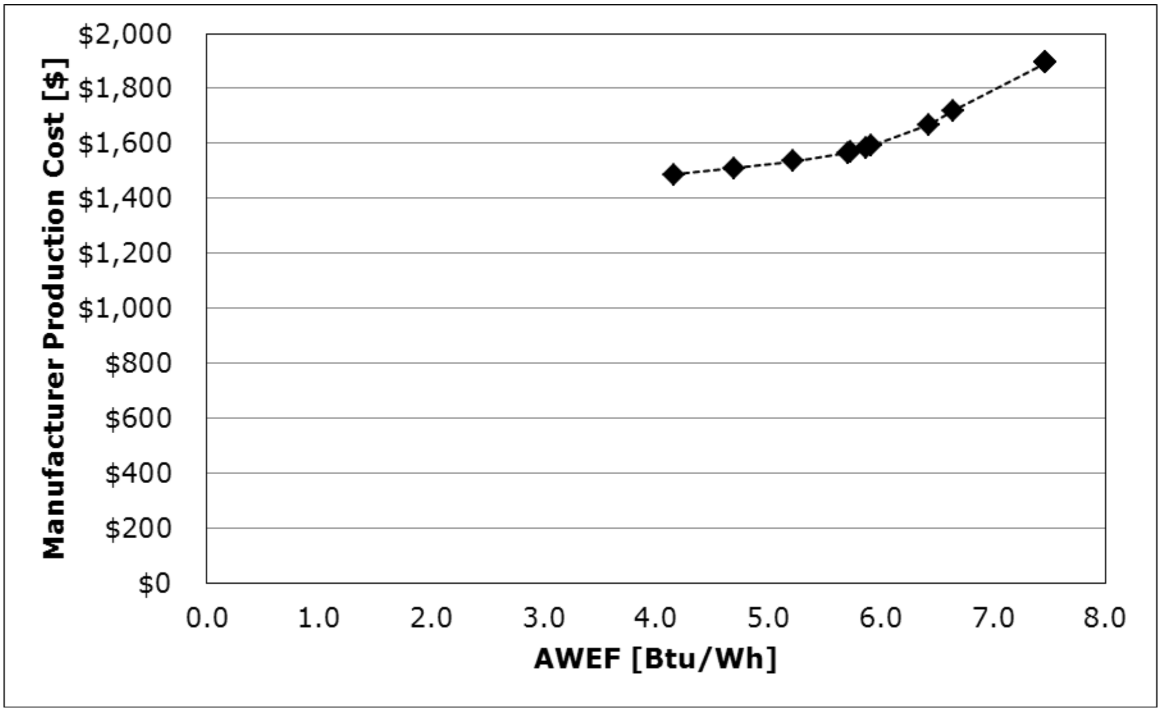


Figure 5A.5.22 Cost-Efficiency Curve for DC.M.O.HER.006.H

Table 5A.5.23 Cost-Efficiency Data for DC.M.O.HER.018.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.91	$2,198	$3,109	Baseline
L1	5.87	$2,248	$3,177	L0 + MEF
L2	6.91	$2,298	$3,244	L1 + VEF
L3	7.62	$2,328	$3,285	L2 + FHP
L4	8.27	$2,401	$3,391	L3 + ASC
L5	8.30	$2,406	$3,397	L4 + CB2
L6	8.50	$2,444	$3,448	L5 + EC
L7	8.75	$2,494	$3,516	L6 + VSCF
L8	9.60	$2,656	$3,769	L7 + CD2
L9	9.71	$2,678	$3,799	L8 + EB2

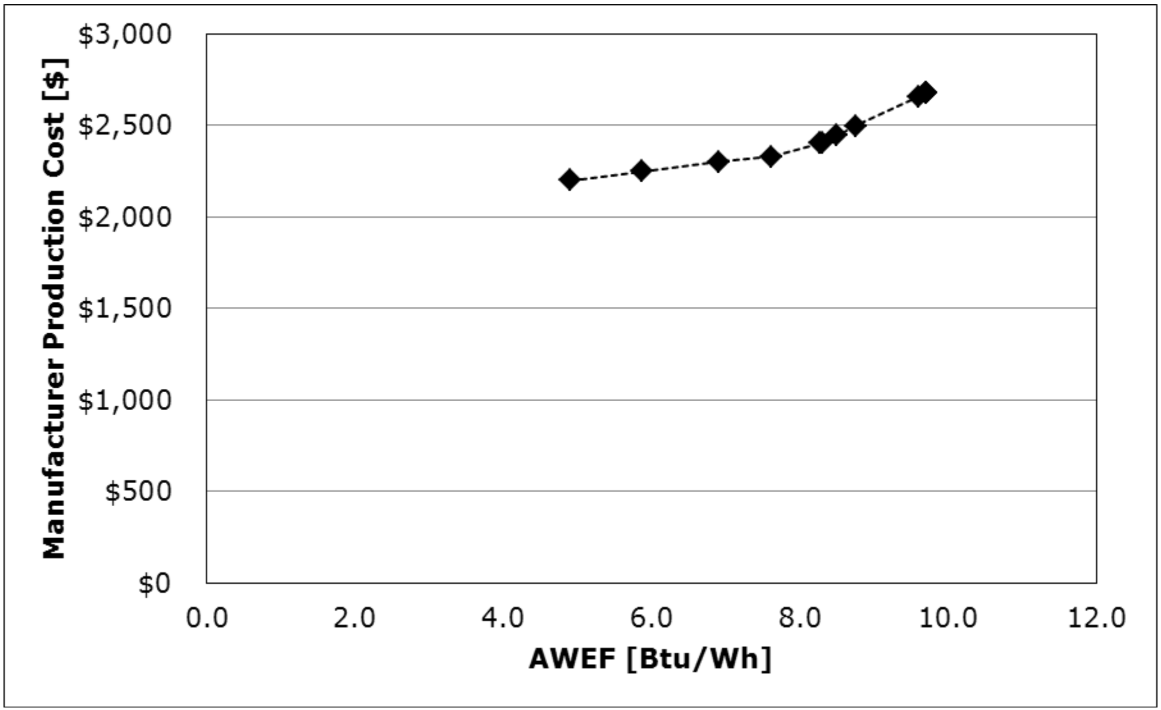


Figure 5A.5.23 Cost-Efficiency Curve for DC.M.O.HER.018.H

Table 5A.5.24 Cost-Efficiency Data for DC.M.O.SCR.018.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	5.52	$2,414	$3,401	Baseline
L1	6.69	$2,464	$3,469	L0 + MEF
L2	8.01	$2,514	$3,536	L1 + VEF
L3	9.06	$2,544	$3,577	L2 + FHP
L4	9.79	$2,617	$3,683	L3 + ASC
L5	10.08	$2,655	$3,734	L4 + EC
L6	10.45	$2,705	$3,801	L5 + VSCF
L7	11.42	$2,869	$4,057	L6 + CD2
L8	11.56	$2,891	$4,087	L7 + EB2
L9	12.19	$3,041	$4,289	L8 + FHPEV
L10	12.21	$3,048	$4,298	L9 + CB2

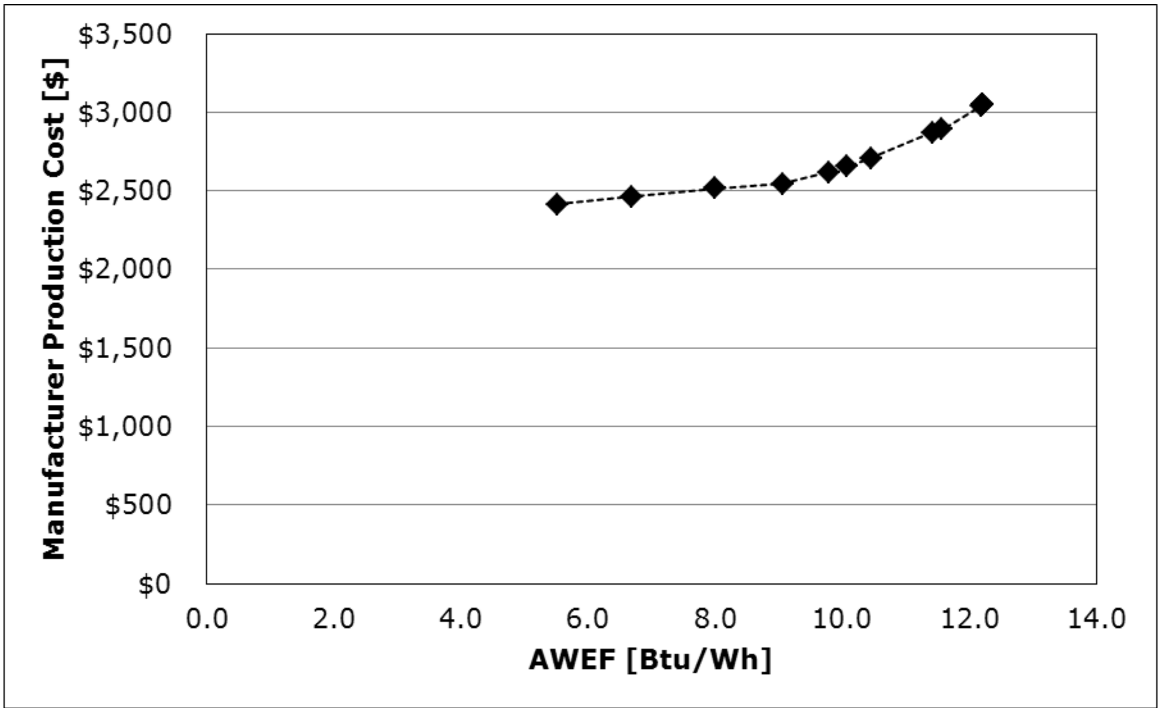


Figure 5A.5.24 Cost-Efficiency Curve for DC.M.O.SCR.018.H

Table 5A.5.25 Cost-Efficiency Data for DC.M.O.SCR.054.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.82	$3,638	$5,383	Baseline
L1	5.98	$3,688	$5,450	L0 + MEF
L2	7.38	$3,738	$5,518	L1 + VEF
L3	8.24	$3,768	$5,558	L2 + FHP
L4	8.92	$3,855	$5,693	L3 + ASC
L5	9.12	$3,892	$5,743	L4 + EC
L6	9.38	$3,942	$5,810	L5 + VSCF
L7	11.01	$4,228	$6,285	L6 + CD2
L8	11.53	$4,378	$6,488	L7 + FPEV
L9	11.72	$4,460	$6,599	L8 + EB2
L10	13.41	$5,397	$7,864	L9 + CMP2
L11	13.43	$5,416	$7,889	L10 + CB2

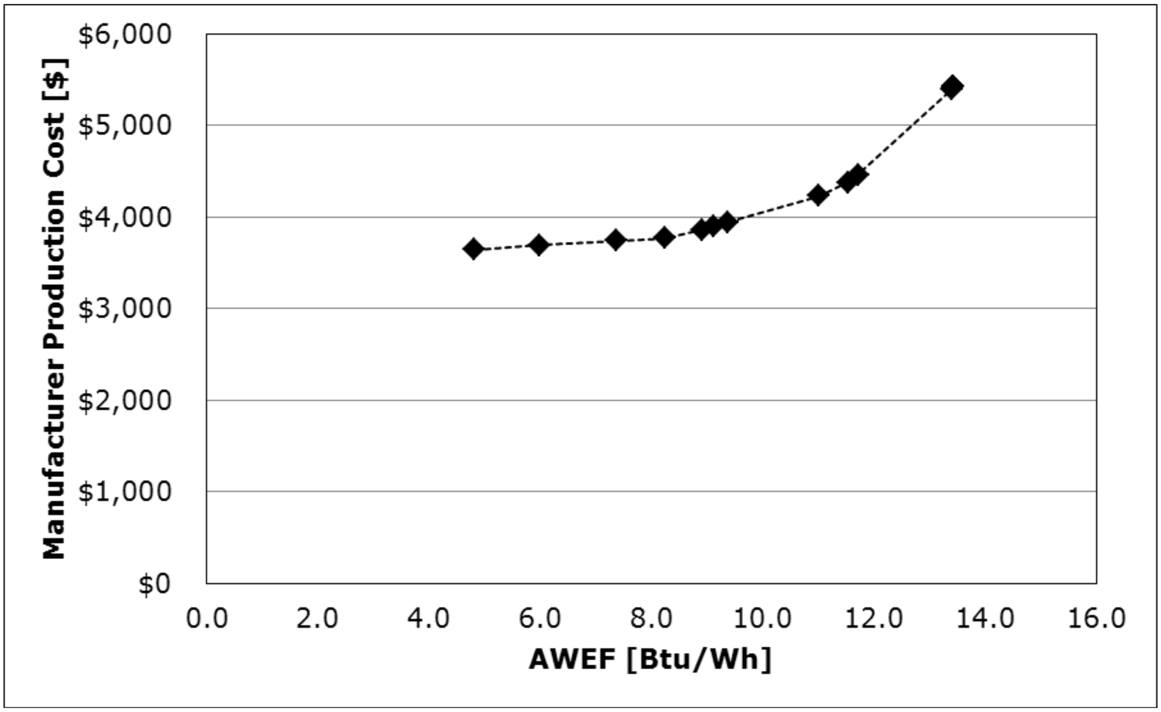


Figure 5A.5.25 Cost-Efficiency Curve for DC.M.O.SCR.054.H

Table 5A.5.26 Cost-Efficiency Data for DC.M.O.SCR.096.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.47	$6,333	$9,499	Baseline
L1	5.62	$6,433	$9,634	L0 + MEF
L2	7.05	$6,533	$9,769	L1 + VEF
L3	7.80	$6,563	$9,810	L2 + FHP
L4	8.44	$6,670	$9,991	L3 + ASC
L5	8.82	$6,770	$10,126	L4 + VSCF
L6	8.91	$6,793	$10,158	L5 + EC
L7	9.64	$7,358	$11,101	L6 + CD2
L8	9.98	$7,508	$11,303	L7 + FHPEV
L9	10.15	$7,672	$11,525	L8 + EB2
L10	11.60	$9,338	$13,774	L9 + CMP2
L11	11.61	$9,375	$13,824	L10 + CB2

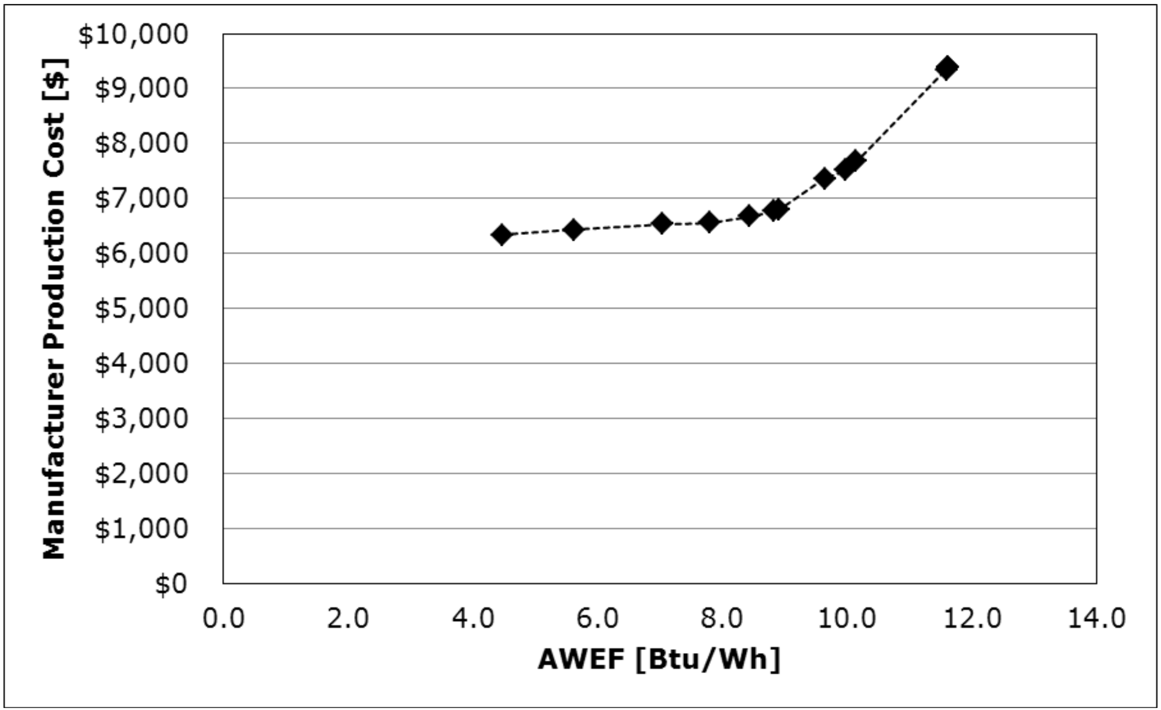


Figure 5A.5.26 Cost-Efficiency Curve for DC.M.O.SCR.096.H

Table 5A.5.27 Cost-Efficiency Data for DC.M.O.SEM.006.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.85	$1,613	$2,307	Baseline
L1	5.55	$1,638	$2,340	L0 + MEF
L2	6.24	$1,663	$2,374	L1 + VEF
L3	6.94	$1,693	$2,415	L2 + FHP
L4	6.98	$1,696	$2,418	L3 + CB2
L5	7.18	$1,713	$2,441	L4 + EC
L6	7.23	$1,718	$2,448	L5 + EB2
L7	7.86	$1,797	$2,565	L6 + ASC
L8	8.18	$1,847	$2,632	L7 + VSCF
L9	9.44	$2,004	$2,897	L8 + CD2

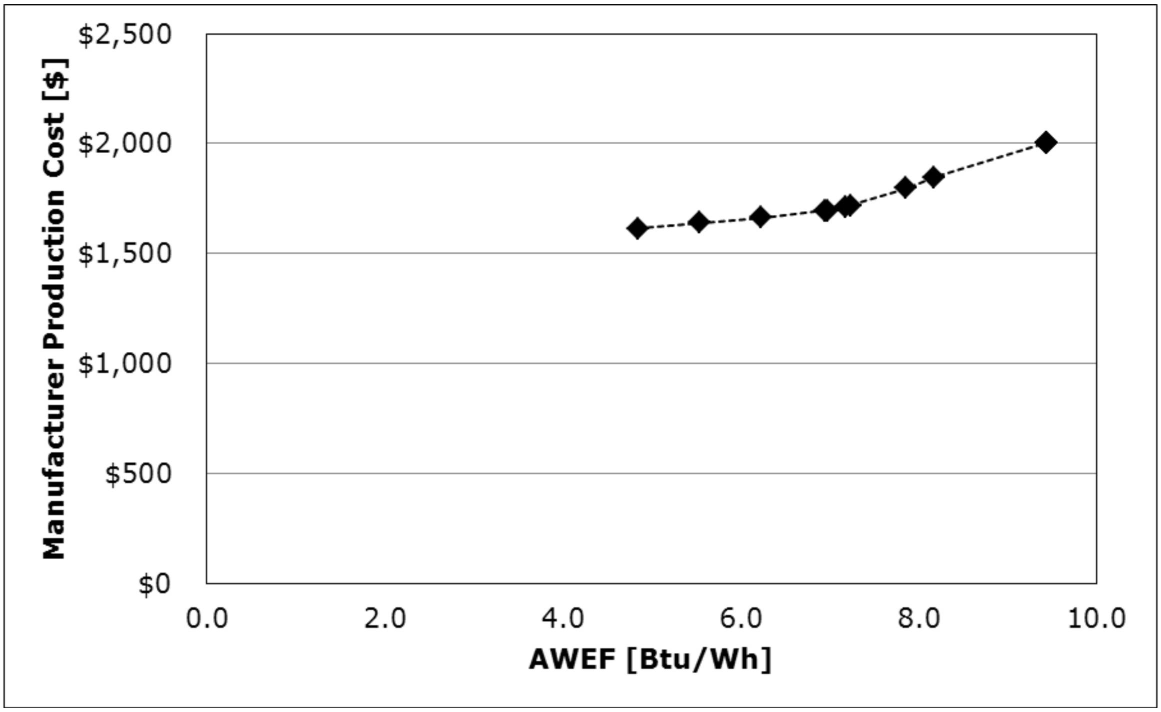


Figure 5A.5.27 Cost-Efficiency Curve for DC.M.O.SEM.006.H

Table 5A.5.28 Cost-Efficiency Data for DC.M.O.SEM.018.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.82	$2,657	$3,729	Baseline
L1	5.75	$2,707	$3,797	L0 + MEF
L2	6.75	$2,757	$3,864	L1 + VEF
L3	7.61	$2,787	$3,905	L2 + FHP
L4	8.25	$2,860	$4,011	L3 + ASC
L5	8.28	$2,865	$4,017	L4 + CB2
L6	8.47	$2,903	$4,068	L5 + EC
L7	8.72	$2,953	$4,136	L6 + VSCF
L8	9.51	$3,115	$4,389	L7 + CD2
L9	9.62	$3,137	$4,418	L8 + EB2

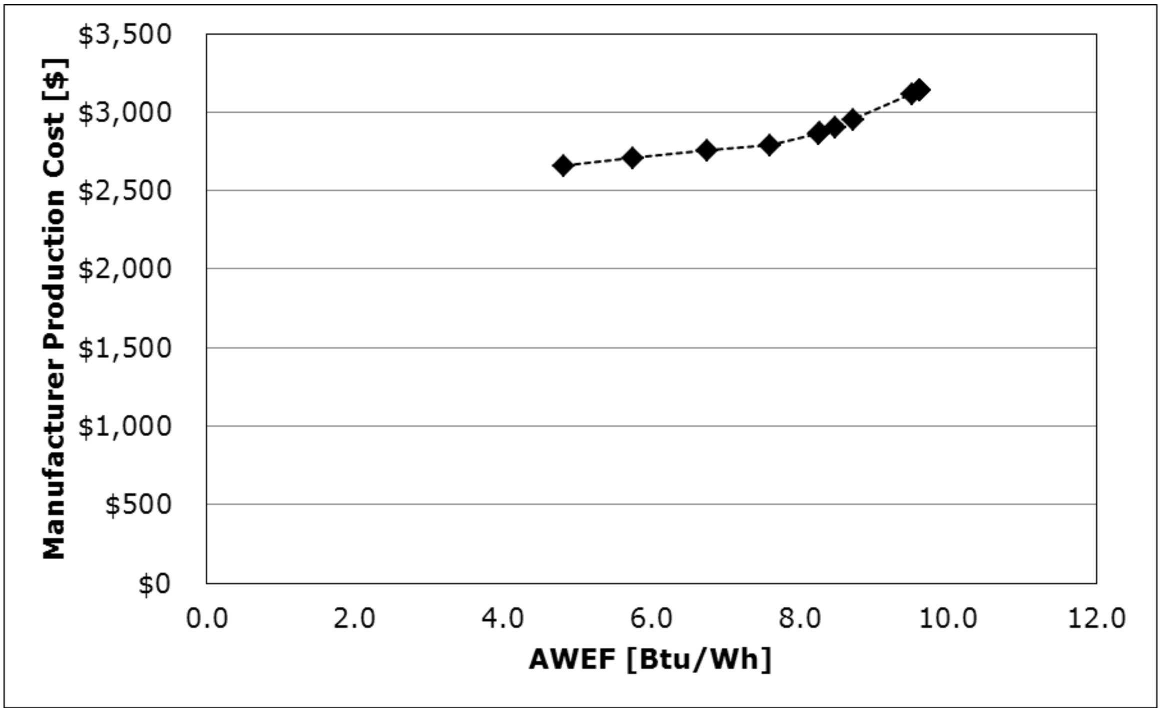


Figure 5A.5.28 Cost-Efficiency Curve for DC.M.O.SEM.018.H

Table 5A.5.29 Cost-Efficiency Data for DC.M.O.SEM.054.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	5.05	$4,221	$6,169	Baseline
L1	6.31	$4,271	$6,237	L0 + MEF
L2	7.84	$4,321	$6,304	L1 + VEF
L3	8.85	$4,351	$6,345	L2 + FHP
L4	9.58	$4,437	$6,480	L3 + ASC
L5	9.81	$4,474	$6,529	L4 + EC
L6	10.11	$4,524	$6,597	L5 + VSCF
L7	10.90	$4,784	$7,036	L6 + CD2
L8	11.08	$4,866	$7,147	L7 + EB2
L9	12.64	$6,344	$9,142	L8 + CMP2
L10	12.66	$6,363	$9,167	L9 + CB2

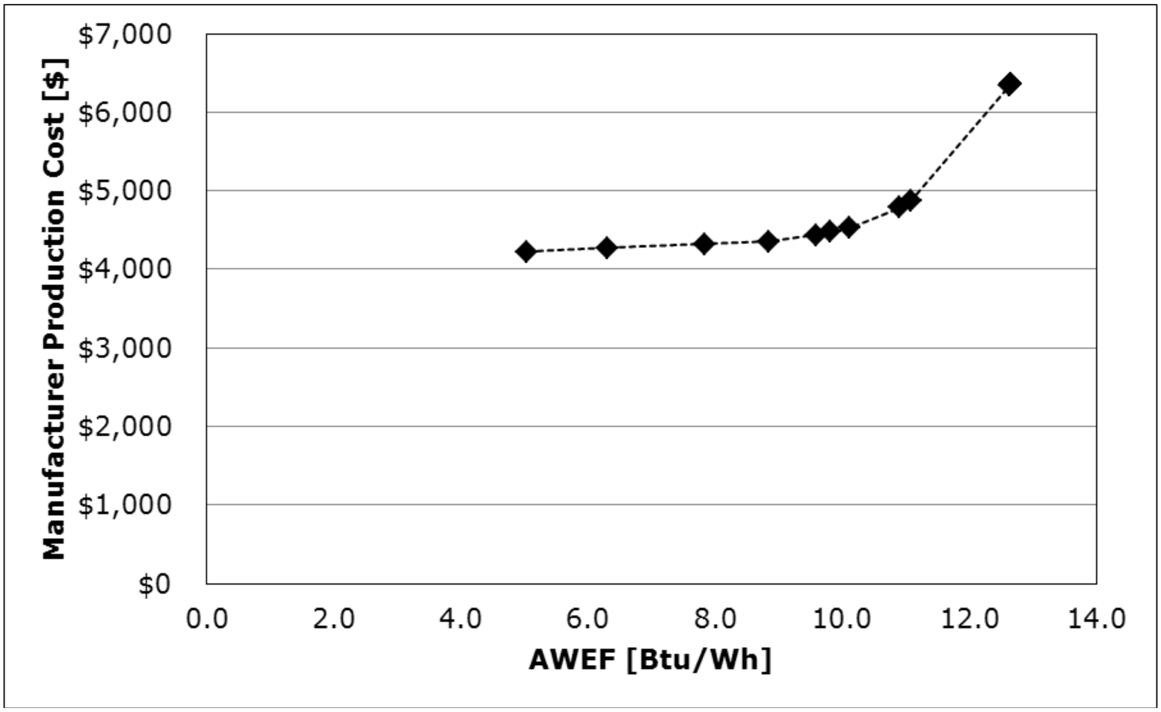


Figure 5A.5.29 Cost-Efficiency Curve for DC.M.O.SEM.054.H

Table 5A.5.30 Cost-Efficiency Data for DC.M.O.SEM.096.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.61	$7,086	$10,516	Baseline
L1	5.82	$7,186	$10,651	L0 + MEF
L2	7.35	$7,286	$10,786	L1 + VEF
L3	8.26	$7,316	$10,826	L2 + FHP
L4	8.93	$7,423	$11,008	L3 + ASC
L5	9.35	$7,523	$11,143	L4 + VSCF
L6	9.45	$7,546	$11,175	L5 + EC
L7	10.21	$8,042	$12,025	L6 + CD2
L8	10.39	$8,207	$12,247	L7 + EB2
L9	11.81	$10,215	$14,958	L8 + CMP3
L10	11.83	$10,253	$15,009	L9 + CB2

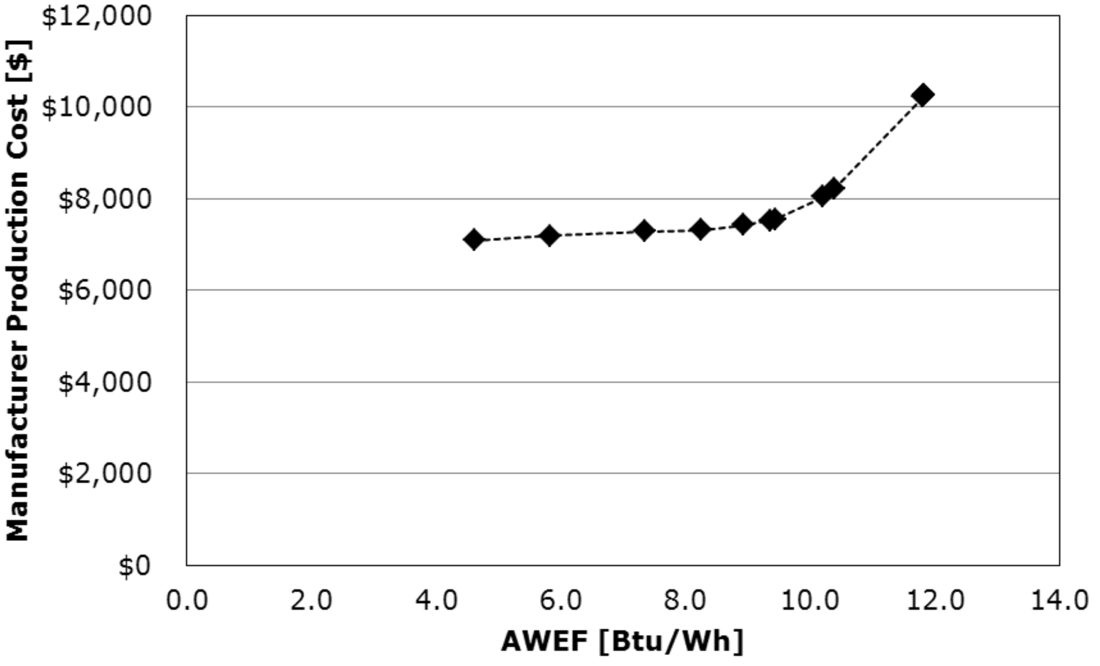


Figure 5A.5.30 Cost-Efficiency Curve for DC.M.O.SEM.096.H

Table 5A.5.31 Cost-Efficiency Data for DC.L.I.HER.006.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.34	$1,554	$2,207	Baseline
L1	2.45	$1,579	$2,241	L0 + MEF
L2	2.55	$1,604	$2,275	L1 + VEF
L3	2.56	$1,608	$2,281	L2 + CB2
L4	2.64	$1,643	$2,327	L3 + EC
L5	2.66	$1,654	$2,342	L4 + EB2
L6	2.82	$1,801	$2,573	L5 + CD2
L7	2.85	$1,851	$2,640	L6 + DFC1

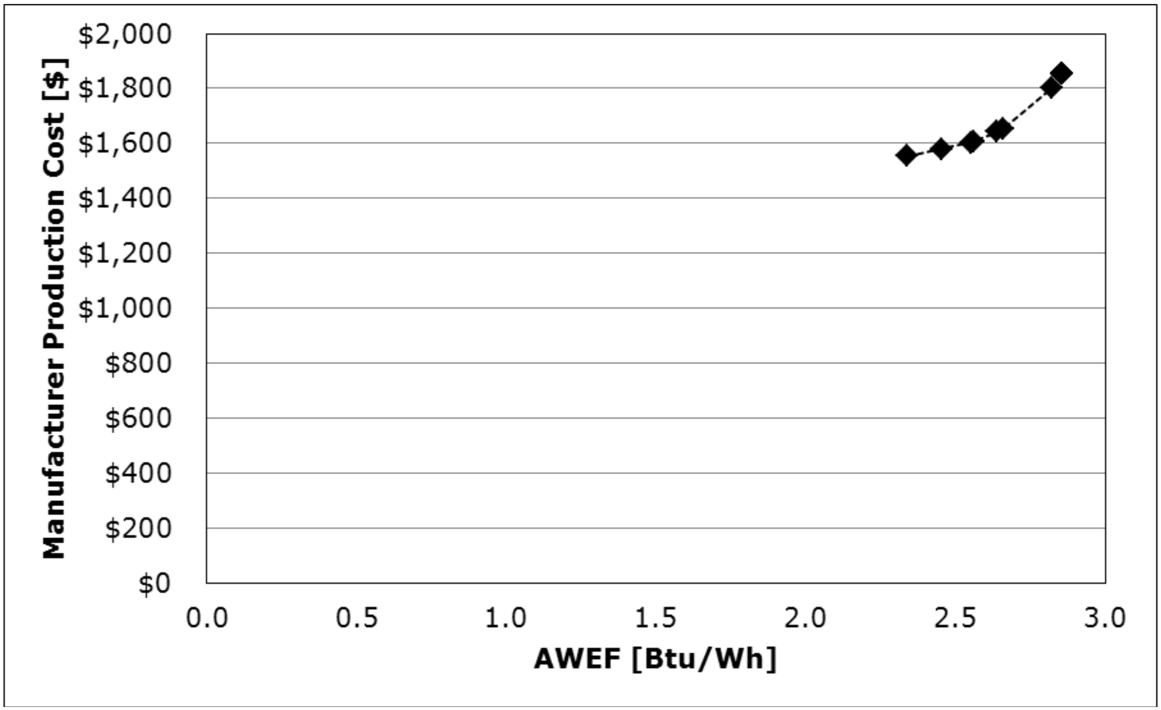


Figure 5A.5.31 Cost-Efficiency Curve for DC.L.I.HER.006.H

Table 5A.5.32 Cost-Efficiency Data for DC.L.I.HER.009.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.77	$1,676	$2,391	Baseline
L1	2.87	$1,701	$2,425	L0 + MEF
L2	2.95	$1,726	$2,459	L1 + VEF
L3	2.96	$1,731	$2,465	L2 + CB2
L4	3.02	$1,765	$2,512	L3 + EC
L5	3.26	$1,918	$2,756	L4 + CD2
L6	3.28	$1,929	$2,771	L5 + EB2
L7	3.31	$1,979	$2,839	L6 + DFC1

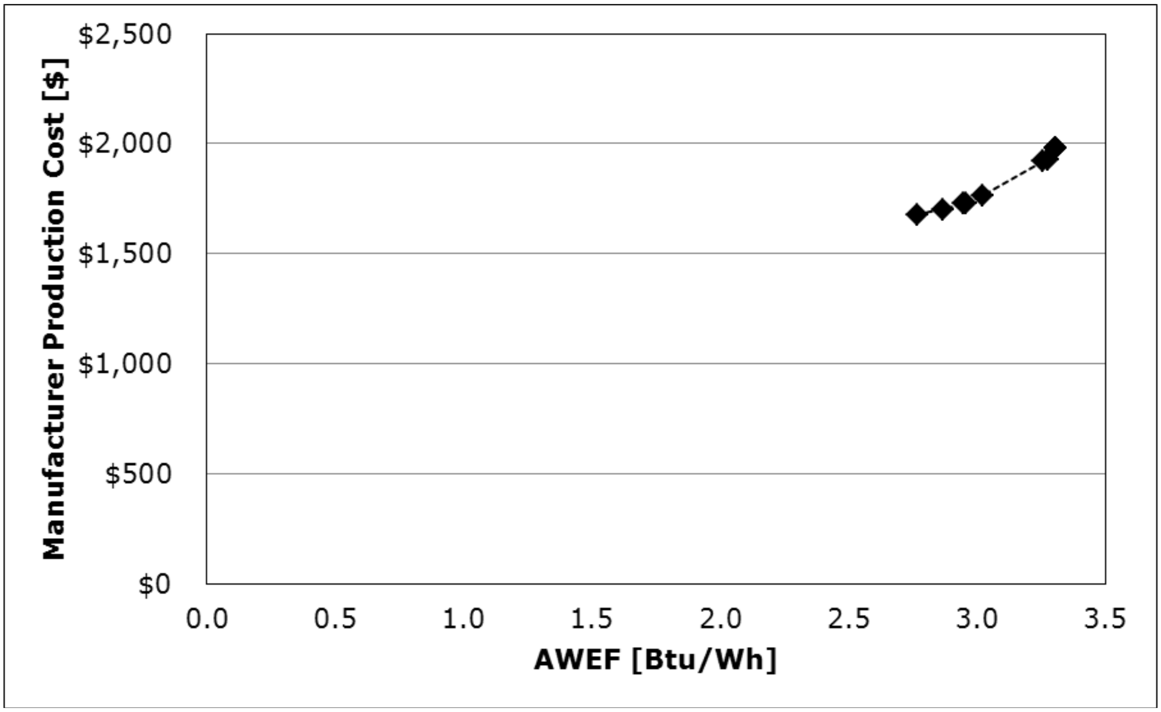


Figure 5A.5.32 Cost-Efficiency Curve for DC.L.I.HER.009.H

Table 5A.5.33 Cost-Efficiency Data for DC.L.I.SCR.006.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.42	$1,805	$2,547	Baseline
L1	2.54	$1,830	$2,581	L0 + MEF
L2	2.65	$1,855	$2,614	L1 + VEF
L3	2.66	$1,859	$2,621	L2 + CB2
L4	2.74	$1,894	$2,667	L3 + EC
L5	2.76	$1,905	$2,682	L4 + EB2
L6	3.05	$2,047	$2,906	L5 + CD2
L7	3.09	$2,097	$2,973	L6 + DFC1

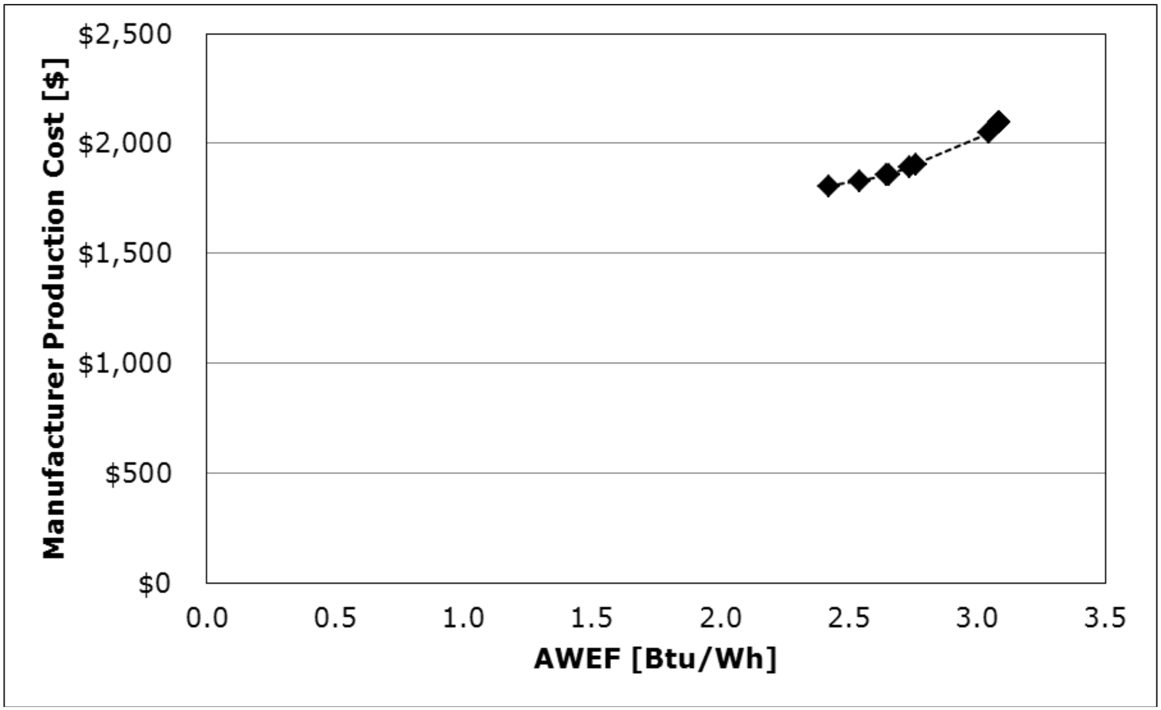


Figure 5A.5.33 Cost-Efficiency Curve for DC.L.I.SCR.006.H

Table 5A.5.34 Cost-Efficiency Data for DC.L.I.SCR.009.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	3.04	$1,910	$2,707	Baseline
L1	3.15	$1,935	$2,741	L0 + MEF
L2	3.25	$1,960	$2,775	L1 + VEF
L3	3.26	$1,965	$2,781	L2 + CB2
L4	3.34	$1,999	$2,828	L3 + EC
L5	3.36	$2,010	$2,842	L4 + EB2
L6	3.63	$2,174	$3,102	L5 + CD2
L7	3.67	$2,224	$3,170	L6 + DFC1

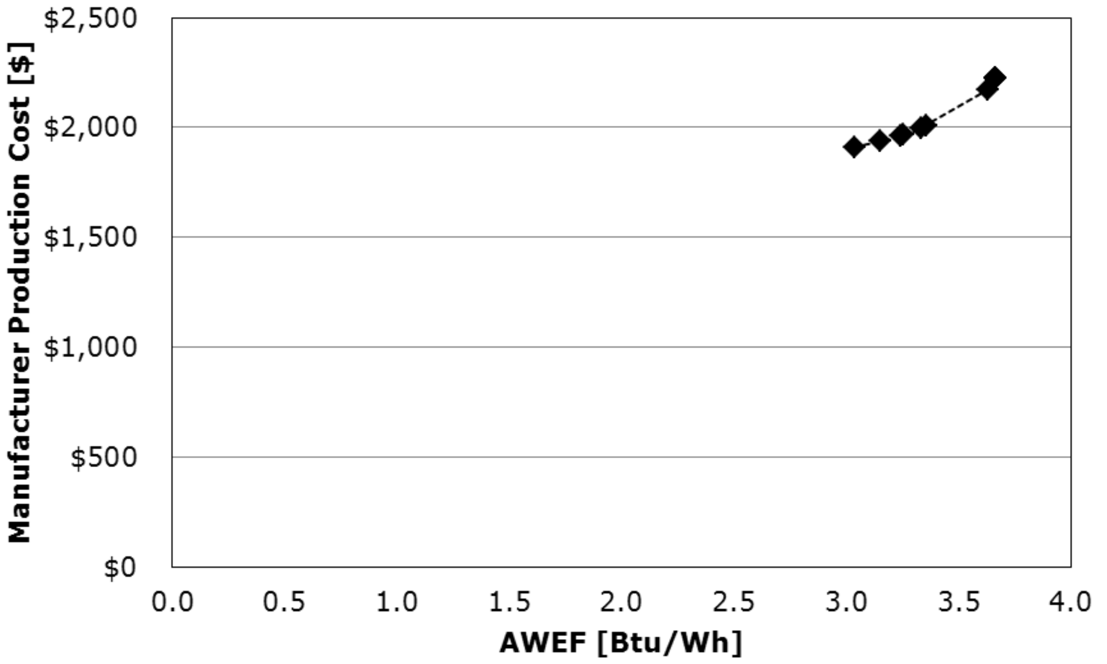


Figure 5A.5.34 Cost-Efficiency Curve for DC.L.I.SCR.009.H

Table 5A.5.35 Cost-Efficiency Data for DC.L.I.SCR.054.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	3.28	$6,853	$10,611	Baseline
L1	3.44	$6,903	$10,678	L0 + MEF
L2	3.58	$6,953	$10,746	L1 + VEF
L3	3.66	$7,020	$10,836	L2 + EC
L4	3.69	$7,070	$10,903	L3 + DFC1
L5	3.70	$7,093	$10,934	L4 + CB2
L6	3.73	$7,175	$11,045	L5 + EB2
L7	3.79	$7,932	$12,339	L6 + CD2

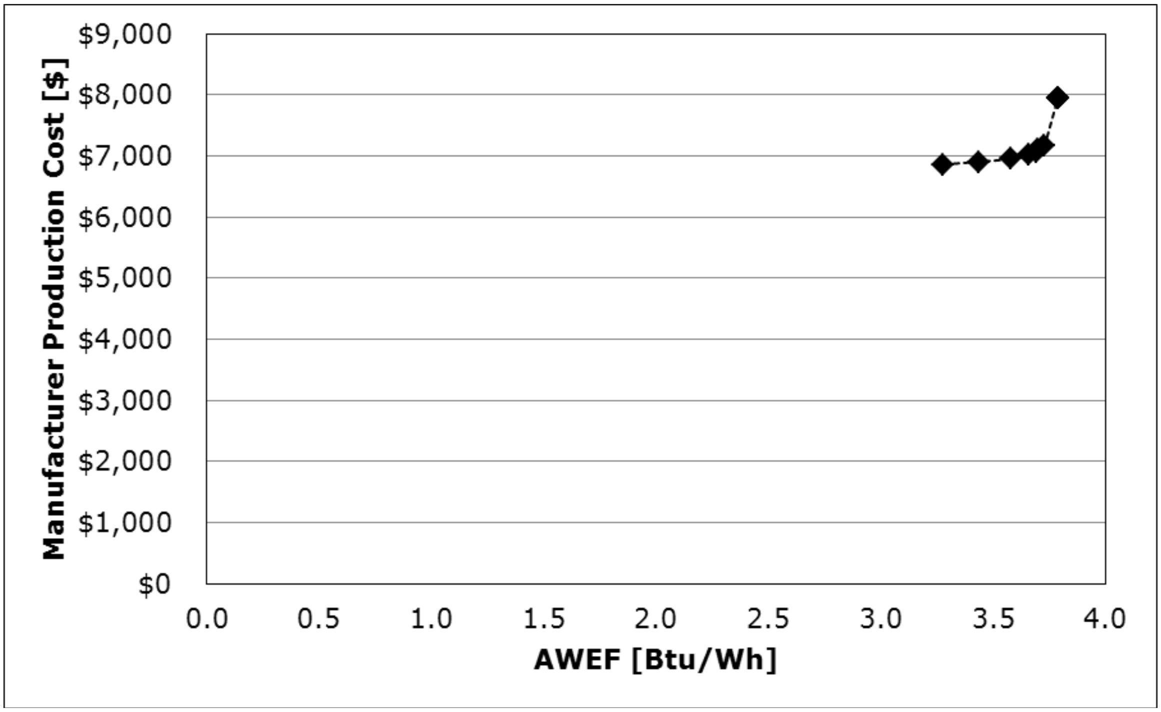


Figure 5A.5.35 Cost-Efficiency Curve for DC.L.I.SCR.054.H

Table 5A.5.36 Cost-Efficiency Data for DC.L.I.SEM.006.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.36	$2,054	$2,883	Baseline
L1	2.47	$2,079	$2,917	L0 + MEF
L2	2.57	$2,104	$2,950	L1 + VEF
L3	2.58	$2,109	$2,956	L2 + CB2
L4	2.66	$2,143	$3,003	L3 + EC
L5	2.68	$2,154	$3,018	L4 + EB2
L6	2.81	$2,286	$3,227	L5 + CD2
L7	2.84	$2,336	$3,294	L6 + DFC1

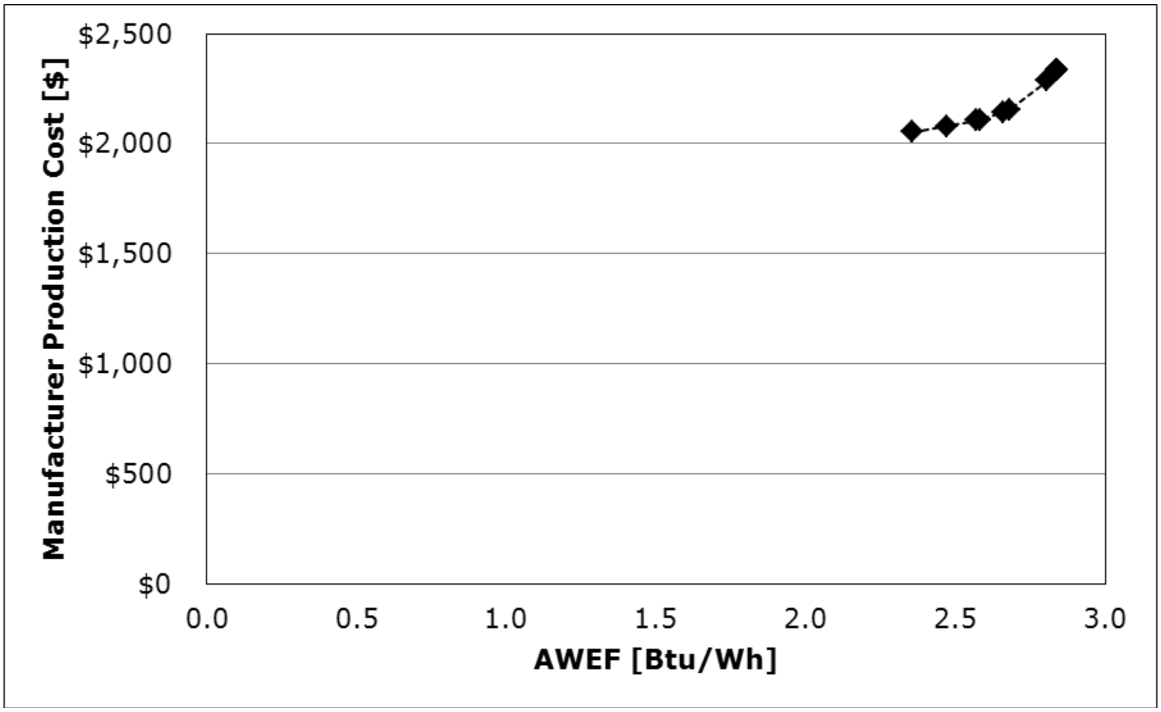


Figure 5A.5.36 Cost-Efficiency Curve for DC.L.I.SEM.006.H

Table 5A.5.37 Cost-Efficiency Data for DC.L.I.SEM.009.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.64	$2,213	$3,116	Baseline
L1	2.73	$2,238	$3,149	L0 + MEF
L2	2.81	$2,263	$3,183	L1 + VEF
L3	2.82	$2,267	$3,189	L2 + CB2
L4	2.88	$2,302	$3,236	L3 + EC
L5	3.11	$2,443	$3,465	L4 + CD2
L6	3.13	$2,454	$3,480	L5 + EB2
L7	3.16	$2,504	$3,547	L6 + DFC1

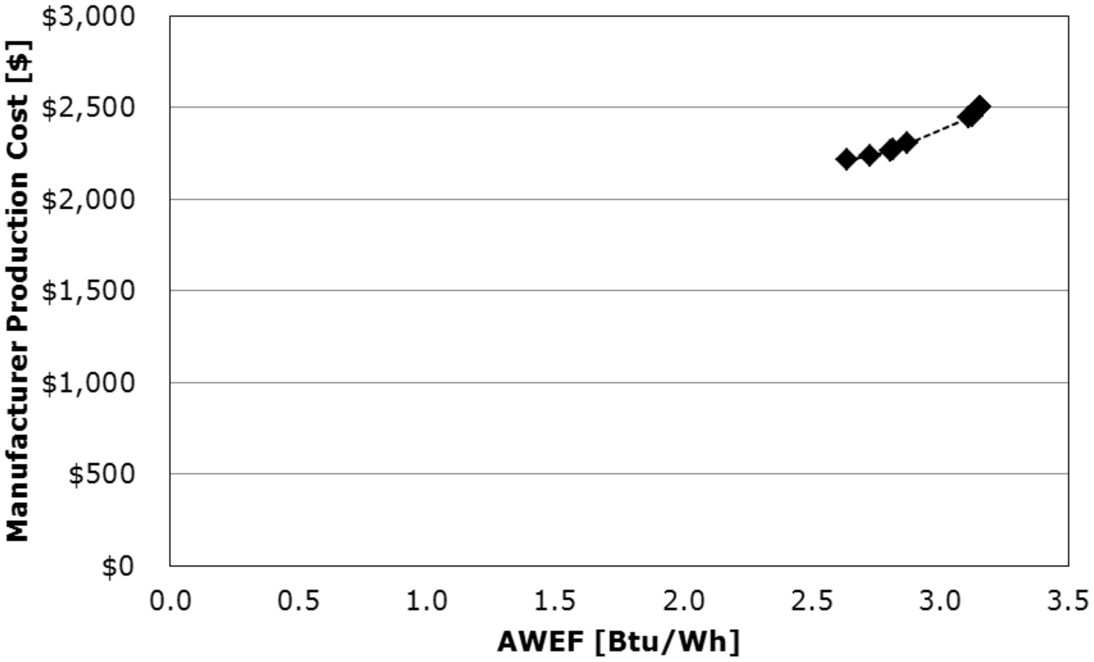


Figure 5A.5.37 Cost-Efficiency Curve for DC.L.I.SEM.009.H

Table 5A.5.38 Cost-Efficiency Data for DC.L.I.SEM.054.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	3.02	$7,511	$11,499	Baseline
L1	3.16	$7,561	$11,567	L0 + MEF
L2	3.28	$7,611	$11,634	L1 + VEF
L3	3.45	$7,728	$11,792	L2 + EC
L4	3.48	$7,778	$11,860	L3 + DFC1
L5	3.49	$7,829	$11,929	L4 + CB2
L6	3.52	$7,912	$12,039	L5 + EB2
L7	3.69	$8,562	$13,191	L6 + CD2

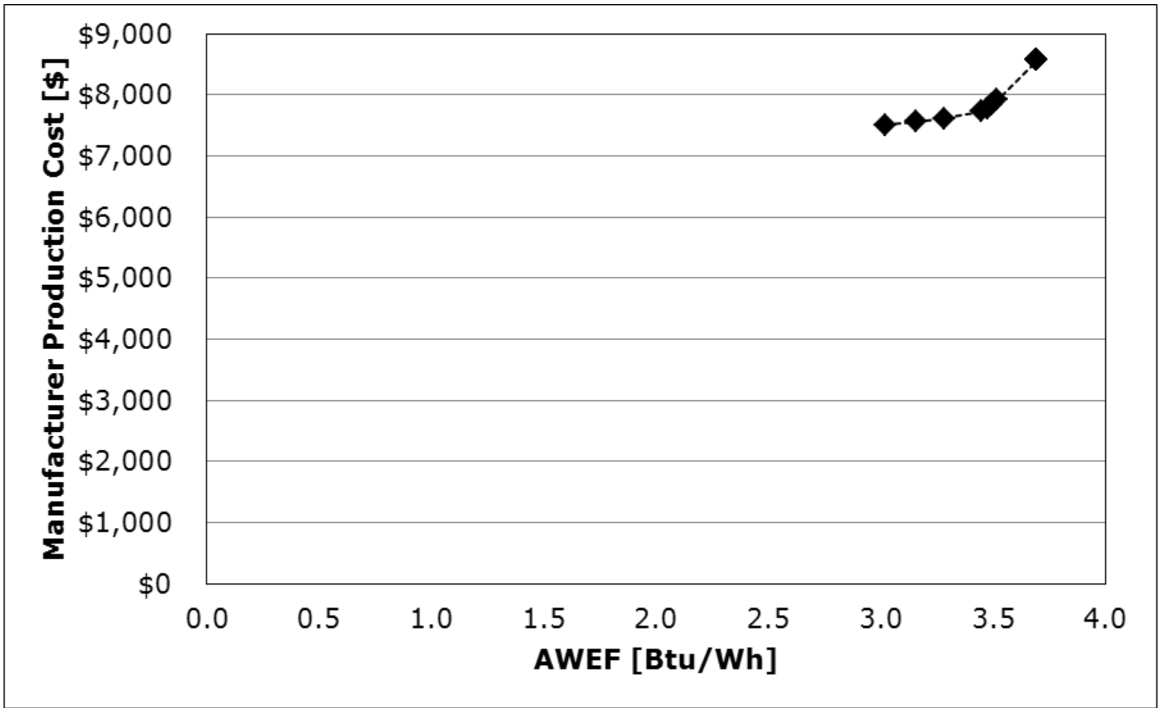


Figure 5A.5.38 Cost-Efficiency Curve for DC.L.I.SEM.054.H

Table 5A.5.39 Cost-Efficiency Data for DC.L.O.HER.006.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.40	$1,591	$2,258	Baseline
L1	2.62	$1,616	$2,291	L0 + MEF
L2	2.81	$1,641	$2,325	L1 + VEF
L3	2.97	$1,671	$2,366	L2 + FHP
L4	3.30	$1,745	$2,472	L3 + ASC
L5	3.31	$1,749	$2,478	L4 + CB2
L6	3.34	$1,760	$2,493	L5 + EB2
L7	3.43	$1,798	$2,544	L6 + EC
L8	3.56	$1,848	$2,612	L7 + VSCF
L9	3.62	$1,898	$2,679	L8 + DFC1
L10	3.65	$2,058	$2,930	L9 + CD2

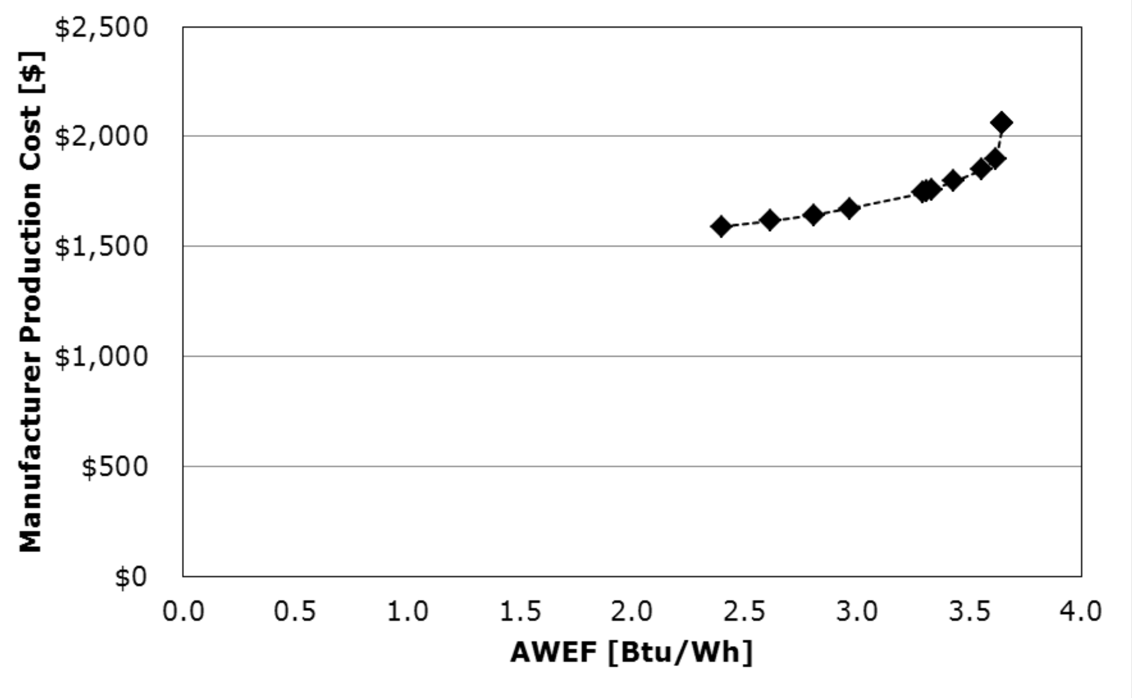


Figure 5A.5.39 Cost-Efficiency Curve for DC.L.O.HER.006.H

Table 5A.5.40 Cost-Efficiency Data for DC.L.O.HER.009.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.91	$1,720	$2,451	Baseline
L1	3.10	$1,745	$2,484	L0 + MEF
L2	3.27	$1,770	$2,518	L1 + VEF
L3	3.47	$1,800	$2,559	L2 + FHP
L4	3.86	$1,876	$2,670	L3 + ASC
L5	3.87	$1,881	$2,677	L4 + CB2
L6	3.96	$1,919	$2,728	L5 + EC
L7	4.07	$1,969	$2,795	L6 + VSCF
L8	4.09	$1,980	$2,810	L7 + EB2
L9	4.38	$2,144	$3,075	L8 + CD2
L10	4.44	$2,194	$3,142	L9 + DFC1

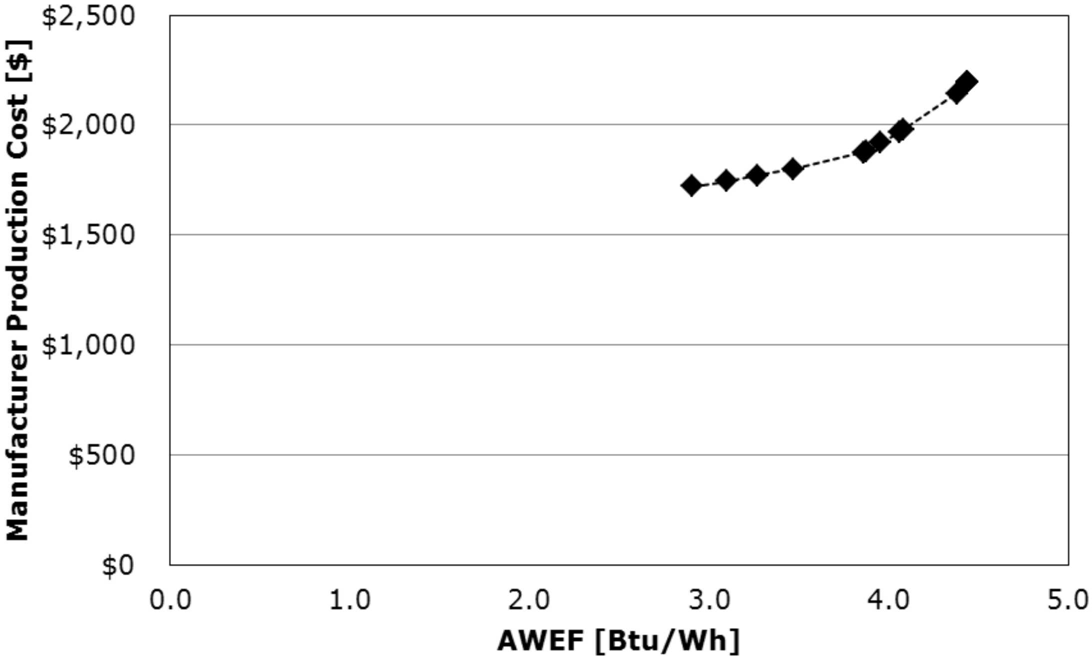


Figure 5A.5.40 Cost-Efficiency Curve for DC.L.O.HER.009.H

Table 5A.5.41 Cost-Efficiency Data for DC.L.O.SCR.006.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.86	$1,838	$2,592	Baseline
L1	3.14	$1,863	$2,626	L0 + MEF
L2	3.39	$1,888	$2,659	L1 + VEF
L3	3.70	$1,918	$2,700	L2 + FHP
L4	4.07	$1,992	$2,807	L3 + ASC
L5	4.09	$1,996	$2,813	L4 + CB2
L6	4.24	$2,034	$2,864	L5 + EC
L7	4.44	$2,084	$2,932	L6 + VSCF
L8	4.48	$2,095	$2,946	L7 + EB2
L9	4.79	$2,250	$3,190	L8 + CD2
L10	4.89	$2,300	$3,258	L9 + DFC1

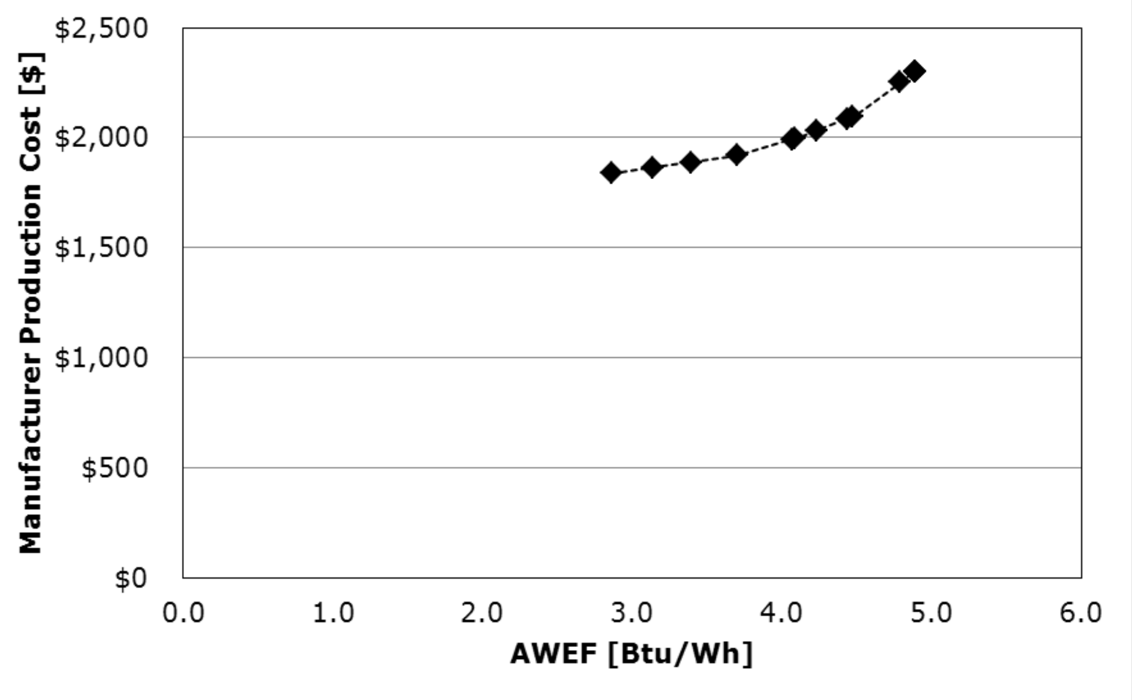


Figure 5A.5.41 Cost-Efficiency Curve for DC.L.O.SCR.006.H

Table 5A.5.42 Cost-Efficiency Data for DC.L.O.SCR.009.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	3.70	$1,944	$2,753	Baseline
L1	3.98	$1,969	$2,786	L0 + MEF
L2	4.35	$1,999	$2,827	L1 + FHP
L3	4.64	$2,024	$2,861	L2 + VEF
L4	5.11	$2,100	$2,972	L3 + ASC
L5	5.13	$2,105	$2,979	L4 + CB2
L6	5.28	$2,143	$3,030	L5 + EC
L7	5.48	$2,193	$3,097	L6 + VSCF
L8	5.52	$2,204	$3,112	L7 + EB2
L9	5.86	$2,381	$3,395	L8 + CD2
L10	6.15	$2,531	$3,597	L9 + FHPEV
L11	6.25	$2,581	$3,665	L10 + DFC1

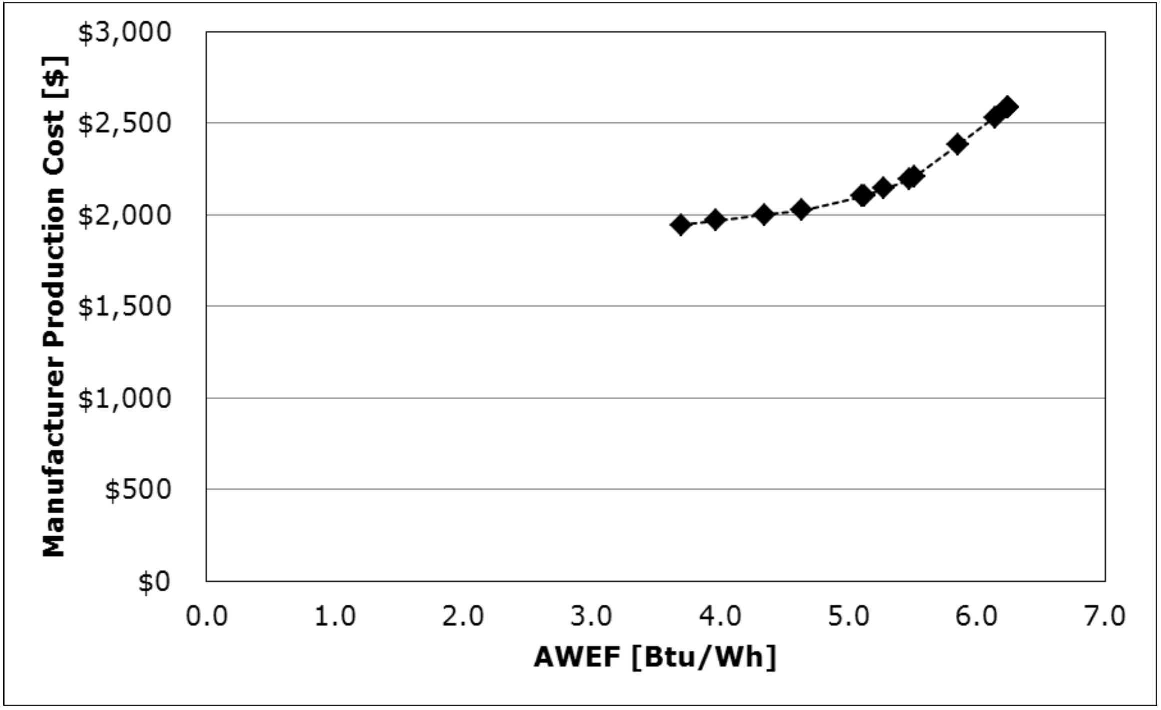


Figure 5A.5.42 Cost-Efficiency Curve for DC.L.O.SCR.009.H

Table 5A.5.43 Cost-Efficiency Data for DC.L.O.SCR.054.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.09	$6,938	$10,726	Baseline
L1	4.44	$6,968	$10,766	L0 + FHP
L2	4.92	$7,018	$10,834	L1 + MEF
L3	5.38	$7,068	$10,901	L2 + VEF
L4	5.93	$7,188	$11,125	L3 + ASC
L5	6.27	$7,288	$11,260	L4 + VSCF
L6	6.34	$7,312	$11,291	L5 + EC
L7	6.43	$7,362	$11,359	L6 + DFC1
L8	6.58	$7,512	$11,561	L7 + FHPEV
L9	6.64	$7,594	$11,672	L8 + EB2
L10	7.77	$10,312	$15,342	L9 + CMP2
L11	7.78	$10,337	$15,376	L10 + CB2
L12	7.91	$11,062	$16,655	L11 + CD2

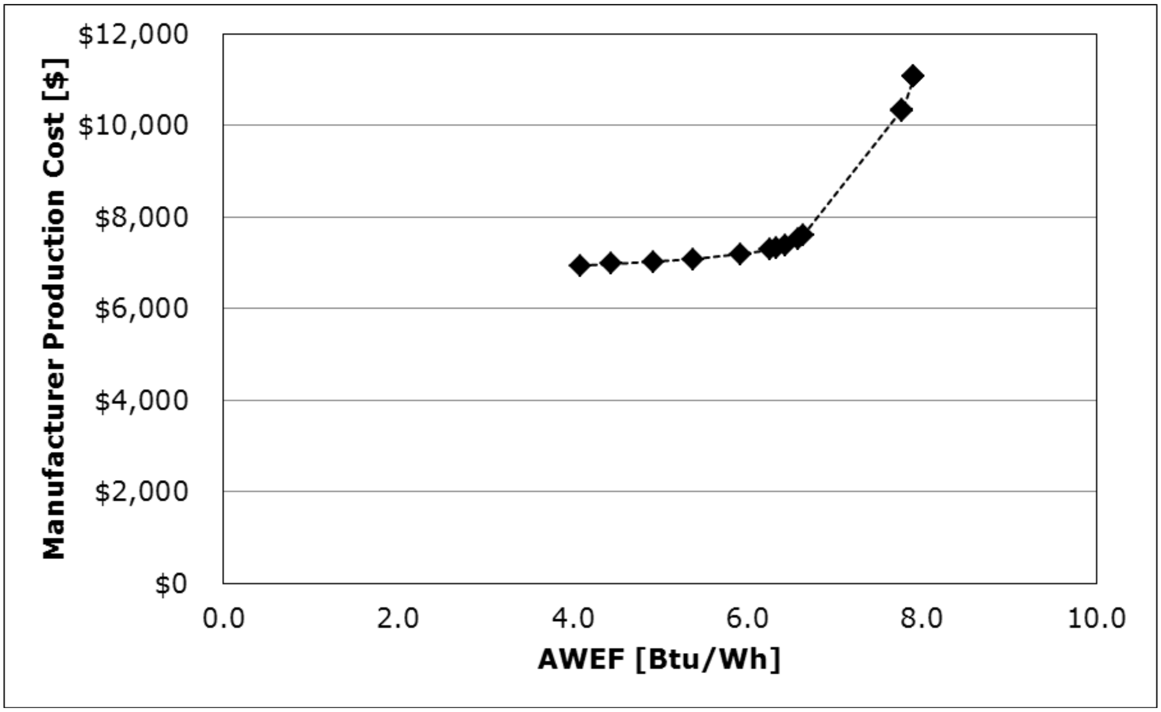


Figure 5A.5.43 Cost-Efficiency Curve for DC.L.O.SCR.054.H

Table 5A.5.44 Cost-Efficiency Data for DC.L.O.SEM.006.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.47	$2,095	$2,938	Baseline
L1	2.69	$2,120	$2,971	L0 + MEF
L2	2.90	$2,145	$3,005	L1 + VEF
L3	3.15	$2,175	$3,046	L2 + FHP
L4	3.48	$2,248	$3,152	L3 + ASC
L5	3.50	$2,253	$3,158	L4 + CB2
L6	3.60	$2,291	$3,210	L5 + EC
L7	3.74	$2,341	$3,277	L6 + VSCF
L8	3.77	$2,352	$3,292	L7 + EB2
L9	3.84	$2,402	$3,360	L8 + DFC1
L10	3.93	$2,555	$3,600	L9 + CD2

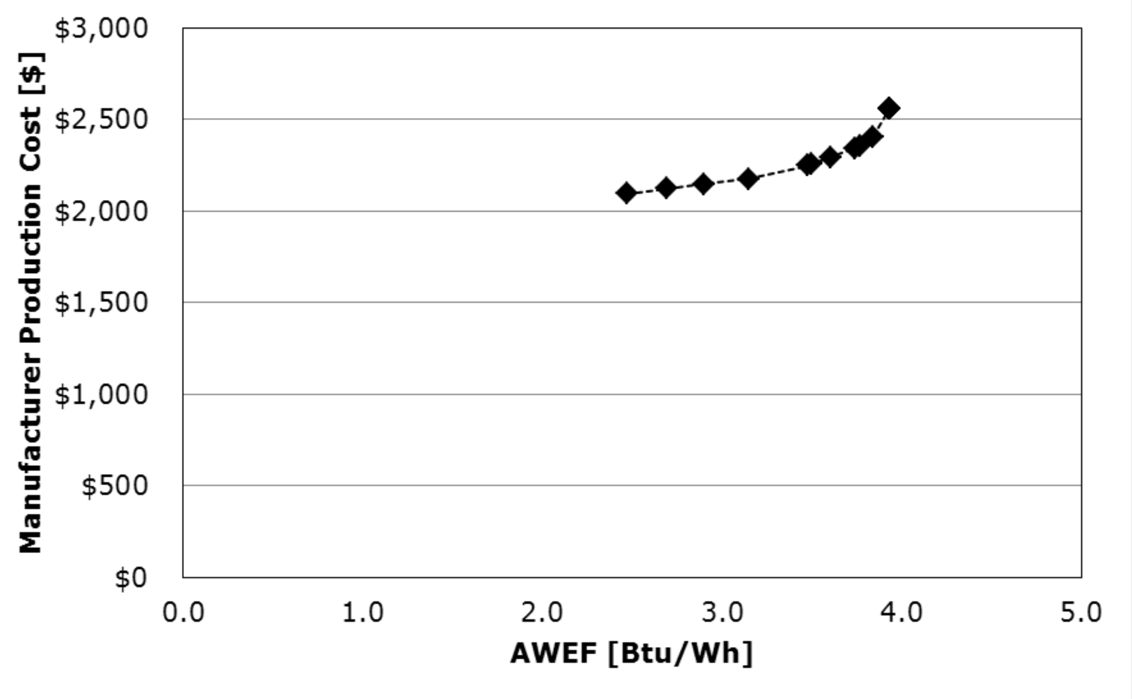


Figure 5A.5.44 Cost-Efficiency Curve for DC.L.O.SEM.006.H

Table 5A.5.45 Cost-Efficiency Data for DC.L.O.SEM.009.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.78	$2,270	$3,192	Baseline
L1	2.96	$2,295	$3,226	L0 + MEF
L2	3.12	$2,320	$3,260	L1 + VEF
L3	3.40	$2,350	$3,300	L2 + FHP
L4	3.77	$2,426	$3,412	L3 + ASC
L5	3.78	$2,430	$3,418	L4 + CB2
L6	3.86	$2,468	$3,470	L5 + EC
L7	3.96	$2,518	$3,537	L6 + VSCF
L8	4.28	$2,666	$3,780	L7 + CD2
L9	4.30	$2,677	$3,794	L8 + EB2
L10	4.36	$2,727	$3,862	L9 + DFC1

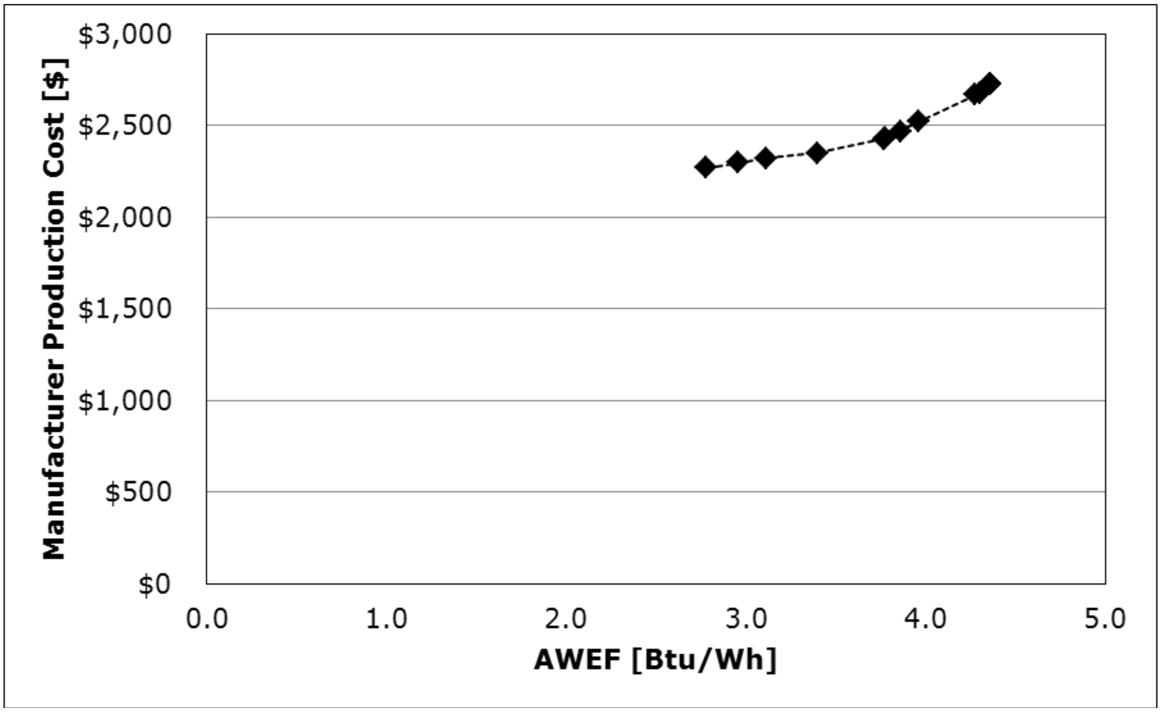


Figure 5A.5.45 Cost-Efficiency Curve for DC.L.O.SEM.009.H

Table 5A.5.46 Cost-Efficiency Data for DC.L.O.SEM.054.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	3.36	$7,776	$11,856	Baseline
L1	3.63	$7,806	$11,896	L0 + FHP
L2	3.99	$7,856	$11,964	L1 + MEF
L3	4.32	$7,906	$12,031	L2 + VEF
L4	4.74	$8,006	$12,166	L3 + VSCF
L5	5.24	$8,129	$12,395	L4 + ASC
L6	5.36	$8,208	$12,502	L5 + EC
L7	5.43	$8,258	$12,569	L6 + DFC1
L8	5.47	$8,340	$12,680	L7 + EB2
L9	6.37	$11,254	$16,614	L8 + CMP3
L10	6.52	$11,720	$17,543	L9 + CD2
L11	6.54	$11,804	$17,656	L10 + CB2

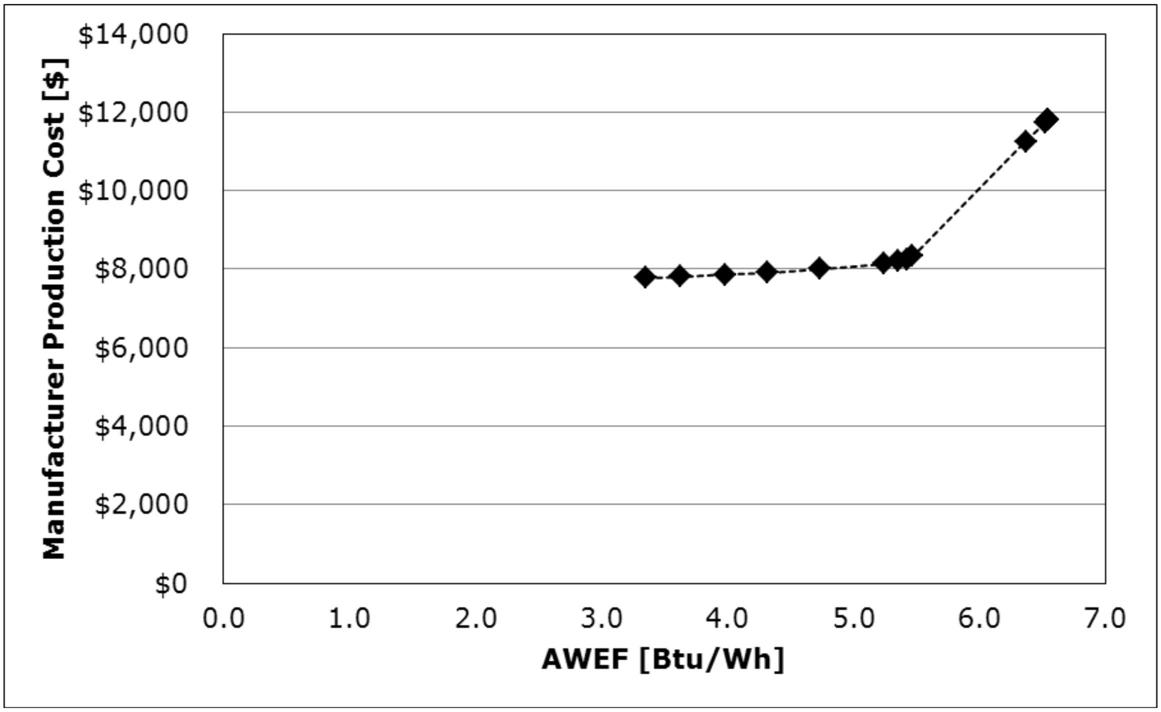


Figure 5A.5.46 Cost-Efficiency Curve for DC.L.O.SEM.054.H

Table 5A.5.47 Cost-Efficiency Data for DC.L.O.SEM.072.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	3.41	$9,772	$14,920	Baseline
L1	3.70	$9,802	$14,960	L0 + FHP
L2	4.11	$9,877	$15,062	L1 + MEF
L3	4.50	$9,952	$15,163	L2 + VEF
L4	4.96	$10,075	$15,392	L3 + ASC
L5	5.36	$10,175	$15,527	L4 + VSCF
L6	5.44	$10,225	$15,594	L5 + DFC1
L7	5.53	$10,304	$15,701	L6 + EC
L8	5.58	$10,427	$15,867	L7 + EB2
L9	5.79	$11,091	$17,063	L8 + CD2
L10	6.71	$13,999	$20,989	L9 + CMP3
L11	6.72	$14,083	$21,102	L10 + CB2

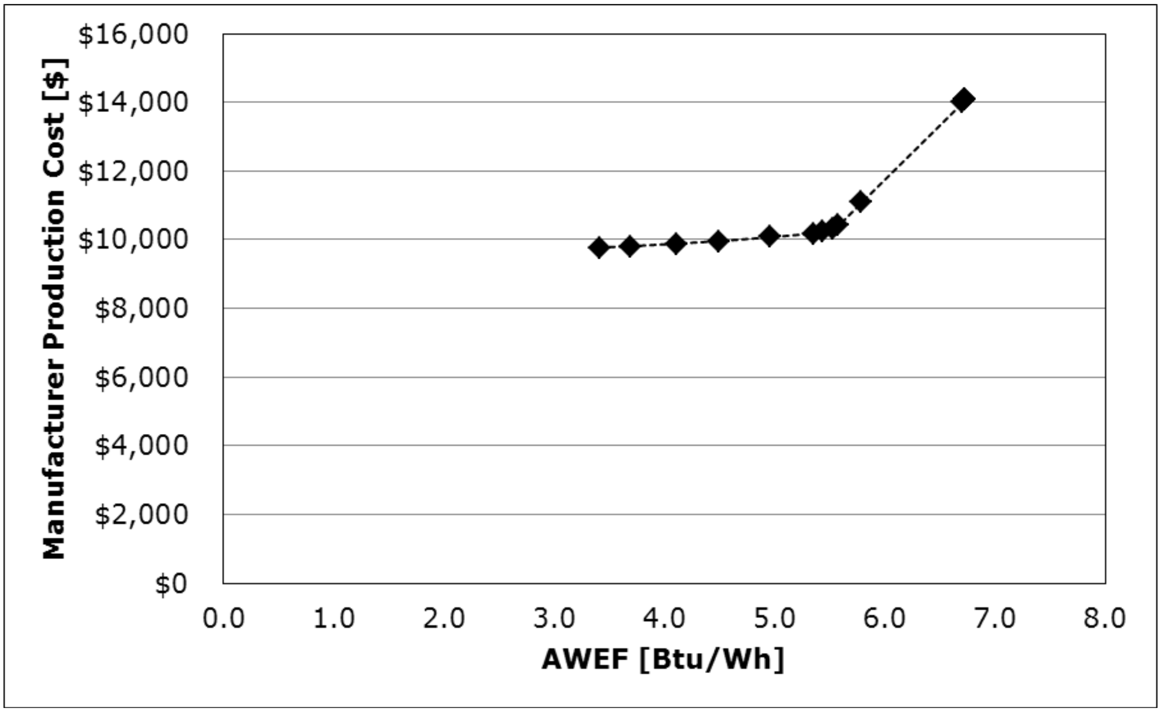


Figure 5A.5.47 Cost-Efficiency Curve for DC.L.O.SEM.072.H

Table 5A.5.48 Cost-Efficiency Data for MC.M.N.006.004.1

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	6.42	$370	$521	Baseline
L1	7.68	$395	$555	L0 + MEF
L2	10.57	$420	$589	L1 + VEF
L3	10.65	$426	$596	L2 + EB2

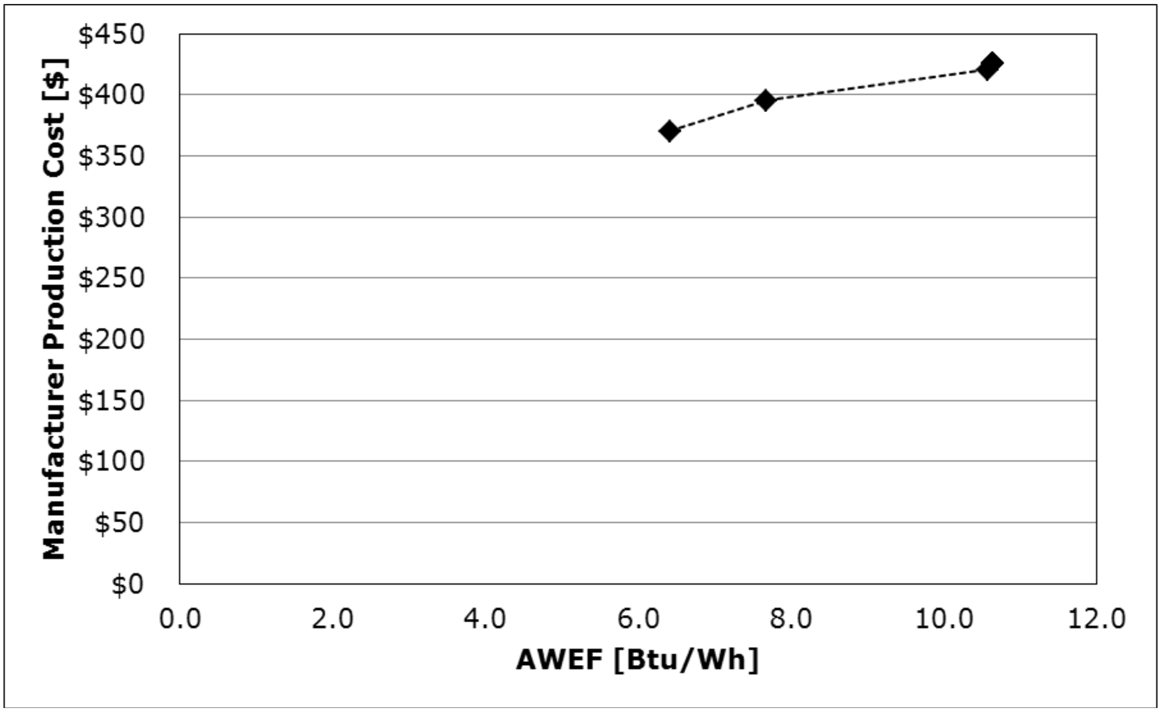


Figure 5A.5.48 Cost-Efficiency Curve for MC.M.N.006.004.1

Table 5A.5.49 Cost-Efficiency Data for MC.M.N.006.009.2

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	6.80	$530	$749	Baseline
L1	8.04	$555	$783	L0 + MEF
L2	10.74	$580	$816	L1 + VEF
L3	10.82	$591	$831	L2 + EB2

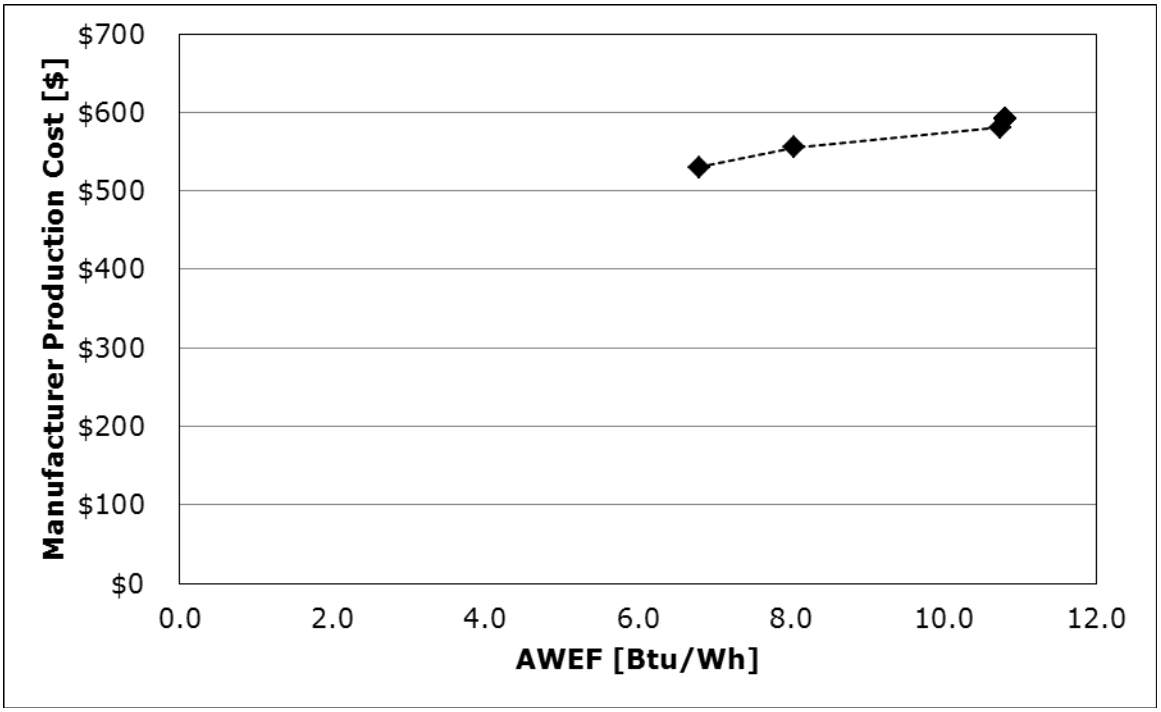


Figure 5A.5.49 Cost-Efficiency Curve for MC.M.N.006.009.2

Table 5A.5.50 Cost-Efficiency Data for MC.M.N.006.024.6

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	5.75	$821	$1,206	Baseline
L1	7.02	$846	$1,240	L0 + MEF
L2	10.23	$871	$1,274	L1 + VEF
L3	10.32	$912	$1,329	L2 + EB2

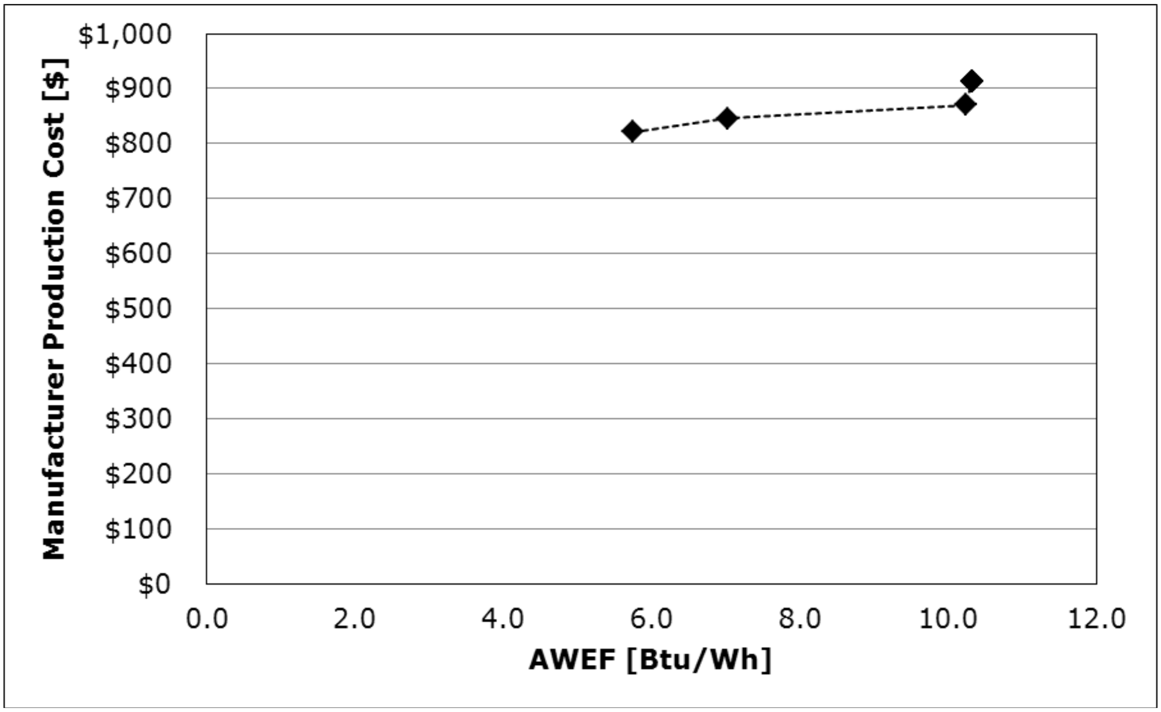


Figure 5A.5.50 Cost-Efficiency Curve for MC.M.N.006.024.6

Table 5A.5.51 Cost-Efficiency Data for MC.M.N.004.004.1

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	6.42	$416	$583	Baseline
L1	7.68	$441	$617	L0 + MEF
L2	10.57	$466	$651	L1 + VEF
L3	10.65	$472	$658	L2 + EB2

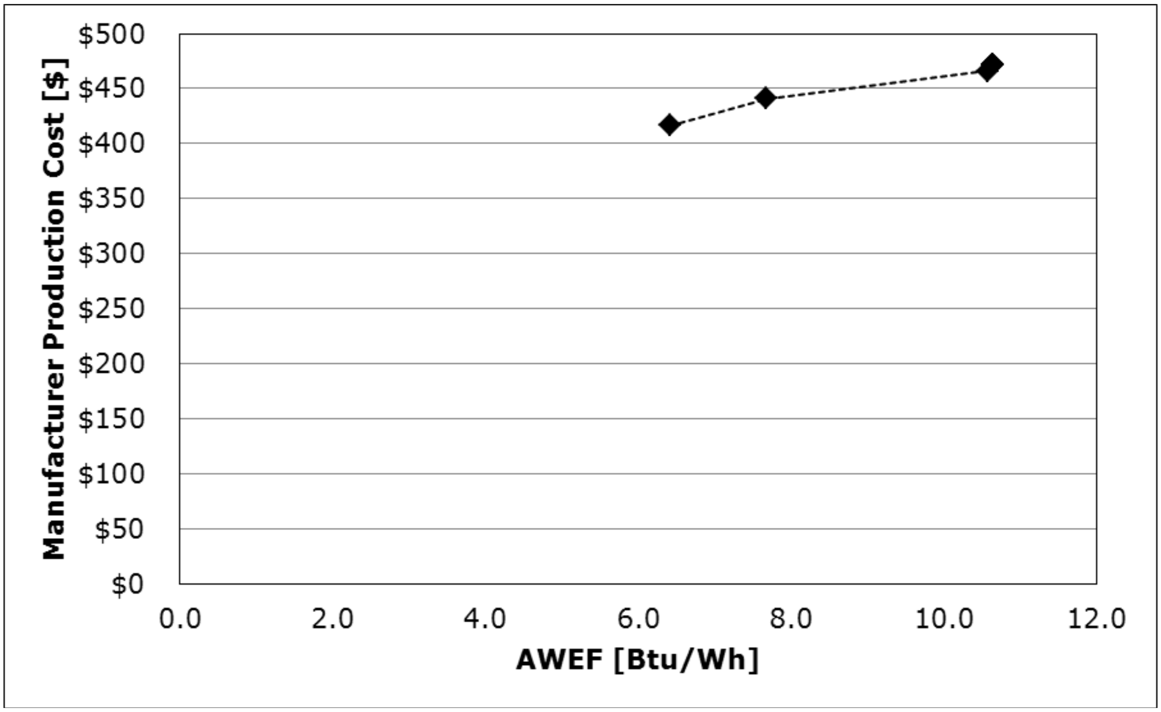


Figure 5A.5.51 Cost-Efficiency Curve for MC.M.N.004.004.1

Table 5A.5.52 Cost-Efficiency Data for MC.M.N.004.009.2

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	6.80	$533	$758	Baseline
L1	8.04	$558	$792	L0 + MEF
L2	10.74	$583	$825	L1 + VEF
L3	10.82	$594	$840	L2 + EB2

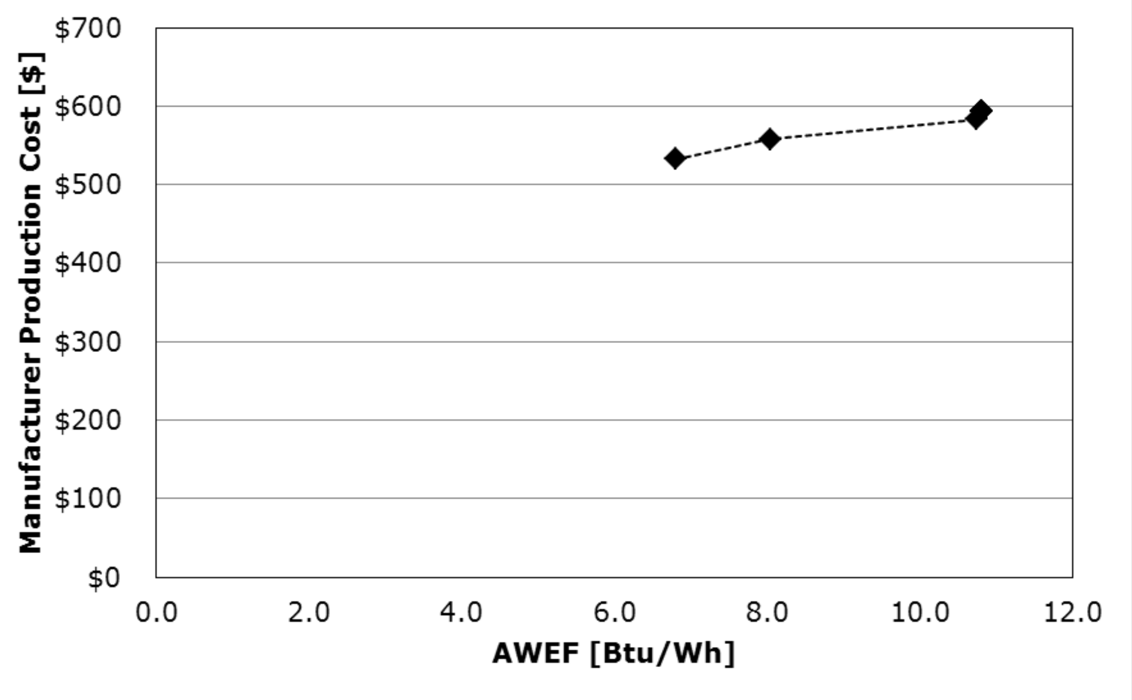


Figure 5A.5.52 Cost-Efficiency Curve for MC.M.N.004.009.2

Table 5A.5.53 Cost-Efficiency Data for MC.L.N.006.004.1

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.40	$357	$503	Baseline
L1	4.62	$382	$536	L0 + MEF
L2	5.27	$407	$570	L1 + VEF
L3	5.29	$412	$578	L2 + EB2
L4	5.40	$462	$645	L3 + DFC1
L5	5.82	$699	$966	L4 + HGD

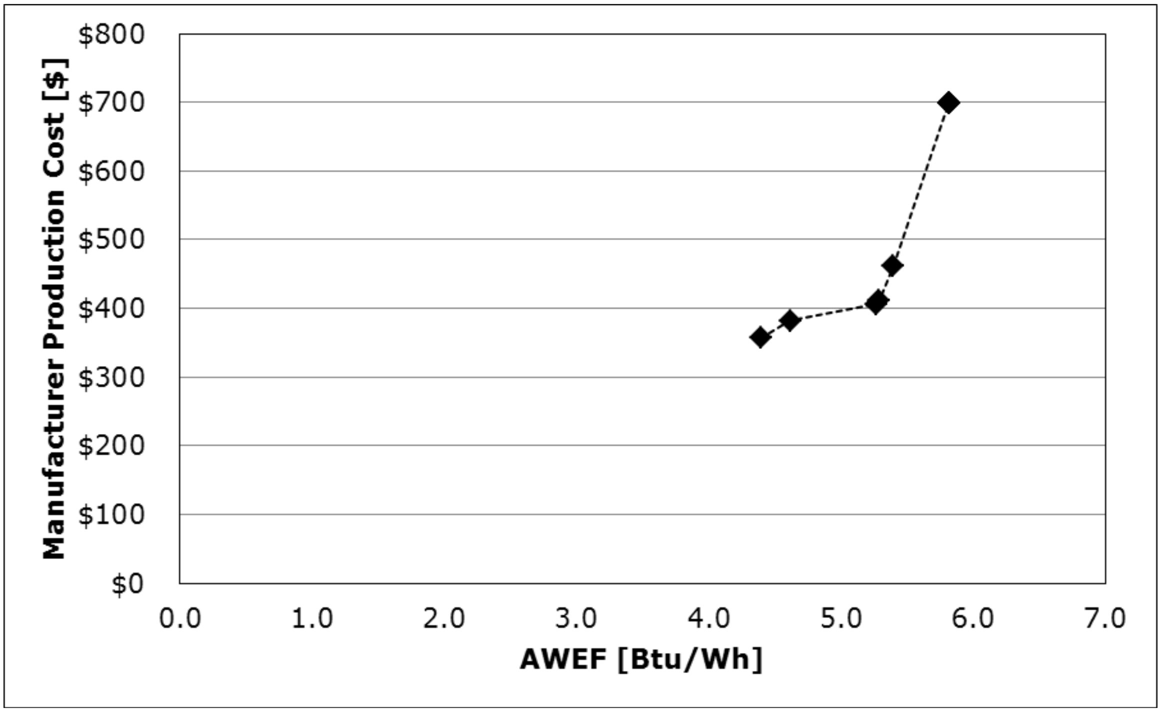


Figure 5A.5.53 Cost-Efficiency Curve for MC.L.N.006.004.1

Table 5A.5.54 Cost-Efficiency Data for MC.L.N.006.009.2

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.66	$530	$749	Baseline
L1	4.89	$555	$783	L0 + MEF
L2	5.53	$580	$816	L1 + VEF
L3	5.63	$630	$884	L2 + DFC1
L4	5.65	$641	$899	L3 + EB2
L5	5.91	$881	$1,222	L4 + HGD

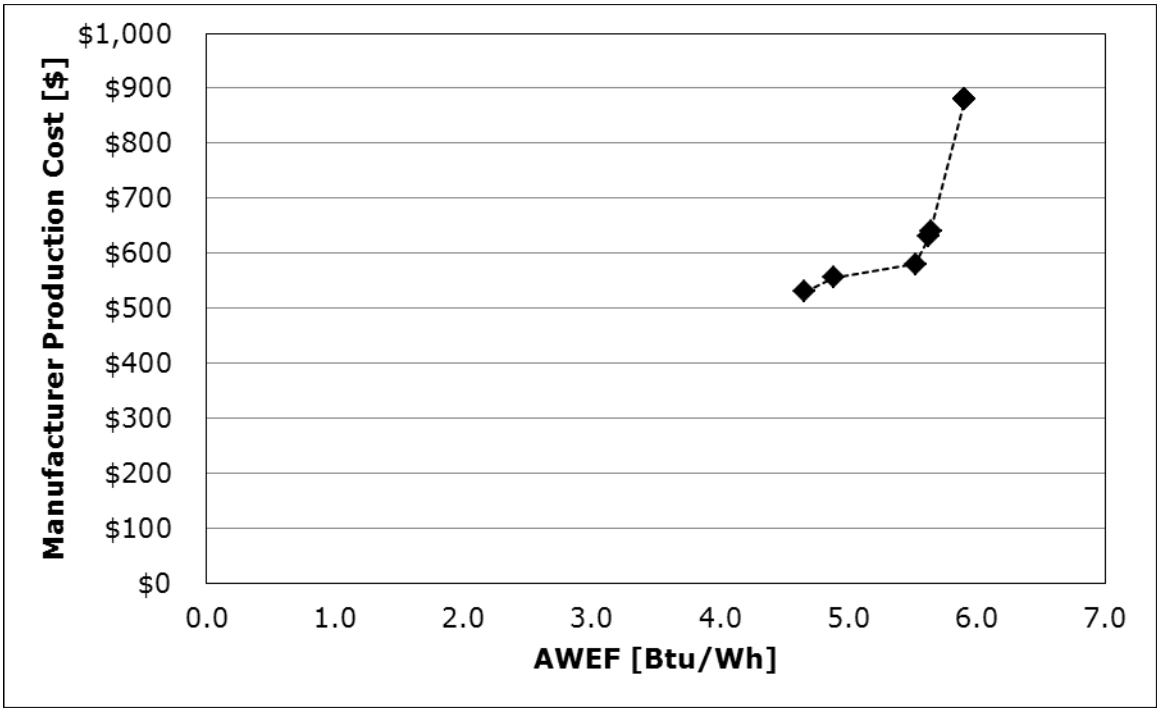


Figure 5A.5.54 Cost-Efficiency Curve for MC.L.N.006.009.2

Table 5A.5.55 Cost-Efficiency Data for MC.L.N.006.018.2

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	3.93	$749	$1,104	Baseline
L1	4.25	$774	$1,138	L0 + MEF
L2	5.34	$799	$1,172	L1 + VEF
L3	5.42	$849	$1,239	L2 + DFC1
L4	5.59	$1,089	$1,563	L3 + HGD
L5	5.62	$1,130	$1,619	L4 + EB2

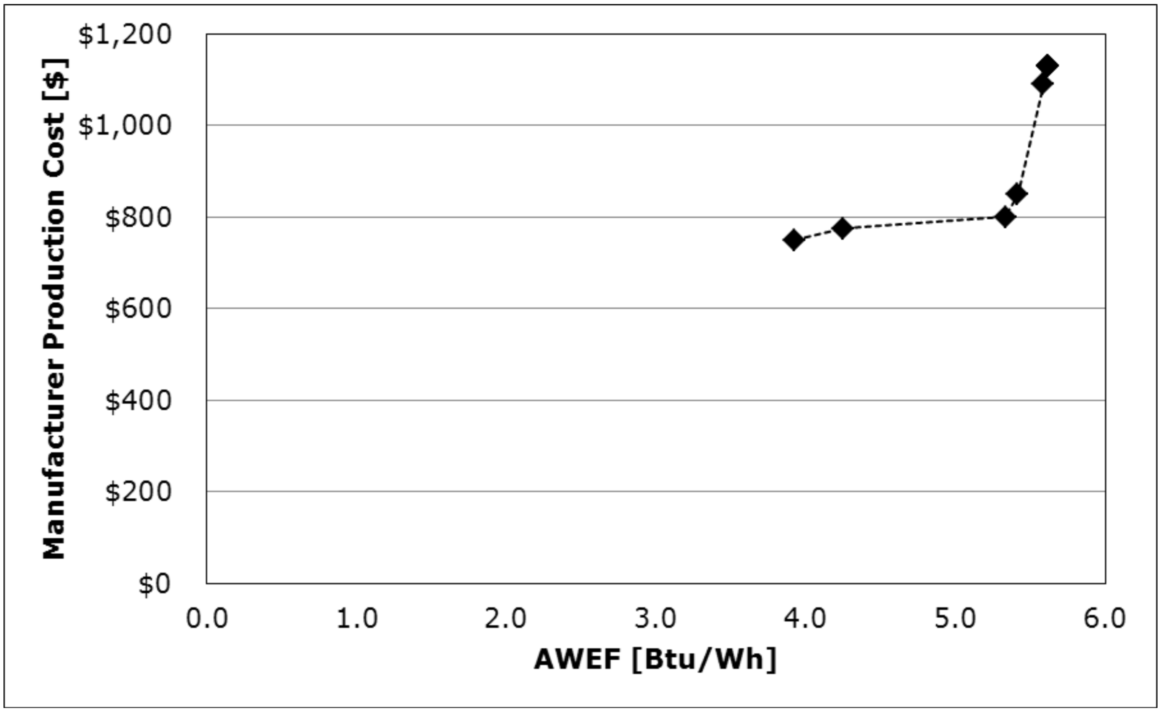


Figure 5A.5.55 Cost-Efficiency Curve for MC.L.N.006.018.2

Table 5A.5.56 Cost-Efficiency Data for MC.L.N.004.004.1

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.43	$352	$497	Baseline
L1	4.66	$377	$530	L0 + MEF
L2	5.32	$402	$564	L1 + VEF
L3	5.34	$407	$571	L2 + EB2
L4	5.43	$457	$639	L3 + DFC1
L5	5.82	$695	$959	L4 + HGD

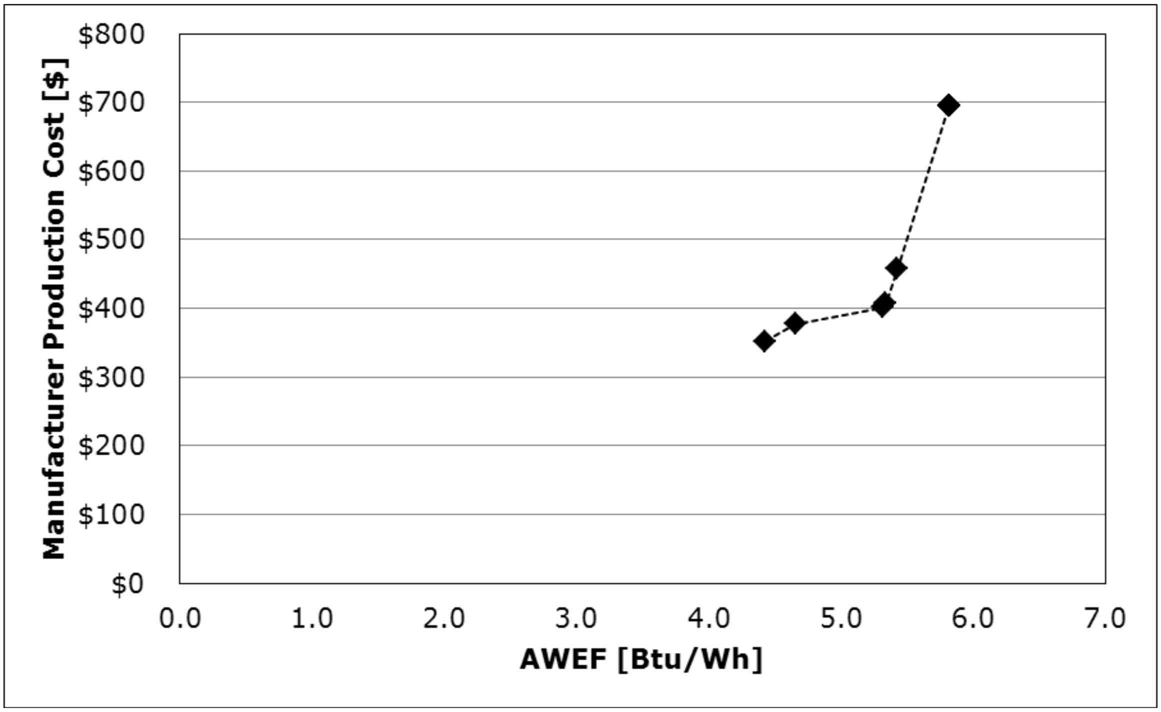


Figure 5A.5.56 Cost-Efficiency Curve for MC.L.N.004.004.1

Table 5A.5.57 Cost-Efficiency Data for MC.L.N.004.009.2

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.71	$510	$728	Baseline
L1	4.94	$535	$762	L0 + MEF
L2	5.60	$560	$796	L1 + VEF
L3	5.67	$610	$863	L2 + DFC1
L4	5.69	$621	$878	L3 + EB2
L5	5.91	$858	$1,198	L4 + HGD

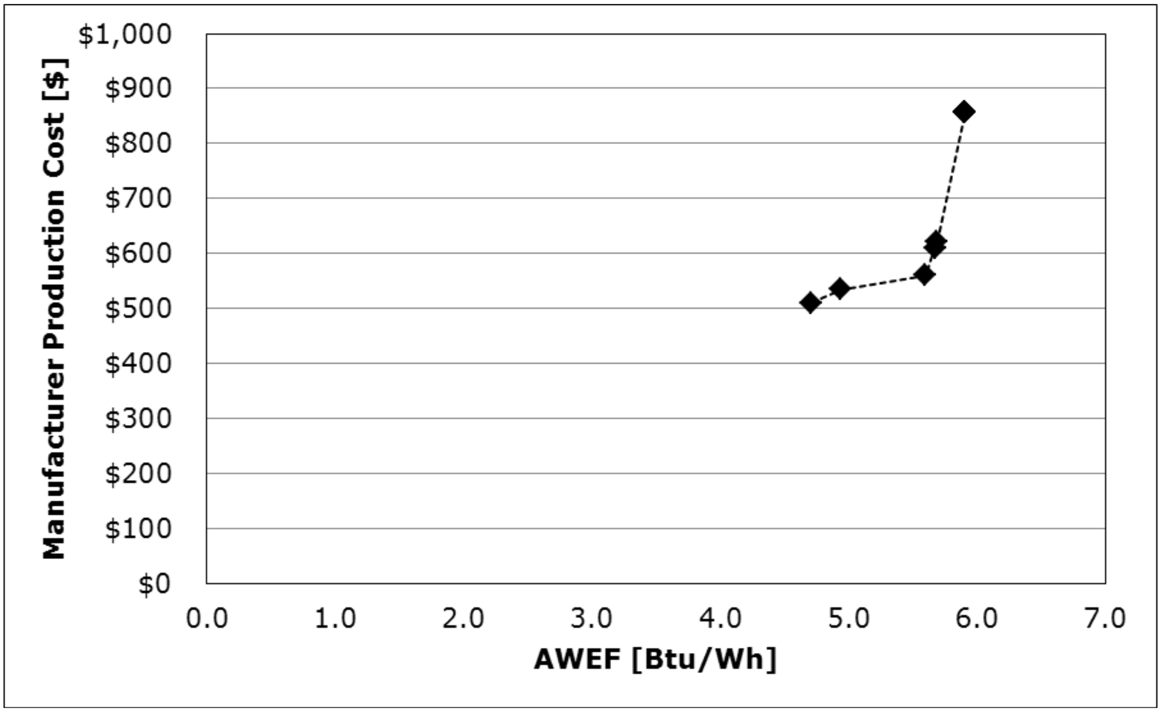


Figure 5A.5.57 Cost-Efficiency Curve for MC.L.N.004.009.2

Table 5A.5.58 Cost-Efficiency Data for MC.L.N.004.018.2

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.46	$939	$1,339	Baseline
L1	4.73	$964	$1,373	L0 + MEF
L2	5.52	$989	$1,406	L1 + VEF
L3	5.61	$1,039	$1,474	L2 + DFC1
L4	5.81	$1,278	$1,796	L3 + HGD
L5	5.84	$1,305	$1,833	L4 + EB2

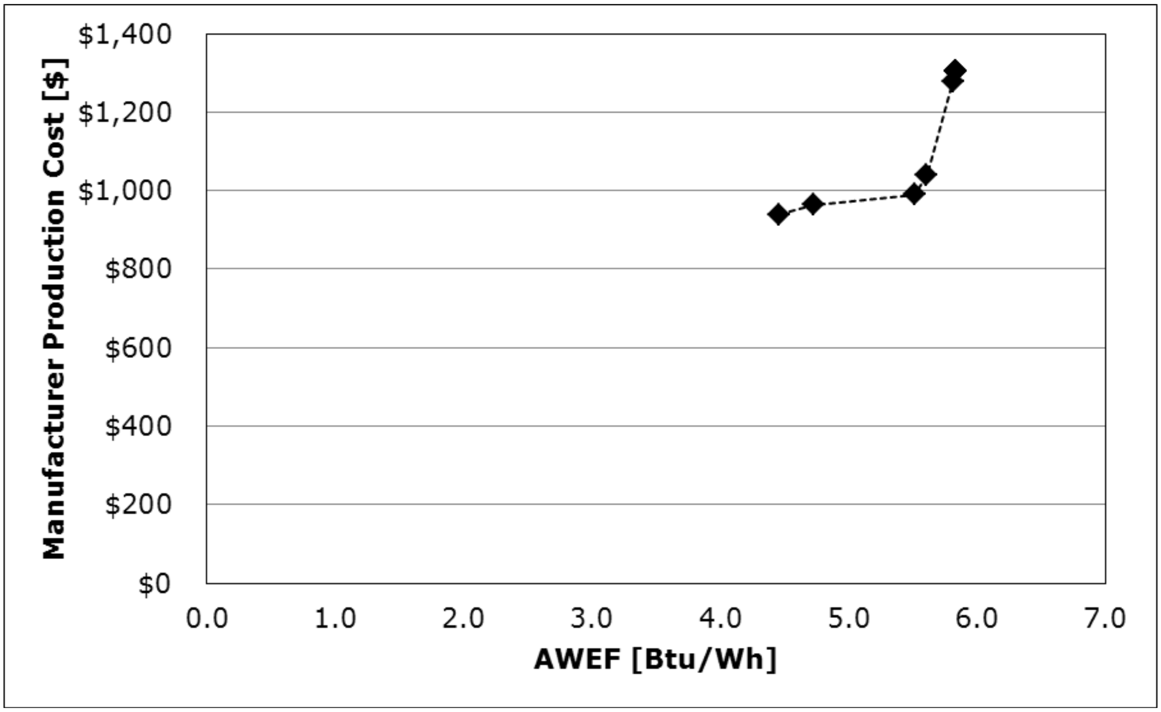


Figure 5A.5.58 Cost-Efficiency Curve for MC.L.N.004.018.2

Table 5A.5.59 Cost-Efficiency Data for MC.L.N.004.040.2

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	4.14	$1,483	$2,402	Baseline
L1	4.46	$1,508	$2,436	L0 + MEF
L2	5.49	$1,533	$2,470	L1 + VEF
L3	5.55	$1,583	$2,537	L2 + DFC1
L4	5.65	$1,824	$2,863	L3 + HGD
L5	5.68	$1,906	$2,974	L4 + EB2

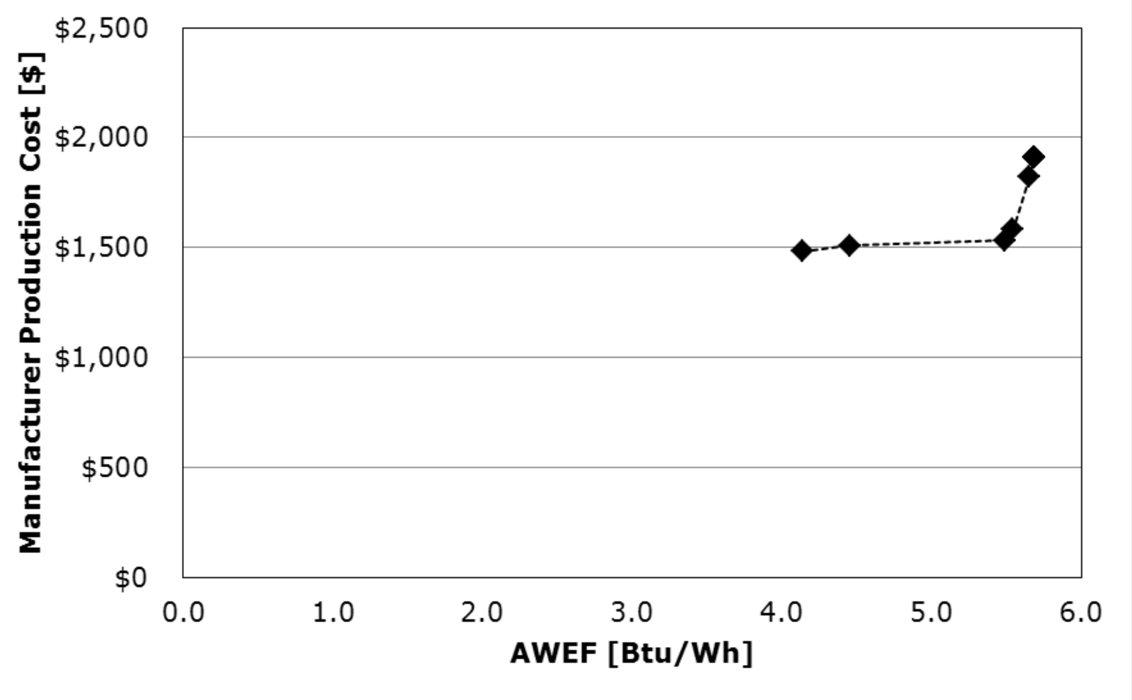


Figure 5A.5.59 Cost-Efficiency Curve for MC.L.N.004.040.2

APPENDIX 6A. DATA FOR REFRIGERATION SYSTEM WHOLESALERS

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 6A. DATA FOR REFREGERATION SYSTEM WHOLESALERS

6A.1 INTRODUCTION

This appendix provides further details on the markup analysis for refrigeration system wholesalers presented in chapter 6, Markups for Equipment Price Determination.

6A.2 DETAILED WHOLESALER COST DATA

Chapter 6 presents wholesaler revenues and costs in aggregated form, based on the Heating, Airconditioning & Refrigeration Distributors International (HARDI) *2012 Profit Report (2011 Data)*. Table 6A.2.1 provides the complete breakdown of costs and expenses for the controls and refrigeration group from the *2012 Profit Report (2011 Data)*. The column labeled "Scaling" indicates which expenses were assumed to scale with only the baseline markup and which were assumed to scale with both the baseline and the incremental markups. As described in chapter 6, only those expenses that scale with baseline and incremental costs are marked up when there is an incremental change in equipment costs.

Table 6A.2.1 Disaggregated Costs and Expenses for Wholesalers*

Item	Percent of Revenue	Scaling
Cost of Goods Sold	**71.3%**	
Gross Margin	**28.7%**	
Payroll Expenses	**16.5%**	Baseline
Executive Salaries & Bonuses	2.0%	
Branch Manager Salaries and Commissions	2.0%	
Sales Executive Salaries & Commissions	0.4%	
Outside Sales Salaries & Commissions	2.0%	
Inside/Counter Sales/Wages	4.0%	
Purchasing Salaries/Wages	0.6%	
Credit Salaries/Wages	0.2%	
IT Salaries/Wages	0.1%	
Accounting Salaries and Wages	0.8%	
Warehouse Salaries/Wages	0.5%	
Delivery Salaries/Wages	0.4%	
All Other Salaries/Wages & Bonuses	0.9%	
Payroll Taxes	1.1%	
Group Insurance	1.1%	
Benefit Plans	0.4%	
Occupancy Expenses	**3.6%**	Baseline
Utilities: Heat, Light, Power, Water	0.4%	
Telephone	0.3%	
Building Repairs & Maintenance	0.3%	
Rent or Ownership in Real Estate	2.6%	
Other Operating Expenses	**4.1%**	
Advertising & Promotion	0.8%	Baseline & Incremental
Insurance (business liability & casualty)	0.2%	
Depreciation	0.2%	
Vehicle Expenses	0.5%	
Personal Property Taxes/Licenses	0.1%	
Collection Expenses	0.2%	

Table 6A.2.1 (Continued)

Item	Percent of Revenue	Scaling
Bad Debt Losses	0.1%	
All Other Operating Expenses	2.0%	
Total Operating Expenses	**24.2%**	
Operating Profit	**4.5%**	
Other Income	0.6%	
Interest Expense	0.5%	Baseline & Incremental
Other Non-operating Expenses	0.0%	
Profit Before Taxes*	4.6%	

* Source: Heating, Airconditioning & Refrigeration Distributors International. *2012 Profit Report (2011 Data)*. 2012. Columbus, OH.

*Wholesaler costs and expenses are *percentage* values as opposed to the *per dollar of sales revenue* values shown in chapter 6.

APPENDIX 6B. DATA FOR GENERAL CONTRACTORS

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 6B. DATA FOR GENERAL CONTRCTORS

6B.1 INTRODUCTION

This appendix provides further details on the markup analysis for general contractors presented in chapter 6, Markups for Equipment Price Determination.

6B.2 DETAILED GENERAL CONTRACTOR COST DATA

Chapter 6 presents general contractors revenues and costs in aggregated form, based on US census data on preliminary detailed statistics for establishments, 2007. Table 6B.2.1 provides the breakdown of costs and expenses for the general contractors. The column labeled "Scaling" indicates which expenses were assumed to scale with only the baseline markup and which were assumed to scale with both the baseline and the incremental markups. As described in chapter 6, only those expenses that scale with baseline and incremental costs are marked up when there is an incremental change in equipment costs.

Table 6B.2.1 Disaggregated Costs and Expenses for General Contractors*

Item	Dollar Value	Percentage	Scaling
Total Cost of Equipment Sales	**$250,657,006**	76.24%	Baseline
Cost of materials, components, and supplies	$74,148,280	22.55%	
Payroll, construction workers	$16,449,830	5.00%	
Cost of construction work subcontracted out to others	$157,873,840	48.02%	
Cost of selected power, fuels, and lubricants	$2,185,056	0.66%	
Gross Margin	**$78,113,967**	23.76%	
Payroll Expenses	**$25,318,870**	7.70%	Baseline
Fringe benefits, all employees	$8,666,079	2.64%	
Payroll, other employees	$16,652,791	5.07%	
Occupancy Expenses	**$3,301,046**	1.00%	
Rent, Communications, maintenance, and utilities	$3,301,046	1.00%	Baseline
Other Operating Expenses	**$5,079,007**	1.54%	Baseline & Incremental
Depreciation charges during year	$1,581,228	0.48%	
Computing, Acctg, Advertising, Insurance, and other	$3,497,779	1.06%	
Net Profit Before Income Taxes	**$44,415,044**	**13.51%**	Baseline & Incremental

* Source: Source: U.S. Census Bureau. 2007. Commercial and Institutional Building Construction. Sector 23: 236220. Construction: Industry Series: Preliminary Detailed Statistics for Establishments: 2007.

APPENDIX 7A. DETAILED METHODOLOGY FOR DEVELOPING THE STATE WEIGHTING FACTORS

TABLE OF CONTENTS

LIST OF FIGURES

APPENDIX 7A. DETAILED METHODOLOGY FOR DEVELOPING THE STATE WEIGHTING FACTORS

7A.1 INTRODUCTION

7A.1.1 Purpose and Intent

This appendix describes the methodology by which *weighting factors* were developed to scale the influence of each TMY2 weather station on each state's results. The intent is to ensure that the cost-effectiveness calculations properly reflect the geographic distribution of buildings in which the walk-ins coolers and freezers (WICF or walk-ins) will be used. State-level aggregate results need to be most heavily influenced by the climates having the most commercial buildings that may have walk-in units.

7A.1.2 Issues

TMY2 stations, of which there are 239 in the United States, are distributed throughout the country so as to give good coverage of the climatic variation in the United States. Unfortunately for this study, the TMY2 stations are not distributed so as to match the distribution of buildings. It is therefore necessary to identify a reasonable mapping between the climate-based (TMY2) simulation results and the geographical distribution of buildings in each state. Although TMY2 data give good *climatic* coverage, they do not give sufficient *geographical* coverage.

Detailed data on the geographical/climatic distribution of buildings were not readily available for this task. However, data on the geographical distribution of persons (population data) can serve as a reasonable surrogate for buildings data, and are available from a number of sources. The problem facing this study was to match up population data, which are available in great geographical detail but not matched to climate indicators, with TMY2 data, which characterize climate quite well but are not connected to any population indicators.

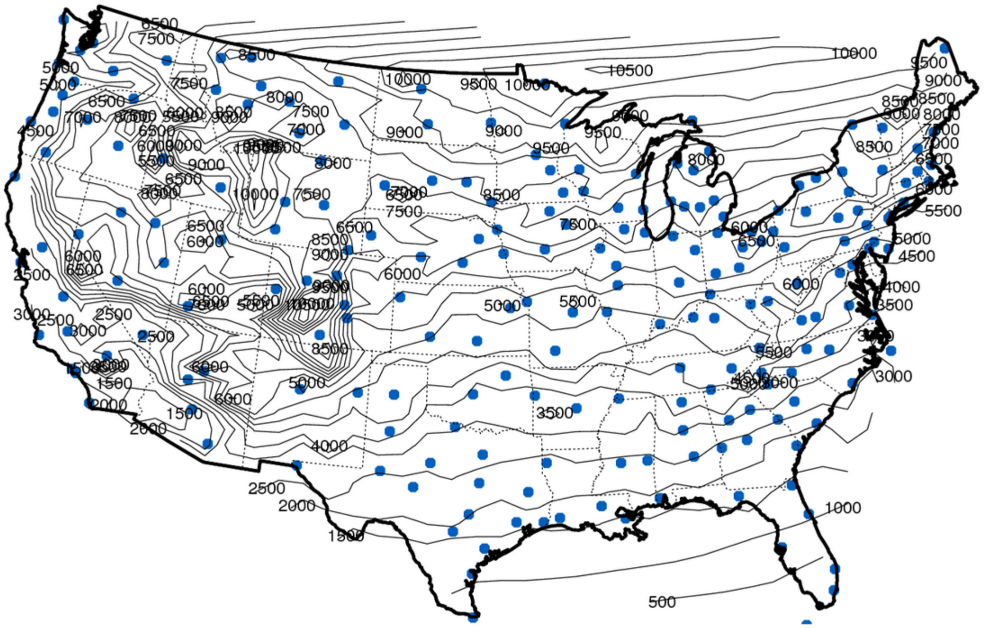
7A.2 APPROACH

Figure 7B.2.1 shows the locations of the 239 TMY2 stations superimposed on a contour map showing heating degree-days (HDD). It is clear that the geographic distribution of the TMY2 stations is too sparse to capture many of the climate variations that occur over relatively short distances, especially in mountainous regions. It is therefore not feasible to develop weighting factors based solely on the TMY2 stations within a state.

7A.2.1 Additional Data Sets

To develop weighting factors, the U.S. Department of Energy (DOE) identified two data sets (in addition to the TMY2 data set) that provide a connection between detailed population distribution and TMY2 stations. These are:

- ***NOAA Climate Stations*** **–** The National Climatic Data Center's (NCDC's) "CLIM81" database contains summary statistics from a large number of climate stations in the United States. DOE used the 1961–1990 period of record (POR), which corresponds to the POR used to define the TMY2 weather tapes, for which 4775 climate stations are represented (see http://lwf.ncdc.noaa.gov/oa/documentlibrary/clim81supp3/clim81.html). Each NOAA station is characterized by its location (latitude/longitude), annual heating and cooling degree-days (CDD), elevation, and various other metrics.



Points are TMY2 stations; contours are hdd65

Figure 7A.2.1 Locations of TMY2 Stations Superimposed on Heating Degree-Day Contours

- ***USGS Populated Places*** **–** The United States Geological Survey (USGS), in its Geographic Names Information System, maintains a detailed database of cities, towns, and other important features. (For the latest version of this data set, see http://geonames.usgs.gov/stategaz/00README.html. DOE's analysis used a version of this data set from the early 1990s, making it contemporaneous with the TMY2 and NOAA data sets.) Of interest to this task are the PPL features known as "populated places," which are generally cities and towns, but also include large housing subdivisions, trailer parks, and other places where people may live. For many of these populated places, the USGS has a population estimate. The populated places (PPL) data give excellent geographical coverage. The version of the data set used here has over 22,000 entries that include a population estimate out of more than 164,000 total.[1] Each PPL location is characterized by its location (latitude/longitude), elevation, population, and various other metrics.

The NOAA data are important because they contain climate summary information that can be mapped to the TMY2 stations, greatly increasing the geographical coverage. Figure

---

[1] Locations without USGS population estimates tend to be those with very little population. DOE has kept these smaller sites in our mapping analysis by assigning each a population estimate of one. This gives them negligible influence against the more populous locations but allows the mapping procedure to work even in very sparsely populated regions of some states.

7B.2.2 shows the locations of the 4775 NOAA stations. The PPL database is used to make the final link between the climate information in the mapped NOAA/TMY2 stations and the geographical distribution of population. Figure 7B.2.3 shows the PPL locations.

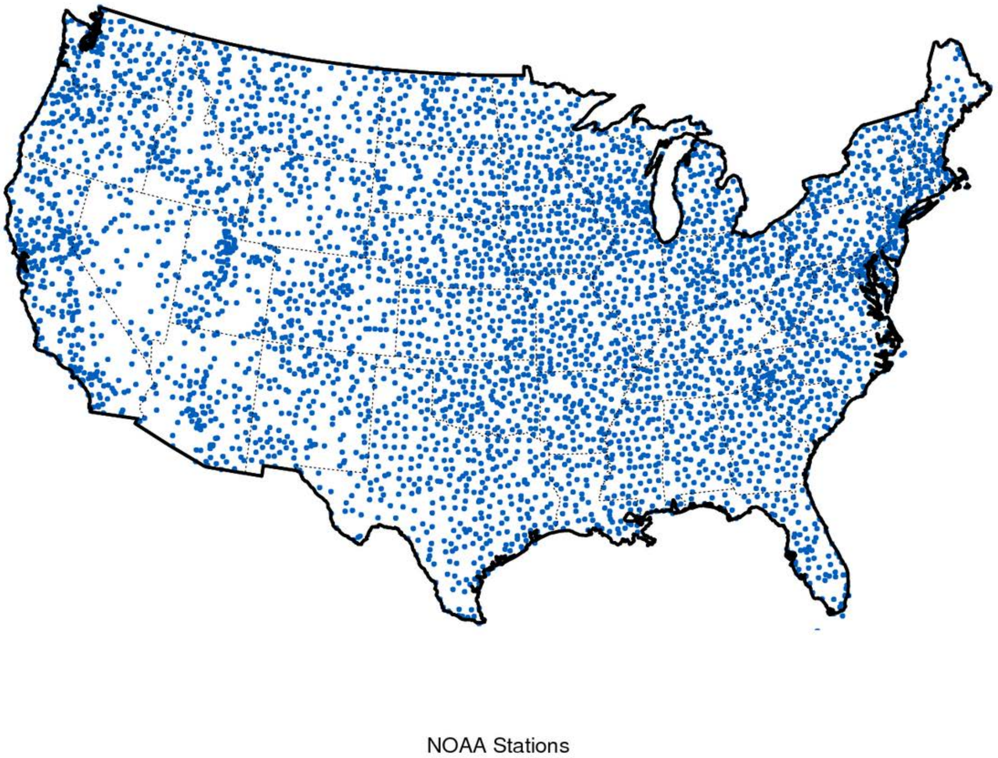


Figure 7A.2.2 Locations of 4775 NOAA Stations

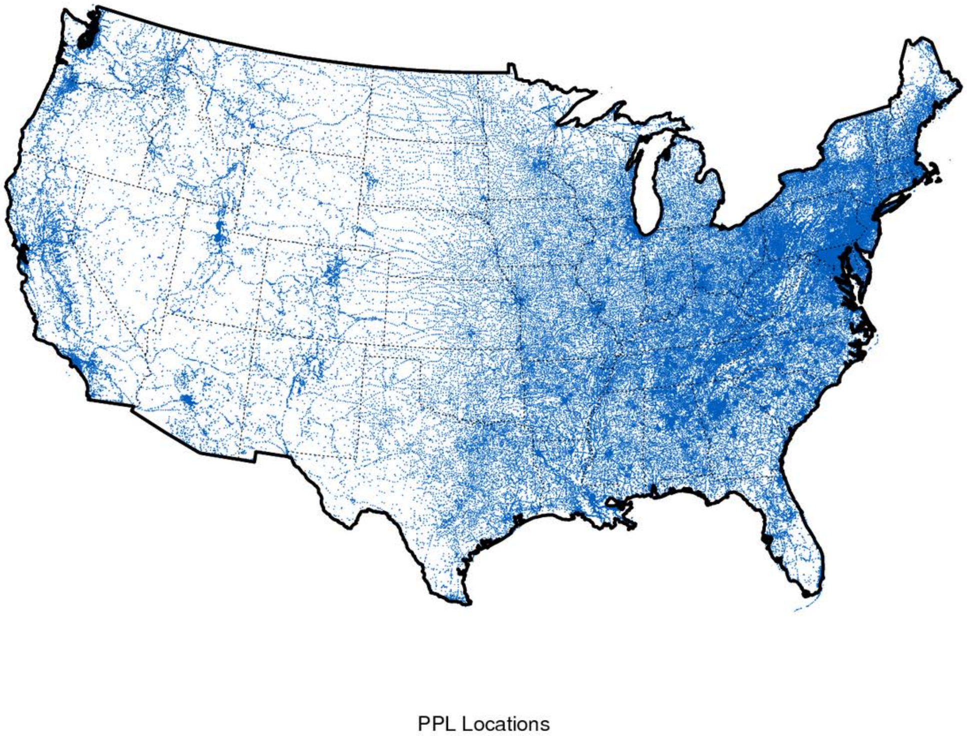


Figure 7A.2.3 Locations of Populated Places (PPL)

7A.2.2 Mapping Approach

DOE’s approach to generating TMY2 weighting factors involves three major steps:

1. Map each PPL location in the United States to a best-representative NOAA station. This gives each location some summary climate metrics (chiefly, heating and cooling degree-days) that facilitate further mapping.

2. Map each NOAA station to a best-representative TMY2 station. This completes the link between the geographic population estimates (PPL data) and the TMY2 stations.

3. For each state, compute the fraction of the total PPL population that “points” (via its PPL→NOAA→TMY2 mappings) to each TMY2 station.

These are described in order below.

7A.2.2.1 MAPPING *POPULATED PLACES* LOCATIONS TO NOAA STATIONS

Mapping each of the 164,000+ PPL locations to a best-representative NOAA station is a mostly straightforward process. Because there is no climate information in the PPL database, the only metrics available to associate each PPL location with a NOAA station are location (latitude/longitude) and elevation (although elevation is not known for all PPL locations). The mapping algorithm is as follows.

1. For each PPL location, identify the nearest NOAA station. Distances between PPL/NOAA pairs are calculated using the latitudes and longitudes of the two locations and simple spherical geometry. If the elevation of the nearest NOAA station is within 300 feet of the PPL location or if the elevation of the PPL location is unknown, then the nearest NOAA station is the final mapping.

2. If the nearest NOAA station differs in elevation from the PPL location by more than 300 feet:

   a) Identify the 20 closest NOAA stations to the PPL location.

   b) Choose, from among the 20, the NOAA station that is nearest in elevation to the PPL location.

This algorithm is imperfect in many situations, but was designed by trial and error to give reasonable mappings in a large majority of cases. In locations with relatively flat terrain and fairly dense population, the algorithm almost always maps to the closest NOAA station. Figure 7B.2.4 shows the mappings in the state of Iowa as an example. Each plotted point on the graphic is one NOAA station; the “hairs” are drawn outward to the various PPL locations mapped to that station. In mountainous terrain or in locations with large distances between PPL locations (*e.g.*, Alaska), the second part of the algorithm does a reasonable job of identifying a representative NOAA station, even if that station is some distance from the PPL location. Figure 7B.2.5 shows the mappings for Washington State as an example. Note that many of the PPL locations (the ends of the hairs) are mapped to distant NOAA stations.

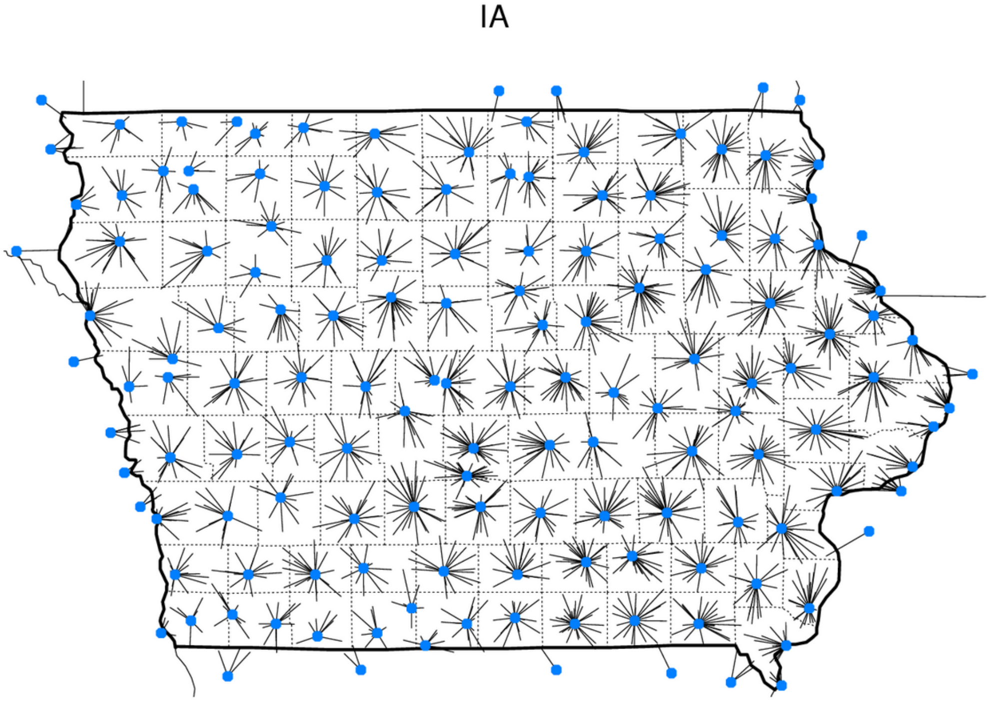


Figure 7A.2.4 PPL→NOAA Mappings for Iowa Showing a Predominance of Nearest-Location Mappings

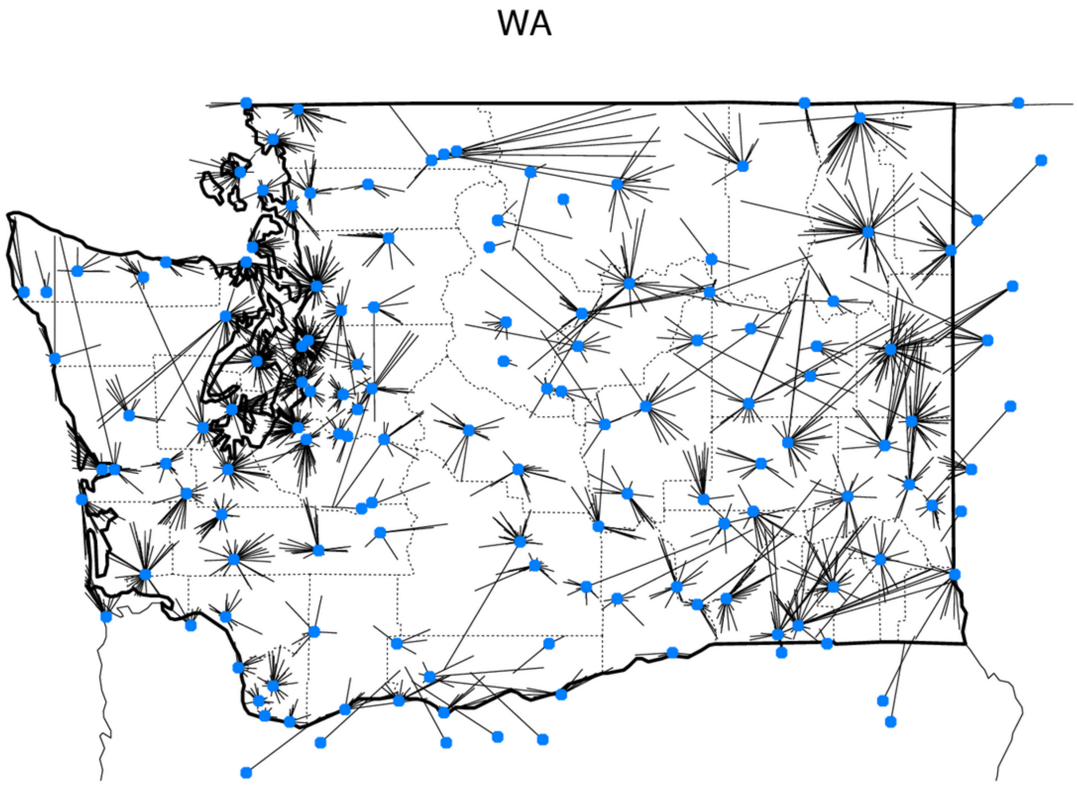


Figure 7A.2.5 PPL→NOAA Mappings for Washington State Showing Some Distant Mappings in Mountainous Regions

7A.2.2.2 MAPPING NOAA STATIONS TO TMY2 STATIONS

Having mapped each PPL location to a best-representative NOAA station, the next step is to map each NOAA station to a best representative TMY2 station. Because the NOAA and TMY2 data sets provide less dense geographical coverage and because both data sets contain climate information, this mapping process relies less on spatial proximity and more on similarity of climate. Proximity remains important, though. In finding a best TMY2 mapping for a NOAA station, DOE hopes for similarity in a number of climate variables: temperature (HDD and CDD), solar and wind characteristics, rainfall and humidity characteristics, snowfall, etc. The NOAA data set supports direct comparison only of heating and cooling degree-days, but DOE relies on spatial proximity to ensure similarity in the other variables.

The NOAA-to-TMY2 mapping algorithm is as follows.

1. For each NOAA station, identify the nearest TMY2 station. If the elevation of the nearest TMY2 station is within 300 feet of the NOAA station, then the nearest TMY2 station is the final mapping.

2. If the nearest TMY2 station differs in elevation from the NOAA station by more than 300 feet, then select instead the TMY2 station that has the minimum “combined distance” from the NOAA station. The combined distance is defined as the sum of the literal distance (miles) between the two stations and an “equivalent latitude miles” value that

accounts for known differences in heating and cooling degree-days and elevation. This latter metric requires some explanation (see below).

The *equivalent latitude miles* metric was developed as a means to characterize temperature (HDD and CDD) and elevation in the same units as literal distance (*i.e.*, miles). By casting HDD, CDD, and elevation effects into units of miles, DOE is able to simply sum the literal distance between two locations with the equivalent HDD/CDD/elevation distance to give the two values equal weight in assigning a best-representative TMY2 station to each NOAA station.

The equivalent latitude miles values are based on several related observations. First, differences in both heating and cooling degree-days correlate with differences in latitude. Second, those same degree-day differences also correlate with differences in elevation. Combining these observations, DOE discovered that differences in north-south distances (*i.e.*, latitude miles) can be characterized in terms of differences in HDD, CDD, and elevation. That is, as one moves northward (increasing latitude) and upward (increasing elevation), HDD tends to increase and CDD tends to decrease. A regression analysis of these correlations allows DOE to cast HDD, CDD, and elevation differences into units of distance (miles). A linear regression on NOAA/TMY2 station pairs within 300 miles of each other gives the following result.

$$d_{equiv} = I + \alpha \times \Delta HDD + \beta \times CDD + \gamma \times \Delta Elev$$

Eq. 7B.1

Where:

d_{equiv} = equivalent latitude distance (miles),
ΔHDD = difference in heating degree-days (base-65 °F)
ΔCDD = difference in cooling degree-days (base-65 °F)
$\Delta Elev$ = difference in elevation (feet)
I = -6.8938
α = 0.1061
β = -0.0149
γ = -0.0718

The best representative TMY2 station for each NOAA station was selected as the one with the minimum sum of actual distance and equivalent latitude distance. Figure 7B.2.6 shows the final NOAA→TMY2 mappings for the continental United States. Each plotted point is a TMY2 station, from which lines are drawn outward to the NOAA stations mapped to it.

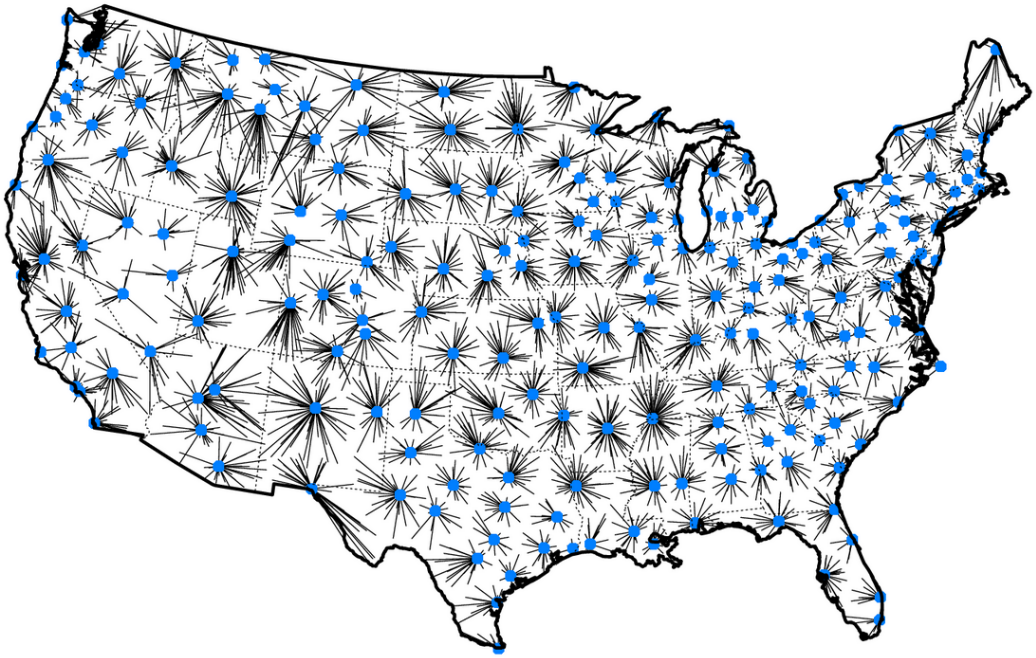


Figure 7A.2.6 NOAA→TMY2 Mappings

7A.2.3 Calculating State-by-State Weighting Factors

Weighting factors were developed for each U.S. state that express the fraction of that state’s population that is represented by each TMY2 station. These weighting factors are based directly on the PPL→NOAA→TMY2 mappings described above. The weighting factor for a TMY2 station is defined as the summed population of all PPL locations in the state that point to that TMY2 station divided by the summed population of all PPL locations in the state. Thus, the sum of all the TMY2 weighting factors for a state is 1.0.

APPENDIX 8A. USER INSTRUCTIONS FOR LCC AND PBP SPREADSHEETS

TABLE OF CONTENTS

APPENDIX 8A. USER INSTRUCTIONS FOR LCC AND PBP SPREADSHEETS

8A.1 INTRODUCTION

It is possible to examine and reproduce the detailed results of the life-cycle cost (LCC) and payback period (PBP) analyses using Microsoft Excel spreadsheets available on the U.S. Department of Energy's (DOE's) website at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/26

To fully execute the spreadsheets requires both Microsoft Excel and Crystal Ball® (CB) software. Both applications are commercially available. Crystal Ball is available at: www.oracle.com/us/crystalball/index.htm.

The seven spreadsheets posted on the DOE website represent the latest versions and have been tested with Microsoft Excel 2007 and 2010.

The walk-in cooler and freezer refrigeration system and component LCC spreadsheets or workbooks (used interchangeably) consist of the following worksheets.

LCC Summary	Contains the input selections and a summary table of energy use, operating costs, LCC, and Payback. This worksheet also works as an interface between user inputs and the rest of the worksheets — do not modify this sheet. This is the only worksheet a user needs to interact with directly to successfully run this model.
State Level Variables	Tables and graphics detailing taxes, outdoor energy use modifiers and electricity prices for all U.S. states can be found here. CB inputs for load variations can also be found here.
CB Baselines&MktChnls	This worksheet organizes various baselines forecasts and assumptions for CB.
Markups and Market	This worksheet contains the table structure for equipment markups.
Maint & Repair	Total repair and maintenance costs are organized here.
Discount Rates	Contains a variety of tables detailing the data sources and methodology for developing discount rates.
Lifetime and Experience	Yearly equipment failure and survival rates are described by the Weibull distribution and its parameters contained here.
Engineering Tables	Contains detailed engineering data for all representative equipment classes from the Engineering Analysis in chapter 5.

Outdoor Energy Use	This worksheet contains the outdoor energy use dataset used in the “State Level Variables” worksheet.
Energy Price Projections	*Annual Energy Outlook (AEO)* datasets for electricity prices and electricity price multipliers by building type are organized here.
Electricity Price Ratios CBECS	This worksheet structures Commercial Building Energy Consumption Survey (CBECS) data to derive price ratios by building types. Refrigeration system shares by building type are also stored here.
Labels	This worksheet translates user settings in the LCC Summary worksheet into model inputs.

8A.2 BASIC INSTRUCTIONS FOR THE REFIGERATION SYSTEM AND ENVELOPE COMPONENT LCC SPREADSHEETS

Basic instructions for operating the LCC spreadsheets are as follows:

1. Once you have downloaded the LCC file from the Web, open the file using Excel. At the bottom, click on the tab for sheet “LCC Summary.”

2. Use Excel’s “View/Zoom” commands at the top menu bar to change the size of the display to make it fit your monitor.

3. The user interacts with the spreadsheet by clicking choices or entering data using the graphical interface that comes with the spreadsheet. Select choices from the various inputs listed under “User Options” heading.

4. To change inputs listed under “User Input,” select the input you wish to change by selecting the appropriate input from the input box.

5. This spreadsheet has been designed to provide two distinct types of analysis by varying the Uncertainty Option:
   a. If the “Sensitivity Analysis (Certainty Equivalent)” is selected, then all calculations are performed for single input values, usually an average. The new results are shown on the same sheet as soon as the new values are entered.
   b. Alternately, if the “Uncert. Analysis Using Crystal Ball” is selected the spreadsheet generates results that are distributions. Some of the inputs are also distributions. The results from the LCC distribution are shown as single values and refer only to the results from the last Monte Carlo sample and are therefore not meaningful. To run the distribution version of the spreadsheet, the Microsoft Excel add-in software Crystal Ball must be enabled.

To produce sensitivity results using Crystal Ball, simply select Run from the Run menu (on the menu bar). To make basic changes in the run sequence, including altering the number of trials, select Run Preferences from the Run menu. After each simulation run, the user needs to select Reset (also from the Run menu) before Run can be selected again. Once Crystal Ball has completed its run sequence it will produce a series of distributions. Using the menu bars on the distribution results, it is possible to obtain further statistical information. The time taken to complete a run sequence can be reduced by minimizing the Crystal Ball window in Microsoft Excel. A step-by-step summary of the procedure for running a distribution analysis is outlined below:

1. Find the Crystal Ball toolbar (at top of screen).

2. Click on Run from the menu bar.

3. Select Run Preferences and choose from the following choices:
    a. Monte Carlo[a]
    b. Latin Hypercube (recommended)
    c. Initial seed choices and whether you want it to be constant between runs
    d. Select number of Monte Carlo Trials (DOE suggests 10,000)

4. To run the simulation, follow the following sequence (on the Crystal Ball toolbar):
    a. Run
    b. Rest
    c. Run
5. Now wait until the program informs you that the simulation is completed.

The following instructions are provided to view the output generated by Crystal Ball.

1. After the simulation has finished, to see the distribution charts generated, click on the Windows tab bar that is labeled Crystal Ball.

2. The life-cycle cost savings and payback periods are defined as Forecast cells. The frequency charts display the results of the simulations, or trials, performed by Crystal Ball. Click on any chart to bring it into view. The charts show the low and high endpoints of the forecasts. The View selection on the Crystal Ball toolbar can be used to specify whether you want cumulative or frequency plots shown.

3. To calculate the probability that a particular value of LCC savings will occur, either type 0 in the box by the left arrow, or move the arrow key with the cursor to 0 on the scale. The value in the Certainty box shows the likelihood that the LCC savings will occur. To calculate the certainty of payback period being below a certain number of years, choose that value as the high endpoint.

4. To generate a printout report, select Create Report from the Run menu. The toolbar choice of Forecast Windows allows you to select the charts and statistics in which you

---

[a] Because of the nature of the program, there is some variation in results due to random sampling when Monte Carlo or Latin Hypercube sampling is used.

are interested. For further information on Crystal Ball outputs, please refer to Understanding the Forecast Chart in the Crystal Ball manual.

APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN LCC ANALYSIS

TABLE OF CONTENTS

LIST OF FIGURES

APPENDIX 8B. DISTRIBUTIONS USED FOR DISCOUNT RATES

8B.1 INTRODUCTION

DOE's approach to analysis of an energy-efficiency standard also includes analyzing the range of potential impacts of higher efficiency equipment on consumers. DOE uses the consumer life-cycle cost (LCC) as the key metric for this analysis and examine the variability of the LCC of higher efficiency equipment by varying a wide range of input assumptions. 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, this is rarely the case. In almost all cases, the model and/or the numerical values for each quantity in the model are not completely known (i.e., there is uncertainty) or the model and/or the numerical values for each quantity in the model depend upon other conditions (i.e., there is variability).

Thorough analysis involves accounting for uncertainty and variability. While the simplest analysis involves a single numerical value for each quantity in a calculation, arguments can arise about what the appropriate value is for each quantity. Explicit analysis of uncertainty and variability is intended to provide more complete information to the decision-making process.

8B.2 UNCERTAINTY

When making observations of past events or speculating about the future, imperfect knowledge is the rule rather than the exception. For example, the energy actually consumed by an equipment type (such as an. walk-in cooler and freezer in a restaurant) is not directly recorded, but rather estimated based upon available information. When estimating numerical values expected for quantities at some future date, the exact outcome is rarely known in advance.

8B.3 VARIABILITY

Variability means that different applications or situations produce different numerical values when calculating a quantity. Specifying an exact value for a quantity may be difficult because the value depends on something else. For example, the number of hours a walk-in cooler and freezer is used by or operated by a user 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, etc.). Variability makes specifying an appropriate population value more difficult in as much as anyone value may not be representative of the entire population.

8B.4 APPROACHES TO UNCERTAINTY AND VARIABILITY

This section describes two approaches to uncertainty and variability:

- scenario analysis, and
- probability analysis.

Scenario analysis uses a single numerical value for each quantity in a calculation, then changes one (or more) of the numerical values and repeats the calculation. A number of calculations are done, which provide some indication of the extent to which the result depends upon the assumptions. For example, the life-cycle cost of a walk-in cooler or freezer refrigeration system 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 paid by different users), surveys can be used to generate a frequency distribution of numerical values (e.g., the number of commercial buildings 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 $100 ± $20). The major disadvantage of the probability approach is that it requires more information, namely information about the shapes and magnitudes of the variability and uncertainty of each quantity. The advantage of the probability approach is that it provides greater information about the outcome of the calculations, that is, it provides the probability that the outcome will be in a particular range. Scenario and probability analysis provide some indication of the robustness of the policy given the uncertainties and variability. A policy is robust when the impacts are acceptable over a wide range of possible conditions.

8B.5 PROBABILITY ANALYSIS AND THE USE OF CRYSTAL BALL

To quantify the uncertainty and variability that exist in inputs to the engineering, LCC, and payback period (PBP) analyses, the Department 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. The random behavior in games of chance is similar to how Monte Carlo simulation selects variable values at random to simulate a model. It's the same with the variables that have a known range of values but an uncertain value for any particular time or event (e.g., equipment lifetime, discount rate, and installation cost).

For each uncertain variable (one that has a range of possible values), possible values are defined with a probability distribution. The type of distribution selected is based on the conditions surrounding that variable. Probability distribution types include well known standard forms of distribution like Normal distribution, Poisson distribution, Uniform distribution and others.

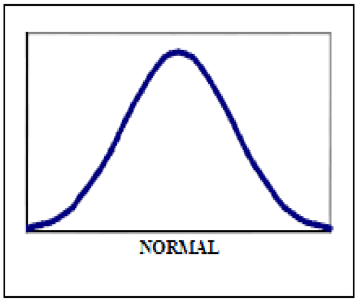


Figure 8B.5.1 Normal Probability Distribution

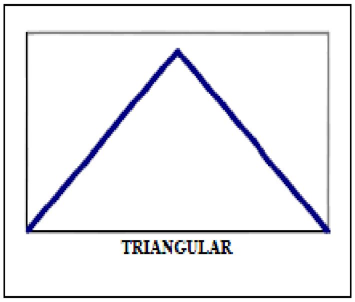


Figure 8B.5.2 Triangular Probability Distribution

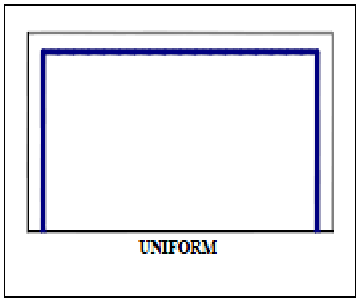


Figure 8B.5.3 Uniform Probability Distribution

During a simulation, multiple scenarios of a model are calculated by repeatedly sampling values from the probability distributions for the uncertain variables and using those values for the cell. Crystal Ball simulations can consist of as many trials (or scenarios) as desired—hundreds or even thousands. During a single trial, Crystal Ball randomly selects a value from the defined possibilities (the range and shape of the probability distribution) for each uncertain variable and then recalculates the spreadsheet.

APPENDIX 8C. DISTRIBUTIONS USED FOR DISCOUNT RATES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX 8C. DISTRIBUTIONS USED FOR DISCOUNT RATES

8C.1 INTRODUCTION

DOE derived discount rates for the LCC analysis using data on interest or return rates for various types of debt and equity. DOE derived the discount rates for the WICF analysis by estimating the cost of capital for businesses that purchase WICF refrigeration systems and envelope components. The cost of capital is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment. Most companies use both debt and equity capital to fund investments, so their cost of capital is the weighted average of the cost to the company of equity and debt financing.

To account for variation among business types in rates for each of the types, DOE sampled a rate for each business from a distribution of rates for each debt and equity type. This appendix describes the distributions used.

8C.2 METHODOLOGY

DOE estimated the cost of equity financing by using the Capital Asset Pricing Model (CAPM).[i] The CAPM, among the most widely used models to estimate the cost of equity financing, assumes that the cost of equity is proportional to the amount of systematic risk associated with a company. The cost of equity financing tends to be high when a company faces a large degree of systematic risk and it tends to be low when the company faces a small degree of systematic risk.

DOE determined the cost of equity financing by using several variables, including the risk coefficient of a company, β (beta), the expected return on "risk free" assets (R_f), and the additional return expected on assets facing average market risk, also known as the equity risk premium or *ERP*. The risk coefficient of a company, β, indicates the degree of risk associated with a given firm relative to the level of risk (or price variability) in the overall stock market. Risk coefficients usually vary between 0.5 and 2.0. A company with a risk coefficient of 0.5 faces half the risk of other stocks in the market; a company with a risk coefficient of 2.0 faces twice the overall stock market risk.

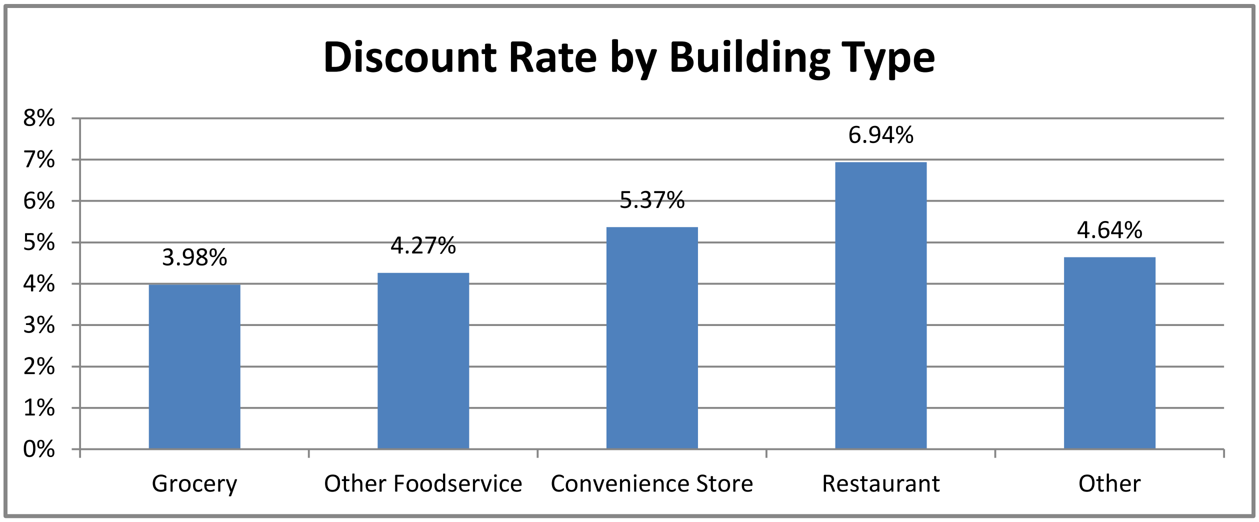
The following equation gives the cost of equity financing for a particular company:

$$k_e = R_f + (\beta \times ERP)$$

where

k_e = the cost of equity for a company, expressed as a percentage,
R_f = the expected return of the risk free asset, expressed as a percentage,
β = the risk coefficient,
ERP = the expected equity risk premium, expressed as a percentage.

DOE defined the risk-free rate as the yield (January 2012) on long-term government bonds. DOE used a 6.41-percent estimate for the *ERP* based on data from the Damodaran Online[ii] site.



The cost of debt financing is the yield or interest rate paid on money borrowed by a company (for example, by selling bonds). As defined here, the cost of debt includes compensation for default risk (the risk that a firm will go bankrupt) and excludes deductions for taxes. DOE estimated the cost of debt for companies by adding a risk adjustment factor to the current yield on long term corporate bonds (the risk free rate). It used this procedure to estimate current (and future) company costs to obtain debt financing. It based the adjustment factor on indicators of company risk, such as credit rating or variability of stock returns.

The weighted-average cost of capital (WACC) of a company is the weighted-average cost of debt and equity financing:

$$k = k_e \; x \; w_e + k_d \; x \; w_d$$

where

k = the (nominal) cost of capital, expressed as a percentage
k_e = the expected rate of return on equity, expressed as a percentage,
k_d = the expected rate of return on debt, expressed as a percentage,
w_e = the proportion of equity financing in total annual financing,
w_d = the proportion of debt financing in total annual financing.

The cost of capital is a nominal rate, because it includes anticipated future inflation in the expected returns from stocks and bonds. The real discount rate or WACC deducts expected inflation (r) from the nominal rate. DOE calculated expected inflation (3.68 percent) from the projected change in gross domestic product (GDP) prices.

8C.3 DISTRIBUTION AND DATASETS

The following tables and figure provide details about the distributions DOE used to describe the discount rates used in this analysis. Figure 8D.3.1 shows the weighted average discount rates across building types and Table 8D.3.1 through Table 8-D.3.5 provide the data used to obtain these estimate

Figure 8C.3.1 Weighted Average Discount Rates by Business Type

Table 8C.3.1 Discount Rate Inputs for Grocery Stores

Grocery Stores										
Company	*Firm Value*	*Value Line Beta*	*Cost of Equity*	E/(D+E)	*Std Dev in Stock*	*Cost of Debt*	*Eff Tax Rate*	*After Tax Cost of Debt*	*Market Debt to Capital (D/(D+E)*	*Cost of Capital*
A	$ 61	0.65	9.00%	65.95%	29.15%	7.41%	40.59%	4.45%	34.05%	7.45%
B	$ 283	0.70	9.20%	99.58%	19.80%	6.91%	40.17%	4.15%	0.42%	9.18%
C	$ 630	0.80	9.60%	85.67%	27.76%	7.41%	39.35%	4.45%	14.33%	8.86%
D	$ 5,160	0.45	8.21%	78.09%	12.29%	6.91%	25.78%	4.15%	21.91%	7.32%
E	$ 7,022	1.00	10.40%	91.70%	75.69%	8.41%	33.59%	5.05%	8.30%	9.96%
F	$ 2,128	0.65	9.00%	86.50%	22.74%	6.91%	38.46%	4.15%	13.50%	8.35%
G	$ 1,272	0.95	10.20%	32.78%	21.49%	6.91%	35.66%	4.15%	67.22%	6.13%
H	$ 21,508	0.60	8.80%	62.04%	17.70%	6.91%	33.92%	4.15%	37.96%	7.04%
I	$ 7,152	0.45	8.21%	86.04%	13.01%	6.91%	26.31%	4.15%	13.96%	7.64%
J	$ 560	0.70	9.20%	46.89%	29.02%	7.41%	38.83%	4.45%	53.11%	6.68%
K	$ 1,486	0.90	10.00%	18.95%	42.54%	7.41%	32.97%	4.45%	81.05%	5.50%
L	$ 9,656	0.65	9.00%	43.97%	25.63%	7.41%	30.04%	4.45%	56.03%	6.45%
M	$ 480	0.75	9.40%	71.27%	25.37%	7.41%	38.18%	4.45%	28.73%	7.98%
N	$ 6,785	0.85	9.80%	7.79%	57.28%	7.91%	37.62%	4.75%	92.21%	5.14%
O	$ 21,640	0.70	9.20%	86.05%	16.89%	6.91%	37.13%	4.15%	13.95%	8.50%
P	$ 2,769	0.75	9.40%	95.81%	19.53%	6.91%	39.42%	4.15%	4.19%	9.18%
Q	$ 481	0.75	9.40%	91.04%	31.11%	7.41%	42.11%	4.45%	8.96%	8.96%
R	$ 1,043	0.65	9.00%	100.00%	14.02%	6.91%	35.73%	4.15%	0.00%	9.00%
S	$ 17,287	0.45	8.21%	52.99%	14.75%	6.91%	26.07%	4.15%	47.01%	6.30%
T	$ 16,644	1.05	10.60%	99.89%	26.53%	7.41%	37.90%	4.45%	0.11%	10.59%

Table 8C.3.2 Discount Rate Inputs for Multiline Retailers

Multiline Retailers										
Company	*Firm Value*	*Value Line Beta*	*Cost of Equity*	E/(D+E)	*Std Dev in Stock*	*Cost of Debt*	*Eff Tax Rate*	*After Tax Cost of Debt*	*Market Debt to Capital*	*Cost of Capital*
A	$44,731	0.75	9.40%	95.19%	15.60%	6.91%	35.29%	4.15%	4.81%	9.15%
B	$7,835	0.50	8.41%	93.20%	24.75%	6.91%	37.06%	4.15%	6.80%	8.12%
C	$7,659	1.10	10.80%	54.39%	72.88%	8.41%	60.00%	5.05%	45.61%	8.18%
D	$56,053	0.90	10.00%	68.81%	18.58%	6.91%	34.27%	4.15%	31.19%	8.17%
E	$282,083	0.60	8.80%	81.18%	15.22%	6.91%	33.37%	4.15%	18.82%	7.93%

Table 8C.3.3 Discount Rate Inputs for Convenience Stores

Convenience Stores

Company	Firm Value	Value Line Beta	Cost of Equity	E/(D+E)	Std Dev in Stock	Cost of Debt	Eff Tax Rate	After Tax Cost of Debt	Market Debt to Capital	Cost of Capital
A	$9,251	0.55	8.60%	92.81%	26.23%	7.41%	24.23%	4.45%	7.19%	8.31%
B	$2,676	0.70	9.20%	74.64%	22.24%	6.91%	36.36%	4.15%	25.36%	7.92%
C	$1,486	0.90	10.00%	18.95%	42.54%	7.41%	32.97%	4.45%	81.05%	5.50%
D	$1,160	0.75	9.40%	61.11%	35.25%	7.41%	35.69%	4.45%	38.89%	7.47%
E	$231	1.35	11.80%	56.73%	80.43%	8.91%	5.53%	5.35%	43.27%	9.01%

Table 8C.3.4 Discount Rate Inputs for Full Service Restaurants

Full Service Restaurants

Company	Firm Value	Value Line Beta	Cost of Equity	E/(D+E)	Std Dev in Stock	Cost of Debt	Eff Tax Rate	After Tax Cost of Debt	Market Debt to Capital (D/(D+E))	Cost of Capital
A	$55	0.65	9.00%	99.82%	19.03%	6.91%	20.31%	4.15%	0.18%	8.99%
B	$743	1.10	10.80%	64.22%	35.28%	7.41%	28.99%	4.45%	35.78%	8.53%
C	$956	1.05	10.60%	100.00%	35.09%	7.41%	27.68%	4.45%	0.00%	10.60%
D	$1,263	0.95	10.20%	89.26%	22.91%	6.91%	30.59%	4.15%	10.74%	9.55%
E	$1,326	0.95	10.20%	100.00%	34.81%	7.41%	30.83%	4.45%	0.00%	10.20%
F	$416	1.30	11.60%	33.00%	54.20%	7.91%	27.19%	4.75%	67.00%	7.01%
G	$1,720	1.25	11.40%	100.00%	25.71%	7.41%	25.88%	4.45%	0.00%	11.40%
H	$9,320	0.95	10.20%	100.00%	35.41%	7.41%	38.54%	4.45%	0.00%	10.20%
I	$2,023	1.00	10.40%	74.04%	22.05%	6.91%	29.57%	4.15%	25.96%	8.78%
J	$7,513	1.00	10.40%	76.43%	20.69%	6.91%	25.31%	4.15%	23.57%	8.93%
K	$2,956	1.35	11.80%	41.96%	51.96%	7.91%	28.39%	4.75%	58.04%	7.70%
L	$86	1.10	10.80%	75.06%	29.04%	7.41%	33.19%	4.45%	24.94%	9.21%
M	$116	0.65	9.00%	80.41%	32.49%	7.41%	17.38%	4.45%	19.59%	8.11%
N	$22	0.45	8.21%	12.16%	138.60%	10.41%	0.00%	6.25%	87.84%	6.48%
O	$74	1.25	11.40%	99.87%	44.95%	7.41%	0.39%	4.45%	0.13%	11.39%
P	$196	1.10	10.80%	93.35%	41.54%	7.41%	18.47%	4.45%	6.65%	10.38%
Q	$12	0.45	8.21%	55.56%	102.21%	10.41%	0.00%	6.25%	44.44%	7.33%
R	$639	1.20	11.20%	77.00%	41.78%	7.41%	0.00%	4.45%	23.00%	9.64%
S	$829	1.50	12.40%	60.57%	45.12%	7.41%	0.00%	4.45%	39.43%	9.26%
T	$269	1.65	12.99%	91.82%	49.56%	7.41%	7.72%	4.45%	8.18%	12.29%
U	$26	0.45	8.21%	33.98%	208.10%	10.41%	0.00%	6.25%	66.02%	6.91%
V	$1,238	1.00	10.40%	95.00%	23.34%	6.91%	28.72%	4.15%	5.00%	10.09%

Table 8C.3.5 Discount Rate Inputs for Limited Service Restaurants

Limited Service Restaurants										
Company	*Firm Value*	*Value Line Beta*	*Cost of Equity*	E/(D+E)	*Std Dev in Stock*	*Cost of Debt*	*Eff Tax Rate*	*After Tax Cost of Debt*	*Market Debt to Capital (D/(D+E)*	*Cost of Capital*
A	$9,320	0.95	10.20%	100.00%	35.41%	7.41%	38.54%	4.45%	0.00%	10.20%
B	$55	1.50	12.40%	100.00%	56.39%	7.91%	0.00%	4.75%	0.00%	12.40%
C	$3,912	1.15	11.00%	62.90%	37.28%	7.41%	38.03%	4.45%	37.10%	8.57%
D	$343	1.15	11.00%	78.36%	32.97%	7.41%	37.61%	4.45%	21.64%	9.58%
E	$9	0.90	10.00%	73.56%	262.59%	10.41%	0.00%	6.25%	26.44%	9.01%
F	$1,742	0.95	10.20%	73.10%	23.36%	6.91%	35.93%	4.15%	26.90%	8.57%
G	$163	1.30	11.60%	100.00%	66.72%	8.41%	0.00%	5.05%	0.00%	11.60%
H	$629	1.25	11.40%	95.61%	52.12%	7.91%	9.09%	4.75%	4.39%	11.11%
I	$101,573	0.60	8.80%	87.69%	11.98%	6.91%	31.32%	4.15%	12.31%	8.23%
J	$149	0.40	8.01%	100.00%	21.58%	6.91%	38.46%	4.15%	0.00%	8.01%
K	$18	0.60	8.80%	72.78%	29.84%	7.41%	39.61%	4.45%	27.22%	7.62%
L	$4,590	0.95	10.20%	100.00%	27.83%	7.41%	38.18%	4.45%	0.00%	10.20%
M	$1,277	0.80	9.60%	95.97%	20.78%	6.91%	31.17%	4.15%	4.03%	9.38%
N	$1,076	1.15	11.00%	54.82%	43.01%	7.41%	37.74%	4.45%	45.18%	8.04%
O	$41,001	1.10	10.80%	98.66%	24.20%	6.91%	32.00%	4.15%	1.34%	10.71%
P	$7,989	0.90	10.00%	94.39%	16.28%	6.91%	29.04%	4.15%	5.61%	9.67%
Q	$3,202	1.00	10.40%	57.62%	25.86%	7.41%	34.91%	4.45%	42.38%	7.88%
R	$32,905	0.90	10.00%	89.92%	19.17%	6.91%	24.22%	4.15%	10.08%	9.41%

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ii Damodaran Online. Leonard N. Stern School of Business, New York University: <http://www.stern.nyu.edu/~adamodar/New_Home_Page/data.html>. Accessed January, 2013.

APPENDIX 8D. ESTIMATION OF POTENTIAL EQUIPMENT PRICE TRENDS FOR WALK-IN COOLERS AND FREEZERS

TABLE OF CONTENTS

LIST OF FIGURES

APPENDIX 8D. ESTIMATION OF POTENTIAL EQUIPMENT PRICE TRENDS FOR WALK-IN COOLER AND FREEZERS

8D.1 INTRODUCTION

In developing the proposed standards, the U.S. Department of Energy (DOE) assumes that the manufacturer costs and retail prices of products meeting various efficiency levels remain fixed, in real terms, after 2012 (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 for walk-in cooler and freezer (WICF) refrigeration equipment and envelope components and found both slightly positive and slightly negative real price trends depending on the specific time period examined. Therefore, in the absence of a definitive trend, DOE assumes in its price projections that the real prices of WICF equipment are constant in time and prices will trend the same way as prices in the economy as a whole.

In the following paragraphs, another potential method for projecting long-term price trends is presented. DOE expects that improvements in the presented methods will be made in future revisions to its analysis.

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 U.S. 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 projections for selected appliances and equipment.

The extensive literature on the "learning" or "experience" curve phenomenon is typically based on observations in the manufacturing sector.[1] In the experience curve method, the real cost of production is related to the cumulative production or "experience" with a manufactured product. To explain the empirical relationship, DOE would use the theory of technology learning 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 in this case is:

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[1] 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.

$$Y = aX^{-b}$$

Equation 8D.1

Where:

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

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

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

Equation 8D.2

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

DOE examined historical prices through the use of the Bureau of Labor Statistics' (BLS) Producer Price Index (PPI) and Gross Domestic Product Deflator (GDP-Deflator), available from the Bureau of Economic Analysis (BEA). The PPI data for air conditioning, refrigeration, and forced air heating is available for 1978 -2012 and is used to represent aggregate refrigeration system prices. Figure 8D.1 shows the PPI data series used. However, because WICF envelope components cover a wide variety of equipment, which include floor and wall panels, display and opaque doors, and because manufacturing this range of equipment relies on component specific materials and practices, it is difficult to accurately characterize learning across this market. Therefore, DOE did not attempt to summarize price learning across WICF envelope components and instead focused on developing only refrigeration system learning curves.

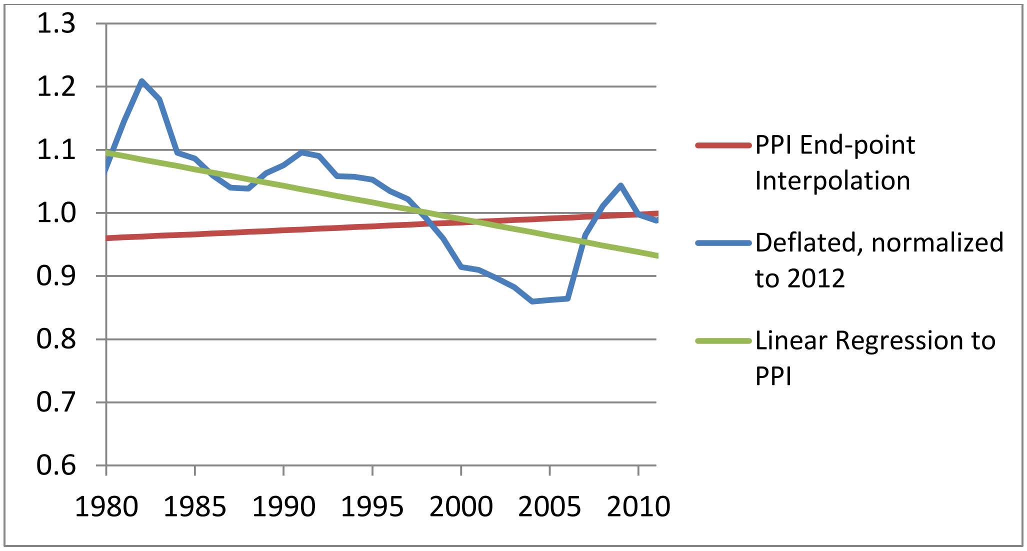

Figure 8D-1 PPI Data for WICF Refrigeration Systems

Inflation-adjusted price indices were calculated by dividing the fitted PPI series by the GDP-Deflator for the same years. The GDP-Deflator was used as opposed to the Consumer Price Index (CPI) because nearly all WICF refrigeration systems are shipped to commercial customers and to be consistent with energy price projection assumptions by Energy Information Administration (EIA).

8D.2 DATA EVALUATION AND ANALYSIS

Figure 8D-1 shows an apparent price trend in refrigeration systems that is trending slightly upward from 1978 to 2012, but shows a decrease in the real PPI during two significant periods of time: 1982–1988 and1992–1996. Based on the price trends shown in Figure 8D-1, DOE expects that, in the future, the PPI is likely to resume a downward trend.

In order to perform an experience curve fit, DOE assembled a time-series of annual shipments for 1940–2010 for refrigeration systems (for calculating cumulative production) from the Census Bureau.[2]

Projected shipments after 2010 were obtained from the base-case projections made for the national impact analysis (see chapter 10 of this technical support document). Projected annual shipments from 2015–2046 are depicted in Figure 8D-2.

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[2] U.S. Census Bureau, *Current Industrial Reports*, *1940 through 2009:* MA333M: Refrigeration, Air Conditioning, and Warm Air Heating Equipment. http://www.census.gov/manufacturing/cir/index.html July 2010.

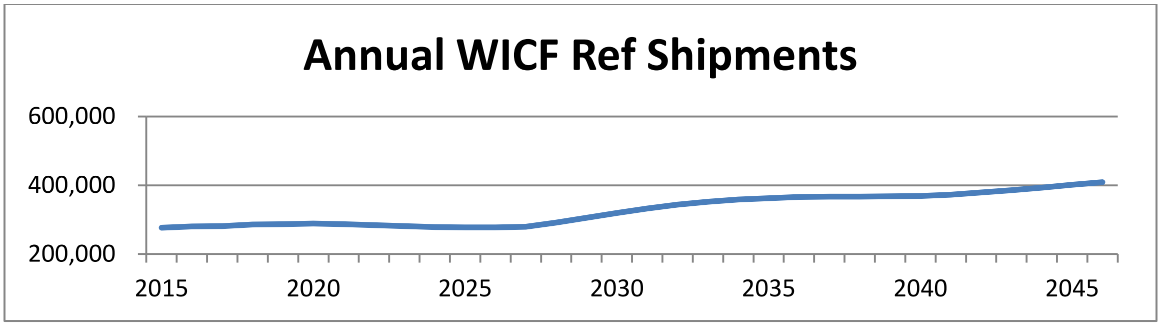


Figure 8D-2 Projected Annual Shipments for WICF Refrigeration Systems

To estimate potential product price trends, DOE performed a least-squares power-law fit on the WICF price index versus cumulative shipments. The form of the fitting equation is:

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

Equation 8D.3

Where:

b = the learning rate parameter, and
P_o = the price or cost of the first unit of production.

Both b and P_o are obtained by fitting the model to the data.

DOE notes that the cumulative shipments on the right-hand side of the equation can depend 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.

After modeling the data to Equation 8D.3, DOE estimated the learning rate (defined as the fractional reduction in price expected from each doubling of cumulative production) as 19 percent.

With cumulative shipments through 2046 projected to reach 46.8 million (compared with 35.8 million in 2012), the modeled trend predicts a drop of 8.6 percent in real price compared to the 2012 prices in the economy as a whole. Figure 8D-3 shows the model fit for the projected values for the period after 2012.

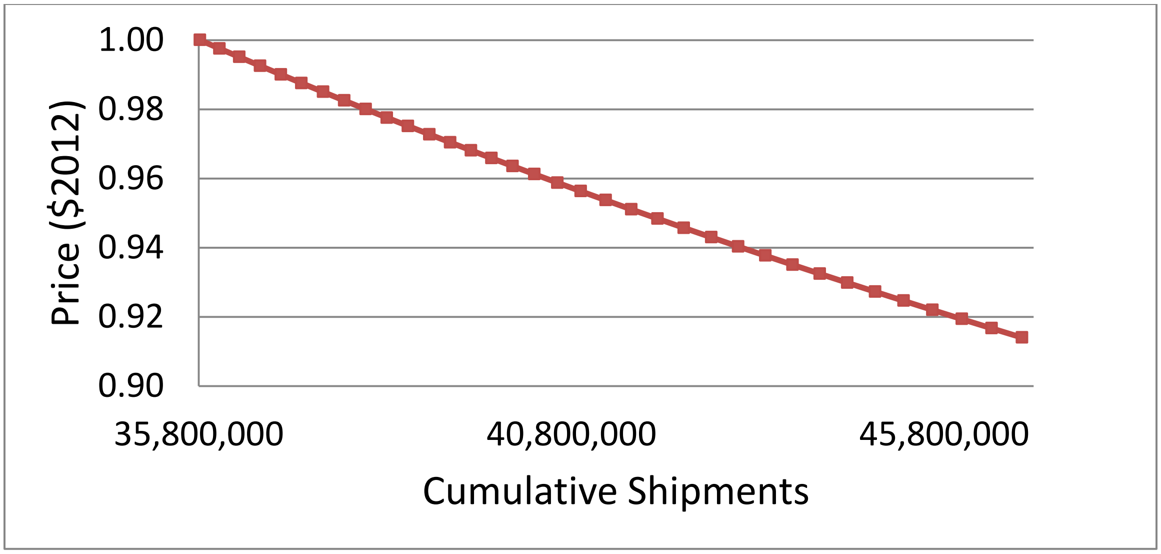


Figure 8D-3 Model Fit for Existing Technologies Scenario

APPENDIX 8E. LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS FOR REFRIGERATION SYSTEMS WITH RESPECT TO ITS OWN BASELINE (DISCRETE INPUTS)

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 8E. LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS FOR REFRIGERATION SYSTEMS WITH RESPECT TO ITS OWN BASELINE (DISCRETE INPUTS)

8E.1 INTRODUCTION

This appendix provides detailed life-cycle cost (LCC) and payback period (PBP) results for the refrigeration systems for all the sizes analysis in the engineering analysis. The LCC savings are computed using the baseline efficiency level of the same equipment of same specification. The results could be used to specifically analyze effectiveness of the design options used to determine its effectiveness.

8E.2 DETAILED LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

As discussed in TSD chapter 8, LCC is the total (discounted) customer cost over the analysis period, including purchase price, operating costs (including energy expenditures), and installation costs. LCC savings is the reduction in LCC that a customer would benefit from by switching to more efficient equipment. The PBP represents the amount of time it would take a customer to recover the assumed higher purchase cost of a more energy-efficient product from the lower operating costs. The results in this Appendix are based on discrete values of inputs and probability distributions of the input variables are not considered.

Table 8E.2.1 LCC and PBP Results for Dedicated Condensing, Medium Temperature, Indoor Refrigeration Systems (6 kBtu/hr)

Efficiency Level	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**
	Hermetic				**Semi-Hermetic**			
0	3,803	10,594	0	N/A	4,056	9,996	598	N/A
1	3,845	10,526	68	3.3	4,098	9,928	666	3.3
2	3,888	10,485	109	3.7	4,141	9,887	707	3.7
3	3,917	10,387	207	3.0	4,170	9,789	805	3.0
4	3,921	10,378	216	3.0	4,174	9,780	814	3.0
5	3,930	10,372	222	3.1	4,183	9,774	819	3.1
6	4,264	10,201	393	4.6	4,492	9,640	954	4.7

Table 8E.2.2 LCC and PBP Results for Dedicated Condensing, Medium Temperature, Indoor Refrigeration Systems (18 kBtu/hr)

Efficiency Level	**Installed Cost** *2012$*	**LCC** *2012$*	**LCC Savings** *2012$*	**PBP**	**Installed Cost** *2012$*	**LCC** *2012$*	**LCC Savings** *2012$*	**PBP**	**Installed Cost** *2012$*	**LCC** *2012$*	**LCC Savings** *2012$*	**PBP**
	Hermetic				**Scroll**				**Semi-Hermetic**			
0	6,143	20,284	0	N/A	6,615	20,294	-10	N/A	7,134	21,843	-1,559	N/A
1	6,228	19,926	358	1.6	6,700	19,936	348	1.6	7,219	21,485	-1,201	1.6
2	6,313	19,679	606	1.9	6,785	19,689	595	1.9	7,304	21,237	-953	1.9
3	6,570	18,965	1,319	2.1	7,050	18,849	1,436	2.0	7,529	20,435	-151	1.9
4	6,658	18,663	1,621	2.1	7,138	18,547	1,737	2.0	7,617	20,134	150	1.9
5	6,669	18,636	1,648	2.1	7,149	18,519	1,765	2.0	7,628	20,106	178	1.9
6	6,707	18,615	1,669	2.2	7,187	18,499	1,785	2.1	7,666	20,086	198	2.0

Table 8E.2.3 LCC and PBP Results for Dedicated Condensing, Medium Temperature, Indoor Refrigeration Systems (54 kBtu/hr)

Efficiency Level	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**
	Scroll				**Semi-Hermetic**			
0	13,498	51,236	0	N/A	14,720	50,688	549	N/A
1	13,583	49,660	1,577	0.4	14,805	49,111	2,125	0.4
2	13,668	48,499	2,738	0.5	14,889	47,950	3,286	0.5
3	13,724	47,907	3,329	0.5	14,946	47,359	3,878	0.5
4	14,277	44,426	6,811	0.9	15,458	44,805	6,432	1.0
5	14,306	44,356	6,880	0.9	15,487	44,735	6,501	1.0
6	14,446	44,279	6,958	1.0	15,626	44,658	6,578	1.1

Table 8E.2.4 LCC and PBP Results for Dedicated Condensing, Medium Temperature, Indoor Refrigeration Systems (96 kBtu/hr)

Efficiency Level	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**
	Scroll				**Semi-Hermetic**			
0	21,938	92,841	0	N/A	23,471	89,943	2,899	N/A
1	22,108	89,688	3,153	0.4	23,641	86,790	6,052	0.4
2	22,278	87,366	5,475	0.5	23,811	84,467	8,374	0.5
3	22,391	86,177	6,664	0.5	23,924	83,278	9,563	0.5
4	23,497	79,533	13,308	0.9	24,926	78,767	14,074	1.0
5	23,555	79,394	13,447	0.9	24,984	78,628	14,213	1.0
6	23,834	79,239	13,602	1.0	25,263	78,473	14,368	1.2

Table 8E.2.5 LCC and PBP Results for Dedicated Condensing, Medium Temperature, Outdoor Refrigeration Systems (6 kBtu/hr)

Efficiency Level	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**
	Hermetic				**Semi-Hermetic**			
0	3,874	9,710	0	N/A	4,150	9,290	420	N/A
1	3,917	9,616	94	2.7	4,192	9,196	513	2.7
2	3,959	9,556	154	3.0	4,235	9,137	573	3.0
3	4,010	9,228	482	1.9	4,285	8,812	898	1.9
4	4,014	9,217	493	1.9	4,289	8,801	909	1.9
5	4,043	9,155	555	2.0	4,319	8,740	969	2.0
6	4,053	9,154	556	2.1	4,328	8,740	970	2.1
7	4,199	8,982	728	2.6	4,474	8,629	1,080	2.8
8	4,284	8,947	763	3.0	4,559	8,598	1,112	3.2
9	4,645	8,950	760	4.3	4,892	8,568	1,142	4.3

Table 8E.2.6 LCC and PBP Results for Dedicated Condensing, Medium Temperature, Outdoor Refrigeration Systems (18 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	Hermetic				**Scroll**				**Semi-Hermetic**			
0	6,220	17,947	0	N/A	6,687	17,054	892	N/A	7,211	19,177	-1,230	N/A
1	6,305	17,485	461	1.3	6,772	16,593	1,354	1.3	7,296	18,716	-769	1.3
2	6,390	17,161	786	1.5	6,857	16,268	1,678	1.5	7,381	18,391	-444	1.5
3	6,441	16,282	1,665	1.0	6,908	15,336	2,611	1.0	7,432	17,319	628	0.9
4	6,574	15,720	2,227	1.2	7,041	14,916	3,030	1.2	7,565	16,755	1,191	1.1
5	6,582	15,698	2,249	1.2	7,105	14,787	3,159	1.3	7,573	16,734	1,213	1.1
6	6,646	15,578	2,368	1.3	7,190	14,625	3,322	1.5	7,637	16,616	1,331	1.2
7	6,731	15,426	2,521	1.4	7,512	14,452	3,495	2.1	7,722	16,469	1,478	1.4
8	7,050	15,105	2,842	1.9	7,549	14,448	3,499	2.1	8,041	16,189	1,758	1.9
9	7,087	15,101	2,845	2.0	7,804	14,368	3,579	2.5	8,078	16,186	1,761	1.9
10	-	-	-	-	7,815	14,371	3,576	2.5	-	-	-	-

Table 8E.2.7 LCC and PBP Results for Dedicated Condensing, Medium Temperature, Outdoor Refrigeration Systems (54 kBtu/hr)

Efficiency Level	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**
	Scroll				**Semi-Hermetic**			
0	13,599	44,112	0	N/A	14,856	43,889	222	N/A
1	13,684	42,144	1,968	0.4	14,941	41,922	2,190	0.4
2	13,769	40,690	3,422	0.4	15,026	40,467	3,645	0.4
3	13,820	37,912	6,200	0.3	15,077	37,607	6,505	0.3
4	13,989	36,238	7,874	0.4	15,246	36,057	8,054	0.4
5	14,052	35,817	8,295	0.4	15,309	35,639	8,472	0.4
6	14,136	35,285	8,826	0.5	15,393	35,117	8,994	0.5
7	14,734	32,897	11,215	0.8	15,946	34,364	9,747	0.9
8	14,989	32,247	11,865	0.9	16,085	34,351	9,761	1.0
9	15,128	32,236	11,876	1.0	18,594	34,824	9,288	2.5
10	16,719	31,848	12,264	1.7	18,626	34,836	9,275	2.5
11	16,750	31,859	12,252	1.7	-	-	-	-

Table 8E.2.8 LCC and PBP Results for Dedicated Condensing, Medium Temperature, Outdoor Refrigeration Systems (96 kBtu/hr)

Efficiency Level	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**
	Scroll				**Semi-Hermetic**			
0	22,086	77,598	0	N/A	23,711	77,341	257	N/A
1	22,256	73,657	3,941	0.4	23,881	73,400	4,198	0.4
2	22,426	70,744	6,854	0.4	24,051	70,487	7,111	0.4
3	22,476	66,053	11,545	0.3	24,102	65,295	12,304	0.3
4	22,705	62,850	14,748	0.3	24,330	62,294	15,305	0.3
5	22,875	61,177	16,421	0.4	24,500	60,648	16,950	0.4
6	22,915	60,861	16,737	0.4	24,540	60,329	17,269	0.4
7	24,100	59,308	18,290	0.8	25,609	58,876	18,722	0.8
8	24,355	58,186	19,412	0.9	25,888	58,852	18,746	0.9
9	24,634	58,169	19,429	1.0	29,297	58,483	19,115	1.9
10	27,461	56,992	20,607	1.8	29,361	58,509	19,090	2.0
11	27,525	57,015	20,584	1.8	-	-	-	-

Table 8E.2.9 LCC and PBP Results for Dedicated Condensing, Low Temperature, Indoor Refrigeration Systems (6 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	Hermetic				**Scroll**				**Semi-Hermetic**			
0	3,991	15,623	0	N/A	4,534	15,825	-201	N/A	5,071	16,660	-1,037	N/A
1	4,033	15,484	139	2.0	4,576	15,686	-62	2.0	5,113	16,521	-898	2.0
2	4,076	15,391	233	2.3	4,619	15,592	31	2.3	5,156	16,428	-804	2.3
3	4,083	15,353	270	2.2	4,626	15,554	69	2.2	5,163	16,390	-767	2.2
4	4,142	15,128	495	2.0	4,685	15,329	294	2.0	5,222	16,165	-541	2.0
5	4,160	15,114	509	2.1	4,704	15,315	308	2.1	5,240	16,151	-528	2.1
6	4,451	14,856	768	3.2	4,985	14,731	893	2.5	5,503	15,991	-368	3.3
7	4,535	14,895	728	3.6	5,070	14,770	853	2.9	5,588	16,030	-407	3.8

Table 8E.2.10 LCC and PBP Results for Dedicated Condensing, Low Temperature, Indoor Refrigeration Systems (9 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	Hermetic				**Scroll**				**Semi-Hermetic**			
0	4,448	19,533	0	N/A	4,953	18,826	708	N/A	5,605	21,406	-1,872	N/A
1	4,490	19,394	139	2.0	4,995	18,687	847	2.0	5,648	21,267	-1,733	2.0
2	4,533	19,301	233	2.3	5,038	18,593	940	2.3	5,690	21,173	-1,640	2.3
3	4,540	19,263	270	2.2	5,045	18,555	978	2.2	5,698	21,135	-1,602	2.2
4	4,599	19,038	495	2.0	5,104	18,330	1,203	2.0	5,756	20,910	-1,377	2.0
5	4,907	18,407	1,126	2.5	5,122	18,316	1,217	2.1	6,045	20,153	-619	2.2
6	4,925	18,393	1,140	2.5	5,449	17,741	1,793	2.7	6,063	20,139	-605	2.3
7	5,010	18,429	1,105	2.9	5,534	17,776	1,757	3.0	6,148	20,175	-641	2.6

Table 8E.2.11 LCC and PBP Results for Dedicated Condensing, Low Temperature, Indoor Refrigeration Systems (54 kBtu/hr)

Efficiency Level	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**
	Scroll				**Semi-Hermetic**			
0	21,956	91,553	0	N/A	23,376	98,937	-7,384	N/A
1	22,040	90,277	1,276	0.5	23,460	97,661	-6,109	0.5
2	22,125	89,342	2,211	0.6	23,545	96,726	-5,173	0.6
3	22,239	87,950	3,603	0.6	23,744	93,535	-1,983	0.5
4	22,323	87,779	3,774	0.8	23,829	93,364	-1,811	0.6
5	22,362	87,666	3,887	0.8	23,915	93,110	-1,558	0.7
6	22,501	87,562	3,991	1.0	24,055	93,007	-1,454	0.9
7	22,501	87,562	3,991	1.0	25,503	91,216	336	1.8

Table 8E.2.12 LCC and PBP Results for Dedicated Condensing, Low Temperature, Outdoor Refrigeration Systems (6 kBtu/hr)

Efficiency Level	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**	**Installed Cost** ***2012$***	**LCC** ***2012$***	**LCC Savings** ***2012$***	**PBP**
	Hermetic				**Scroll**				**Semi-Hermetic**			
0	4,071	14,190	0	N/A	4,606	13,230	961	N/A	5,158	15,039	-849	N/A
1	4,114	13,981	210	1.4	4,648	13,020	1,171	1.4	5,201	14,829	-639	1.4
2	4,156	13,834	356	1.6	4,691	12,873	1,317	1.6	5,243	14,683	-492	1.6
3	4,207	13,439	752	1.3	4,742	12,358	1,832	1.1	5,294	14,100	90	1.1
4	4,341	12,755	1,436	1.3	4,876	11,898	2,292	1.4	5,428	13,491	699	1.3
5	4,349	12,731	1,460	1.4	4,883	11,874	2,316	1.4	5,436	13,467	723	1.3
6	4,368	12,735	1,455	1.4	4,948	11,739	2,451	1.6	5,500	13,336	855	1.4
7	4,432	12,601	1,590	1.6	5,033	11,559	2,632	1.7	5,455	13,472	718	1.3
8	4,517	12,426	1,764	1.7	5,051	11,561	2,630	1.8	5,519	13,340	850	1.5
9	4,602	12,466	1,724	2.0	5,358	11,551	2,639	2.6	5,604	13,166	1,024	1.6
10	4,917	12,763	1,427	3.2	5,443	11,591	2,600	2.9	5,689	13,205	985	1.9
11	-	-	-	-	-	-	-	-	5,992	13,377	813	2.8

Table 8E.2.13 LCC and PBP Results for Dedicated Condensing, Low Temperature, Outdoor Refrigeration Systems (9 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	Hermetic				**Scroll**				**Semi-Hermetic**			
0	4,542	17,545	0	N/A	5,025	15,401	2,144	N/A	5,728	19,317	-1,772	N/A
1	4,585	17,337	208	1.4	5,067	15,192	2,353	1.4	5,771	19,109	-1,564	1.4
2	4,627	17,191	354	1.6	5,118	14,466	3,079	0.8	5,813	18,963	-1,418	1.6
3	4,678	16,583	962	1.1	5,161	14,311	3,234	0.9	5,864	18,047	-502	0.8
4	4,819	15,620	1,925	1.1	5,301	13,707	3,838	1.2	6,005	17,083	462	0.9
5	4,827	15,596	1,949	1.1	5,309	13,682	3,863	1.2	6,012	17,059	486	0.9
6	4,891	15,459	2,086	1.2	5,374	13,546	3,999	1.3	6,077	16,925	620	1.1
7	4,976	15,283	2,262	1.4	5,458	13,362	4,183	1.5	6,162	16,749	796	1.2
8	4,994	15,286	2,259	1.4	5,477	13,363	4,182	1.5	6,466	16,378	1,167	1.7
9	5,327	15,037	2,508	2.0	5,833	13,368	4,177	2.4	6,485	16,379	1,166	1.7
10	5,412	15,073	2,472	2.2	6,087	13,271	4,274	2.8	6,570	16,415	1,130	1.9
11	-	-	-	-	6,172	13,307	4,238	3.0	-	-	-	-

Table 8E.2.14 LCC and PBP Results for Dedicated Condensing, Low Temperature, Outdoor Refrigeration Systems (54 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	Scroll				**Semi-Hermetic**			
0	22,139	70,931	0	N/A	23,946	83,904	-2,973	N/A
1	22,190	67,039	3,892	0.1	23,997	79,331	-8,400	0.1
2	22,275	65,144	5,787	0.2	24,082	77,415	-6,484	0.2
3	22,360	63,744	7,187	0.3	24,166	75,999	-5,068	0.2
4	22,641	60,156	10,775	0.4	24,336	71,367	-436	0.3
5	22,811	58,216	12,715	0.4	24,624	67,075	3,856	0.3
6	22,850	57,896	13,035	0.4	24,758	66,385	4,546	0.4
7	22,935	57,725	13,206	0.5	24,843	66,214	4,717	0.4
8	23,190	57,097	13,834	0.6	24,982	66,226	4,705	0.5
9	23,329	57,099	13,832	0.7	29,929	65,884	5,047	2.1
10	27,945	57,269	13,662	2.5	31,097	66,297	4,634	2.5
11	27,987	57,273	13,658	2.5	31,239	66,345	4,586	2.5
12	29,595	58,402	12,529	3.2	-	-	-	-

Table 8E.2.15 LCC and PBP Results for Dedicated Condensing, Low Temperature, Outdoor Refrigeration Systems (72 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	Semi-Hermetic			
0	30,100	106,509	0	N/A
1	30,151	100,515	5,994	0.1
2	30,278	97,635	8,874	0.2
3	30,406	95,507	11,002	0.2
4	30,693	89,624	16,885	0.3
5	30,863	85,190	21,320	0.3
6	30,948	84,900	21,609	0.3
7	31,082	84,213	22,296	0.4
8	31,291	84,230	22,279	0.4
9	32,795	83,974	22,535	0.9
10	37,732	82,455	24,054	2.0
11	37,874	82,502	24,007	2.1

Table 8E.2.16 LCC and PBP Results for Multiplex, Medium Temperature Refrigeration Systems (4 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	4 fins per inch				**6 fins per inch**			
0	1,489	4,754	0	N/A	1,394	4,659	0	N/A
1	1,534	4,683	72	3.6	1,439	4,587	72	3.6
2	1,580	4,013	741	1.0	1,484	3,918	741	1.0
3	1,590	4,020	735	1.1	1,494	3,924	735	1.1

Table 8E.2.17 LCC and PBP Results for Multiplex, Medium Temperature Refrigeration Systems (9 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	4 fins per inch				**6 fins per inch**			
0	2,155	7,635	0	N/A	2,141	7,621	0	N/A
1	2,201	7,446	189	1.8	2,187	7,432	189	1.8
2	2,246	5,963	1,671	0.5	2,232	5,950	1,671	0.5
3	2,266	5,976	1,659	0.6	2,252	5,962	1,659	0.6

Table 8E.2.18 LCC and PBP Results for Multiplex, Medium Temperature Refrigeration Systems (24 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	6 fins per inch			
0	3,304	16,831	0	N/A
1	3,349	15,997	834	0.5
2	3,395	11,218	5,613	0.1
3	3,469	11,268	5,563	0.3

Table 8E.2.19 LCC and PBP Results for Multiplex, Low Temperature Refrigeration Systems (4 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	4 fins per inch			
0	1,356	6,488	0.00	N/A
1	1,401	6,438	50	4.4
2	1,446	5,651	838	0.9
3	1,456	5,654	834	1.0
4	1,547	5,703	785	1.8
5	1,977	5,958	530	5.0

Table 8E.2.20 LCC and PBP Results for Multiplex, Low Temperature Refrigeration Systems (9 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	4 fins per inch				**6 fins per inch**			
0	2,110	11,617	0	N/A	2,141	11,700	0	N/A
1	2,155	11,471	146	2.2	2,187	11,554	146	2.2
2	2,200	9,650	1,967	0.4	2,232	9,755	1,945	0.4
3	2,291	9,666	1,951	0.8	2,323	9,742	1,957	0.8
4	2,311	9,674	1,943	0.9	2,342	9,751	1,949	0.9
5	2,741	9,899	1,718	2.5	2,777	9,935	1,765	2.4

Table 8E.2.21 LCC and PBP Results for Multiplex, Low Temperature Refrigeration Systems (18 kBtu/hr)

Efficiency Level	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP	Installed Cost *2012$*	LCC *2012$*	LCC Savings *2012$*	PBP
	4 fins per inch				**6 fins per inch**			
0	3,383	21,520	0	N/A	3,022	22,338	0	N/A
1	3,428	21,087	433	0.9	3,068	21,666	673	0.6
2	3,473	17,101	4,419	0.2	3,113	16,857	5,481	0.1
3	3,564	16,998	4,522	0.4	3,204	16,778	5,561	0.3
4	3,996	17,039	4,481	1.1	3,639	16,855	5,483	0.9
5	4,045	17,064	4,456	1.2	3,713	16,902	5,437	1.0

APPENDIX 8F. DISTRIBUTION OF CONSUMER IMPACTS FOR REFRIGERATION SYSTEMS

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 8F. DISTRIBUTION OF CONSUMER IMPACTS FOR REFRIGERATION SYSTEMS

8F.1 INTRODUCTION

This appendix provides detailed life-cycle cost and payback period distribution results for the refrigeration systems at each trial standard level (TSL). The method of calculation is described in chapter 8 of this technical support document).

Table 8F.1.1 Life-Cycle Cost Savings Distributions for Medium Temperature Dedicated Condensing Systems in 2012$

Life-Cycle Cost Savings ($)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Dedicated Condensing-Small (6 kBtu/h)						
Mean	590	748	748	590	819	819
Median	542	675	675	542	726	726
P(0.05)	223	191	191	223	71	71
Q(0.25)	402	465	465	402	439	439
Q3(0.75)	727	959	959	727	1,103	1,103
P(0.95)	1,103	1,534	1,534	1,103	1,831	1,831
Medium Temperature Dedicated Condensing-Medium (18 kBtu/h)						
Mean	1,817	2,874	1,817	2,874	2,874	2,874
Median	1,686	2,635	1,686	2,635	2,635	2,635
P(0.05)	847	970	847	970	970	970
Q(0.25)	1,319	1,915	1,319	1,915	1,915	1,915
Q3(0.75)	2,182	3,583	2,182	3,583	3,583	3,583
P(0.95)	9,767	20,246	9,767	20,246	20,246	20,246
Medium Temperature Dedicated Condensing-Large (54 kBtu/h)						
Mean	12,494	13,068	12,494	13,068	13,068	13,068
Median	11,669	12,133	11,669	12,133	12,133	12,133
P(0.05)	5,869	5,340	5,869	5,340	5,340	5,340
Q(0.25)	9,162	9,182	9,162	9,182	9,182	9,182
Q3(0.75)	14,965	15,986	14,965	15,986	15,986	15,986
P(0.95)	74,339	91,411	74,339	91,411	91,411	91,411

Table 8F.1.2 Life-Cycle Cost Savings Distributions for Low Temperature Dedicated Condensing Systems in 2012$

Life-Cycle Cost Savings ($)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Dedicated Condensing-Small (6 kBtu/h)						
Mean	72	385	72	385	385	385
Median	65	335	65	335	335	335
P(0.05)	18	-6	18	-6	-6	-6
Q(0.25)	45	189	45	189	189	189
Q3(0.75)	93	532	93	532	532	532
P(0.95)	145	911	145	911	911	911
Low Temperature Dedicated Condensing-Medium (18 kBtu/h)						
Mean	1,381	1,879	1,381	1,879	1,879	1,879
Median	1,273	1,732	1,273	1,732	1,732	1,732
P(0.05)	531	725	531	725	725	725
Q(0.25)	956	1,302	956	1,302	1,302	1,302
Q3(0.75)	1,708	2,323	1,708	2,323	2,323	2,323
P(0.95)	7,898	10,729	7,898	10,729	10,729	10,729
Low Temperature Dedicated Condensing-Large (54 kBtu/h)						
Mean	14,126	14,590	14,126	14,590	13,761	13,761
Median	13,145	13,590	13,145	13,590	12,504	12,504
P(0.05)	7,032	7,167	7,032	7,167	3,624	3,624
Q(0.25)	10,462	10,753	10,462	10,753	8,664	8,664
Q3(0.75)	16,784	17,373	16,784	17,373	17,609	17,609
P(0.95)	76,788	76,559	76,788	76,559	114,752	114,752

Table 8F.1.3 Life-Cycle Cost Savings Distributions for Medium and Low Temperature Multiplex Systems in 2012$

Life-Cycle Cost Savings ($)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Multiplex (9 kBtu/h)						
Mean	1,745	1,752	1,745	1,752	1,745	1,745
Median	1,650	1,659	1,650	1,659	1,650	1,650
P(0.05)	826	838	826	838	826	826
Q(0.25)	1,275	1,287	1,275	1,287	1,275	1,275
Q3(0.75)	2,105	2,113	2,105	2,113	2,105	2,105
P(0.95)	2,912	2,903	2,912	2,903	2,912	2,912
Low Temperature Multiplex (9 kBtu/h)						
Mean	1,893	2,101	1,893	2,101	1,893	1,893
Median	1,717	1,924	1,717	1,924	1,717	1,717
P(0.05)	625	909	625	909	625	625
Q(0.25)	1,236	1,431	1,236	1,431	1,236	1,236
Q3(0.75)	2,409	2,612	2,409	2,612	2,409	2,409
P(0.95)	9,819	7,987	9,819	7,987	9,819	9,819

Table 8F.1.4 Payback Period Distributions for Medium Temperature Dedicated Condensing Systems

Payback Period (*years*)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Dedicated Condensing-Small (6 kBtu/h)						
Mean	2.1	3.2	3.2	2.1	4.3	4.3
Median	2.1	3.2	3.2	2.1	4.3	4.3
P(0.05)	1.3	2.0	2.0	1.3	2.7	2.7
Q(0.25)	1.7	2.6	2.6	1.7	3.5	3.5
Q3(0.75)	2.4	3.7	3.7	2.4	5.0	5.0
P(0.95)	2.9	4.4	4.4	2.9	5.9	5.9
Medium Temperature Dedicated Condensing-Medium (18 kBtu/h)						
Mean	1.0	2.5	1.0	2.5	2.5	2.5
Median	1.0	2.5	1.0	2.5	2.5	2.5
P(0.05)	0.6	1.6	0.6	1.6	1.6	1.6
Q(0.25)	0.8	2.1	0.8	2.1	2.1	2.1
Q3(0.75)	1.1	2.9	1.1	2.9	2.9	2.9
P(0.95)	1.8	4.6	1.8	4.6	4.6	4.6
Medium Temperature Dedicated Condensing-Large (54 kBtu/h)						
Mean	1.0	1.7	1.0	1.7	1.7	1.7
Median	1.0	1.7	1.0	1.7	1.7	1.7
P(0.05)	0.6	1.1	0.6	1.1	1.1	1.1
Q(0.25)	0.8	1.4	0.8	1.4	1.4	1.4
Q3(0.75)	1.1	2.0	1.1	2.0	2.0	2.0
P(0.95)	1.8	3.2	1.8	3.2	3.2	3.2

Table 8F.1.5 Payback Period Distributions for Low Temperature Dedicated Condensing Systems

Payback Period (*years*)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Dedicated Condensing-Small (6 kBtu/h)						
Mean	2.0	1.7	2.0	1.7	2.8	2.8
Median	2.0	1.7	2.0	1.7	2.8	2.8
P(0.05)	1.2	1.1	1.2	1.1	1.8	1.8
Q(0.25)	1.6	1.4	1.6	1.4	2.3	2.3
Q3(0.75)	2.3	2.0	2.3	2.0	3.3	3.3
P(0.95)	2.8	2.4	2.8	2.4	3.9	3.9
Low Temperature Dedicated Condensing-Large (18 kBtu/h)						
Mean	0.7	2.8	0.7	2.8	3.0	3.0
Median	0.7	2.8	0.7	2.8	3.0	3.0
P(0.05)	0.4	1.8	0.4	1.8	1.9	1.9
Q(0.25)	0.6	2.3	0.6	2.3	2.5	2.5
Q3(0.75)	0.9	3.3	0.9	3.3	3.5	3.5
P(0.95)	1.4	5.1	1.4	5.1	5.5	5.5
Medium Temperature Dedicated Condensing-Large (54 kBtu/h)						
Mean	0.5	0.6	0.5	0.6	3.1	3.1
Median	0.5	0.6	0.5	0.6	3.1	3.1

P(0.05)	0.3	0.4	0.3	0.4	2.0	2.0
Q(0.25)	0.4	0.5	0.4	0.5	2.6	2.6
Q3(0.75)	0.6	0.7	0.6	0.7	3.6	3.6
P(0.95)	0.9	1.1	0.9	1.1	5.8	5.8

Table 8F.1.6 Payback Period Distributions for Medium and Low Temperature Multiplex Systems

Payback Period (*years*)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Multiplex (9 kBtu/h)						
Mean	0.6	0.5	0.6	0.5	0.6	0.6
Median	0.6	0.5	0.6	0.5	0.6	0.6
P(0.05)	0.4	0.3	0.4	0.3	0.4	0.4
Q(0.25)	0.5	0.4	0.5	0.4	0.5	0.5
Q3(0.75)	0.7	0.5	0.7	0.5	0.7	0.7
P(0.95)	0.8	0.7	0.8	0.7	0.8	0.8
Low Temperature Multiplex (9 kBtu/h)						
Mean	2.4	0.4	2.4	0.4	2.4	2.4
Median	2.5	0.4	2.5	0.4	2.5	2.5
P(0.05)	1.5	0.2	1.5	0.2	1.5	1.5
Q(0.25)	1.9	0.3	1.9	0.3	1.9	1.9
Q3(0.75)	2.9	0.5	2.9	0.5	2.9	2.9
P(0.95)	4.4	0.8	4.4	0.8	4.4	4.4

APPENDIX 8G. DISTRIBUTION OF CONSUMER IMPACTS FOR ENVELOPE COMPONENTS

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 8G. DISTRIBUTION OF CONSUMER IMPACTS FOR ENVELOPE COMPONENTS

8G.1 INTRODUCTION

This appendix provides detailed life-cycle cost and payback period distribution results for the envelope components at each trial standard level (TSL). The method of calculation is described in Chapter 8 of this technical support document).

Table 8G.1.1 Life-Cycle Cost Savings Distributions for Standard, Medium Temperature WICF Panels in 2012$

Life-Cycle Cost Savings						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Standard Panel-Small						
Mean	26.4	0.0	-2.7	12.6	-24.4	-2,146.4
Median	21.7	0.0	-8.1	9.4	-29.3	-2,150.0
P(0.05)	-5.2	0.0	-39.0	-14.6	-49.9	-2,210.8
Q(0.25)	10.2	0.0	-21.2	-3.9	-39.4	-2,176.9
Q3(0.75)	45.8	0.0	19.3	27.9	-9.6	-2,109.9
P(0.95)	400.0	0.0	428.1	330.4	348.0	-1,445.0
Medium Temperature Standard Panel-Medium						
Mean	13.5	0.0	-10.1	6.7	-22.0	-2,137.2
Median	11.1	0.0	-13.1	5.2	-24.6	-2,139.6
P(0.05)	-1.7	0.0	-29.6	-6.5	-35.9	-2,191.6
Q(0.25)	5.7	0.0	-20.2	-1.3	-30.2	-2,163.2
Q3(0.75)	22.8	0.0	1.9	14.2	-14.0	-2,104.3
P(0.95)	195.8	0.0	226.0	161.8	182.2	-1,625.7
Medium Temperature Standard Panel-Large						
Mean	10.7	0.0	-11.8	5.4	-21.7	-2,135.6
Median	8.8	0.0	-14.3	4.2	-23.9	-2,138.2
P(0.05)	-1.1	0.0	-27.9	-5.0	-33.3	-2,188.4
Q(0.25)	4.6	0.0	-20.2	-1.0	-28.5	-2,160.6
Q3(0.75)	18.1	0.0	-1.9	11.2	-15.0	-2,103.0
P(0.95)	154.3	0.0	185.0	127.6	148.4	-1,662.4

Table 8G.1.2 Life-Cycle Cost Savings Distributions for Standard, Low Temperature WICF Panels in 2012$

Life-Cycle Cost Savings						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Standard Panel-Small						
Mean	214.5	0.0	42.9	135.5	-67.8	-1,818.4
Median	188.2	0.0	10.5	115.4	-92.9	-1,842.4
P(0.05)	93.9	0.0	-104.8	38.5	-177.4	-1,963.2
Q(0.25)	144.0	0.0	-43.5	72.8	-136.4	-1,899.3
Q3(0.75)	302.0	0.0	149.9	198.0	5.2	-1,729.8
P(0.95)	1,854.1	0.0	2,027.2	1,701.6	1,829.8	596.0
Low Temperature Standard Panel-Medium						
Mean	104.4	0.0	-86.1	59.5	-153.4	-1,904.0
Median	89.5	0.0	-106.2	47.7	-169.1	-1,918.7
P(0.05)	35.4	0.0	-177.0	3.7	-220.4	-2,010.2
Q(0.25)	64.1	0.0	-139.1	23.5	-195.2	-1,959.0
Q3(0.75)	154.5	0.0	-21.3	95.9	-108.7	-1,839.6
P(0.95)	1,045.1	0.0	1,118.0	959.2	1,000.8	-219.3
Low Temperature Standard Panel-Large						
Mean	82.0	0.0	-112.2	44.0	-170.8	-1,921.4
Median	69.4	0.0	-129.8	33.8	-184.5	-1,934.0
P(0.05)	23.3	0.0	-191.4	-3.5	-229.4	-2,020.0
Q(0.25)	47.8	0.0	-158.3	13.4	-207.1	-1,971.4
Q3(0.75)	124.5	0.0	-55.6	75.1	-131.8	-1,861.3
P(0.95)	882.5	0.0	935.9	809.4	833.9	-383.3

Table 8G.1.3 Life-Cycle Cost Savings Distributions for Standard, Low Temperature WICF Floor Panels in 2012$

Life-Cycle Cost Savings						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Floor Panel-Small						
Mean	119.8	0.0	37.7	67.9	-42.3	-1506.8
Median	102.7	0.0	14.1	54.5	-60.6	-1522.0
P(0.05)	40.4	0.0	-69.1	3.8	-121.5	-1605.6
Q(0.25)	73.5	0.0	-24.9	26.5	-91.9	-1560.3
Q3(0.75)	177.4	0.0	115.3	109.4	10.7	-1446.7
P(0.95)	1201.1	0.0	1467.7	1102.4	1328.4	96.5
Low Temperature Floor Panel-Medium						
Mean	65.6	0.0	-4.5	30.3	-64.9	-1652.9
Median	53.9	0.0	-22.4	20.8	-79.0	-1663.9
P(0.05)	11.1	0.0	-85.5	-13.8	-124.8	-1738.5
Q(0.25)	33.9	0.0	-52.0	1.9	-102.4	-1696.4
Q3(0.75)	105.0	0.0	54.2	59.0	-24.6	-1600.7
P(0.95)	808.1	0.0	1075.7	740.4	970.4	-318.7
Low Temperature Floor Panel-Large						
Mean	43.7	0.0	-21.7	15.0	-74.3	-1710.2
Median	34.0	0.0	-37.4	7.3	-86.8	-1720.0
P(0.05)	-0.8	0.0	-92.5	-21.0	-126.5	-1790.5
Q(0.25)	17.7	0.0	-63.1	-8.1	-107.1	-1750.3
Q3(0.75)	75.8	0.0	29.3	38.7	-39.1	-1661.4
P(0.95)	650.8	0.0	918.6	595.5	827.0	-483.8

Table 8G.1.4 Life-Cycle Cost Savings Distributions for Standard, Medium Temperature WICF Display Doors in 2012$

Life-Cycle Cost Savings						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Display Door-Small						
Mean	186.2	176.7	186.2	176.7	172.2	-2061.5
Median	170.3	160.1	170.3	160.1	155.4	-2168.1
P(0.05)	88.0	89.0	88.0	89.0	86.6	-2310.3
Q(0.25)	134.1	127.2	134.1	127.2	123.4	-2242.6
Q3(0.75)	252.4	236.6	252.4	236.6	232.0	-1749.8
P(0.95)	1369.5	1364.3	1369.5	1364.3	1364.3	-437.6
Medium Temperature Display Door-Medium						
Mean	238.2	227.1	238.2	227.1	221.9	-2657.2
Median	219.5	207.6	219.5	207.6	202.0	-2796.5
P(0.05)	124.4	125.9	124.4	125.9	123.2	-2963.7
Q(0.25)	177.7	169.7	177.7	169.7	165.5	-2883.7
Q3(0.75)	315.0	296.9	315.0	296.9	291.0	-2256.2
P(0.95)	1614.3	1608.5	1614.3	1608.5	1608.5	-713.0
Medium Temperature Display Door-Large						
Mean	333.6	319.1	333.6	319.1	312.2	-3473.9
Median	308.3	292.7	308.3	292.7	286.3	-3656.0
P(0.05)	183.9	185.9	183.9	185.9	182.6	-3873.9
Q(0.25)	253.9	243.4	253.9	243.4	237.3	-3769.5
Q3(0.75)	435.3	411.2	435.3	411.2	403.2	-2949.8
P(0.95)	2151.7	2145.1	2151.7	2145.1	2145.1	-930.6

Table 8G.1.5 Life-Cycle Cost Savings Distributions for Standard, Low Temperature WICF Display Doors in 2012$

Life-Cycle Cost Savings						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Display Door-Small						
Mean	215.5	198.6	-12.9	198.6	196.2	-1310.0
Median	203.2	187.8	-24.9	187.8	185.1	-1364.0
P(0.05)	159.6	147.0	-89.9	147.0	145.6	-1585.9
Q(0.25)	182.4	168.2	-55.0	168.2	166.1	-1485.9
Q3(0.75)	255.9	234.9	38.1	234.9	232.0	-1100.9
P(0.95)	927.6	894.0	867.9	894.0	891.8	1272.9
Low Temperature Display Door-Medium						
Mean	215.7	198.7	-12.9	198.7	196.2	-1722.3
Median	203.3	187.7	-24.9	187.7	185.0	-1796.1
P(0.05)	159.9	147.3	-89.7	147.3	146.0	-2063.5
Q(0.25)	182.6	168.3	-54.9	168.3	166.1	-1942.8
Q3(0.75)	255.9	234.8	38.2	234.8	231.8	-1453.1
P(0.95)	924.1	887.0	869.9	887.0	884.8	1413.6
Low Temperature Display Door-Large						
Mean	247.9	226.5	1.6	226.5	223.4	-2272.9
Median	232.0	212.5	-31.5	212.5	209.4	-2370.7
P(0.05)	177.0	161.1	-207.1	161.1	159.4	-2721.5
Q(0.25)	205.6	187.8	-113.0	187.8	185.3	-2562.7
Q3(0.75)	299.1	272.6	142.0	272.6	268.4	-1918.3
P(0.95)	1150.0	1103.8	2387.8	1103.8	1101.0	1841.3

Table 8G.1.6 Life-Cycle Cost Savings Distributions for Standard, Medium Temperature WICF Passage Doors in 2012$

Life-Cycle Cost Savings						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Passage Door-Small						
Mean	1.8	0.0	1.8	0.2	-0.4	-766.5
Median	1.3	0.0	1.3	-0.2	-0.8	-767.4
P(0.05)	-1.4	0.0	-1.4	-2.7	-2.7	-791.4
Q(0.25)	0.1	0.0	0.1	-1.6	-1.7	-777.1
Q3(0.75)	3.8	0.0	3.8	2.0	1.1	-750.7
P(0.95)	44.0	0.0	44.0	36.2	36.2	-489.3
Medium Temperature Passage Door-Medium						
Mean	2.1	0.0	2.1	0.3	-0.3	-862.4
Median	1.5	0.0	1.5	-0.2	-0.8	-863.3
P(0.05)	-1.5	0.0	-1.5	-2.9	-2.9	-889.6
Q(0.25)	0.2	0.0	0.2	-1.7	-1.9	-873.8
Q3(0.75)	4.4	0.0	4.4	2.3	1.4	-845.4
P(0.95)	49.7	0.0	49.7	40.9	40.9	-570.2
Medium Temperature Passage Door-Large						
Mean	2.5	0.0	2.5	0.5	-0.2	-1044.7
Median	1.9	0.0	1.9	-0.1	-0.8	-1045.6
P(0.05)	-1.7	0.0	-1.7	-3.3	-3.3	-1076.0
Q(0.25)	0.3	0.0	0.3	-1.9	-2.1	-1057.6
Q3(0.75)	5.2	0.0	5.2	2.8	1.7	-1025.3
P(0.95)	58.2	0.0	58.2	47.9	47.9	-715.0

Table 8G.1.7 Life-Cycle Cost Savings Distributions for Standard, Low Temperature WICF Passage Doors in 2012$

Life-Cycle Cost Savings						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Passage Door-Small						
Mean	68.8	0.0	-18.0	47.4	-51.6	-558.1
Median	47.9	0.0	-44.7	26.7	-76.9	-582.2
P(0.05)	-9.3	0.0	-121.7	-25.7	-145.7	-667.1
Q(0.25)	20.6	0.0	-81.7	1.4	-108.8	-622.7
Q3(0.75)	127.5	0.0	65.3	112.8	37.5	-463.1
P(0.95)	946.5	0.0	1069.5	896.9	1002.8	612.5
Low Temperature Passage Door-Medium						
Mean	73.1	0.0	-16.0	51.3	-51.5	-645.0
Median	51.1	0.0	-43.5	29.4	-78.1	-669.9
P(0.05)	-7.2	0.0	-125.5	-24.4	-150.4	-761.5
Q(0.25)	23.2	0.0	-83.0	3.4	-111.7	-713.9
Q3(0.75)	133.9	0.0	72.2	119.3	42.3	-543.6
P(0.95)	968.6	0.0	1112.5	917.3	1041.7	586.4
Low Temperature Passage Door-Large						
Mean	79.5	0.0	-13.5	57.2	-52.4	-810.9
Median	56.3	0.0	-43.0	33.6	-80.2	-836.9
P(0.05)	-4.5	0.0	-132.3	-22.7	-159.2	-940.7
Q(0.25)	26.9	0.0	-86.2	6.6	-117.5	-886.9
Q3(0.75)	143.0	0.0	83.0	128.7	51.2	-698.8
P(0.95)	1001.6	0.0	1185.0	947.7	1107.2	529.8

Table 8G.1.8 Life-Cycle Cost Savings Distributions for Standard, Medium Temperature WICF Freight Doors in 2012$

Life-Cycle Cost Savings						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Freight Door-Small						
Mean	3.0	0.0	3.0	0.6	-0.2	-1255.1
Median	2.3	0.0	2.3	0.0	-0.9	-1256.0
P(0.05)	-1.8	0.0	-1.8	-3.7	-3.7	-1290.9
Q(0.25)	0.5	0.0	0.5	-2.0	-2.3	-1269.9
Q3(0.75)	6.1	0.0	6.1	3.3	2.0	-1232.9
P(0.95)	66.6	0.0	66.6	54.8	54.8	-884.4
Medium Temperature Freight Door-Medium						
Mean	3.7	0.0	3.7	0.7	-0.3	-1058.5
Median	2.7	0.0	2.7	-0.1	-1.1	-1060.1
P(0.05)	-2.1	0.0	-2.1	-4.7	-4.7	-1095.4
Q(0.25)	0.5	0.0	0.5	-2.6	-2.9	-1074.2
Q3(0.75)	7.4	0.0	7.4	4.1	2.5	-1035.6
P(0.95)	82.1	0.0	82.1	67.6	67.6	-641.9
Medium Temperature Freight Door-Large						
Mean	4.5	0.0	4.5	1.0	-0.3	-1098.5
Median	3.4	0.0	3.4	0.0	-1.2	-1100.5
P(0.05)	-2.4	0.0	-2.4	-5.5	-5.5	-1138.2
Q(0.25)	0.7	0.0	0.7	-3.0	-3.3	-1115.7
Q3(0.75)	9.0	0.0	9.0	4.9	3.1	-1073.7
P(0.95)	98.4	0.0	98.4	81.0	81.0	-635.4

Table 8G.1.9 Life-Cycle Cost Savings Distributions for Standard, Low Temperature WICF Freight Doors in 2012$

Life-Cycle Cost Savings						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Freight Door-Small						
Mean	85.9	0.0	-19.9	71.7	-62.4	-1001.4
Median	61.1	0.0	-51.1	54.7	-91.6	-1028.2
P(0.05)	-2.2	0.0	-148.2	15.4	-177.8	-1146.0
Q(0.25)	30.4	0.0	-98.8	36.6	-133.1	-1084.6
Q3(0.75)	152.6	0.0	85.0	112.1	50.0	-878.2
P(0.95)	1033.9	0.0	1253.1	734.5	1167.9	458.1
Low Temperature Freight Door-Medium						
Mean	207.6	0.0	70.4	191.5	-2.5	-1523.4
Median	166.9	0.0	16.5	163.1	-53.9	-1572.2
P(0.05)	56.8	0.0	-137.0	94.9	-188.5	-1750.6
Q(0.25)	114.5	0.0	-56.8	131.2	-116.3	-1654.0
Q3(0.75)	321.6	0.0	235.7	267.4	172.4	-1334.0
P(0.95)	1900.6	0.0	2299.0	1364.2	2156.2	1028.3
Low Temperature Freight Door-Large						
Mean	219.4	0.0	68.3	199.9	-12.3	-1916.5
Median	176.3	0.0	10.9	169.6	-66.8	-1967.3
P(0.05)	62.7	0.0	-156.9	98.3	-213.2	-2168.4
Q(0.25)	121.5	0.0	-69.9	136.4	-134.8	-2060.5
Q3(0.75)	338.1	0.0	248.8	277.4	177.7	-1708.8
P(0.95)	1964.3	0.0	2450.7	1422.5	2292.8	883.1

Table 8G.1.10 Payback Period Distributions for Standard, Medium Temperature WICF Panels

Payback Period (years)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Standard Panel-Small						
Mean	4.1	0.0	6.2	5.0	8.0	111.3
Median	3.9	0.0	5.9	4.6	7.8	108.3
P(0.05)	2.5	0.0	3.8	2.9	5.0	69.2
Q(0.25)	3.2	0.0	4.9	4.0	6.6	91.9
Q3(0.75)	5.0	0.0	7.7	6.6	10.0	140.0
P(0.95)	10.1	0.0	15.5	10.1	15.5	216.3
Medium Temperature Standard Panel-Medium						
Mean	4.0	0.0	7.2	4.8	9.3	156.3
Median	3.8	0.0	6.9	4.5	9.1	152.4
P(0.05)	2.4	0.0	4.4	2.8	5.8	97.0
Q(0.25)	3.2	0.0	5.8	3.9	7.7	129.2
Q3(0.75)	4.9	0.0	8.9	6.4	11.7	196.9
P(0.95)	9.9	0.0	18.0	9.8	18.0	304.0
Medium Temperature Standard Panel-Large						
Mean	3.9	0.0	7.7	4.8	9.9	170.6
Median	3.8	0.0	7.4	4.5	9.7	166.4
P(0.05)	2.4	0.0	4.7	2.8	6.2	105.9
Q(0.25)	3.2	0.0	6.1	3.9	8.2	141.0
Q3(0.75)	4.9	0.0	9.5	6.4	12.5	214.9
P(0.95)	9.9	0.0	19.2	9.8	19.2	331.8

Table 8G.1.11 Payback Period Distributions for Standard, Low Temperature WICF Panels

Payback Period (years)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Standard Panel-Small						
Mean	2.4	0.0	5.4	3.1	7.1	31.7
Median	2.4	0.0	5.3	3.0	7.1	31.4
P(0.05)	1.6	0.0	3.5	2.0	4.6	20.6
Q(0.25)	2.0	0.0	4.3	2.5	5.9	26.2
Q3(0.75)	3.0	0.0	6.5	3.9	8.8	39.3
P(0.95)	5.3	0.0	11.7	5.9	13.8	61.6
Low Temperature Standard Panel-Medium						
Mean	3.0	0.0	7.8	3.8	10.4	45.1
Median	2.9	0.0	7.7	3.7	10.4	44.8
P(0.05)	1.9	0.0	5.1	2.4	6.7	29.3
Q(0.25)	2.4	0.0	6.3	3.1	8.6	37.2
Q3(0.75)	3.6	0.0	9.5	4.7	12.9	55.9
P(0.95)	6.5	0.0	17.2	7.2	20.3	87.7
Low Temperature Standard Panel-Large						
Mean	3.2	0.0	8.8	4.1	11.6	49.4
Median	3.1	0.0	8.7	4.0	11.6	49.1
P(0.05)	2.1	0.0	5.7	2.6	7.5	32.1
Q(0.25)	2.6	0.0	7.1	3.3	9.6	40.7
Q3(0.75)	3.9	0.0	10.7	5.1	14.5	61.2
P(0.95)	7.0	0.0	19.3	7.7	22.7	96.1

Table 8G.1.12 Payback Period Distributions for Standard, Low Temperature WICF Floor Panels

Payback Period (years)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Floor Panel-Small						
Mean	3.0	0.0	5.2	3.8	6.9	38.2
Median	2.9	0.0	5.2	3.7	6.9	38.0
P(0.05)	2.0	0.0	3.4	2.4	4.5	24.8
Q(0.25)	2.4	0.0	4.2	3.1	5.7	31.5
Q3(0.75)	3.6	0.0	6.4	4.8	8.6	47.4
P(0.95)	6.5	0.0	11.5	7.2	13.5	74.4
Low Temperature Floor Panel-Medium						
Mean	3.6	0.0	6.0	4.5	8.0	49.0
Median	3.5	0.0	6.0	4.5	8.0	48.7
P(0.05)	2.3	0.0	3.9	2.9	5.2	31.8
Q(0.25)	2.9	0.0	4.9	3.7	6.6	40.4
Q3(0.75)	4.3	0.0	7.4	5.7	10.0	60.7
P(0.95)	7.8	0.0	13.3	8.7	15.6	95.3
Low Temperature Floor Panel-Large						
Mean	4.0	0.0	6.5	5.1	8.7	54.7
Median	3.9	0.0	6.5	5.0	8.7	54.3
P(0.05)	2.6	0.0	4.3	3.3	5.6	35.5
Q(0.25)	3.2	0.0	5.3	4.1	7.2	45.1
Q3(0.75)	4.9	0.0	8.0	6.4	10.8	67.8
P(0.95)	8.7	0.0	14.4	9.7	17.0	106.4

Table 8G.1.13 Payback Period Distributions for Standard, Medium Temperature WICF Display Doors

Payback Period (years)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Display Door-Small						
Mean	2.5	2.6	2.5	2.6	2.6	35.1
Median	2.4	2.5	2.4	2.5	2.6	34.7
P(0.05)	1.7	1.8	1.7	1.8	1.8	24.9
Q(0.25)	2.1	2.2	2.1	2.2	2.2	30.1
Q3(0.75)	3.0	3.1	3.0	3.1	3.1	42.1
P(0.95)	5.0	4.8	5.0	4.8	4.8	65.5
Medium Temperature Display Door-Medium						
Mean	2.2	2.2	2.2	2.2	2.2	38.2
Median	2.1	2.2	2.1	2.2	2.2	37.8
P(0.05)	1.5	1.6	1.5	1.6	1.6	27.1
Q(0.25)	1.8	1.9	1.8	1.9	1.9	32.8
Q3(0.75)	2.6	2.7	2.6	2.7	2.7	45.9
P(0.95)	4.3	4.2	4.3	4.2	4.2	71.6
Medium Temperature Display Door-Large						
Mean	1.9	2.0	1.9	2.0	2.0	38.5
Median	1.9	1.9	1.9	1.9	2.0	38.0
P(0.05)	1.3	1.4	1.3	1.4	1.4	27.2
Q(0.25)	1.6	1.7	1.6	1.7	1.7	33.0
Q3(0.75)	2.3	2.4	2.3	2.4	2.4	46.2
P(0.95)	3.9	3.7	3.9	3.7	3.7	72.2

Table 8G.1.14 Payback Period Distributions for Standard, Low Temperature WICF Display Doors

Payback Period (years)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Display Door-Small						
Mean	N/A	N/A	N/A	N/A	N/A	N/A
Median	N/A	N/A	N/A	N/A	N/A	N/A
P(0.05)	N/A	N/A	N/A	N/A	N/A	N/A
Q(0.25)	N/A	N/A	N/A	N/A	N/A	N/A
Q3(0.75)	N/A	N/A	N/A	N/A	N/A	N/A
P(0.95)	N/A	N/A	N/A	N/A	N/A	N/A
Low Temperature Display Door-Medium						
Mean	N/A	N/A	N/A	N/A	N/A	N/A
Median	N/A	N/A	N/A	N/A	N/A	N/A
P(0.05)	N/A	N/A	N/A	N/A	N/A	N/A
Q(0.25)	N/A	N/A	N/A	N/A	N/A	N/A
Q3(0.75)	N/A	N/A	N/A	N/A	N/A	N/A
P(0.95)	N/A	N/A	N/A	N/A	N/A	N/A
Low Temperature Display Door-Large						
Mean	N/A	N/A	N/A	N/A	N/A	N/A
Median	N/A	N/A	N/A	N/A	N/A	N/A
P(0.05)	N/A	N/A	N/A	N/A	N/A	N/A
Q(0.25)	N/A	N/A	N/A	N/A	N/A	N/A
Q3(0.75)	N/A	N/A	N/A	N/A	N/A	N/A
P(0.95)	N/A	N/A	N/A	N/A	N/A	N/A

Table 8G.1.15 Payback Period Distributions for Standard, Medium Temperature WICF Passage Doors

Payback Period (years)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Passage Door-Small						
Mean	4.8	0.0	4.8	5.9	6.3	73.3
Median	4.6	0.0	4.6	5.6	6.1	72.9
P(0.05)	3.1	0.0	3.1	3.6	4.1	52.2
Q(0.25)	3.9	0.0	3.9	4.7	5.2	63.1
Q3(0.75)	5.8	0.0	5.8	7.8	7.8	87.3
P(0.95)	12.1	0.0	12.1	12.1	12.1	134.1
Medium Temperature Passage Door-Medium						
Mean	4.7	0.0	4.7	5.9	6.2	78.2
Median	4.5	0.0	4.5	5.5	6.0	77.8
P(0.05)	3.1	0.0	3.1	3.5	4.0	55.6
Q(0.25)	3.9	0.0	3.9	4.6	5.2	67.3
Q3(0.75)	5.8	0.0	5.8	7.7	7.7	93.4
P(0.95)	12.0	0.0	12.0	11.9	12.0	143.5
Medium Temperature Passage Door-Large						
Mean	4.7	0.0	4.7	5.8	6.1	86.8
Median	4.5	0.0	4.5	5.4	6.0	86.3
P(0.05)	3.0	0.0	3.0	3.5	3.9	61.5
Q(0.25)	3.8	0.0	3.8	4.6	5.1	74.5
Q3(0.75)	5.7	0.0	5.7	7.6	7.6	104.0
P(0.95)	11.9	0.0	11.9	11.8	11.9	160.1

Table 8G.1.16 Payback Period Distributions for Standard, Low Temperature WICF Passage Doors

Payback Period (years)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Passage Door-Small						
Mean	4.3	0.0	6.2	4.7	7.0	16.9
Median	4.3	0.0	6.3	4.8	7.1	16.8
P(0.05)	2.8	0.0	3.9	3.0	4.4	10.4
Q(0.25)	3.7	0.0	5.3	4.1	6.0	14.1
Q3(0.75)	5.2	0.0	7.8	5.7	8.7	21.1
P(0.95)	7.6	0.0	11.1	8.8	14.2	38.9
Low Temperature Passage Door-Medium						
Mean	4.2	0.0	6.2	4.6	7.0	18.3
Median	4.3	0.0	6.2	4.7	7.0	18.1
P(0.05)	2.8	0.0	3.9	3.0	4.3	11.1
Q(0.25)	3.6	0.0	5.2	4.0	6.0	15.0
Q3(0.75)	5.2	0.0	7.7	5.7	8.7	22.9
P(0.95)	7.5	0.0	11.4	8.8	15.3	45.8
Low Temperature Passage Door-Large						
Mean	4.1	0.0	6.2	4.5	7.0	20.7
Median	4.2	0.0	6.2	4.6	7.0	20.2
P(0.05)	2.7	0.0	3.8	2.9	4.2	12.2
Q(0.25)	3.5	0.0	5.2	3.9	5.9	16.7
Q3(0.75)	5.1	0.0	7.7	5.6	8.7	26.1
P(0.95)	7.5	0.0	12.1	8.7	17.3	59.5

Table 8G.1.17 Payback Period Distributions for Standard, Medium Temperature WICF Freight Doors

Payback Period (years)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Medium Temperature Freight Door-Small						
Mean	4.7	0.0	4.7	5.7	6.1	95.8
Median	4.4	0.0	4.4	5.4	5.9	94.9
P(0.05)	3.0	0.0	3.0	3.4	3.9	67.5
Q(0.25)	3.8	0.0	3.8	4.6	5.1	82.0
Q3(0.75)	5.7	0.0	5.7	7.5	7.5	114.9
P(0.95)	11.8	0.0	11.8	11.7	11.8	177.3
Medium Temperature Freight Door-Medium						
Mean	4.7	0.0	4.7	5.8	6.1	70.8
Median	4.5	0.0	4.5	5.4	5.9	70.5
P(0.05)	3.0	0.0	3.0	3.5	3.9	49.6
Q(0.25)	3.8	0.0	3.8	4.6	5.1	60.8
Q3(0.75)	5.7	0.0	5.7	7.6	7.6	85.0
P(0.95)	11.8	0.0	11.8	11.7	11.8	128.2
Medium Temperature Freight Door-Large						
Mean	4.6	0.0	4.6	5.7	6.1	67.8
Median	4.4	0.0	4.4	5.4	5.9	67.4
P(0.05)	3.0	0.0	3.0	3.4	3.9	47.2
Q(0.25)	3.8	0.0	3.8	4.5	5.1	58.0
Q3(0.75)	5.6	0.0	5.6	7.5	7.6	81.6
P(0.95)	11.7	0.0	11.7	11.6	11.7	123.3

Table 8G.1.18 Payback Period Distributions for Standard, Low Temperature WICF Freight Doors

Payback Period (years)						
Statistic	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**	**TSL6**
Low Temperature Freight Door-Small						
Mean	4.1	0.0	6.3	3.5	7.2	23.3
Median	4.1	0.0	6.3	3.5	7.1	22.5
P(0.05)	2.6	0.0	3.8	2.1	4.3	13.5
Q(0.25)	3.5	0.0	5.2	3.0	6.0	18.4
Q3(0.75)	5.0	0.0	7.9	4.2	9.0	29.3
P(0.95)	7.4	0.0	13.1	7.5	20.1	76.2
Low Temperature Freight Door-Medium						
Mean	3.4	0.0	5.2	2.4	5.9	20.3
Median	3.4	0.0	5.3	2.4	6.0	20.3
P(0.05)	2.2	0.0	3.3	1.5	3.7	12.6
Q(0.25)	2.9	0.0	4.4	2.1	5.1	17.0
Q3(0.75)	4.2	0.0	6.5	2.9	7.3	25.2
P(0.95)	6.0	0.0	9.4	4.7	11.7	43.0
Low Temperature Freight Door-Large						
Mean	3.3	0.0	5.3	2.3	6.1	22.9
Median	3.4	0.0	5.3	2.4	6.1	22.8
P(0.05)	2.2	0.0	3.3	1.5	3.8	14.1
Q(0.25)	2.9	0.0	4.5	2.1	5.2	19.0
Q3(0.75)	4.1	0.0	6.6	2.8	7.5	28.6
P(0.95)	6.0	0.0	9.7	4.8	12.9	52.3

APPENDIX 9A. USER INSTRUCTIONS FOR SHIPMENTS

TABLE OF CONTENTS

APPENDIX 9A. USER INSTRUCTIONS FOR SHIPMENTS

9A.1 INTRODUCTION

The results obtained for the shipments analysis can be examined and reproduced using the Microsoft Excel spreadsheets available on the U.S. Department of Energy (DOE) Building Technologies website at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/26. The spreadsheets that are posted on the DOE website represent the latest versions and have been tested with both Microsoft Excel 2003 and Microsoft Excel 2007. To execute the spreadsheets requires Microsoft Excel 2003 or a later version.

Given the component level approach DOE is considering in the current analysis, there are three spreadsheets for the shipments analysis, one for each of the complete walk-in cooler and freezer (WICF) units, refrigeration systems, and envelope components. The output from the WICF complete units shipment model forms the basis of the shipment models for the refrigeration systems and envelope components. While the envelope component shipment model included the shipments for display and non-display doors, it did not separately model shipments of the panels because these could be directly calculated from the results of the shipment model for complete WICF units. Because of this relationship among the shipments models, DOE is only submitting the complete WICF unit shipments model, which is the focus of this appendix.

The shipment model results are inputs for the national impact analysis (NIA) spreadsheets (described in appendix 10A of this technical support document (TSD)). DOE structured both the life-cycle cost (LCC) spreadsheet (described in TSD appendix 8A) and the shipments spreadsheets so as to reduce the complexity of the NIA spreadsheet. DOE used this approach out of concern that the large number of equipment classes, and combinations of their efficiency levels in proposing trial standards levels (TSLs), would require very large amounts of calculation space for the NIA spreadsheets, and might exceed the limits of what is supported by Microsoft Excel 2003. The spreadsheet models do not need to be "run"; permutations are presented in parallel and calculated in real-time. Strictly speaking, there are essentially no instructions necessary to operate the spreadsheets. Rather, in this appendix, DOE describes the models for users who wish to examine DOE's assumptions and methods or to test alternative assumptions.

9A.2 MODEL CONVENTIONS

As noted above, because of the large number of WICF equipment classes and combinations of their efficiency levels in proposing TSLs considered in this analysis, the WICF shipment models may be structured somewhat differently than other LCC models DOE has published in the past. DOE uses several conventions throughout the spreadsheets to reduce the complexity of the models:

- Many worksheets are arranged with each row representing a particular complete WICF unit use-category.

- The models tracks how much equipment shipped before or after any energy conservation standard,
- Efficiency levels are not presented in the same way that they are in the LCC and NIA spreadsheets. Rather, all equipment that shipped before the standard is baseline equipment, and all equipment that ships afterwards is of whatever TSL is in place. Efficiency levels are not used in the complete WICF unit shipments analysis, but this information is relevant for the NIA.
- In general, logic flows from data sources and assumptions are assembled on the right-most worksheets toward outputs, which are produced on the left-most worksheets.
- This spreadsheet makes use of the Microsoft Excel named ranges feature. These ranges function like variables in mathematics or programming, rather than according to cell references. To locate a particular named range, users can press the F5 key. In many cases, the first two letters of a named range describe its function: The prefix "c_" indicates a constant, the prefix "t_" indicates a table, and the prefix "o_" indicates a cell that is used for the Microsoft Excel offset function.
- Shipments and stocks are calculated as a factor of the initial (2007) stock for use on the red "workhorse" worksheets that do the main calculations. For example, in 2016, complete WICF unit shipments for the restaurant sector amount to 17 percent of the initial stock. Many of the worksheets to the right of the highlighted worksheets are devoted to calculating those ratios for different building types, years, and equipment types. They are then used on the highlighted sheets to calculate the actual number of complete WICF units shipped, and stock in a particular year.

Given the large number of equipment classes and TSLs considered in this rulemaking, DOE also found it necessary to take various measures to contain spreadsheet size. Accordingly, in several places DOE compresses a very large but straightforward calculation into a shorter but less intuitive calculation. In every case, the less intuitive calculation is mathematically identical to the longer calculation. In most cases, the purpose of such calculations is to provide information that feeds into the NIA spreadsheet. Key examples:

- *Stock-years.* By adding up the size of the stock in each year, DOE can arrive at a single number that, when multiplied by an annual operating cost or energy use, will produce the total operating costs or energy use over the entire analysis period in a much shorter calculation than if DOE were to calculate each year separately, and then add them together.
- *Discounted shipments.* By adding up the shipments in each year and applying the same discount rate to those shipments that are used in the NIA, DOE can find a single number that takes the place of long lists of shipments by year that will later have to be discounted. For example, to find the discounted total first costs over the analysis period, the NIA model can simply multiply the discounted shipment

by a single purchase price, rather than multiplying shipments by purchase price in each year, then discounting, then adding the results together.

9A.3 INDIVIDUAL SHIPMENTS MODEL WORKSHEETS

The complete WICF unit shipments workbook consists of the following worksheets:

Shipments Summary	This sheet aggregates shipment results by complete WICF unit use-category.
Stock Summary	This sheet is identical to the Shipments Summary sheet, but aggregates stock information rather than shipments information. This is for informational purposes only.
Shipments Aggregation	This sheet gathers shipments and stock data in a useful format for aggregation in the Shipments Summary and Stock Summary tabs.
Box Shipments	This sheet is the "workhorse" of the model. The main envelope shipment calculations take place on this sheet. Most of the tabs to the right simply aggregate inputs into the appropriate format for this sheet. The left summarize key information that is useful for the National Impact Analysis (NIA) spreadsheet, including several of the highly non-intuitive calculations described above.
Stock	This sheet is laid out in the same manner as the Box Shipments worksheet, but provides the size of the stock rather than the number of shipments.
Constants etc	Constants are put on this sheet and can be manipulated by users, *e.g.*, the analysis begins in 2015, but by changing the First Year input on this tab, users can cause the model to begin in some other year. This tab contains the only user input in the model: The discount rate can be set to 7 percent on this sheet. Note that this does not affect Shipment Model results in any way; it simply alters the few outputs that the National Impacts Model uses (*e.g.*, discounted stock-years).
Small Tables	This sheet handles several miscellaneous concepts that require tables in smaller format than the 2,880 rows of the Summary sheets. Heat rates, electricity costs, and equipment lifespan are all included.
Growth Rates Summary	This sheet summarizes growth in the five examined building types in addition to tracking the type and quantity

	of replacements, across the analysis period. Please note that all values are expressed as a percent of the initial stock.
Growth	This sheets “translates” growth rates expressed as a share of initial stock into stock and shipments numbers expressed as a share of initial stock.
OldBoxOldRef Replacem.	This sheet tracks the phasing out of the old, pre-standard, stock. For each year, the share of units that are of each complete WICF unit age is tracked according to the stock accounting methods described in chapter 9 of this TSD.
NewBox Replacem.	This sheet is similar to the OldBoxOldRed Replacement sheet and calculates the shipments and stock of replacements of original units.
NewBox Growth	This sheet is similar to the OldBoxOldRed Replacement sheet and calculates the shipments and stock of growth over and above the stock of original units.
Lifetime calcs, All	This sheet is where DOE specifies the Weibull lifetime distribution functions and derives estimates of the initial age distribution of the stock, as described in TSD chapter 9.
Initial Distribution Calcs	This sheet calculates the shipments and stock of replacements of original units.
WICF Stock	This worksheet is where DOE summarizes stock share distributions for complete WICF unit use-categories and building types, as explained in TSD chapter 9.
AEO Buildings Data	This sheet contains data on building stock from the *Annual Energy Outlook*, and on milk production over time from the U.S. Agricultural Census. DOE uses this information to forecast growth rates in the WICF industry as described in TSD chapter 9.

APPENDIX 10A. USER INSTRUCTIONS FOR NATIONAL IMPACT ANALYSIS SPREADSHEETS

TABLE OF CONTENTS

APPENDIX 10A. USER INSTRUCTIONS FOR NATIONAL IMPACT ANALYSIS SPREADSHEETS

10A.1 INTRODUCTION

It is possible to examine and reproduce the detailed results of the national impact analysis (NIA) using Microsoft Excel spreadsheets available on the U.S. Department of Energy's (DOE's) website at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/26.

The spreadsheets posted on the DOE website represent the latest versions and have been tested with Microsoft Excel 2007 and 2010.

The walk-in cooler and freezer refrigeration system and component NIA spreadsheets or workbooks (used interchangeably) consist of the following worksheets:

Setup & Summary	Contains the input selections and a summary table of input LCC values (energy use, operating costs, etc). This worksheet also works as an interface between user inputs and the rest of the worksheets. This is the only worksheet a user needs to interact with directly to successfully run this model.
NIA_NPV	This worksheet calculates all NIA metrics (AEC, AOC, IC, and NPV) for the equipment class chosen by the user in the previous worksheet.
AEC	This worksheet calculates the Annual Energy Consumption for all evaluated TSL options.
AOC	Functions as the AEC above, except that it calculates Annual Operating Costs.
IC	Functions as the AEC and AOC above, except that it calculates Installed Costs.
INPUT_Shipments	Contains all imported data from chapter 9 shipments model.
INPUT_LCC	Contains all imported data from chapter 8 LCC model.
TSL Summary	This tab summarizes the "TSLX_LCC Setup" series of worksheets.
Base Case_LCC Setup	This worksheet, and the worksheets named similarly, describes the efficiency levels details for all analyzed product classes.
TSL1_LCC Setup…	TSL1_LCC Setup to TSL15_LCC Setup allow the user to

	customize efficiency levels for all analyzed product classes.
Labels	This worksheet translates user settings in the Setup & Summary worksheet into model inputs.

10A.2 BASIC INSTRUCTIONS FOR NATIONAL IMPACT ANALYSIS SPREADSHEETS

Basic instructions for operating the NIA spreadsheets are as follows:

1. Once you have downloaded the NIA file from the Web, open the file using Excel. At the bottom, click on the tab for sheet “Setup & Summary.”
2. Use Excel’s “View/Zoom” commands at the top menu bar to change the size of the display to make it fit your monitor; some of these worksheets are very wide.
3. The user interacts with the spreadsheet by clicking the orange “input” cells. Follow the on screen instructions when an input cell is selected and chose from the various options presented.
4. To change inputs listed under “User Input,” select the input you wish to change by selecting the appropriate input from the input box.

APPENDIX 10B. DETAILED NATIONAL ENERGY SAVINGS

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 10B. DETAILED NATIONAL ENERGY SAVINGS

10B.1 INTRODUCTION

This appendix provides detailed national energy savings for the refrigeration systems and the components matched to refrigeration systems at different efficiency levels. The method of calculation is described in the net present value analysis (chapter 10 of this technical support document).

Table 10B.1.1 Energy Savings (Quads)for Dedicated Condensing, Medium Temperature Refrigeration Systems

Equipment Class	**DC.M.O Capacity *kBtu/hr***			**DC.M.I Capacity *kBtu/hr***	
Efficiency Level	**6**	**18**	**54**	**6**	**18**
0	0.000	0.000	0.000	0	0
1	0.022	0.269	0.065	0.000	0.000
2	0.146	0.387	0.099	0.002	0.001
3	0.175	0.178	0.197	0.003	0.002
4	0.127	0.380	0.198	0.016	0.006
5	0.130	0.531	0.296	0.018	0.008
6	0.151	0.537	0.380	0.020	0.008
7	0.153	0.578	0.499	0.022	0.008
8	0.222	0.630	0.530	0.022	0.010
9	0.248	0.690	0.570	0.023	0.010
10	0.302	0.810	0.664	0.031	0.010
11	0.305	0.853	0.762	0.031	0.010
12	0.360	0.907	0.820	0.031	0.010
13	0.386	1.023	0.830	0.031	0.010
14	0.464	1.097	0.963	0.031	0.010

Table 10B.1.2 Energy Savings (Quads) for Dedicated Condensing, Low Temperature Refrigeration Systems

Equipment Class	**DC.L.O Capacity *kBtu/hr***			**DC.L.I Capacity *kBtu/hr***	
Efficiency Level	**6**	**9**	**54**	**6**	**9**
0	0.000	0.000	0.000	0	0
1	0.017	0.023	0.030	0.001	0.000
2	0.034	0.046	0.050	0.001	0.001
3	0.132	0.125	0.065	0.001	0.001
4	0.155	0.312	0.104	0.002	0.004
5	0.172	0.343	0.125	0.003	0.004
6	0.195	0.437	0.129	0.005	0.005
7	0.199	0.461	0.131	0.005	0.005
8	0.223	0.551	0.140	0.008	0.005
9	0.277	0.580	0.142	0.008	0.006
10	0.298	0.612	0.188	0.008	0.006
11	0.323	0.614	0.189	0.008	0.009
12	0.324	0.657	0.194	0.008	0.009
13	0.353	0.699	0.194	0.008	0.009
14	0.357	0.705	0.194	0.008	0.009

Table 10B.1.3 Energy Savings (Quads) for Multiplex Refrigeration Systems

Equipment Class	**MCM Capacity *kBtu/hr***	**MC.L Capacity *kBtu/hr***
Efficiency Level	**9**	**9**
0	0.000	0.000
1	0.039	0.006
2	0.376	0.104
3	0.378	0.088
4		0.088
5		0.099

Table 10B.1.4 Energy Savings (Quads) for WICF Panels at Refrigeration Efficiency Level 8 (Max NES with NPV>0)

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0.000	0.000	0.000
1	0.218	0.253	0.031
2	0.273	0.354	0.038
3	0.350	0.422	0.048
4	0.402	0.447	0.055
5	0.421	0.619	0.069
6	0.553	0.619	0.069
7	0.553	0.619	0.069
8	0.553	0.619	0.069
9	0.553	0.619	0.069

Table 10B.1.5 Energy Savings (Quads) for WICF Panels at Refrigeration Efficiency Level 7 (Max Net Present Value)

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0.000	0.000	0.000
1	0.221	0.271	0.033
2	0.276	0.380	0.040
3	0.355	0.453	0.051
4	0.408	0.479	0.059
5	0.426	0.665	0.074
6	0.560	0.665	0.074
7	0.560	0.665	0.074
8	0.560	0.665	0.074
9	0.560	0.665	0.074

Table 10B.1.6 Energy Savings (Quads) for WICF Panels at Refrigeration Efficiency Level 6 (All Compressors)

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0.000	0.000	0.000
1	0.259	0.319	0.039
2	0.324	0.447	0.048
3	0.416	0.533	0.060
4	0.479	0.564	0.069
5	0.501	0.782	0.087
6	0.658	0.782	0.087
7	0.658	0.782	0.087
8	0.658	0.782	0.087
9	0.658	0.782	0.087

Table 10B.1.7 Energy Savings (Quads) for WICF Panels at Refrigeration Efficiency Level 5 (Max Tech)

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0.000	0.000	0.000
1	0.218	0.253	0.031
2	0.273	0.354	0.038
3	0.350	0.422	0.048
4	0.402	0.447	0.055
5	0.421	0.619	0.069
6	0.553	0.619	0.069
7	0.553	0.619	0.069
8	0.553	0.619	0.069
9	0.553	0.619	0.069

Table 10B.1.8 Energy Savings (Quads) for WICF Panels at Refrigeration Efficiency Level 4

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0.000	0.000	0.000
1	0.237	0.266	0.032
2	0.296	0.373	0.040
3	0.381	0.445	0.050
4	0.437	0.470	0.058
5	0.458	0.652	0.072
6	0.601	0.652	0.072
7	0.601	0.652	0.072
8	0.601	0.652	0.072
9	0.601	0.652	0.072

Table 10B.1.9 Energy Savings (Quads) for WICF Panels at Refrigeration Efficiency Level 3

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0.000	0.000	0.000
1	0.284	0.297	0.036
2	0.355	0.416	0.044
3	0.455	0.497	0.056
4	0.523	0.525	0.065
5	0.548	0.729	0.081
6	0.720	0.729	0.081
7	0.720	0.729	0.081
8	0.720	0.729	0.081
9	0.720	0.729	0.081

Table 10B.1.10 Energy Savings (Quads) for WICF Panels at Refrigeration Efficiency Level 2

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0.000	0.000	0.000
1	0.307	0.319	0.039
2	0.385	0.447	0.048
3	0.494	0.534	0.060
4	0.568	0.565	0.069
5	0.594	0.783	0.087
6	0.780	0.783	0.087
7	0.780	0.783	0.087
8	0.780	0.783	0.087
9	0.780	0.783	0.087

Table 10B.1.11 Energy Savings (Quads) for WICF Panels at Refrigeration Efficiency Level 1

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0.000	0.000	0.000
1	0.337	0.361	0.044
2	0.421	0.506	0.054
3	0.541	0.603	0.068
4	0.621	0.638	0.078
5	0.650	0.885	0.098
6	0.854	0.885	0.098
7	0.854	0.885	0.098
8	0.854	0.885	0.098
9	0.854	0.885	0.098

Table 10B.1.12 Energy Savings (Quads) for WICF Doors at Refrigeration Efficiency Level 8 (Max NES with NPV>0)

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0.000	0.000	0.000	0.000	0.000	0.000
1	-0.048	0.020	0.007	0.012	0.000	0.001
2	0.394	0.027	0.020	0.069	0.001	0.007
3	0.426	0.063	0.021	0.103	0.001	0.009
4	0.500	0.085	0.024	0.107	0.001	0.010
5	0.527	0.095	0.034	0.110	0.002	0.010
6	0.620	0.095	0.036	0.128	0.002	0.012
7	0.620	0.095	0.069	0.135	0.003	0.013
8	0.620	0.095	0.073	0.140	0.003	0.013
9	0.620	0.095	0.073	0.140	0.004	0.013

Table 10B.1.13 Energy Savings (Quads) for WICF Doors at Refrigeration Efficiency Level 7 (Max Net Present Value)

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0.000	0.000	0.000	0.000	0.000	0.000
1	-0.048	0.020	0.007	0.013	0.000	0.001
2	0.394	0.028	0.020	0.072	0.001	0.006
3	0.427	0.065	0.022	0.106	0.001	0.009
4	0.501	0.087	0.024	0.110	0.002	0.010
5	0.528	0.097	0.034	0.113	0.002	0.010
6	0.622	0.097	0.036	0.131	0.002	0.011
7	0.622	0.097	0.070	0.139	0.003	0.012
8	0.622	0.097	0.074	0.145	0.003	0.013
9	0.622	0.097	0.074	0.145	0.004	0.013

Table 10B.1.14 Energy Savings (Quads) for WICF Doors at Refrigeration Efficiency Level 6 (All Compressors)

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0.000	0.000	0.000	0.000	0.000	0.000
1	-0.049	0.021	0.009	0.015	0.000	0.001
2	0.405	0.029	0.022	0.077	0.001	0.007
3	0.439	0.068	0.024	0.113	0.001	0.010
4	0.515	0.091	0.027	0.119	0.002	0.011
5	0.543	0.102	0.037	0.122	0.002	0.012
6	0.640	0.102	0.039	0.141	0.002	0.013
7	0.640	0.102	0.074	0.150	0.003	0.014
8	0.640	0.102	0.079	0.156	0.003	0.015
9	0.640	0.102	0.079	0.156	0.004	0.015

Table 10B.1.15 Energy Savings (Quads) for WICF Doors at Refrigeration Efficiency Level 5 (Max Tech)

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0.000	0.000	0.000	0.000	0.000	0.000
1	-0.048	0.020	0.007	0.012	0.000	0.001
2	0.394	0.027	0.020	0.069	0.001	0.007
3	0.426	0.063	0.021	0.103	0.001	0.009
4	0.500	0.085	0.024	0.107	0.001	0.010
5	0.527	0.095	0.034	0.110	0.002	0.010
6	0.620	0.095	0.036	0.128	0.002	0.012
7	0.620	0.095	0.069	0.135	0.003	0.013
8	0.620	0.095	0.073	0.140	0.003	0.013
9	0.620	0.095	0.073	0.140	0.004	0.013

Table 10B.1.16 Energy Savings (Quads) for WICF Doors at Refrigeration Efficiency Level 4

Envelope Efficiency Level	Envelope Component Class					
	DD.M	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**
0	0.000	0.000	0.000	0.000	0.000	0.000
1	-0.048	0.020	0.008	0.013	0.000	0.001
2	0.399	0.028	0.021	0.071	0.001	0.007
3	0.432	0.064	0.023	0.105	0.001	0.009
4	0.507	0.086	0.025	0.109	0.002	0.010
5	0.535	0.096	0.036	0.113	0.002	0.011
6	0.629	0.096	0.037	0.130	0.002	0.012
7	0.629	0.096	0.071	0.138	0.003	0.013
8	0.629	0.096	0.076	0.143	0.003	0.014
9	0.629	0.096	0.076	0.143	0.004	0.014

Table 10B.1.17 Net Present Value Energy Savings (Quads) for WICF Doors at Refrigeration Efficiency Level 3

Envelope Efficiency Level	Envelope Component Class					
	DD.M	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**
0	0.000	0.000	0.000	0.000	0.000	0.000
1	-0.050	0.021	0.010	0.014	0.000	0.001
2	0.412	0.029	0.023	0.075	0.001	0.007
3	0.447	0.067	0.025	0.110	0.002	0.010
4	0.524	0.089	0.028	0.115	0.002	0.011
5	0.553	0.099	0.039	0.118	0.002	0.011
6	0.651	0.099	0.041	0.137	0.002	0.013
7	0.651	0.099	0.077	0.145	0.003	0.013
8	0.651	0.099	0.082	0.151	0.003	0.015
9	0.651	0.099	0.082	0.151	0.004	0.015

Table 10B.1.18 Net Present Value Energy Savings (Quads) for WICF Doors at Refrigeration Efficiency Level 2

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0.000	0.000	0.000	0.000	0.000	0.000
1	-0.051	0.021	0.010	0.015	0.001	0.001
2	0.419	0.029	0.024	0.077	0.001	0.007
3	0.454	0.068	0.027	0.113	0.002	0.010
4	0.533	0.091	0.030	0.119	0.002	0.011
5	0.562	0.102	0.041	0.122	0.002	0.012
6	0.662	0.102	0.043	0.141	0.002	0.013
7	0.662	0.102	0.080	0.150	0.003	0.014
8	0.662	0.102	0.085	0.156	0.004	0.015
9	0.662	0.102	0.085	0.156	0.004	0.015

Table 10B.1.19 Net Present Value Energy Savings (Quads) for WICF Doors at Refrigeration Efficiency Level 1

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0.000	0.000	0.000	0.000	0.000	0.000
1	-0.052	0.022	0.011	0.017	0.001	0.002
2	0.427	0.031	0.026	0.082	0.001	0.008
3	0.464	0.071	0.028	0.120	0.002	0.011
4	0.543	0.095	0.032	0.126	0.002	0.012
5	0.574	0.106	0.044	0.130	0.002	0.012
6	0.675	0.106	0.046	0.150	0.003	0.014
7	0.675	0.106	0.083	0.159	0.003	0.015
8	0.675	0.106	0.089	0.166	0.004	0.016
9	0.675	0.106	0.089	0.166	0.005	0.016

APPENDIX 10C. DETAILED NET PRESENT VALUE RESULTS

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 10C. DETAILED NET PRESENT VALUE RESULTS

10C.1 INTRODUCTION

This appendix provides detailed net present value (NPV) results for the refrigeration systems and the components matched to refrigeration systems at different efficiency levels. The method of calculation is described in the net present value analysis (chapter 10 of this technical support document).

Table 10C.1.1 NPV Values for Dedicated Condensing, Medium Temperature Refrigeration Systems at 7-Percent Discount Rates (values in million 2012$)

Equipment Class	**DC.M.O Capacity *kBtu/hr***			**DC.M.I Capacity *kBtu/hr***	
Efficiency Level	**6**	**18**	**54**	**6**	**18**
0	0	0	0	0	0
1	34	373	-64	0	0
2	188	605	224	2	2
3	233	337	235	4	4
4	229	787	445	25	10
5	234	1,068	456	28	13
6	264	1,079	869	29	13
7	264	1,136	1,121	34	13
8	344	1,210	1,185	34	14
9	356	1,245	1,264	34	14
10	461	1,453	1,266	39	14
11	461	1,516	1,618	39	14
12	508	1,594	1,712	39	14
13	519	1,662	1,711	39	14
14	513	1,685	1,739	39	14

Table 10C.1.2 NPV Values for Dedicated Condensing, Low Temperature Refrigeration Systems at 7-Percent Discount Rates (values in million 2012$)

Equipment Class	**DC.L.O Capacity *kBtu/hr***			**DC.L.I Capacity *kBtu/hr***	
Efficiency Level	**6**	**9**	**54**	**6**	**9**
0	0	0	0	0	0
1	33	44	70	1	1
2	64	84	115	2	1
3	182	257	148	2	2
4	226	585	233	4	5
5	256	643	279	4	6
6	357	850	287	7	8
7	347	893	291	6	8
8	366	1,062	305	7	8
9	462	1,106	305	7	8
10	494	1,155	287	7	8
11	531	1,155	287	7	12
12	530	1,140	255	7	12
13	523	1,159	255	7	12
14	513	1,145	255	7	12

Table 10C.1.3 NPV Values for Multiplex Refrigeration Systems at 7-Percent Discount Rates (values in million 2012$)

Equipment Class	**MCM Capacity *kBtu/hr***	**MC.L Capacity *kBtu/hr***
Efficiency Level	**9**	**9**
0	0	0
1	71	10
2	843	189
3	835	189
4		187
5		161

Table 10C.1.4 NPV Values for WICF Panels at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 8 (Max NES with NPV>0)

Envelope Efficiency Level	**Envelope Component Class**		
	SP.M	**SP.L**	**FP.L**
0	0	0	0
1	202	446	39
2	11	465	42
3	-472	420	35
4	-991	21	22
5	-2,446	-4,298	-578
6	-17,715	-4,298	-578
7	-17,715	-4,298	-578
8	-17,715	-4,298	-578
9	-17,715	-4,298	-578

Table 10C.1.5 NPV Values for WICF Panels at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 7 (Max NPV)

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0	0	0
1	207	485	44
2	19	520	48
3	-463	486	42
4	-980	91	30
5	-2,435	-4,202	-567
6	-17,700	-4,202	-567
7	-17,700	-4,202	-567
8	-17,700	-4,202	-567
9	-17,700	-4,202	-567

Table 10C.1.6 NPV Values for WICF Panels at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 6 (All Compressors)

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0	0	0
1	289	586	56
2	121	662	63
3	-332	655	61
4	-830	269	52
5	-2,277	-3,955	-540
6	-17,494	-3,955	-540
7	-17,494	-3,955	-540
8	-17,494	-3,955	-540
9	-17,494	-3,955	-540

Table 10C.1.7 NPV Values for WICF Panels at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 5 (Max Tech)

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0	0	0
1	202	446	39
2	11	465	42
3	-472	420	35
4	-991	21	22
5	-2,446	-4,298	-578
6	-17,715	-4,298	-578
7	-17,715	-4,298	-578
8	-17,715	-4,298	-578
9	-17,715	-4,298	-578

Table 10C.1.8 NPV Values for WICF Panels at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 4

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0	0	0
1	242	474	43
2	62	505	46
3	-408	468	40
4	-917	72	28
5	-2,369	-4,229	-570
6	-17,614	-4,229	-570
7	-17,614	-4,229	-570
8	-17,614	-4,229	-570
9	-17,614	-4,229	-570

Table 10C.1.9 NPV Values for WICF Panels at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 3

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0	0	0
1	340	540	51
2	185	597	56
3	-249	578	52
4	-735	188	42
5	-2,178	-4,067	-552
6	-17,363	-4,067	-552
7	-17,363	-4,067	-552
8	-17,363	-4,067	-552
9	-17,363	-4,067	-552

Table 10C.1.10 NPV Values for WICF Panels at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 2

Envelope Efficiency Level	Envelope Component Class		
	SP.M	SP.L	FP.L
0	0	0	0
1	391	587	56
2	249	663	63
3	-168	656	61
4	-641	271	52
5	-2,080	-3,952	-540
6	-17,234	-3,952	-540
7	-17,234	-3,952	-540
8	-17,234	-3,952	-540
9	-17,234	-3,952	-540

Table 10C.1.11 NPV Values for WICF Panels at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 1

Envelope Efficiency Level	Envelope Component Class		
	SP.M	**SP.L**	**FP.L**
0	0	0	0
1	453	675	67
2	326	787	76
3	-68	804	78
4	-527	427	71
5	-1,960	-3,736	-516
6	-17,077	-3,736	-516
7	-17,077	-3,736	-516
8	-17,077	-3,736	-516
9	-17,077	-3,736	-516

Table 10C.1.12 NPV Values for WICF Doors at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 8 (Max NES with NPV>0)

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0	0	0	0	0	0
1	91	50	1	21	0	2
2	543	-5	-60	79	-3	8
3	-392	-41	-77	81	-4	8
4	-1,334	-109	-113	74	-7	7
5	-3,296	-395	-271	63	-11	5
6	-11,200	-395	-309	6	-14	2
7	-11,200	-395	-960	-169	-28	-11
8	-11,200	-395	-1,764	-513	-67	-59
9	-11,200	-395	-1,764	-513	-106	-59

Table 10C.1.13 NPV Values for WICF Doors at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 7 (Max NPV)

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0	0	0	0	0	0
1	91	51	1	23	0	2
2	545	-3	-60	85	-3	9
3	-390	-38	-77	88	-4	9
4	-1,331	-105	-113	81	-7	8
5	-3,293	-390	-270	71	-11	6
6	-11,197	-390	-308	15	-14	3
7	-11,197	-390	-959	-159	-28	-11
8	-11,197	-390	-1,763	-503	-67	-58
9	-11,197	-390	-1,763	-503	-106	-58

Table 10C.1.14 NPV Values for WICF Doors at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 6 (All Compressors)

Envelope Efficiency Level	Envelope Component Class					
	DD.M	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**
0	0	0	0	0	0	0
1	87	54	4	28	0	2
2	571	0	-56	98	-3	10
3	-361	-30	-72	106	-4	10
4	-1,297	-94	-107	101	-7	9
5	-3,257	-378	-263	92	-11	8
6	-11,154	-378	-300	38	-14	5
7	-11,154	-378	-948	-135	-27	-9
8	-11,154	-378	-1,751	-476	-67	-55
9	-11,154	-378	-1,751	-476	-105	-55

Table 10C.1.15 NPV Values for WICF Doors at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 5 (Max Tech)

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0	0	0	0	0	0
1	91	50	1	21	0	2
2	543	-5	-60	79	-3	8
3	-392	-41	-77	81	-4	8
4	-1,334	-109	-113	74	-7	7
5	-3,296	-395	-271	63	-11	5
6	-11,200	-395	-309	6	-14	2
7	-11,200	-395	-960	-169	-28	-11
8	-11,200	-395	-1,764	-513	-67	-59
9	-11,200	-395	-1,764	-513	-106	-59

Table 10C.1.16 NPV Values for WICF Doors at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 4

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0	0	0	0	0	0
1	89	51	3	22	0	2
2	556	-4	-58	83	-3	9
3	-378	-39	-75	86	-4	8
4	-1,317	-106	-110	79	-7	7
5	-3,278	-392	-267	69	-11	6
6	-11,179	-392	-305	12	-14	3
7	-11,179	-392	-954	-162	-28	-11
8	-11,179	-392	-1,758	-506	-67	-58
9	-11,179	-392	-1,758	-506	-106	-58

Table 10C.1.17 NPV Values for WICF Doors at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 3

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0	0	0	0	0	0
1	85	53	6	26	0	2
2	587	-2	-53	92	-3	9
3	-343	-34	-68	98	-4	9
4	-1,276	-99	-103	92	-7	9
5	-3,234	-384	-258	83	-11	7
6	-11,127	-384	-295	27	-14	4
7	-11,127	-384	-942	-146	-27	-9
8	-11,127	-384	-1,743	-488	-67	-56
9	-11,127	-384	-1,743	-488	-105	-56

Table 10C.1.18 NPV Values for WICF Doors at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 2

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0	0	0	0	0	0
1	83	54	8	28	0	2
2	603	0	-50	98	-3	10
3	-325	-30	-65	106	-4	10
4	-1,255	-94	-99	101	-6	9
5	-3,211	-378	-254	92	-11	8
6	-11,100	-378	-290	38	-13	5
7	-11,100	-378	-935	-135	-27	-9
8	-11,100	-378	-1,736	-476	-66	-55
9	-11,100	-378	-1,736	-476	-104	-55

Table 10C.1.19 NPV Values for WICF Doors at 7-Percent Discount Rates (values in million 2012$) for Refrigeration Efficiency Level 1

Envelope Efficiency Level	Envelope Component Class					
	DD.M	DD.L	PD.M	PD.L	FD.M	FD.L
0	0	0	0	0	0	0
1	81	56	11	33	0	3
2	623	3	-46	110	-3	11
3	-303	-23	-61	122	-4	11
4	-1,229	-84	-94	119	-6	11
5	-3,184	-368	-248	111	-10	10
6	-11,068	-368	-284	58	-13	7
7	-11,068	-368	-927	-113	-26	-7
8	-11,068	-368	-1,727	-453	-66	-53
9	-11,068	-368	-1,727	-453	-104	-53

APPENDIX 10D. TRIAL STANDARD LEVELS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX 10D. TRIAL STANDARD LEVELS

10D.1 INTRODUCTION

This chapter describes the U.S. Department of Energy's (DOE's) method for selecting trial standard levels (TSLs) for walk-in coolers and freezers (walk-ins or WICF). DOE develops TSLs as potential standards levels that it may consider based on different criteria. As DOE is proposing setting separate energy conservation standards for the WICF refrigeration system and envelope component classes, which include panels, display doors, and non-display doors, each TSL contains a specific efficiency level designated for each WICF refrigeration system class and for each envelope component equipment class being regulated in this rulemaking. DOE then examines the national, consumer, and manufacturer impacts for each TSL in turn to characterize the benefits and burdens of possible energy conservation standards at that TSL. As there is a strong interaction between the refrigeration and the envelope component equipment classes, DOE limited the number of TSLs considered for the notice of proposed rulemaking by excluding efficiency levels that do not exhibit significantly different economic and/or engineering characteristics at lower efficiencies.

As previously mentioned, DOE adopted a component-level approach addressing the WICF refrigeration system and the envelope components (panels, display doors, and non-display doors) separately. However, DOE analyzed the refrigeration system and envelope component parts of a walk-in together to calculate the national, consumer, and manufacturing impacts of standards, and used this combined impact data to set individual standards for the envelope components and refrigeration systems, respectively. For the component-level approach, DOE first performed separate life-cycle cost (LCC) and preliminary national impact analyses for the refrigeration system and envelope component classes. DOE used the results from the national impact analysis (NIA) and cumulative national energy savings (NES) at different TSLs of WICF refrigeration systems and envelope components to guide the selection process for TSLs combining these classes. DOE used net present value (NPV) and NES results for the separate refrigeration system and envelope component NIA spreadsheets to obtain preliminary TSLs independent of each other, and to develop TSLs for combinations of refrigeration systems and envelope components. This was achieved by analyzing refrigeration systems first—independent of the envelope components—to establish preliminary refrigeration system efficiency level options, then analyzing the envelope components combined with each refrigeration efficiency level option to establish TSLs for the envelope components. DOE then examined these combined TSLs in the final NIA and downstream impacts analyses. Details of this process are provided in subsequent sections of this chapter. Refer to the national impact analysis (chapter 10 of this technical support document (TSD)) for a description of the NES and NPV results.

The following sections describe the criteria and process DOE used to obtain preliminary TSLs for WICF refrigeration systems and envelope components independent of each other, and how DOE combined these independent results to select final TSLs. Section 10D.2 discusses the overall TSL selection process DOE chose for the WICF refrigeration system and envelope component conservation standards. Section 10D.2.1 discusses the scope of the walk-in component standards, while section 10D.2.2 discusses the interaction between the walk-in components, and sections 10D.2.3 and 10D.2.4 discuss details of the TSL selection process and summary of the process, respectively. Section 10D.3 describes the final TSLs and lists the TSL equations for each equipment class.

10D.2 TRIAL STANDARD LEVEL SELECTION METHODOLOGY

10D.2.1 Scope of the Walk-In Component Standards

DOE is proposing to set separate performance standards for the refrigeration system and for the envelope's doors and panels. Manufacturers would be required to comply with the applicable minimum performance standards. For a fully assembled WICF unit in service, the aggregate energy consumption would depend on the individual efficiency levels of both the refrigeration system and the components of the envelope. The energy conservation standards for the components being considered are expressed in terms of the annual walk-in energy factor (AWEF) for refrigeration systems, the maximum allowable U-factor expressed as a function of the ratio of edge area to core area for panels, and the maximum allowable daily energy use expressed as a function of the surface area for display doors and non-display doors.

10D.2.2 Interaction between the Walk-In Components

The refrigeration system plays a primary role in the complete walk-in unit, as it has the central function of heat removal from the interior of the envelope. The refrigeration system removes heat from the interior of the envelope and accounts for most of the walk-in's energy consumption. The envelope components are primarily passive, and reduce the transmission of heat from the exterior to the interior of the walk-in, although in the case of display doors there is also direct energy use for lighting and anti-sweat heaters. The refrigeration system and envelope interact such that they affect each other's energy performance. Consequently, the energy savings for any efficiency improvement technology for the envelope components depends on the refrigeration system's efficiency level. Thus, any potential standard level for the refrigeration system would affect the calculation of the energy that could be saved through standards for the envelope components. On the other hand, the economics of higher-efficiency refrigeration systems depend in part on the refrigeration load profile of the walk-in unit as a whole. The load profile of the whole walk-in unit summarizes the peak and average loads that the matched refrigeration system of the unit is required to provide. Because reductions in the envelope load due to improved envelope components tend to reduce the load at both peak and non-peak hours, the load profile remains similar over the 24-hour load cycle throughout the year. For a discussion on how DOE matched the refrigeration system capacities with the refrigeration load of the walk-in unit, see the energy use analysis (chapter 7 of this TSD). Though improving the envelope component efficiencies could in theory lead to downsizing of the matched refrigeration system, DOE found that it in fact had relatively little impact on the economics of different refrigeration system efficiencies or the choice of TSLs for the refrigeration system. Consequently, DOE identified a set of TSL options for the refrigeration systems independent of the efficiency levels of the envelope components.

To accurately characterize the total of national and consumer benefits and burdens for each of its proposed standard levels, DOE developed a set of TSLs. Each TSL consists of a combination of standard levels for both the refrigeration system and the set of selected envelope components that comprise a walk-in (*i.e.*, a standard for panels, a standard for non-display doors, and a standard for display doors). Given the strong impact of the WICF refrigeration system efficiency on the economics of different envelope component efficiency levels and the relatively weaker impact of the envelope component efficiency on the economics of different refrigeration system efficiencies, DOE first analyzed the refrigeration systems independent of the envelope components, then analyzed refrigeration system and envelope component combinations. The following sections describe this process.

10D.2.3 Trial Standard Level Selection Process

10D.2.3.1 Overview of the Process

DOE used the same analysis points for the engineering analysis (chapter 5 of this TSD) and LCC analysis (chapter 8 of this TSD). The common capacity value of a set of analysis points for the refrigeration system in a specific equipment class is defined as a capacity point that could span up to three corresponding analysis points—one each for three compressor technologies (hermetic, semi-hermetic, and scroll). For example, the three analysis points DC.M.I.HER.018, DC.M.I.SCR.018, and DC.M.I.SEM.018 (see chapter 5 of this TSD) from the refrigeration equipment class dedicated condensing medium temperature indoor (DC.M.I) units have a common capacity designation of 18 kBtu/hr. Consequently, DOE defined a capacity point DC.M.I.XXX.018 for which the LCC was the result of a combination of the LCC analysis results of the underlying analysis points associated with the three different compressor types. The compressor technology that had the most favorable LCC results at a given efficiency level was selected to represent the capacity point from the set of all competing compressor technology choices. The LCC analysis results for each of the refrigeration system equipment class capacity points consisted of these compressor choices from all of the underlying analysis points, and up to 14 distinct efficiency levels. The LCC savings were derived with respect to the baseline of the analysis point with lowest total installed cost. From these 14 efficiency levels, DOE selected up to seven potential refrigeration system efficiency levels to be considered in the TSL selection by performing preliminary NIA analyses for refrigeration systems. These seven levels corresponded to set intervals between the refrigeration system baseline and Max Tech energy saving potential and other economic criteria – as discussed in the next section.

DOE performed LCC analyses for each envelope component equipment class using average annual energy efficiency ratio (AEER) values for calculating the associated energy consumption (see chapter 6 of the TSD). The average AEER is calculated by weighting the AEER values corresponding to each of the seven efficiency levels of the paired refrigeration system equipment classes by the corresponding shipped capacities. DOE performed NIA analyses for each envelope component equipment class at multiple efficiency levels paired with each of the seven selected refrigeration system levels. From these results, DOE selected four efficiency levels for the envelope components for combining with the previously selected seven efficiency levels of refrigeration systems. DOE chose six composite TSLs from these combinations of the seven potential levels for the refrigeration systems and the four potential levels for the envelope components. This process accounts for the fact that, as described above, the choice of refrigeration efficiency level affects the energy savings and NPV of the envelope component levels.

10D.2.3.2 Trial Standard Level Options for the Refrigeration Systems

In selecting potential levels for the refrigeration systems, DOE reduced the number of capacity points for further analysis. First, DOE observed that higher-capacity dedicated condensing (DC) systems tended to be more efficient because of the availability of scroll compressors above a certain capacity. The implication is that different standards are warranted for different capacity DC systems, so DOE divided each DC class into two additional classes corresponding to capacity ranges. The threshold capacity corresponds to the capacity at which scroll compressors become available. (See chapter 3 for more details on the equipment classes.) Then, DOE selected one or two capacity points to represent each range. For the multiplex system equipment classes, DOE chose a single capacity point in each equipment class because DOE found that system capacity did not have a significant effect on the efficiency of the system.

In selecting the refrigeration capacity points for further analysis, DOE chose the capacities with the highest relative share of shipments in each equipment class. The selected capacities are listed in Table 10D.2.1.

Table 10D.2.1 Refrigeration Equipment Class Capacities

Equipment Class	**Analyzed Capacity *kBtu/hr***
DC.M.I, < 9,000	6
DC.M.I, ≥ 9,000	18
DC.M.O, < 9,000	6
DC.M.O, ≥ 9,000	18,54
DC.L.I, < 9,000	6
DC.L.I, ≥ 9,000	9
DC.L.O, < 9,000	6
DC.L.O, ≥ 9,000	9,54
MC.M	9
MC.L	9

DOE enumerated seven potential levels for each refrigeration system class. Each analyzed capacity point in any refrigeration system class has between 3 and 12 efficiency levels above the baseline, each corresponding to an added design option applicable, described in the engineering analysis (TSD chapter 5). DOE also analyzed three competing compressor technologies for each dedicated condensing refrigeration system class. These compressor technologies are hermetic reciprocating (HER), semi-hermetic (SEM), and scroll (SCR). From the results of the individual compressor technology LCC analysis, DOE developed LCC savings plots in which the LCC savings over the LCC cost at the lowest total installed price option were plotted against the refrigeration system efficiency metric (AWEF). The LCC savings plots for the individual compressor technologies were superimposed into a single plot, with an example shown in Figure 10D.2.1. DOE considered 14 distinct efficiency levels for each refrigeration system equipment class capacity point. At a given efficiency level, the compressor with the best LCC result was selected to represent the refrigeration system at that efficiency level. From the set of possible efficiency levels for a given class, DOE selected seven for further analysis. For analyzed refrigeration systems having less than seven engineering design options (*e.g.*, in the multiplex refrigeration system classes), the same efficiency level appeared more than once in the suite of seven efficiency levels. Five of the seven refrigeration system levels selected were based on their relative energy saving potential compared to the baseline level. The other two levels selected were based on maximizing the national net present value ("max NPV") and on achieving the maximum refrigeration system efficiency that can be met using all of the compressor types ("all compressors"). DOE decided to include an all compressors criterion for the refrigeration system partly in response to comments from interested parties that DOE's choice of compressors for higher efficiency equipment options in the preliminary analysis was inappropriate. In particular, interested parties noted that the choice of compressor could affect the potential energy savings, but compressor choice could not be a design option because not all compressor types are available at all capacities for all types of systems.

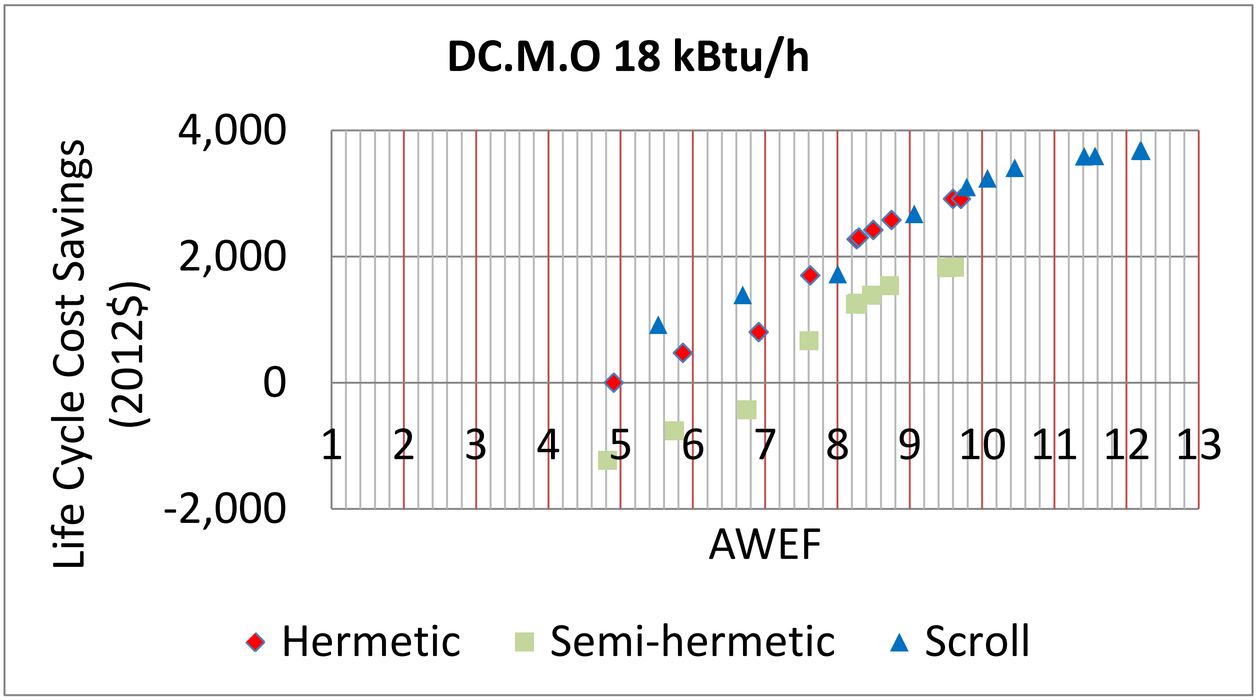


Figure 10D.2.1 Superimposed Plot Sample: Life-Cycle Costs for a 18,000 Btu/hr Medium-Temperature Refrigeration System with Alternative Compressor Technologies

After selecting the refrigeration system efficiency levels, DOE calculated weighted average efficiency levels—AEERs—across the refrigeration system equipment classes. The capacity weighted AEERs were then used to select the TSLs for the envelope components, as described in the following section.)The weighted average efficiency levels were calculated for medium- and low-temperature applications at each refrigeration efficiency level using the refrigeration system capacity points selected for further analysis (listed in Table 10D.2.1). The refrigeration system shipments model, discussed in chapter 10 of this TSD, provided the overall shipment shares for medium- and low-temperature refrigeration system shipments: 80.9 percent and 19.1 percent, respectively. For each refrigeration system efficiency level, shipment shares for each refrigeration system capacity point were applied to the AEERs, summed, and then divided by the overall medium- and low-temperature shipment shares. Capacity weighted AEERs were calculated in this manner and are provided in Table 10D.2.2.

Table 10D.2.2 TSL Capacity Weighted AEERs

Equipment Class	DC.M.I		DC.M.O			DC.L.I		DC.LO			MC.M	MC.L	**Capacity Weighted AEER**	
Capacity *kBtu/hr*	6	18	6	18	54	6	9	6	9	54	9	9	**Medium Temp.**	**Low Temp.**
Shipment Share %	0.8%	0.5%	9.6%	28.7%	25.5%	0.2%	0.2%	4.0%	8.1%	4.0%	15.4%	2.9%	-	-
Ref. TSL	**AEER**												**-**	**-**
0	4.46	5.66	5.19	6.70	7.04	2.57	2.96	2.88	3.34	4.87	9.03	5.05	7.05	3.81
1	5.30	6.03	6.79	8.96	9.84	2.93	3.25	3.71	4.45	6.40	9.58	5.17	9.04	4.78
2	5.43	6.56	7.60	9.86	11.22	3.18	3.35	4.05	5.01	6.80	9.58	6.74	9.90	5.40
3	5.72	6.80	8.33	11.04	12.24	3.18	3.45	4.47	5.54	7.17	9.58	6.85	10.74	5.81
4	5.75	6.88	8.69	12.65	13.11	3.18	3.73	4.91	6.34	8.36	15.95	6.88	12.85	6.49
5	6.41	7.31	10.04	13.49	15.09	3.18	3.75	5.32	6.78	8.52	16.05	7.18	13.97	6.83
6(A)	5.43	6.56	7.64	9.86	13.11	2.93	3.30	3.90	4.88	6.92	16.05	7.18	11.75	5.41
7(B)	6.41	7.31	8.69	13.49	15.09	3.17	3.73	4.91	6.72	7.11	15.95	6.74	13.79	6.36
8(C)	6.41	7.31	10.04	13.49	15.09	3.18	3.75	5.32	6.78	8.52	16.05	7.18	13.97	6.83

10D.2.3.3 TSL Options for the Envelope Components

After selecting the seven potential efficiency levels for each refrigeration system class, as described in section 10D.2.3.2, DOE proceeded with the LCC and NIA analyses of the envelope components (panels and doors). DOE conducted the LCC and NIA analyses on the envelope components by pairing them with each of the seven refrigeration system efficiency levels. DOE used the weighted AEER for each refrigeration efficiency level to determine the expected energy use attributed to each envelope component, using the method previously described in chapter 6. Each panel and door class has between five and nine potential efficiency levels, each corresponding to an engineering design option applicable to that class (see chapter 5 of this TSD). In addition, DOE analyzed three envelope component class sizes (small, medium, and large) where the number of engineering design options vary across the class sizes.

10D.2.3.4 Composite TSLs

In developing the TSLs, DOE selected envelope component levels for further analysis based on efficiency levels that met the following criteria: maximum NPV, maximum NES with positive NPV, and max-tech. At each refrigeration system efficiency level, DOE also considered a fourth selection criterion: maximum NES with positive NPV for display doors only, and no new standard for panels and non-display doors. DOE considered this latter criterion because it observed that due to the nature of the panel and non-display door industry, any standard could have a significant impact on small panel and door manufacturers. This is described in detail in the manufacturer impact analysis (chapter 12 of this TSD).

The interaction among the seven potential levels identified for refrigeration systems and the four criteria used to define envelope component efficiency levels results in a matrix of 28 possible composite TSLs. From this matrix, DOE chose six composite TSLs by selecting from the combinations of the seven potential levels for the refrigeration systems and the four potential levels for the envelope components. The composite TSLs and criteria used to select each one are shown in Table 10D.2.3.

Table 10D.2.3 Criteria Description for the Composite TSLs

	Refrigeration System Criteria			
Envelope Component Criteria	**All Compressors**	**Max NPV**	**Max NES with NPV>0***	**Max Tech**
Display Doors Only		**2**: All display doors only at NPV> 0		
Maximum NPV	**1**: All compressors, max NPV	**4**: Maximum NPV for both refrigeration system and components		
Maximum NES with NPV>0	**3**: All compressors, NPV>0		**5**: Max NES with NPV>0 for both Refrigeration system and Components	
Max-Tech				**6**: Max-tech for both Refrigeration system and Components

*Not counted as a separate efficiency level for the refrigeration system, as it corresponds to the Max Tech level in the current analysis

In Table 10D.2.3, the column headings identify the criteria for the TSL option for the refrigeration system and the row headings identify the criteria for the TSL option for the envelope components. The intersection of the row and the column define the respective choices for the composite TSL. The composite TSLs are numbered from 1 to 6 in order of least to most energy savings.

DOE describes each TSL, from highest to lowest energy savings, as follows. TSL 6 is the max-tech level for each equipment class for all refrigeration systems and for all envelope components. TSL 5 represents the maximum efficiency level of the refrigeration system equipment classes with a positive NPV at a 7-percent discount rate, combined with the maximum efficiency level with a positive NPV at a 7-percent discount rate for each envelope component (panel, non-display door, or display door). TSL 4 corresponds to the efficiency level with the maximum NPV for refrigeration system classes and the efficiency level with the maximum NPV for envelope component classes. TSL 3 is the highest efficiency level for refrigeration systems at which all compressor technologies can compete (“all compressor” level), combined with the maximum efficiency level with a positive NPV at a 7-percent discount rate for each envelope component. TSL 2 is the highest efficiency level for refrigeration systems at which all compressor technologies can compete, combined with the efficiency level with the maximum NPV at a 7-percent discount rate for each envelope component when the components are combined with the selected refrigeration efficiency level. TSL 1 is the efficiency level with the maximum NPV at a 7-percent discount rate for refrigeration systems, combined with the efficiency level with the highest NES with positive NPV at a 7-percent discount rate for display doors only, and does not include a new energy standard for panels and non-display doors.

10D.2.3.5 Design Options Associated with TSLs

As discussed in sections 10D.2.3.2 and 10D.2.3.3, each refrigeration system and envelope component class has a certain number of efficiency levels above the baseline, each corresponding to an added design option, described in the engineering analysis (TSD chapter 5). For each dedicated condensing refrigeration system class, DOE also analyzed three competing compressor technologies: hermetic (HER), semi-hermetic (SEM), and scroll (SCR). Although DOE is proposing a performance standard and does not prescribe the design options that manufacturers must use to meet the standard, DOE has assumed for purposes of its analysis that manufacturers would use the most cost-efficacious design options to meet the standard. Table 10D.2.4, Table 10D.2.5, Table 10D.2.6, and Table 10D.2.7 list the design options that DOE believes manufacturers would be most likely to use to meet the standard associated with each TSL for refrigeration systems, panels, display doors, and non-display doors, respectively.

DOE notes that the efficiency level required for a particular equipment class may not necessarily increase from one TSL to the next higher TSL, even though the TSLs progressively increase in their aggregate national energy saving potential. This is because the TSLs are composite TSLs that are based on the combinations of refrigeration system and envelope component efficiency levels (as shown in Table 10D.2.3) meeting certain economic or market criteria, For example, TSLs 2 and 4 require the same standard level for refrigeration system equipment classes—that is, the level that maximizes the NPV overall. Table 10D.2.4 illustrates this by showing that the refrigeration system design options associated in the analysis with TSL 4 are the same as those associated with TSL 2. However, TSLs 2 and 4 require different criteria for envelope components—TSL 2 only sets requirements for display doors, not panels or non-display doors, while TSL 4 requires the standard level for panels, display doors, and non-display doors which maximizes the NPV overall. On an aggregate basis, then, TSL 4 results in higher energy savings than TSL 2 even though the standard level for refrigeration system equipment classes is the same. Consequently, the progressive increase of efficiency levels from one TSL to the next normally observed in other rules may not be observed for all classes of WICF equipment. Another reason for this is the interaction between the refrigeration systems and envelope components, where the annual energy savings for a given component's design option depend on the efficiency level of the refrigeration system with which it is paired.

Design option abbreviations used in the tables are as follows; for a detailed discussion of each design option, please see chapter 5.

- Refrigeration Design Options:
    - ECM Evap Fan = Electronically Commutated Evaporator Fan Motor
    - PSC Cond Fan = Permanent Split Capacitor Condenser Fan Motor
    - Mod Evap Fan = Modulating Evaporator Fan Control
    - VS Evap Fan = Variable Speed Evaporator Fan Control
    - Float HP = Floating Head Pressure
    - Cond Fan Blades = Improved Condenser Fan Blades
    - Amb Subcool = Ambient Sub-cooling
    - ECM Cond Fan = Electronically Commutated Condenser Fan Motor
    - VS Cond Fan = Variable Speed Condenser Fan Control
    - Enhanced CD Coil = Enhanced Condenser Coil
    - Float HP with EV = Floating Head Pressure with Electronic Expansion Valve
    - Evap Fan Blades = Improved Evaporator Fan Blades
- Envelope Design Options:

- Hybrid VIP = Panel made up of 50 percent vacuum insulation and 50 percent foam
- Anti-sweat ctrl = Anti-sweat heater control
- Low-E = Low-emissivity coating on glass panes

Table 10D.2.4 Refrigeration System Design Options Associated with Each Composite TSL

Equipment Class	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
DC.M.I, < 9,000	HER Compressor ECM Evap Fan PSC Cond Fan	SEM Compressor Baseline PLUS: Mod Evap Fan	SEM Compressor TSL 1 PLUS: VS Evap Fan ECM Cond Fan Cond Fan Blades Evap Fan Blades Enhanced CD Coil	Same as TSL 1	Same as TSL 2	Same as TSL 4	Same as TSL 5
DC.M.I, ≥ 9,000	HER Compressor ECM Evap Fan PSC Cond Fan	SEM Compressor Baseline PLUS: VS Evap Fan Enhanced CD Coil	SCR Compressor TSL 1 PLUS: ECM Cond Fan Cond Fan Blades Evap Fan Blades	Same as TSL 1	Same as TSL 2	Same as TSL 4	Same as TSL 5
DC.M.O, < 9,000	HER Compressor ECM Evap Fan PSC Cond Fan	SEM Compressor Baseline PLUS: VS Evap Fan Float HP Cond Fan Blades ECM Cond Fan Evap Fan Blades	SEM Compressor TSL 1 PLUS: Amb Subcool VS Cond Fan	Same as TSL 1	Same as TSL 2	SEM Compressor TSL 4 PLUS: Enhanced CD Coil	Same as TSL 5
DC.M.O, ≥ 9,000	HER Compressor ECM Evap Fan PSC Cond Fan	SCR Compressor Baseline PLUS: VS Evap Fan Float HP	SCR Compressor TSL 1 PLUS: Amb Subcool ECM Cond Fan VS Cond Fan Enhanced CD Coil Evap Fan Blades Float HP with EV Cond Fan Blades	Same as TSL 1	Same as TSL 2	Same as TSL 4	Same as TSL 5
DC.L.I, < 9,000	HER Compressor ECM Evap Fan PSC Cond Fan	HER Compressor Baseline PLUS: VS Evap Fan Cond Fan Blades ECM Cond Fan Evap Fan Blades Enhanced CD Coil	SCR Compressor with same options as TSL1	Same as TSL 1	Same as TSL 2	SCR Compressor TSL 4 PLUS: Defrost Ctrl	Same as TSL 5

DC.L.I, ≥ 9,000	HER Compressor ECM Evap Fan PSC Cond Fan	SCR Compressor Baseline PLUS: Mod Evap Fan	SCR Compressor TSL 1 PLUS: VS Evap Fan Cond Fan Blades ECM Cond Fan Evap Fan Blades Enhanced CD Coil	Same as TSL 1	Same as TSL 2	SCR Compressor TSL 4 PLUS: Defrost Ctrl	Same as TSL 5
DC.L.O, < 9,000	HER Compressor ECM Evap Fan PSC Cond Fan	HER Compressor Baseline PLUS: VS Evap Fan Float HP Amb Subcool Cond Fan Blades Evap Fan Blades ECM Cond Fan VS Cond Fan Defrost Ctrl	SCR Compressor Baseline PLUS: VS Evap Fan Float HP Amb Subcool Cond Fan Blades ECM Cond Fan VS Cond Fan	Same as TSL 1	Same as TSL 2	SCR Compressor TSL 2 PLUS: Evap Fan Blades Enhanced CD Coil Defrost Control	Same as TSL 5
DC.L.O, ≥ 9,000	HER Compressor ECM Evap Fan PSC Cond Fan	SCR Compressor Baseline PLUS: Mod Evap Fan Float HP	SCR Compressor TSL 1 PLUS: VS Evap Fan Amb Subcool Cond Fan Blades ECM Cond Fan VS Cond Fan Evap Fan Blades Enhanced CD Coil Float HP with EV	Same as TSL 1	Same as TSL 2	SCR Compressor TSL 4 PLUS: Defrost Ctrl	Same as TSL 5
MC.M.I	ECM Evap Fan	Baseline PLUS: VS Evap Fan Evap Fan Blades	Baseline PLUS: VS Evap Fan	Same as TSL 1	Same as TSL 2	Same as TSL 4	Same as TSL 5
MC.L.I	ECM Evap Fan	Baseline PLUS: VS Evap Fan Defrost Ctrl Evap Fan Blades Hot Gas Defrost	Baseline PLUS: VS Evap Fan	Same as TSL 1	Same as TSL 2	Same as TSL 4	Same as TSL 5

Table 10D.2.5 Panel Design Options Associated with Each Composite TSL

Equipment Class	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
SP.M	3.5” Foam Wood Frame	3.5” Foam Softnose Frame	Same as Baseline	4” Foam Softnose Frame	Same as TSL 1	Same as TSL 3	Hybrid VIP No Framing
SP.L	4” Foam Wood Frame	5” Foam Softnose Frame	Same as Baseline	6” Foam No Framing	Same as TSL 1	Same as TSL 3	Hybrid VIP No Framing
FP.L	3.5” Foam Wood Frame	4” Foam Softnose Frame	Same as Baseline	6” Foam Softnose Frame	Same as TSL 1	Same as TSL 3	Hybrid VIP Softnose Frame

Table 10D.2.6 Display Door Design Options Associated with Each Composite TSL

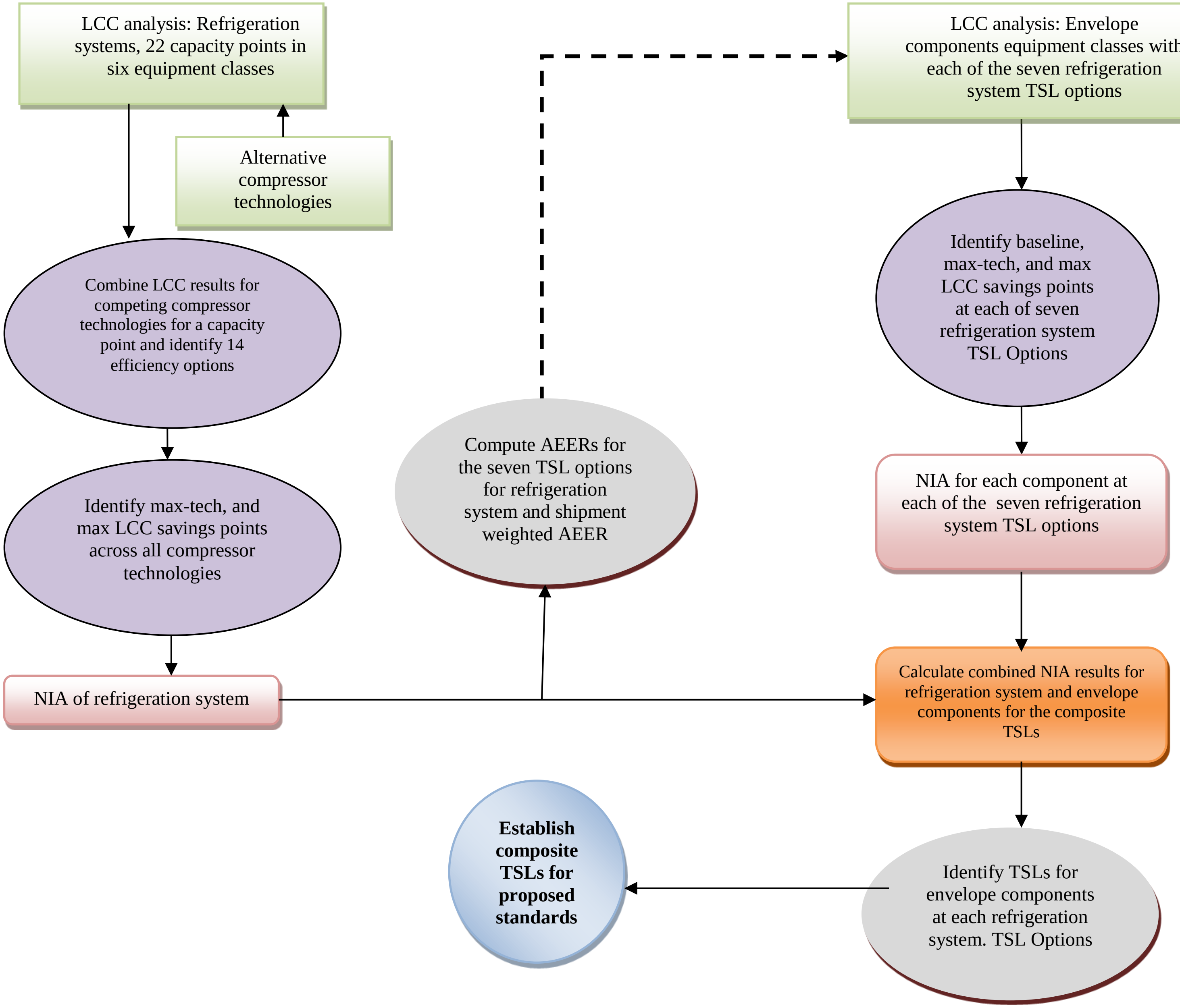
Equipment Class	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
DD.M	2 Panes Hard Coat Low-E Argon Fill T8 Lighting	2 Panes Hard Coat Low-E Argon Fill LED Lighting Anti-Sweat Ctrl	Same as TSL 1	Same as TSL 1	Same as TSL 1	Same as TSL 1	LED Lighting Lighting Sensors 2 Panes, 2 Film Layers Soft Coat Low-E (outer panes) Krypton Fill Anti-Sweat Ctrl
DD.L	3 Panes No Low-E Coat Argon Fill T8 Lighting Anti-Sweat Ctrl	3 Panes No Low-E Coat Argon Fill LED Lighting Anti-Sweat Ctrl	Same as TSL 1	TSL 1 PLUS: Lighting Sensors	Same as TSL 1	Same as TSL 1	LED Lighting Lighting Sensors 2 Panes, 2 Film Layers Soft Coat Low-E (outer panes) Krypton Fill Anti-Sweat Ctrl

Table 10D.2.7 Non-Display Door Design Options Associated with Each Composite TSL

Equipment Class	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
PD.M	3.5” Foam Wood Frame 2 Panes Hard Coat Low-E Argon Fill	3.5” Foam Softnose Frame 2 Panes Hard Coat Low-E Argon Fill	Same as Baseline	Same as TSL 1	Same as TSL 1	Same as TSL 1	Hybrid VIP Softnose Frame 2 Panes, 2 Film Layers Soft Coat Low-E (outer panes) Krypton Fill
PD.L	4” Foam Wood Frame 3 Panes Hard Coat Low-E Argon Fill	4” Foam Softnose Frame 3 Panes Soft Coat Low-E (outer panes) Krypton Fill	Same as Baseline	6” Foam Softnose Frame Anti-Sweat Ctrl 3 Panes Soft Coat Low-E (outer panes) Krypton Fill	Same as TSL 1	Same as TSL 3	Hybrid VIP Softnose Frame Anti-Sweat Ctrl 2 Panes, 2 Film Layers Soft Coat Low-E (outer panes) Krypton Fill
FD.M	3.5” Foam Wood Frame 2 Panes Hard Coat Low-E Argon Fill	3.5” Foam Softnose Frame 2 Panes Hard Coat Low-E Argon Fill	Same as Baseline	Same as TSL 1	Same as TSL 1	Same as TSL 1	Hybrid VIP Softnose Frame Anti-Sweat Ctrl 2 Panes, 2 Film Layers Soft Coat Low-E (outer panes) Krypton Fill
FD.L	4” Foam Wood Frame 3 Panes Hard Coat Low-E Argon Fill	4” Foam Softnose Frame Anti-Sweat Ctrl 3 Panes Soft Coat Low-E (outer panes) Argon Fill	Same as Baseline	6” Foam Softnose Frame Anti-Sweat Ctrl 3 Panes Soft Coat Low-E (outer panes) Krypton Fill	4” Foam Softnose Frame Anti-Sweat Ctrl 3 Panes Hard Coat Low-E Argon Fill	Same as TSL 3	Hybrid VIP Softnose Frame Anti-Sweat Ctrl 2 Panes, 2 Film Layers Soft Coat Low-E (outer panes) Krypton Fill

10D.2.4 Trial Standard Level Selection Process Summary

Figure 10D.2.2 illustrates the TSL selection process discussed in the previous section.



7 TSLs for refrigeration system:
TSL_1: Approx + 30% of the potential range (between max tech and baseline)

TSL_2: Approx + 50% of the potential range (between max tech and baseline)

TSL_3: Approx + 70% of the potential range (between max tech and baseline)

TSL_4: Approx + 85% of the potential range (between max tech and baseline)

TSL_5: Max tech

TSL_A: All compressor technology limit – max energy savings

TSL_B: Max NPV at 7% discount rate

4 TSL options for the panels and the doors:
#1 Display doors only

#2 Max NPV at 7%

#3 Max energy savings possible with NPV>0

4Max Tech

Figure 10D.2.2 TSL Selection Methodology for WICF Refrigeration System and Envelope Components

10D.3 TRIAL STANDARD LEVEL EQUATIONS

For panels and doors, DOE expresses the TSLs in equation form using a normalization metric for different size units. For panels, the normalization metric is the ratio of the edge area to the core area. The TSLs are expressed in terms of polynomial equations that establish maximum U-factor limits in the form of

$$\text{U - factor} = \text{A} \times \left(\frac{\text{Edge Area}}{\text{Core Area}} \right)^2 + \text{B} \times \left(\frac{\text{Edge Area}}{\text{Core Area}} \right) + \text{C}$$

Eq. 10D.1

The form of the equation allows the efficiency requirements to be determined for panels of any dimension within an equipment class. Coefficients A, B, and C were uniquely derived for each equipment class by plotting the U-factor versus the edge area to core area ratio and modeling the relationship as a polynomial equation. The core and edge areas for both floor and structural panels are defined in the walk-in cooler and freezer test procedure final rule. 76 FR 33631, 33632 (June 9, 2011).

For display doors and non-display doors, respectively, the normalization metric is the surface area of the door. The TSLs are expressed in terms of linear equations that establish maximum daily energy consumption (MEC) limits in the form of

$$\text{MEC} = \text{D} \times (\text{Surface Area}) + \text{E}$$ MEC=D×(SurfaceArea)+E

Eq. 10D.2

Coefficients D and E were uniquely derived for each equipment class by plotting the energy consumption at a given performance level versus the surface area of the door and determining the slope of the relationship, D, and the offset, E. (The offset is necessary because not all energy-consuming components of the door scale directly with surface area.) The surface area is defined in the walk-in cooler and freezer test procedure final rule. 76 FR at 33632.

For each class of refrigeration systems, the proposed TSLs are expressed in the form of an equation for the minimum efficiency (AWEF) that the system must meet. For the large-capacity DC classes and the MC classes, the proposed standard is expressed as a single number because DOE observed that the system efficiency did not change significantly with capacity. For small-capacity DC classes, DOE observed that achievable system efficiency increased with increasing capacity and so expressed the standard level as a linear equation. The linear equation for each TSL for each small-capacity equipment class was constructed to pass through the smallest capacity point and be continuous with the minimum AWEF for the large capacity systems at the threshold capacity of 9,000 Btu/h. Figure 10D.3.1 and Figure 10D.3.2 depict the AWEF equation lines for DC.M.O systems and DC.L.O systems, respectively.

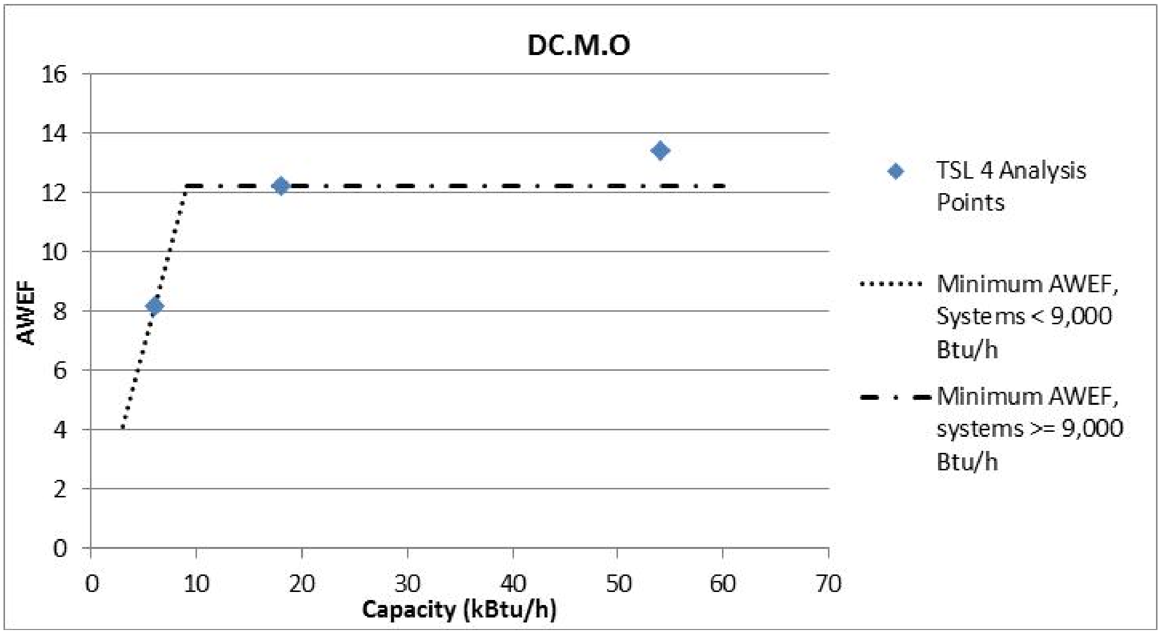


Figure 10D.3.1 AWEFs For Dedicated Condensing, Medium Temperature, Outdoor Systems at TSL 4

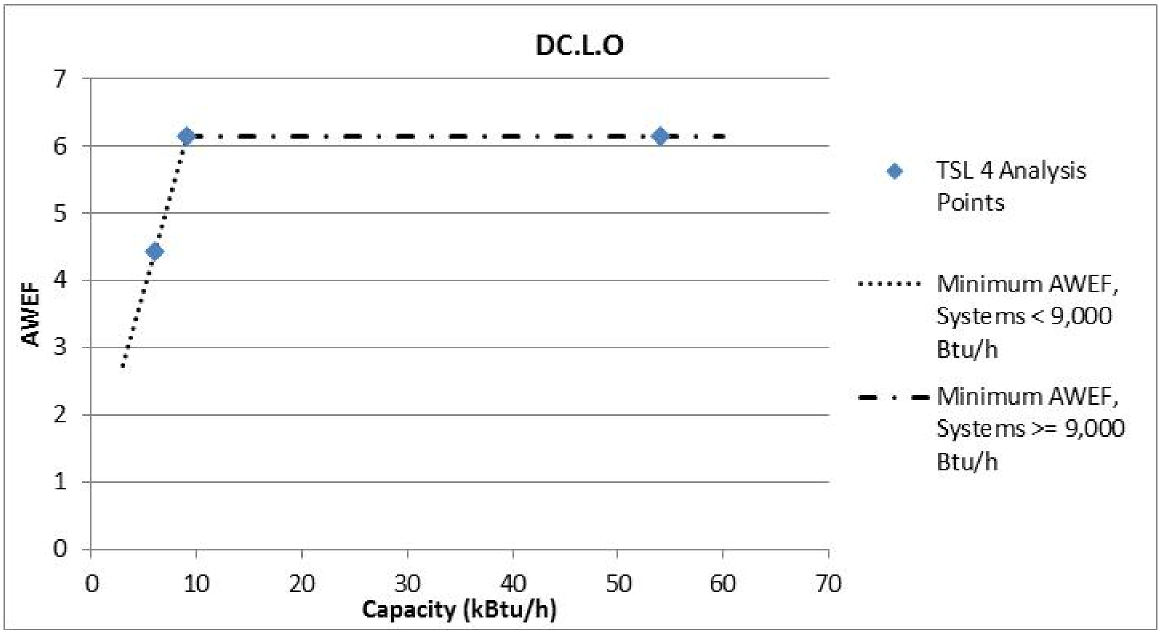


Figure 10D.3.2 AWEFs For Dedicated Condensing, Low Temperature, Outdoor Systems at TSL 4

The following tables present the equations for all TSLs under consideration. Table 10D.3.1 through Table 10D.3.6 show the standards equations for structural cooler panels, structural freezer panels, freezer floor panels, display doors, passage and freight doors, respectively. Table 10D.3.7 shows the equations for refrigeration systems. The equations and AWEFs for a particular equipment class may be the same across more than one TSL. This occurs when the criteria for two different TSLs are satisfied by the same efficiency level for a particular component. For example, for some refrigeration product classes, the max-tech level has a positive NPV; thus, the efficiency level with the maximum energy savings with positive NPV (TSL 5) is the same as the efficiency level corresponding to max-tech (TSL 6).

Table 10D.3.1 U-Factor Equations for All Structural Cooler Panel TSLs

Baseline	$-0.10\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^2+0.19\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.042$
TSL 1	$-0.012\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^2+0.024\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.041$
TSL 2	$-0.10\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^2+0.19\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.042$
TSL 3	$-0.010\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^2+0.021\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.036$
TSL 4	$-0.012\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^2+0.024\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.041$
TSL 5	$-0.010\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^2+0.021\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.036$
TSL 6	0.011

Table 10D.3.2 U-Factor Equations for All Structural Freezer Panel TSLs

Baseline	$-0.088\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.17\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.037$
TSL 1	$-0.0083\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.017\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.029$
TSL 2	$-0.088\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.17\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.037$
TSL 3	0.024
TSL 4	$-0.0083\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.017\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.029$
TSL 5	0.024
TSL 6	0.011

Table 10D.3.3 U-Factor Equations for All Freezer Floor Panel TSLs

TSL	Equations for Maximum U-Factor (Btu/h-ft^{2}-°F)
Baseline	$-0.098\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.18\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.042$
TSL 1	$-0.0091\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.018\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.033$
TSL 2	$-0.098\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.18\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.042$
TSL 3	$-0.0064\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.013\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.023$
TSL 4	$-0.0091\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.018\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.033$
TSL 5	$-0.0064\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.013\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.023$
TSL 6	$-0.021\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)^{2}+0.041\times\left(\frac{A_{\text{nf edge}}}{A_{\text{nf core}}}\right)+0.011$

Table 10D.3.4 Equations for All Display Door TSLs

TSL	**Equations for Maximum Energy Consumption (kWh/day)**	
	DD.M	DD.L
Baseline	$0.14 \times A_{dd} + 0.82$	$0.36 \times A_{dd} + 0.88$
TSL 1	$0.049 \times A_{dd} + 0.39$	$0.33 \times A_{dd} + 0.38$
TSL 2	$0.049 \times A_{dd} + 0.39$	$0.33 \times A_{dd} + 0.38$
TSL 3	$0.049 \times A_{dd} + 0.39$	$0.064 \times A_{dd} + 3.8$
TSL 4	$0.049 \times A_{dd} + 0.39$	$0.33 \times A_{dd} + 0.38$
TSL 5	$0.049 \times A_{dd} + 0.39$	$0.33 \times A_{dd} + 0.38$
TSL 6	$0.0080 \times A_{dd} + 0.29$	$0.11 \times A_{dd} + 0.32$

Table 10D.3.5 Equations for All Passage Door TSLs

TSL	**Equations for Maximum Energy Consumption (kWh/day)**	
	PD.M	PD.L
Baseline	$0.0040 \times A_{nd} + 0.24$	$0.141 \times A_{nd} + 4.81$
TSL 1	$0.0032 \times A_{nd} + 0.22$	$0.138 \times A_{nd} + 4.04$
TSL 2	$0.0040 \times A_{nd} + 0.24$	$0.141 \times A_{nd} + 4.81$
TSL 3	$0.0032 \times A_{nd} + 0.22$	$0.135 \times A_{nd} + 3.91$
TSL 4	$0.0032 \times A_{nd} + 0.22$	$0.138 \times A_{nd} + 4.04$
TSL 5	$0.0032 \times A_{nd} + 0.22$	$0.135 \times A_{nd} + 3.91$
TSL 6	$0.00093 \times A_{nd} + 0.0083$	$0.131 \times A_{nd} + 3.88$

Table 10D.3.6 Equations for All Freight Door TSLs

TSL	Equations for Maximum Energy Consumption (kWh/day)	
	FD.M	FD.L
Baseline	$0.0078 \times A_{nd} + 0.11$	$0.12 \times A_{nd} + 5.6$
TSL 1	$0.0073 \times A_{nd} + 0.082$	$0.11 \times A_{nd} + 5.3$
TSL 2	$0.0078 \times A_{nd} + 0.11$	$0.12 \times A_{nd} + 5.6$
TSL 3	$0.0073 \times A_{nd} + 0.082$	$0.10 \times A_{nd} + 5.2$
TSL 4	$0.0073 \times A_{nd} + 0.082$	$0.11 \times A_{nd} + 5.4$
TSL 5	$0.0073 \times A_{nd} + 0.082$	$0.10 \times A_{nd} + 5.2$
TSL 6	$0.00092 \times A_{nd} + 0.13$	$0.094 \times A_{nd} + 5.2$

Table 10D.3.7 AWEFs for All Refrigeration System TSLs

Equipment Class	Equations for Minimum AWEF (Btu/W-h)			
	Baseline	TSLs 1 and 3	TSLs 2 and 4	TSLs 5 and 6
DC.M.I, < 9,000	$2.47\times10^{-4}\times Q+2.30$	$4.37\times10^{-4}\times Q+2.26$	$2.63\times10^{-4}\times Q+4.53$	$2.63\times10^{-4}\times Q+4.53$
DC.M.I, ≥ 9,000	4.52	6.19	6.90	6.90
DC.M.O, < 9,000	$2.50\times10^{-4}\times Q+2.66$	$6.10\times10^{-4}\times Q+3.57$	$1.34\times10^{-3}\times Q+0.12$	$9.23\times10^{-4}\times Q+3.90$
DC.M.O, ≥ 9,000	4.91	9.06	12.21	12.21
DC.L.I, < 9,000	$1.43\times10^{-4}\times Q+1.48$	$1.10\times10^{-4}\times Q+2.16$	$1.93\times10^{-4}\times Q+1.89$	$1.93\times10^{-4}\times Q+1.93$
DC.L.I, ≥ 9,000	2.77	3.15	3.63	3.67
DC.L.O, < 9,000	$1.70\times10^{-4}\times Q+1.38$	$2.43\times10^{-4}\times Q+2.16$	$5.70\times10^{-4}\times Q+1.02$	$4.53\times10^{-4}\times Q+2.17$
DC.L.O, ≥ 9,000	2.91	4.35	6.15	6.25
MC.M	6.80	10.82	10.74	10.82
MC.L	4.66	5.91	5.53	5.91

APPENDIX 10E. NATIONAL NET PRESENT VALUE USING ALTERNATIVE PRICE FORECASTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX 10E. NATIONAL NET PRESENT VALUE USING ALTERNATIVE PRICE FORECASTS

10E.1 INTRODUCTION

The net present value (NPV) results presented in chapter 10 reflect a price trend based on an experience curve derived using historical data on shipments and refrigeration equipment producer price indices (PPI). The average annual rate of price decline in the default case for the 2017–2046 analysis period is 0.15 percent and is based on historical PPI data for refrigeration equipment between 1978–2012 as discussed in chapter 8. For the national impact analysis (NIA), the U.S. Department of Energy (DOE) analyzed two additional sensitivity cases that also use a price trend based on an exponential-in-time extrapolation of refrigeration equipment PPI data. DOE developed a high price decline case and a low price decline case in this analysis. The high price decline case is based on the upper end of the 95-percent confidence interval for an exponential fit to the inflation-adjusted PPI series in 1978–2012. The low price decline case is based on the lower end of the 95-percent confidence interval for an exponential fit to the nominal PPI series in 1978–2012. The average annual rate of price decline over the analysis period is 0.25 percent in the default price forecast and 0.59 percent in the low price forecast. In the high price forecast the average annual rate of change is an increase of 0.15 percent. Because of the nature of the exponential experience curve, greater annual price declines are found in earlier years in the analysis period and lesser annual price declines are found in the latter years in the analysis period. DOE investigated the impact of these different product price forecasts on the consumer net NPV for the considered trial standard levels (TSL) for refrigeration products.

For the NPV sensitivity, DOE considered three product price forecast sensitivity cases: (1) a high price case based on the PPI trend in 1978–2012; (2) a low price case based on the PPI trend in 1978–2012; (3) a constant real price case. Each price Forecast is expressed in terms of a price factor index time series, which is applied to the 2012 price estimate to forecast per unit prices over the 2017–2046 analysis period. Figure 10E.1.1 shows the equipment price factor indices for the default case and the three additional price decline forecasts considered in this sensitivity analysis. Table 10E.1.1 shows the price factor indices tabulated.

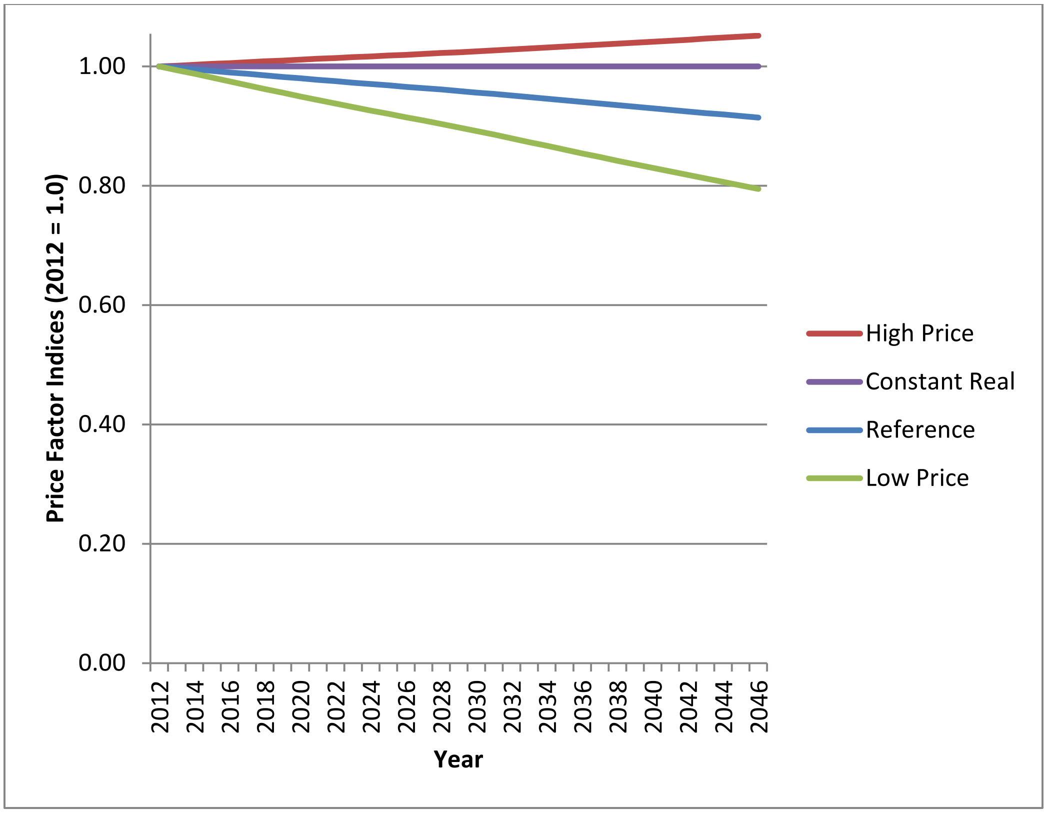


Figure 10E.1.1 Refrigeration Equipment Price Factor Indices for Default Case and Sensitivity Cases

Table 10E.1.1 Price Factor Indicies Used in Default Case and Sensitivity Cases

Year	**Price Factor Index** ***$2012***			
	Default	**High Price Forecast**	**Low Price Forecast**	**Constant Real**
2012	1.00	1.00	1.00	1.00
2013	1.00	1.00	0.99	1.00
2014	1.00	1.00	0.99	1.00
2015	0.99	1.00	0.98	1.00
2016	0.99	1.01	0.97	1.00
2017	0.99	1.01	0.97	1.00
2018	0.99	1.01	0.96	1.00
2019	0.98	1.01	0.96	1.00
2020	0.98	1.01	0.95	1.00
2021	0.98	1.01	0.94	1.00
2022	0.98	1.01	0.94	1.00
2023	0.97	1.02	0.93	1.00
2024	0.97	1.02	0.93	1.00
2025	0.97	1.02	0.92	1.00
2026	0.97	1.02	0.91	1.00
2027	0.96	1.02	0.91	1.00
2028	0.96	1.02	0.90	1.00
2029	0.96	1.02	0.90	1.00
2030	0.96	1.03	0.89	1.00
2031	0.95	1.03	0.89	1.00
2032	0.95	1.03	0.88	1.00
2033	0.95	1.03	0.87	1.00
2034	0.95	1.03	0.87	1.00
2035	0.94	1.03	0.86	1.00
2036	0.94	1.04	0.85	1.00
2037	0.94	1.04	0.85	1.00
2038	0.94	1.04	0.84	1.00
2039	0.93	1.04	0.84	1.00
2040	0.93	1.04	0.83	1.00
2041	0.93	1.04	0.82	1.00
2042	0.92	1.04	0.82	1.00
2043	0.92	1.05	0.81	1.000
2044	0.92	1.05	0.81	1.00
2045	0.92	1.05	0.80	1.00
2046	0.91	1.05	0.79	1.00

Table 10E.1.2 and Table 10E.1.3 provide NPV results for refrigeration systems at each TSL level based on the high price case for 7- and 3-percent discount rates. Table 10E.1.4 and Table 10E.1.5 provide NPV results for refrigeration systems based on the low price decline case. Table 10E.1.6 and Table 10E.1.7 provide NPV results for refrigeration systems based on a constant real price case. These results can be directly compared with the refrigeration system NPV results using the default price Forecast shown in chapter 10.

Table 10E.1.2 WICF Refrigeration Systems: Net Present Value in Millions (2012$) at a 7-Percent Discount Rate – High Price Forecast

Equipment Classes	Trial Standard Levels			
	1, 3	**2,4**	**5**	**6**
DC.M.I	41	59	59	59
DC.M.O	3,643	4,270	4,280	4,280
DC.L.I	14	22	21	21
DC.L.O	1,581	2,145	2,085	2,085
MC.M	877	884	877	877
MC.L	174	198	174	174

Table 10E.1.3 WICF Refrigeration Systems: Net Present Value in Millions (2012$) at a 7-Percent Discount Rate – Constant Real Price Scenario

Equipment Classes	Trial Standard Levels			
	1, 3	**2,4**	**5**	**6**
DC.M.I	38	51	51	51
DC.M.O	3,394	3,894	3,883	3,883
DC.L.I	12	19	18	18
DC.L.O	1,479	1,975	1,885	1,885
MC.M	833	842	833	833
MC.L	159	189	159	159

Table 10E.1.4 WICF Refrigeration Systems: Net Present Value in Millions (2012$) at a 7-Percent Discount Rate – Low Price Forecast

Equipment Classes	Trial Standard Levels			
	1, 3	**2,4**	**5**	**6**
DC.M.I	36	48	48	48
DC.M.O	3,251	3,694	3,674	3,674
DC.L.I	11	18	17	17
DC.L.O	1,420	1,881	1,780	1,780
MC.M	806	815	806	806
MC.L	151	183	151	151

Table 10E.1.5 WICF Refrigeration Systems: Net Present Value in Millions (2012$) at a 3-Percent Discount Rate – High Price Forecast

Equipment Classes	Trial Standard Levels			
	1, 3	**2,4**	**5**	**6**
DC.M.I	116	176	176	176
DC.M.O	9,796	11,959	12,101	12,101
DC.L.I	40	67	67	67
DC.L.O	4,213	5,905	5,934	5,934
MC.M	2,262	2,274	2,262	2,262
MC.L	487	509	487	487

Table 10E.1.6 WICF Refrigeration Systems: Net Present Value in Millions (2012$) at a 3-Percent Discount Rate – Constant Real Price Scenario

Equipment Classes	Trial Standard Levels			
	1, 3	**2,4**	**5**	**6**
DC.M.I	106	156	156	156
DC.M.O	9,101	10,924	11,011	11,011
DC.L.I	36	59	58	58
DC.L.O	3,929	5,433	5,385	5,385
MC.M	2,139	2,154	2,139	2,139
MC.L	445	482	445	445

Table 10E.1.7 WICF Refrigeration Systems: Net Present Value in Millions (2012$) at a 3-Percent Discount Rate – Low Price Forecast

Equipment Classes	Trial Standard Levels			
	1,3	**2,4**	**5**	**6**
DC.M.I	100	145	145	145
DC.M.O	8,648	10,292	10,354	10,354
DC.L.I	33	55	53	53
DC.L.O	3,740	5,137	5,056	5,056
MC.M	2,050	2,066	2,050	2,050
MC.L	419	462	419	419

APPENDIX 10F. RISC & OIRA CONSOLIDATED INFORMATION SYSTEM (ROCIS) TABLES

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 10F. RISC & OIRA CONSOLIDATED INFORMATION SYSTEM (ROCIS) TABLES

10F.1 INTRODUCTION

The net present value (NPV) of the monetized benefits associated with emissions reductions can be viewed as a complement to the NPV of the customer savings calculated for each trial standard level (TSL) considered in this notice of proposed rulemaking for walk-in coolers and freezers (WICF). Although adding the value of customer savings to the values of emission reductions provides a valuable perspective, the following should be considered: (1) the national customer savings are domestic U.S. customer monetary savings found in market transactions, while the values of emissions reductions are based on estimates of marginal social costs, which, in the case of CO_2, are based on a global value; and (2) the assessments of customer savings and emission-related benefits are performed with different computer models, leading to different timeframes for analysis. For WICFs, the present value of national customer savings is measured for the period in which units shipped (2017–2073) continue to operate. However, the time frames of the benefits associated with the emission reductions differ. For example, the value of CO_2 emissions reductions reflects the present value of all future climate-related impacts due to emitting a ton of CO_2 in that year, out to 2300.

The benefits and costs of today's considered standard levels, for products sold in 2017–2073, can also be expressed in terms of annualized values. The annualized monetary values shown in Table 10F.1.1 through Table 10F.1.24 present the sum of (1) the annualized national economic value, expressed in 2012$, of the benefits from consumer operation of products that meet the considered standard levels (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase and installation costs, which is another way of representing consumer NPV); and (2) the annualized monetary value of the benefits of emission reductions, including CO_2 emission reductions. These results tables address all TSLs, product subclasses, and shipment scenarios.

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 the same year used for discounting the NPV of total consumer costs and savings. To calculate the present value, DOE used discount rates of 3 and 7 percent for all costs and benefits except for the value of CO_2 reductions. For the latter, DOE used the range of discount rates discussed above. From the present value, DOE then calculated the corresponding time-series of fixed annual payments over a 30-year period starting in the same year used for discounting the NPV of total consumer costs and savings. 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.

Table 10F.1.1 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017–2073 Analysis Period (TSL 1, 3-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.004	0.097	0.001	0.037	0.005	0.001	0.145
Operating Cost Savings *billion 2012$*	0.012	0.586	0.003	0.232	0.121	0.027	0.981
NPV *billion 2012$*	0.008	0.489	0.002	0.195	0.116	0.026	0.836
Social Cost of Emissions *million 2012$*							
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)	1.392	65.953	0.357	22.896	13.585	3.019	107.201
At $40.8/ton in 2012$ (3% discount rate)	4.943	234.232	1.266	81.315	48.247	10.721	380.724
At $62.2/ton in 2012$ (2.5% discount rate)	7.329	347.291	1.878	120.564	71.534	15.895	564.491
At $117.0/ton in 2012$ (3% discount rate)	15.213	720.882	3.897	250.257	148.486	32.995	1171.729
NOx savings (3% discount rate)							
At $468/ton in 2012$	0.031	1.462	0.008	0.507	0.301	0.067	2.376
At $2,639/ton in 2012$	0.174	8.240	0.045	2.861	1.697	0.377	13.394
At $4,809/ton in 2012$	0.317	15.016	0.081	5.213	3.093	0.687	24.407
NOx savings (7% discount rate)							
At $468/ton in 2012$	0.025	1.190	0.006	0.413	0.245	0.054	1.934
At $2,639/ton in 2012$	0.142	6.709	0.036	2.329	1.382	0.307	10.905
At $4,809/ton in 2012$	0.258	12.226	0.066	4.244	2.518	0.560	19.872
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.013	0.732	0.004	0.279	0.166	0.037	1.230
(NOx at 7% dr)	0.013	0.730	0.004	0.279	0.165	0.037	1.228

Table 10F.1.2 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017‒2073 Analysis Period (TSL 2, 3-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.004	0.069	0.028	0.014	0.021	0.002	0.139
Operating Cost Savings *billion 2012$*	0.013	0.784	0.004	0.314	0.121	0.032	1.268
NPV *billion 2012$*	0.009	0.715	-0.024	0.300	0.100	0.030	1.130
Social Cost of Emissions *million 2012$*							
<u>CO2 savings</u>							
At $12.9/ton in 2012$ (5% discount rate)	1.469	87.318	0.463	34.926	13.419	3.529	141.124
At $40.8/ton in 2012$ (3% discount rate)	5.200	309.048	1.639	123.615	47.494	12.491	499.487
At $62.2/ton in 2012$ (2.5% discount rate)	7.702	457.795	2.427	183.112	70.354	18.503	739.893
At $117.0/ton in 2012$ (3% discount rate)	15.998	950.863	5.042	380.332	146.128	38.431	1536.794
<u>NOx savings (3% discount rate)</u>							
At $468/ton in 2012$	0.033	1.938	0.010	0.775	0.298	0.078	3.132
At $2,639/ton in 2012$	0.184	10.926	0.058	4.370	1.679	0.442	17.658
At $4,809/ton in 2012$	0.335	19.909	0.106	7.963	3.060	0.805	32.178
<u>NOx savings (7% discount rate)</u>							
At $468/ton in 2012$	0.027	1.594	0.008	0.638	0.245	0.064	2.576
At $2,639/ton in 2012$	0.151	8.986	0.048	3.594	1.381	0.363	14.523
At $4,809/ton in 2012$	0.275	16.374	0.087	6.549	2.516	0.662	26.464
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.014	1.035	-0.022	0.428	0.149	0.043	1.647
(NOx at 7% dr)	0.014	1.033	-0.022	0.427	0.149	0.042	1.644

Table 10F.1.3 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017–2073 Analysis Period (TSL 3, 3-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.004	0.097	0.001	0.037	0.005	0.001	0.145
Operating Cost Savings *billion 2012$*	0.012	0.586	0.003	0.232	0.121	0.027	0.981
NPV *billion 2012$*	0.008	0.489	0.002	0.195	0.116	0.026	0.836
Social Cost of Emissions *million 2012$*							
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)	1.388	65.758	0.356	22.828	13.545	3.010	106.884
At $40.8/ton in 2012$ (3% discount rate)	4.932	233.709	1.264	81.133	48.139	10.697	379.873
At $62.2/ton in 2012$ (2.5% discount rate)	7.314	346.583	1.874	120.318	71.389	15.863	563.341
At $117.0/ton in 2012$ (3% discount rate)	15.179	719.314	3.889	249.713	148.163	32.923	1169.181
NOx savings (3% discount rate)							
At $468/ton in 2012$	0.031	1.457	0.008	0.506	0.300	0.067	2.368
At $2,639/ton in 2012$	0.173	8.214	0.044	2.851	1.692	0.376	13.350
At $4,809/ton in 2012$	0.316	14.967	0.081	5.196	3.083	0.685	24.328
NOx savings (7% discount rate)							
At $468/ton in 2012$	0.025	1.184	0.006	0.411	0.244	0.054	1.924
At $2,639/ton in 2012$	0.141	6.673	0.036	2.317	1.375	0.305	10.847
At $4,809/ton in 2012$	0.257	12.160	0.066	4.221	2.505	0.557	19.765
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.013	0.731	0.004	0.279	0.166	0.037	1.229
(NOx at 7% dr)	0.013	0.729	0.004	0.279	0.165	0.037	1.227

Table 10F.1.4 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017–2073 Analysis Period (TSL 4, 3-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	DC.M.I	DC.M.O	DC.L.I	DC.L.O	MC.M	MC.L	TOTAL
Operating Cost Savings *billion 2012$*	0.004	0.069	0.028	0.014	0.021	0.002	0.139
NPV *billion 2012$*	0.013	0.784	0.004	0.314	0.121	0.032	1.268
Social Cost of Emissions *million 2012$*	0.009	0.715	-0.024	0.300	0.100	0.030	1.130
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)							
At $40.8/ton in 2012$ (3% discount rate)	1.460	86.752	0.460	34.700	13.332	3.506	140.209
At $62.2/ton in 2012$ (2.5% discount rate)	5.179	307.818	1.632	123.123	47.305	12.441	497.498
At $117.0/ton in 2012$ (3% discount rate)	7.677	456.284	2.419	182.507	70.122	18.442	737.450
NOx savings (3% discount rate)	15.938	947.275	5.023	378.897	145.577	38.286	1530.996
At $468/ton in 2012$							
At $2,639/ton in 2012$	0.032	1.923	0.010	0.769	0.296	0.078	3.109
At $4,809/ton in 2012$	0.182	10.844	0.057	4.337	1.666	0.438	17.526
NOx savings (7% discount rate)	0.332	19.760	0.105	7.904	3.037	0.799	31.936
At $468/ton in 2012$							
At $2,639/ton in 2012$	0.026	1.570	0.008	0.628	0.241	0.063	2.538
At $4,809/ton in 2012$	0.149	8.853	0.047	3.541	1.361	0.358	14.309
NPV including Social Cost of Emissions *billion 2012$*	0.271	16.133	0.086	6.453	2.479	0.652	26.074
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.014	1.034	-0.022	0.427	0.149	0.042	1.645
(NOx at 7% dr)	0.014	1.032	-0.022	0.426	0.149	0.042	1.641

Table 10F.1.5 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017–2073 Analysis Period (TSL 5, 3-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.005	0.218	0.002	0.113	0.007	0.008	0.353
Operating Cost Savings *billion 2012$*	0.013	0.810	0.005	0.403	0.122	0.032	1.384
NPV *billion 2012$*	0.008	0.592	0.003	0.289	0.115	0.024	1.032
Social Cost of Emissions *million 2012$*							
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)	1.458	89.466	0.595	44.524	13.381	3.504	152.928
At $40.8/ton in 2012$ (3% discount rate)	5.176	317.534	2.111	158.025	47.493	12.435	542.775
At $62.2/ton in 2012$ (2.5% discount rate)	7.674	470.722	3.129	234.261	70.404	18.434	804.626
At $117.0/ton in 2012$ (3% discount rate)	15.930	977.197	6.497	486.316	146.156	38.269	1670.366
NOx savings (3% discount rate)							
At $468/ton in 2012$	0.032	1.983	0.013	0.987	0.297	0.078	3.390
At $2,639/ton in 2012$	0.182	11.182	0.074	5.565	1.672	0.438	19.114
At $4,809/ton in 2012$	0.332	20.376	0.135	10.141	3.048	0.798	34.830
NOx savings (7% discount rate)							
At $468/ton in 2012$	0.026	1.618	0.011	0.805	0.242	0.063	2.766
At $2,639/ton in 2012$	0.149	9.123	0.061	4.540	1.364	0.357	15.594
At $4,809/ton in 2012$	0.271	16.623	0.111	8.273	2.486	0.651	28.415
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.014	0.920	0.005	0.453	0.164	0.037	1.594
(NOx at 7% dr)	0.014	0.918	0.005	0.452	0.164	0.037	1.590

Table 10F.1.6 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017–2073 Analysis Period (TSL 6, 3-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.005	0.218	0.002	0.113	0.007	0.008	0.353
Operating Cost Savings *billion 2012$*	0.013	0.810	0.005	0.403	0.122	0.032	1.384
NPV *billion 2012$*	0.008	0.592	0.003	0.289	0.115	0.024	1.032
Social Cost of Emissions *million 2012$*							
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)	1.455	89.264	0.593	44.423	13.351	3.496	152.582
At $40.8/ton in 2012$ (3% discount rate)	5.170	317.124	2.108	157.821	47.431	12.419	542.074
At $62.2/ton in 2012$ (2.5% discount rate)	7.666	470.236	3.126	234.019	70.332	18.415	803.794
At $117.0/ton in 2012$ (3% discount rate)	15.911	976.025	6.489	485.732	145.981	38.223	1668.362
NOx savings (3% discount rate)							
At $468/ton in 2012$	0.032	1.978	0.013	0.984	0.296	0.077	3.381
At $2,639/ton in 2012$	0.182	11.151	0.074	5.549	1.668	0.437	19.060
At $4,809/ton in 2012$	0.331	20.319	0.135	10.112	3.039	0.796	34.732
NOx savings (7% discount rate)							
At $468/ton in 2012$	0.026	1.609	0.011	0.801	0.241	0.063	2.750
At $2,639/ton in 2012$	0.148	9.069	0.060	4.513	1.356	0.355	15.502
At $4,809/ton in 2012$	0.269	16.526	0.110	8.224	2.472	0.647	28.248
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.014	0.920	0.005	0.453	0.164	0.037	1.593
(NOx at 7% dr)	0.014	0.918	0.005	0.452	0.164	0.037	1.589

Table 10F.1.7 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 1, 3-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.028	0.050	0.007	0.044	0.000	0.002	0.018	0.000	0.001	0.150
Operating Cost Savings *billion 2012$*	0.079	0.162	0.018	0.133	0.007	0.003	0.037	0.000	0.003	0.442
NPV *billion 2012$*	0.051	0.112	0.011	0.088	0.007	0.001	0.019	0.000	0.002	0.292
Social Cost of Emissions *million 2012$*										
CO2 savings										
At $12.9/ton in 2012$ (5% discount rate)	9.330	16.080	1.712	14.641	0.768	0.316	4.097	0.015	0.368	47.329
At $40.8/ton in 2012$ (3% discount rate)	33.135	57.108	6.081	51.999	2.729	1.123	14.551	0.054	1.309	168.088
At $62.2/ton in 2012$ (2.5% discount rate)	49.129	84.673	9.016	77.097	4.046	1.664	21.574	0.081	1.940	249.220
At $117.0/ton in 2012$ (3% discount rate)	101.977	175.758	18.714	160.033	8.398	3.455	44.783	0.167	4.027	517.313
NOx savings (3% discount rate)										
At $468/ton in 2012$	0.207	0.356	0.038	0.324	0.017	0.007	0.091	0.000	0.008	1.049
At $2,639/ton in 2012$	1.166	2.009	0.214	1.829	0.096	0.039	0.512	0.002	0.046	5.913
At $4,809/ton in 2012$	2.124	3.661	0.390	3.333	0.175	0.072	0.933	0.003	0.084	10.776
NOx savings (7% discount rate)										
At $468/ton in 2012$	0.168	0.290	0.031	0.264	0.014	0.006	0.074	0.000	0.007	0.854
At $2,639/ton in 2012$	0.949	1.636	0.174	1.489	0.078	0.032	0.417	0.002	0.037	4.815
At $4,809/ton in 2012$	1.729	2.981	0.317	2.714	0.142	0.059	0.759	0.003	0.068	8.773
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	0.086	0.171	0.018	0.142	0.010	0.002	0.034	0.000	0.003	0.466
(NOx at 7% dr)	0.085	0.171	0.018	0.142	0.010	0.002	0.034	0.000	0.003	0.465

Table 10F.1.8 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 2, 3-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.000	0.000	0.000	0.044	0.021	0.000	0.000	0.000	0.000	0.065
Operating Cost Savings *billion 2012$*	0.000	0.000	0.000	0.129	0.021	0.000	0.000	0.000	0.000	0.150
NPV *billion 2012$*	0.000	0.000	0.000	0.085	0.000	0.000	0.000	0.000	0.000	0.085
Social Cost of Emissions *million 2012$*										
CO2 savings										
At $12.9/ton in 2012$ (5% discount rate)	0.000	0.000	0.000	14.079	0.720	0.000	0.000	0.000	0.000	14.799
At $40.8/ton in 2012$ (3% discount rate)	0.000	0.000	0.000	49.830	2.547	0.000	0.000	0.000	0.000	52.378
At $62.2/ton in 2012$ (2.5% discount rate)	0.000	0.000	0.000	73.814	3.773	0.000	0.000	0.000	0.000	77.587
At $117.0/ton in 2012$ (3% discount rate)	0.000	0.000	0.000	153.315	7.837	0.000	0.000	0.000	0.000	161.152
NOx savings (3% discount rate)										
At $468/ton in 2012$	0.000	0.000	0.000	0.312	0.016	0.000	0.000	0.000	0.000	0.328
At $2,639/ton in 2012$	0.000	0.000	0.000	1.762	0.090	0.000	0.000	0.000	0.000	1.852
At $4,809/ton in 2012$	0.000	0.000	0.000	3.210	0.164	0.000	0.000	0.000	0.000	3.374
NOx savings (7% discount rate)										
At $468/ton in 2012$	0.000	0.000	0.000	0.257	0.013	0.000	0.000	0.000	0.000	0.270
At $2,639/ton in 2012$	0.000	0.000	0.000	1.449	0.074	0.000	0.000	0.000	0.000	1.523
At $4,809/ton in 2012$	0.000	0.000	0.000	2.640	0.135	0.000	0.000	0.000	0.000	2.775
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	0.000	0.000	0.000	0.136	0.003	0.000	0.000	0.000	0.000	0.139
(NOx at 7% dr)	0.000	0.000	0.000	0.136	0.003	0.000	0.000	0.000	0.000	0.139

Table 10F.1.9 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 3, 3-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.060	0.098	0.010	0.044	0.021	0.002	0.032	0.000	0.004	0.272
Operating Cost Savings *billion 2012$*	0.099	0.172	0.021	0.133	0.022	0.003	0.046	0.000	0.004	0.499
NPV *billion 2012$*	0.039	0.073	0.011	0.088	0.001	0.001	0.013	0.000	0.000	0.227
Social Cost of Emissions *million 2012$*										
<u>CO2 savings</u>										
At $12.9/ton in 2012$ (5% discount rate)	11.636	20.229	2.484	14.598	0.766	0.315	5.091	0.015	0.474	55.608
At $40.8/ton in 2012$ (3% discount rate)	41.354	71.897	8.828	51.882	2.723	1.120	18.095	0.054	1.683	197.636
At $62.2/ton in 2012$ (2.5% discount rate)	61.327	106.621	13.092	76.940	4.037	1.661	26.834	0.080	2.496	293.089
At $117.0/ton in 2012$ (3% discount rate)	127.280	221.285	27.172	159.685	8.380	3.447	55.692	0.167	5.181	608.289
<u>NOx savings (3% discount rate)</u>										0.000
At $468/ton in 2012$	0.258	0.448	0.055	0.323	0.017	0.007	0.113	0.000	0.010	1.232
At $2,639/ton in 2012$	1.453	2.527	0.310	1.823	0.096	0.039	0.636	0.002	0.059	6.946
At $4,809/ton in 2012$	2.648	4.604	0.565	3.323	0.174	0.072	1.159	0.003	0.108	12.657
<u>NOx savings (7% discount rate)</u>										
At $468/ton in 2012$	0.209	0.364	0.045	0.263	0.014	0.006	0.092	0.000	0.009	1.001
At $2,639/ton in 2012$	1.181	2.053	0.252	1.481	0.078	0.032	0.517	0.002	0.048	5.643
At $4,809/ton in 2012$	2.152	3.741	0.459	2.699	0.142	0.058	0.941	0.003	0.088	10.283
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	0.081	0.148	0.020	0.142	0.004	0.002	0.032	0.000	0.002	0.432
(NOx at 7% dr)	0.081	0.147	0.020	0.142	0.004	0.002	0.032	0.000	0.002	0.431

Table 10F.1.10 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 4, 3-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.028	0.050	0.007	0.044	0.000	0.002	0.018	0.000	0.001	0.150
Operating Cost Savings *billion 2012$*	0.067	0.138	0.016	0.129	0.007	0.002	0.034	0.000	0.003	0.396
NPV *billion 2012$*	0.040	0.088	0.009	0.085	0.007	0.001	0.017	0.000	0.002	0.246
Social Cost of Emissions *million 2012$*										
CO2 savings										
At $12.9/ton in 2012$ (5% discount rate)	7.799	13.425	1.429	13.988	0.715	0.264	3.755	0.013	0.239	41.626
At $40.8/ton in 2012$ (3% discount rate)	27.672	47.635	5.072	49.632	2.537	0.938	13.322	0.045	0.847	147.701
At $62.2/ton in 2012$ (2.5% discount rate)	41.019	70.610	7.518	73.570	3.761	1.390	19.748	0.067	1.256	218.939
At $117.0/ton in 2012$ (3% discount rate)	85.159	146.592	15.609	152.737	7.808	2.885	40.997	0.140	2.607	454.532
NOx savings (3% discount rate)										
At $468/ton in 2012$	0.173	0.298	0.032	0.310	0.016	0.006	0.083	0.000	0.005	0.923
At $2,639/ton in 2012$	0.975	1.678	0.179	1.748	0.089	0.033	0.469	0.002	0.030	5.203
At $4,809/ton in 2012$	1.776	3.058	0.326	3.186	0.163	0.060	0.855	0.003	0.054	9.482
NOx savings (7% discount rate)										
At $468/ton in 2012$	0.141	0.243	0.026	0.253	0.013	0.005	0.068	0.000	0.004	0.754
At $2,639/ton in 2012$	0.796	1.370	0.146	1.427	0.073	0.027	0.383	0.001	0.024	4.248
At $4,809/ton in 2012$	1.450	2.497	0.266	2.601	0.133	0.049	0.698	0.002	0.044	7.741
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	0.068	0.137	0.014	0.136	0.010	0.002	0.030	0.000	0.003	0.399
(NOx at 7% dr)	0.068	0.137	0.014	0.136	0.010	0.002	0.030	0.000	0.003	0.398

Table 10F.1.11 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 5, 3-Percent Discount Rate)

Annualized Values	WICF Envelope Components Product Class (PC)									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.060	0.098	0.010	0.044	0.008	0.002	0.032	0.000	0.002	0.257
Operating Cost Savings *billion 2012$*	0.083	0.136	0.017	0.129	0.009	0.002	0.041	0.000	0.004	0.421
NPV *billion 2012$*	0.023	0.038	0.007	0.085	0.001	0.001	0.009	0.000	0.001	0.164
Social Cost of Emissions *million 2012$*										
CO2 savings										
At $12.9/ton in 2012$ (5% discount rate)	9.624	15.766	1.936	13.949	0.699	0.261	4.527	0.013	0.418	47.193
At $40.8/ton in 2012$ (3% discount rate)	34.157	55.957	6.871	49.510	2.482	0.925	16.066	0.045	1.485	167.498
At $62.2/ton in 2012$ (2.5% discount rate)	50.635	82.953	10.186	73.395	3.679	1.371	23.817	0.066	2.201	248.303
At $117.0/ton in 2012$ (3% discount rate)	105.116	172.206	21.145	152.364	7.638	2.847	49.442	0.138	4.570	515.466
NOx savings (3% discount rate)										
At $468/ton in 2012$	0.213	0.350	0.043	0.309	0.016	0.006	0.100	0.000	0.009	1.046
At $2,639/ton in 2012$	1.203	1.971	0.242	1.744	0.087	0.033	0.566	0.002	0.052	5.899
At $4,809/ton in 2012$	2.192	3.591	0.441	3.177	0.159	0.059	1.031	0.003	0.095	10.748
NOx savings (7% discount rate)										
At $468/ton in 2012$	0.174	0.285	0.035	0.252	0.013	0.005	0.082	0.000	0.008	0.854
At $2,639/ton in 2012$	0.981	1.608	0.197	1.422	0.071	0.027	0.462	0.001	0.043	4.812
At $4,809/ton in 2012$	1.788	2.929	0.360	2.592	0.130	0.048	0.841	0.002	0.078	8.769
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	0.058	0.096	0.014	0.136	0.004	0.002	0.026	0.000	0.003	0.338
(NOx at 7% dr)	0.058	0.095	0.014	0.136	0.004	0.002	0.026	0.000	0.003	0.337

Table 10F.1.12 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 6, 3-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	2.002	0.595	0.077	1.375	0.067	0.209	0.091	0.012	0.009	4.438
Operating Cost Savings *billion 2012$*	0.168	0.189	0.021	0.203	0.031	0.024	0.045	0.001	0.004	0.686
NPV *billion 2012$*	-1.833	-0.406	-0.056	-1.172	-0.037	-0.186	-0.046	-0.011	-0.005	-3.752
Social Cost of Emissions *million 2012$*										
CO2 savings										
At $12.9/ton in 2012$ (5% discount rate)	19.481	21.817	2.422	21.934	3.341	2.587	4.960	0.131	0.474	77.146
At $40.8/ton in 2012$ (3% discount rate)	69.209	77.508	8.605	77.923	11.871	9.192	17.620	0.464	1.683	274.074
At $62.2/ton in 2012$ (2.5% discount rate)	102.624	114.931	12.759	115.545	17.602	13.629	26.126	0.688	2.495	406.401
At $117.0/ton in 2012$ (3% discount rate)	213.006	238.551	26.483	239.827	36.535	28.289	54.228	1.429	5.180	843.528
NOx savings (3% discount rate)										
At $468/ton in 2012$	0.432	0.483	0.054	0.486	0.074	0.057	0.110	0.003	0.010	1.709
At $2,639/ton in 2012$	2.434	2.725	0.303	2.740	0.417	0.323	0.620	0.016	0.059	9.637
At $4,809/ton in 2012$	4.434	4.966	0.551	4.993	0.761	0.589	1.129	0.030	0.108	17.561
NOx savings (7% discount rate)										
At $468/ton in 2012$	0.351	0.393	0.044	0.395	0.060	0.047	0.089	0.002	0.009	1.390
At $2,639/ton in 2012$	1.979	2.217	0.246	2.228	0.339	0.263	0.504	0.013	0.048	7.838
At $4,809/ton in 2012$	3.607	4.039	0.448	4.061	0.619	0.479	0.918	0.024	0.088	14.283
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	-1.762	-0.326	-0.047	-1.092	-0.024	-0.176	-0.028	-0.011	-0.004	-3.469
(NOx at 7% dr)	-1.762	-0.326	-0.047	-1.092	-0.024	-0.176	-0.028	-0.011	-0.004	-3.471

Table 10F.1.13 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017–2073 Analysis Period (TSL 1, 7-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.004	0.089	0.001	0.034	0.005	0.001	0.133
Operating Cost Savings *billion 2012$*	0.009	0.421	0.002	0.167	0.087	0.019	0.706
NPV *billion 2012$*	0.005	0.332	0.001	0.133	0.082	0.018	0.572
Social Cost of Emissions *million 2012$*							
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)	1.392	65.953	0.357	22.896	13.585	3.019	107.201
At $40.8/ton in 2012$ (3% discount rate)	4.943	234.232	1.266	81.315	48.247	10.721	380.724
At $62.2/ton in 2012$ (2.5% discount rate)	7.329	347.291	1.878	120.564	71.534	15.895	564.491
At $117.0/ton in 2012$ (3% discount rate)	15.213	720.882	3.897	250.257	148.486	32.995	1171.729
NOx savings (3% discount rate)							
At $468/ton in 2012$	0.031	1.462	0.008	0.507	0.301	0.067	2.376
At $2,639/ton in 2012$	0.174	8.240	0.045	2.861	1.697	0.377	13.394
At $4,809/ton in 2012$	0.317	15.016	0.081	5.213	3.093	0.687	24.407
NOx savings (7% discount rate)							
At $468/ton in 2012$	0.025	1.190	0.006	0.413	0.245	0.054	1.934
At $2,639/ton in 2012$	0.142	6.709	0.036	2.329	1.382	0.307	10.905
At $4,809/ton in 2012$	0.258	12.226	0.066	4.244	2.518	0.560	19.872
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.010	0.575	0.003	0.217	0.132	0.030	0.966
(NOx at 7% dr)	0.010	0.573	0.003	0.217	0.132	0.029	0.964

Table 10F.1.14 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017–2073 Analysis Period (TSL 2, 7-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.004	0.063	0.026	0.013	0.019	0.002	0.128
Operating Cost Savings *billion 2012$*	0.009	0.564	0.003	0.226	0.087	0.023	0.912
NPV *billion 2012$*	0.006	0.501	-0.023	0.213	0.068	0.021	0.784
Social Cost of Emissions *million 2012$*							
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)	1.469	87.318	0.463	34.926	13.419	3.529	141.124
At $40.8/ton in 2012$ (3% discount rate)	5.200	309.048	1.639	123.615	47.494	12.491	499.487
At $62.2/ton in 2012$ (2.5% discount rate)	7.702	457.795	2.427	183.112	70.354	18.503	739.893
At $117.0/ton in 2012$ (3% discount rate)	15.998	950.863	5.042	380.332	146.128	38.431	1536.794
NOx savings (3% discount rate)							
At $468/ton in 2012$	0.033	1.938	0.010	0.775	0.298	0.078	3.132
At $2,639/ton in 2012$	0.184	10.926	0.058	4.370	1.679	0.442	17.658
At $4,809/ton in 2012$	0.335	19.909	0.106	7.963	3.060	0.805	32.178
NOx savings (7% discount rate)							
At $468/ton in 2012$	0.027	1.594	0.008	0.638	0.245	0.064	2.576
At $2,639/ton in 2012$	0.151	8.986	0.048	3.594	1.381	0.363	14.523
At $4,809/ton in 2012$	0.275	16.374	0.087	6.549	2.516	0.662	26.464
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.011	0.821	-0.021	0.341	0.117	0.034	1.302
(NOx at 7% dr)	0.011	0.819	-0.021	0.340	0.117	0.034	1.298

Table 10F.1.15 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017–2073 Analysis Period (TSL 3, 7-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.004	0.089	0.001	0.034	0.005	0.001	0.133
Operating Cost Savings *billion 2012$*	0.009	0.421	0.002	0.167	0.087	0.019	0.706
NPV *billion 2012$*	0.005	0.332	0.001	0.133	0.082	0.018	0.572
Social Cost of Emissions *million 2012$*							
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)	1.388	65.758	0.356	22.828	13.545	3.010	106.884
At $40.8/ton in 2012$ (3% discount rate)	4.932	233.709	1.264	81.133	48.139	10.697	379.873
At $62.2/ton in 2012$ (2.5% discount rate)	7.314	346.583	1.874	120.318	71.389	15.863	563.341
At $117.0/ton in 2012$ (3% discount rate)	15.179	719.314	3.889	249.713	148.163	32.923	1169.181
NOx savings (3% discount rate)							
At $468/ton in 2012$	0.031	1.457	0.008	0.506	0.300	0.067	2.368
At $2,639/ton in 2012$	0.173	8.214	0.044	2.851	1.692	0.376	13.350
At $4,809/ton in 2012$	0.316	14.967	0.081	5.196	3.083	0.685	24.328
NOx savings (7% discount rate)							
At $468/ton in 2012$	0.025	1.184	0.006	0.411	0.244	0.054	1.924
At $2,639/ton in 2012$	0.141	6.673	0.036	2.317	1.375	0.305	10.847
At $4,809/ton in 2012$	0.257	12.160	0.066	4.221	2.505	0.557	19.765
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.010	0.574	0.003	0.217	0.132	0.029	0.966
(NOx at 7% dr)	0.010	0.573	0.003	0.216	0.132	0.029	0.963

Table 10F.1.16 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017–2073 Analysis Period (TSL 4, 7-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.004	0.063	0.026	0.013	0.019	0.002	0.128
Operating Cost Savings *billion 2012$*	0.009	0.564	0.003	0.226	0.087	0.023	0.912
NPV *billion 2012$*	0.006	0.501	-0.023	0.213	0.068	0.021	0.784
Social Cost of Emissions *million 2012$*							
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)	1.460	86.752	0.460	34.700	13.332	3.506	140.209
At $40.8/ton in 2012$ (3% discount rate)	5.179	307.818	1.632	123.123	47.305	12.441	497.498
At $62.2/ton in 2012$ (2.5% discount rate)	7.677	456.284	2.419	182.507	70.122	18.442	737.450
At $117.0/ton in 2012$ (3% discount rate)	15.938	947.275	5.023	378.897	145.577	38.286	1530.996
NOx savings (3% discount rate)							
At $468/ton in 2012$	0.032	1.923	0.010	0.769	0.296	0.078	3.109
At $2,639/ton in 2012$	0.182	10.844	0.057	4.337	1.666	0.438	17.526
At $4,809/ton in 2012$	0.332	19.760	0.105	7.904	3.037	0.799	31.936
NOx savings (7% discount rate)							
At $468/ton in 2012$	0.026	1.570	0.008	0.628	0.241	0.063	2.538
At $2,639/ton in 2012$	0.149	8.853	0.047	3.541	1.361	0.358	14.309
At $4,809/ton in 2012$	0.271	16.133	0.086	6.453	2.479	0.652	26.074
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.011	0.819	-0.021	0.340	0.117	0.034	1.299
(NOx at 7% dr)	0.011	0.817	-0.021	0.339	0.116	0.034	1.296

Table 10F.1.17 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017–2073 Analysis Period (TSL 5, 7-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.004	0.200	0.002	0.104	0.006	0.007	0.324
Operating Cost Savings *billion 2012$*	0.009	0.582	0.004	0.290	0.087	0.023	0.995
NPV *billion 2012$*	0.005	0.382	0.002	0.186	0.081	0.016	0.671
Social Cost of Emissions *million 2012$*							
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)	1.458	89.466	0.595	44.524	13.381	3.504	152.928
At $40.8/ton in 2012$ (3% discount rate)	5.176	317.534	2.111	158.025	47.493	12.435	542.775
At $62.2/ton in 2012$ (2.5% discount rate)	7.674	470.722	3.129	234.261	70.404	18.434	804.626
At $117.0/ton in 2012$ (3% discount rate)	15.930	977.197	6.497	486.316	146.156	38.269	1670.366
NOx savings (3% discount rate)							
At $468/ton in 2012$	0.032	1.983	0.013	0.987	0.297	0.078	3.390
At $2,639/ton in 2012$	0.182	11.182	0.074	5.565	1.672	0.438	19.114
At $4,809/ton in 2012$	0.332	20.376	0.135	10.141	3.048	0.798	34.830
NOx savings (7% discount rate)							
At $468/ton in 2012$	0.026	1.618	0.011	0.805	0.242	0.063	2.766
At $2,639/ton in 2012$	0.149	9.123	0.061	4.540	1.364	0.357	15.594
At $4,809/ton in 2012$	0.271	16.623	0.111	8.273	2.486	0.651	28.415
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.010	0.711	0.004	0.349	0.131	0.028	1.233
(NOx at 7% dr)	0.010	0.709	0.004	0.348	0.130	0.028	1.230

Table 10F.1.18 Annualized Benefits and Costs of Considered Standard Levels for WICF Refrigeration Systems for 2017‒2073 Analysis Period (TSL 6, 7-Percent Discount Rate)

Annualized Values	**WICF Refrigeration Product Class (PC)**						
	DC.M.I	**DC.M.O**	**DC.L.I**	**DC.L.O**	**MC.M**	**MC.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.004	0.200	0.002	0.104	0.006	0.007	0.324
Operating Cost Savings *billion 2012$*	0.009	0.582	0.004	0.290	0.087	0.023	0.995
NPV *billion 2012$*	0.005	0.382	0.002	0.186	0.081	0.016	0.671
Social Cost of Emissions *million 2012$*							
CO2 savings							
At $12.9/ton in 2012$ (5% discount rate)	1.455	89.264	0.593	44.423	13.351	3.496	152.582
At $40.8/ton in 2012$ (3% discount rate)	5.170	317.124	2.108	157.821	47.431	12.419	542.074
At $62.2/ton in 2012$ (2.5% discount rate)	7.666	470.236	3.126	234.019	70.332	18.415	803.794
At $117.0/ton in 2012$ (3% discount rate)	15.911	976.025	6.489	485.732	145.981	38.223	1668.362
NOx savings (3% discount rate)							
At $468/ton in 2012$	0.032	1.978	0.013	0.984	0.296	0.077	3.381
At $2,639/ton in 2012$	0.182	11.151	0.074	5.549	1.668	0.437	19.060
At $4,809/ton in 2012$	0.331	20.319	0.135	10.112	3.039	0.796	34.732
NOx savings (7% discount rate)							
At $468/ton in 2012$	0.026	1.609	0.011	0.801	0.241	0.063	2.750
At $2,639/ton in 2012$	0.148	9.069	0.060	4.513	1.356	0.355	15.502
At $4,809/ton in 2012$	0.269	16.526	0.110	8.224	2.472	0.647	28.248
NPV including Social Cost of Emissions *billion 2012$*							
(refers to: $40.8/ton CO2, $2,639/ton NOx)							
(NOx at 3% dr)	0.010	0.710	0.004	0.349	0.130	0.028	1.232
(NOx at 7% dr)	0.010	0.708	0.004	0.348	0.130	0.028	1.229

Table 10F.1.19 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 1, 7-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.026	0.028	0.004	0.040	0.000	0.002	0.016	0.000	0.001	0.117
Operating Cost Savings *billion 2012$*	0.053	0.092	0.010	0.096	0.005	0.002	0.026	0.000	0.002	0.286
NPV *billion 2012$*	0.027	0.064	0.006	0.055	0.005	0.000	0.010	0.000	0.001	0.169
Social Cost of Emissions *million 2012$*										
CO2 savings										
At $12.9/ton in 2012$ (5% discount rate)	9.330	16.080	1.712	14.641	0.768	0.316	4.097	0.015	0.368	47.329
At $40.8/ton in 2012$ (3% discount rate)	33.135	57.108	6.081	51.999	2.729	1.123	14.551	0.054	1.309	168.088
At $62.2/ton in 2012$ (2.5% discount rate)	49.129	84.673	9.016	77.097	4.046	1.664	21.574	0.081	1.940	249.220
At $117.0/ton in 2012$ (3% discount rate)	101.977	175.758	18.714	160.033	8.398	3.455	44.783	0.167	4.027	517.313
NOx savings (3% discount rate)										
At $468/ton in 2012$	0.207	0.356	0.038	0.324	0.017	0.007	0.091	0.000	0.008	1.049
At $2,639/ton in 2012$	1.166	2.009	0.214	1.829	0.096	0.039	0.512	0.002	0.046	5.913
At $4,809/ton in 2012$	2.124	3.661	0.390	3.333	0.175	0.072	0.933	0.003	0.084	10.776
NOx savings (7% discount rate)										
At $468/ton in 2012$	0.168	0.290	0.031	0.264	0.014	0.006	0.074	0.000	0.007	0.854
At $2,639/ton in 2012$	0.949	1.636	0.174	1.489	0.078	0.032	0.417	0.002	0.037	4.815
At $4,809/ton in 2012$	1.729	2.981	0.317	2.714	0.142	0.059	0.759	0.003	0.068	8.773
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	0.062	0.123	0.012	0.109	0.008	0.002	0.025	0.000	0.002	0.343
(NOx at 7% dr)	0.062	0.122	0.012	0.109	0.008	0.002	0.025	0.000	0.002	0.342

Table 10F.1.20 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 2, 7-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.000	0.000	0.000	0.040	0.000	0.000	0.000	0.000	0.000	0.040
Operating Cost Savings *billion 2012$*	0.000	0.000	0.000	0.093	0.005	0.000	0.000	0.000	0.000	0.098
NPV *billion 2012$*	0.000	0.000	0.000	0.053	0.005	0.000	0.000	0.000	0.000	0.058
Social Cost of Emissions *million 2012$*										
CO2 savings										
At $12.9/ton in 2012$ (5% discount rate)	0.000	0.000	0.000	14.079	0.720	0.000	0.000	0.000	0.000	14.799
At $40.8/ton in 2012$ (3% discount rate)	0.000	0.000	0.000	49.830	2.547	0.000	0.000	0.000	0.000	52.378
At $62.2/ton in 2012$ (2.5% discount rate)	0.000	0.000	0.000	73.814	3.773	0.000	0.000	0.000	0.000	77.587
At $117.0/ton in 2012$ (3% discount rate)	0.000	0.000	0.000	153.315	7.837	0.000	0.000	0.000	0.000	161.152
NOx savings (3% discount rate)										
At $468/ton in 2012$	0.000	0.000	0.000	0.312	0.016	0.000	0.000	0.000	0.000	0.328
At $2,639/ton in 2012$	0.000	0.000	0.000	1.762	0.090	0.000	0.000	0.000	0.000	1.852
At $4,809/ton in 2012$	0.000	0.000	0.000	3.210	0.164	0.000	0.000	0.000	0.000	3.374
NOx savings (7% discount rate)										
At $468/ton in 2012$	0.000	0.000	0.000	0.257	0.013	0.000	0.000	0.000	0.000	0.270
At $2,639/ton in 2012$	0.000	0.000	0.000	1.449	0.074	0.000	0.000	0.000	0.000	1.523
At $4,809/ton in 2012$	0.000	0.000	0.000	2.640	0.135	0.000	0.000	0.000	0.000	2.775
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	0.000	0.000	0.000	0.104	0.008	0.000	0.000	0.000	0.000	0.112
(NOx at 7% dr)	0.000	0.000	0.000	0.104	0.008	0.000	0.000	0.000	0.000	0.112

Table 10F.1.21 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 3, 7-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.056	0.091	0.009	0.040	0.000	0.002	0.029	0.000	0.002	0.230
Operating Cost Savings *billion 2012$*	0.066	0.116	0.014	0.096	0.005	0.002	0.033	0.000	0.003	0.334
NPV *billion 2012$*	0.011	0.024	0.005	0.055	0.005	0.000	0.003	0.000	0.000	0.105
Social Cost of Emissions *million 2012$*										
<u>CO2 savings</u>										
At $12.9/ton in 2012$ (5% discount rate)	11.636	20.229	2.484	14.598	0.766	0.315	5.091	0.015	0.474	55.608
At $40.8/ton in 2012$ (3% discount rate)	41.354	71.897	8.828	51.882	2.723	1.120	18.095	0.054	1.683	197.636
At $62.2/ton in 2012$ (2.5% discount rate)	61.327	106.621	13.092	76.940	4.037	1.661	26.834	0.080	2.496	293.089
At $117.0/ton in 2012$ (3% discount rate)	127.280	221.285	27.172	159.685	8.380	3.447	55.692	0.167	5.181	608.289
<u>NOx savings (3% discount rate)</u>										
At $468/ton in 2012$	0.258	0.448	0.055	0.323	0.017	0.007	0.113	0.000	0.010	1.232
At $2,639/ton in 2012$	1.453	2.527	0.310	1.823	0.096	0.039	0.636	0.002	0.059	6.946
At $4,809/ton in 2012$	2.648	4.604	0.565	3.323	0.174	0.072	1.159	0.003	0.108	12.657
<u>NOx savings (7% discount rate)</u>										
At $468/ton in 2012$	0.209	0.364	0.045	0.263	0.014	0.006	0.092	0.000	0.009	1.001
At $2,639/ton in 2012$	1.181	2.053	0.252	1.481	0.078	0.032	0.517	0.002	0.048	5.643
At $4,809/ton in 2012$	2.152	3.741	0.459	2.699	0.142	0.058	0.941	0.003	0.088	10.283
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	0.054	0.099	0.014	0.109	0.008	0.002	0.022	0.000	0.002	0.309
(NOx at 7% dr)	0.053	0.098	0.014	0.109	0.008	0.002	0.022	0.000	0.002	0.308

Table 10F.1.22 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 4, 7-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.026	0.028	0.004	0.040	0.000	0.002	0.016	0.000	0.001	0.116
Operating Cost Savings *billion 2012$*	0.045	0.078	0.008	0.093	0.005	0.002	0.024	0.000	0.001	0.257
NPV *billion 2012$*	0.020	0.050	0.005	0.053	0.005	0.000	0.008	0.000	0.001	0.141
Social Cost of Emissions *million 2012$*										
CO2 savings										
At $12.9/ton in 2012$ (5% discount rate)	7.799	13.425	1.429	13.988	0.715	0.264	3.755	0.013	0.239	41.626
At $40.8/ton in 2012$ (3% discount rate)	27.672	47.635	5.072	49.632	2.537	0.938	13.322	0.045	0.847	147.701
At $62.2/ton in 2012$ (2.5% discount rate)	41.019	70.610	7.518	73.570	3.761	1.390	19.748	0.067	1.256	218.939
At $117.0/ton in 2012$ (3% discount rate)	85.159	146.592	15.609	152.737	7.808	2.885	40.997	0.140	2.607	454.532
NOx savings (3% discount rate)										
At $468/ton in 2012$	0.173	0.298	0.032	0.310	0.016	0.006	0.083	0.000	0.005	0.923
At $2,639/ton in 2012$	0.975	1.678	0.179	1.748	0.089	0.033	0.469	0.002	0.030	5.203
At $4,809/ton in 2012$	1.776	3.058	0.326	3.186	0.163	0.060	0.855	0.003	0.054	9.482
NOx savings (7% discount rate)										
At $468/ton in 2012$	0.141	0.243	0.026	0.253	0.013	0.005	0.068	0.000	0.004	0.754
At $2,639/ton in 2012$	0.796	1.370	0.146	1.427	0.073	0.027	0.383	0.001	0.024	4.248
At $4,809/ton in 2012$	1.450	2.497	0.266	2.601	0.133	0.049	0.698	0.002	0.044	7.741
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	0.048	0.099	0.010	0.104	0.008	0.001	0.022	0.000	0.002	0.294
(NOx at 7% dr)	0.048	0.099	0.010	0.104	0.008	0.001	0.022	0.000	0.002	0.293

Table 10F.1.23 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 5, 7-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	0.056	0.091	0.009	0.040	0.000	0.002	0.029	0.000	0.002	0.230
Operating Cost Savings *billion 2012$*	0.056	0.092	0.011	0.093	0.005	0.002	0.030	0.000	0.002	0.290
NPV *billion 2012$*	0.000	0.000	0.002	0.053	0.005	0.000	0.000	0.000	0.000	0.060
Social Cost of Emissions *million 2012$*										
CO2 savings										
At $12.9/ton in 2012$ (5% discount rate)	9.624	15.766	1.936	13.949	0.699	0.261	4.527	0.013	0.418	47.193
At $40.8/ton in 2012$ (3% discount rate)	34.157	55.957	6.871	49.510	2.482	0.925	16.066	0.045	1.485	167.498
At $62.2/ton in 2012$ (2.5% discount rate)	50.635	82.953	10.186	73.395	3.679	1.371	23.817	0.066	2.201	248.303
At $117.0/ton in 2012$ (3% discount rate)	105.116	172.206	21.145	152.364	7.638	2.847	49.442	0.138	4.570	515.466
NOx savings (3% discount rate)										
At $468/ton in 2012$	0.213	0.350	0.043	0.309	0.016	0.006	0.100	0.000	0.009	1.046
At $2,639/ton in 2012$	1.203	1.971	0.242	1.744	0.087	0.033	0.566	0.002	0.052	5.899
At $4,809/ton in 2012$	2.192	3.591	0.441	3.177	0.159	0.059	1.031	0.003	0.095	10.748
NOx savings (7% discount rate)										
At $468/ton in 2012$	0.174	0.285	0.035	0.252	0.013	0.005	0.082	0.000	0.008	0.854
At $2,639/ton in 2012$	0.981	1.608	0.197	1.422	0.071	0.027	0.462	0.001	0.043	4.812
At $4,809/ton in 2012$	1.788	2.929	0.360	2.592	0.130	0.048	0.841	0.002	0.078	8.769
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	0.035	0.058	0.009	0.104	0.007	0.001	0.017	0.000	0.002	0.234
(NOx at 7% dr)	0.035	0.058	0.009	0.104	0.007	0.001	0.017	0.000	0.002	0.233

Table 10F.1.24 Annualized Benefits and Costs of Considered Standard Levels for WICF Envelope Components for 2017–2073 Analysis Period (TSL 6, 7-Percent Discount Rate)

Annualized Values	**WICF Envelope Components Product Class (PC)**									
	SP.M	**SP.L**	**FP.L**	**DD.M**	**DD.L**	**PD.M**	**PD.L**	**FD.M**	**FD.L**	**TOTAL**
Increased Equipment Cost *billion 2012$*	1.859	0.552	0.071	1.249	0.061	0.191	0.083	0.011	0.009	4.087
Operating Cost Savings *billion 2012$*	0.113	0.127	0.014	0.146	0.022	0.017	0.032	0.001	0.003	0.476
NPV *billion 2012$*	-1.746	-0.425	-0.057	-1.103	-0.039	-0.174	-0.051	-0.010	-0.006	-3.611
Social Cost of Emissions *million 2012$*										
CO2 savings										
At $12.9/ton in 2012$ (5% discount rate)	19.481	21.817	2.422	21.934	3.341	2.587	4.960	0.131	0.474	77.146
At $40.8/ton in 2012$ (3% discount rate)	69.209	77.508	8.605	77.923	11.871	9.192	17.620	0.464	1.683	274.074
At $62.2/ton in 2012$ (2.5% discount rate)	102.624	114.931	12.759	115.545	17.602	13.629	26.126	0.688	2.495	406.401
At $117.0/ton in 2012$ (3% discount rate)	213.006	238.551	26.483	239.827	36.535	28.289	54.228	1.429	5.180	843.528
NOx savings (3% discount rate)										
At $468/ton in 2012$	0.432	0.483	0.054	0.486	0.074	0.057	0.110	0.003	0.010	1.709
At $2,639/ton in 2012$	2.434	2.725	0.303	2.740	0.417	0.323	0.620	0.016	0.059	9.637
At $4,809/ton in 2012$	4.434	4.966	0.551	4.993	0.761	0.589	1.129	0.030	0.108	17.561
NOx savings (7% discount rate)										
At $468/ton in 2012$	0.351	0.393	0.044	0.395	0.060	0.047	0.089	0.002	0.009	1.390
At $2,639/ton in 2012$	1.979	2.217	0.246	2.228	0.339	0.263	0.504	0.013	0.048	7.838
At $4,809/ton in 2012$	3.607	4.039	0.448	4.061	0.619	0.479	0.918	0.024	0.088	14.283
NPV including Social Cost of Emissions *billion 2012$*										
(refers to: $40.8/ton CO2, $2,639/ton NOx)										
(NOx at 3% dr)	-1.674	-0.345	-0.048	-1.022	-0.027	-0.164	-0.033	-0.010	-0.004	-3.328
(NOx at 7% dr)	-1.675	-0.346	-0.048	-1.023	-0.027	-0.164	-0.033	-0.010	-0.004	-3.329

APPENDIX 12A. GOVERNMENT REGULATORY IMPACT MODEL (GRIM) OVERVIEW

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 12A. GOVERNMENT REGULATORY IMPACT MODEL (GRIM) OVERVIEW

12A.1 INTRODUCTION AND PURPOSE

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards 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 (*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.

12A.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 is 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)***.

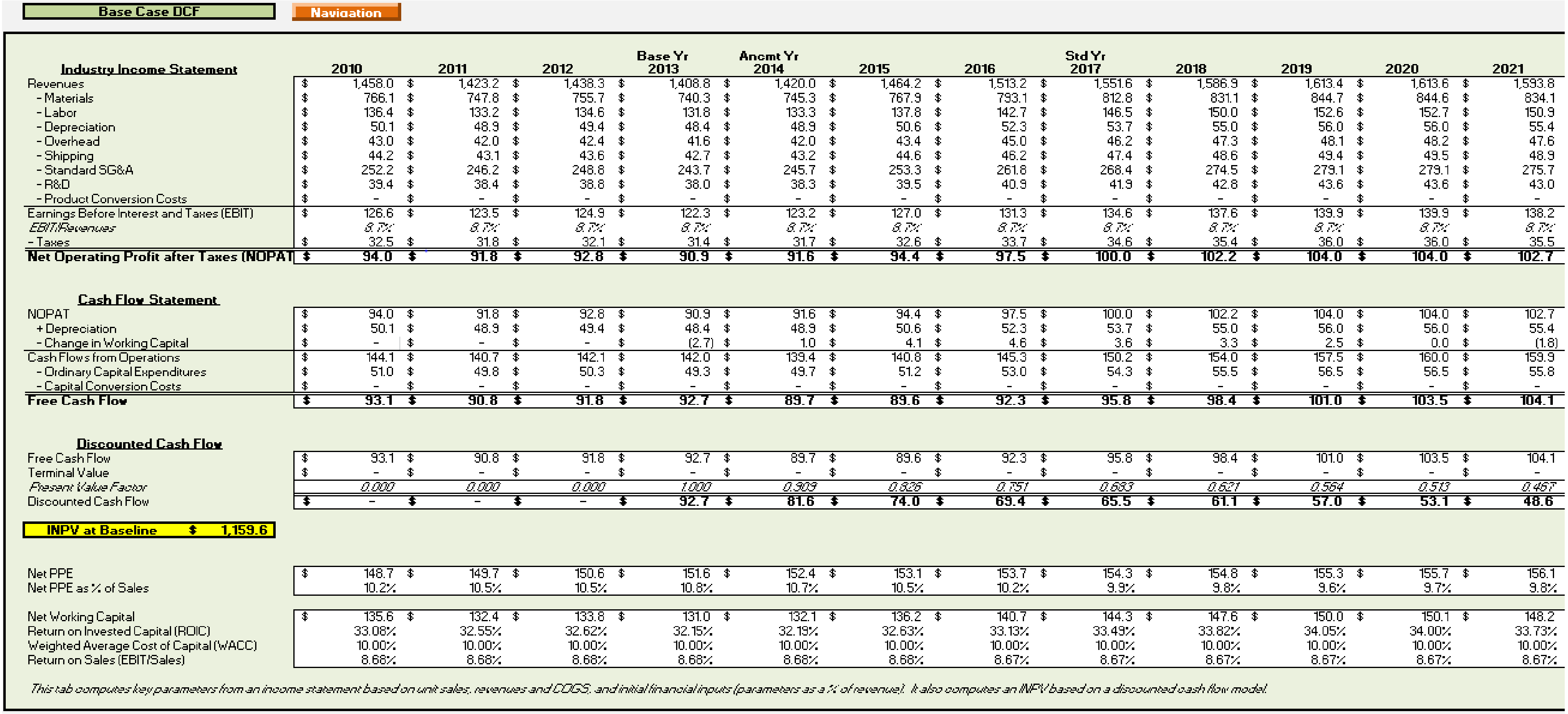
(23) ***Terminal Value:*** Estimate of the continuing value of the industry after the analysis period. Computed by growing the Free Cash Flow at the beginning of 2047 at a constant rate in perpetuity.

(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 2046, the discounted cash flow includes the discounted ***Terminal Value (23)***.

(26) ***Industry Value thru the end of 2046:*** The sum of ***Discounted Cash Flows (25)***.

Table 12A.2.1 Detailed Cash Flow Example



Base Case DCF

Navigation

Industry Income Statement	2010	2011	2012	Base Yr 2013	Ancmt Yr 2014	2015	2016	Std Yr 2017	2018	2019	2020	2021
Revenues	$ 1,458.0	$ 1,423.2	$ 1,438.3	$ 1,408.8	$ 1,420.0	$ 1,464.2	$ 1,513.2	$ 1,551.6	$ 1,586.9	$ 1,613.4	$ 1,613.6	$ 1,593.8
- Materials	$ 766.1	$ 747.8	$ 755.7	$ 740.3	$ 745.3	$ 767.9	$ 793.1	$ 812.8	$ 831.1	$ 844.7	$ 844.6	$ 834.1
- Labor	$ 136.4	$ 133.2	$ 134.6	$ 131.8	$ 133.3	$ 137.8	$ 142.7	$ 146.5	$ 150.0	$ 152.6	$ 152.7	$ 150.9
- Depreciation	$ 50.1	$ 48.9	$ 49.4	$ 48.4	$ 48.9	$ 50.6	$ 52.3	$ 53.7	$ 55.0	$ 56.0	$ 56.0	$ 55.4
- Overhead	$ 43.0	$ 42.0	$ 42.4	$ 41.6	$ 42.0	$ 43.4	$ 45.0	$ 46.2	$ 47.3	$ 48.1	$ 48.2	$ 47.6
- Shipping	$ 44.2	$ 43.1	$ 43.6	$ 42.7	$ 43.2	$ 44.6	$ 46.2	$ 47.4	$ 48.6	$ 49.4	$ 49.5	$ 48.9
- Standard SG&A	$ 252.2	$ 246.2	$ 248.8	$ 243.7	$ 245.7	$ 253.3	$ 261.8	$ 268.4	$ 274.5	$ 279.1	$ 279.1	$ 275.7
- R&D	$ 39.4	$ 38.4	$ 38.8	$ 38.0	$ 38.3	$ 39.5	$ 40.9	$ 41.9	$ 42.8	$ 43.6	$ 43.6	$ 43.0
- Product Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Earnings Before Interest and Taxes (EBIT)	$ 126.6	$ 123.5	$ 124.9	$ 122.3	$ 123.2	$ 127.0	$ 131.3	$ 134.6	$ 137.6	$ 139.9	$ 139.9	$ 138.2
EBIT/Revenues	*8.7%*	*8.7%*	*8.7%*	*8.7%*	*8.7%*	*8.7%*	*8.7%*	*8.7%*	*8.7%*	*8.7%*	*8.7%*	*8.7%*
- Taxes	$ 32.5	$ 31.8	$ 32.1	$ 31.4	$ 31.7	$ 32.6	$ 33.7	$ 34.6	$ 35.4	$ 36.0	$ 36.0	$ 35.5
Net Operating Profit after Taxes (NOPAT	**$ 94.0**	**$ 91.8**	**$ 92.8**	**$ 90.9**	**$ 91.6**	**$ 94.4**	**$ 97.5**	**$ 100.0**	**$ 102.2**	**$ 104.0**	**$ 104.0**	**$ 102.7**
Cash Flow Statement												
NOPAT	$ 94.0	$ 91.8	$ 92.8	$ 90.9	$ 91.6	$ 94.4	$ 97.5	$ 100.0	$ 102.2	$ 104.0	$ 104.0	$ 102.7
+ Depreciation	$ 50.1	$ 48.9	$ 49.4	$ 48.4	$ 48.9	$ 50.6	$ 52.3	$ 53.7	$ 55.0	$ 56.0	$ 56.0	$ 55.4
- Change in Working Capital	$ -	$ -	$ -	$ (2.7)	$ 1.0	$ 4.1	$ 4.6	$ 3.6	$ 3.3	$ 2.5	$ 0.0	$ (1.8)
Cash Flows from Operations	$ 144.1	$ 140.7	$ 142.1	$ 142.0	$ 139.4	$ 140.8	$ 145.3	$ 150.2	$ 154.0	$ 157.5	$ 160.0	$ 159.9
- Ordinary Capital Expenditures	$ 51.0	$ 49.8	$ 50.3	$ 49.3	$ 49.7	$ 51.2	$ 53.0	$ 54.3	$ 55.5	$ 56.5	$ 56.5	$ 55.8
- Capital Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Free Cash Flow	**$ 93.1**	**$ 90.8**	**$ 91.8**	**$ 92.7**	**$ 89.7**	**$ 89.6**	**$ 92.3**	**$ 95.8**	**$ 98.4**	**$ 101.0**	**$ 103.5**	**$ 104.1**
Discounted Cash Flow												
Free Cash Flow	$ 93.1	$ 90.8	$ 91.8	$ 92.7	$ 89.7	$ 89.6	$ 92.3	$ 95.8	$ 98.4	$ 101.0	$ 103.5	$ 104.1
Terminal Value	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor	*0.000*	*0.000*	*0.000*	*1.000*	*0.909*	*0.826*	*0.751*	*0.683*	*0.621*	*0.564*	*0.513*	*0.467*
Discounted Cash Flow	**$ -**	**$ -**	**$ -**	**$ 92.7**	**$ 81.6**	**$ 74.0**	**$ 69.4**	**$ 65.5**	**$ 61.1**	**$ 57.0**	**$ 53.1**	**$ 48.6**
INPV at Baseline $ 1,159.6												
Net PPE	$ 148.7	$ 149.7	$ 150.6	$ 151.6	$ 152.4	$ 153.1	$ 153.7	$ 154.3	$ 154.8	$ 155.3	$ 155.7	$ 156.1
Net PPE as % of Sales	10.2%	10.5%	10.5%	10.8%	10.7%	10.5%	10.2%	9.9%	9.8%	9.6%	9.7%	9.8%
Net Working Capital	$ 135.6	$ 132.4	$ 133.8	$ 131.0	$ 132.1	$ 136.2	$ 140.7	$ 144.3	$ 147.6	$ 150.0	$ 150.1	$ 148.2
Return on Invested Capital (ROIC)	33.08%	32.55%	32.62%	32.15%	32.19%	32.63%	33.13%	33.49%	33.82%	34.05%	34.00%	33.73%
Weighted Average Cost of Capital (WACC)	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%
Return on Sales (EBIT/Sales)	8.68%	8.68%	8.68%	8.68%	8.68%	8.68%	8.67%	8.67%	8.67%	8.67%	8.67%	8.67%

This tab computes key parameters from an income statement based on unit sales, revenues and COGS, and initial financial inputs (parameters as a % of revenue). It also computes an INPV based on a discounted cash flow model.

APPENDIX 16A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866: TECHNICAL MODEL UPDATE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX 16A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866: TECHNICAL MODEL UPDATE

16A.1 PREFACE

The following text is reproduced almost verbatim from the draft (Feb. 13, 2013) report of the Interagency Working Group on the Social Cost of Carbon of the United States Government, titled "Technical Model Update for the Social Cost of Carbon (SCC)." Minor changes were made to the working group's report to make it more consistent with the rest of this technical support document.

16A.2 PURPOSE

The purpose of this document is to update the schedule of social cost of carbon (SCC) [a] estimates from the 2010 interagency technical support document (TSD) (Interagency Working Group on Social Cost of Carbon 2010).[1] E.O. 13563 commits the Administration to regulatory decision making "based on the best available science."[b] Additionally, the interagency group recommended in 2010 that the SCC estimates be revisited on a regular basis or as model updates that reflect the growing body of scientific and economic knowledge become available.[c] New versions of the three integrated assessment models used by the U.S. government to estimate the SCC (DICE, FUND, and PAGE), are now available and have been published in the peer reviewed literature. While acknowledging the continued limitations of the approach taken by the interagency group in 2010 (documented in the original 2010 TSD), this document provides an update of the SCC estimates based solely on the latest peer-reviewed version of the models, replacing model versions that were developed up to ten years ago in a rapidly evolving field. It does not revisit other assumptions with regard to the discount rate, reference case socioeconomic and emission scenarios, or equilibrium climate sensitivity. Improvements in the way damages are modeled are confined to those that have been incorporated into the latest versions of the models by the developers themselves in the peer-reviewed literature. The Environmental Protection Agency (EPA), in collaboration with other Federal agencies such as the Department of Energy (DOE), continues to investigate potential improvements to the way in which economic damages associated with changes in CO_2 emissions are quantified.

Section II summarizes the major updates relevant to SCC estimation that are contained in the new versions of the integrated assessment models released since the 2010 interagency report. Section III presents the updated schedule of SCC estimates for 2010 – 2050 based on these versions of the models. Section IV provides a discussion of recent workshops to support improvements in SCC estimation.

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[a] In this document, we present all values of the SCC as the cost per metric ton of CO_2 emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of CO_2 and the mass of carbon is 3.67.

[b] http://www.whitehouse.gov/sites/default/files/omb/inforeg/eo12866/eo13563_01182011.pdf

[c] See p. 1, 3, 4, 29, and 33 (Interagency Working Group on Social Cost of Carbon 2010).[1]

16A.3 SUMMARY OF MODEL UPDATES

This section briefly summarizes changes integrated into the most recent versions of the three integrated assessment models (IAMs) used by the interagency group in 2010. We focus on describing those model updates that are relevant to estimating the social cost of carbon. For example, both the DICE and PAGE models now include an explicit representation of sea level rise damages. Other revisions to PAGE include: updated adaptation assumptions, revisions to ensure damages are constrained GDP, updated regional scaling of damages, and a revised treatment of potentially abrupt shifts in climate damages. In the most recent version of DICE, the model's simple carbon cycle has been updated to be more consistent with a relatively more complex climate model. The FUND model includes updated damage functions for sea level rise impacts, the agricultural sector, and reduced space heating requirements, as well as changes to the response of temperature to the buildup of GHG concentrations and the inclusion of indirect effects of methane emissions. Changes made to parts of the models that are superseded by the interagency working group's modeling assumptions – regarding climate sensitivity, discounting, and socioeconomic variables – are not discussed.

16A.3.1 DICE

Changes in the DICE model relevant for the SCC estimates developed by the interagency working group include: 1) updated parameter values for the carbon cycle model, 2) an explicit representation of sea level dynamics, and 3) a re-calibrated damage function that includes an explicit representation of economic damages from sea level rise. Changes were also made to other parts of the DICE model—including the equilibrium climate sensitivity parameter, the rate of change of total factor productivity, and the elasticity of the marginal utility of consumption—but these components of DICE are superseded by the interagency working group's assumptions and so will not be discussed here. More details on DICE2007 can be found in Nordhaus (2008)[2] and on DICE2010 in Nordhaus (2010)[3] and the associated on-line appendix containing supplemental information.

16-A.3.1.1 Carbon Cycle Parameters

DICE uses a three-box model of carbon stocks and flows to represent the accumulation and transfer of carbon among the atmosphere, the shallow ocean and terrestrial biosphere, and the deep ocean. These parameters are "calibrated to match the carbon cycle in the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC)" (Nordhaus 2008 p 44).[2][d] Carbon cycle transfer coefficient values in DICE2010 are based on re-calibration of the model to match the newer version of MAGICC (Nordhaus 2010 p 2).[3] For example, in DICE2010 in each decade, 12 percent of the carbon in the atmosphere is transferred to the shallow ocean, 4.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 94.8 percent remains in the shallow ocean, and 0.5 percent is transferred to the deep ocean. For comparison, in DICE 2007, 18.9 percent of the carbon in the atmosphere is transferred to the shallow ocean each

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[d] MAGICC is a simple climate model initially developed within the U.S. National Center for Atmospheric Research that has been used heavily by the Intergovernmental Panel on Climate Change (IPCC) to emulate projections from much more sophisticated state of the art earth system simulation models (Randall et al. 2007).[4]

decade, 9.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 85.3 percent remains in the shallow ocean, and 5 percent is transferred to the deep ocean.

The implication of these changes for DICE2010 is in general a weakening of the ocean as a carbon sink and therefore a higher concentration of carbon in the atmosphere than in DICE2007, for a given path of emissions. All else equal, these changes will generally increase the level of warming and therefore the SCC estimates in DICE2010 relative to those from DICE2007.

16-A.3.1.2 Sea Level Dynamics

A new feature of DICE2010 is an explicit representation of the dynamics of the global average sea level anomaly to be used in the updated damage function (discussed below). This section contains a brief description of the sea level rise (SLR) module; a more detailed description can be found on the model developer's website.[e] The average global sea level anomaly is modeled as the sum of four terms that represent contributions from: 1) thermal expansion of the oceans, 2) melting of glaciers and small ice caps, 3) melting of the Greenland ice sheet, and 4) melting of the Antarctic ice sheet.

The parameters of the four components of the SLR module are calibrated to match consensus results from the IPCC's Fourth Assessment Report.[4] [f] The rise in sea level from thermal expansion in each time period (decade) is 2 percent of the difference between the sea level in the previous period and the long run equilibrium sea level, which is 0.5 meters per degree Celsius (°C) above the average global temperature in 1900. The rise in sea level from the melting of glaciers and small ice caps occurs at a rate of 0.008 meters per decade per °C above the average global temperature in 1900.

The contribution to sea level rise from melting of the Greenland ice sheet is more complex. The equilibrium contribution to SLR is 0 meters for temperature anomalies less than 1 ^{o}C and increases linearly from 0 meters to a maximum of 7.3 meters. The contribution to SLR in each period is proportional to the difference between the previous period's sea level anomaly and the equilibrium sea level anomaly, where the constant of proportionality increases with the temperature anomaly in the current period.

The contribution to SLR from the melting of the Antarctic ice sheet is -0.001 meters per decade when the temperature anomaly is below 3 °C and increases linearly to a maximum rate of 0.025 meters per decade at a temperature anomaly of 6 °C.

16-A.3.1.3 Re-calibrated Damage Function

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[e] Documentation on the new sea level rise module of DICE is available on William Nordhaus' website at: http://nordhaus.econ.yale.edu/documents/SLR_021910.pdf.

[f] For a review of post-IPCC AR4 research on sea level rise, see Nicholls et al. (2011)[5] and NAS (2011).[6]

Economic damages from climate change in the DICE model are represented by a fractional loss of gross economic output in each period. A portion of the remaining economic output in each period (net of climate change damages) is consumed and the remainder is invested in the physical capital stock to support future production, so each period's climate damages will reduce consumption in that period and in all future periods due to the lost investment. The fraction of output in each period that is lost due to climate change impacts is represented as one minus a fraction, which is one divided by a quadratic function of the temperature anomaly, producing a sigmoid ("S"-shaped) function. The loss function in DICE2010 has been expanded by adding a quadratic function of SLR to the quadratic function of temperature. In DICE2010 the temperature anomaly coefficients have been recalibrated to avoid double-counting damages from sea level rise that were implicitly included in these parameters in DICE2007.

The aggregate damages in DICE2010 are illustrated by Nordhaus (2010 p 3),[3] who notes that "…damages in the uncontrolled (baseline) [i.e., reference] case … in 2095 are $12 trillion, or 2.8 percent of global output, for a global temperature increase of 3.4 ^{o}C above 1900 levels." This compares to a loss of 3.2 percent of global output at 3.4 ^{o}C in DICE2007. However, in DICE2010 (as downloaded from the homepage of William Nordhaus), annual damages are lower in most of the early periods but higher in later periods of the time horizon than would be calculated using the DICE2007 damage function. Specifically, the percent difference between damages in the base run of DICE2010 and those that would be calculated using the DICE2007 damage function starts at +7 percent in 2005, decreases to a low of -14 percent in 2065, then continuously increases to +20 percent by 2300 (the end of the interagency analysis time horizon), and to +160 percent by the end of the model time horizon in 2595. The large increases in the far future years of the time horizon are due to the permanence associated with damages from sea level rise, along with the assumption that the sea level is projected to continue to rise long after the global average temperature begins to decrease. The changes to the loss function generally decrease the interagency working group SCC estimates slightly, all else equal.

16A.3.2 FUND

FUND version 3.8 includes a number of changes over the previous version 3.5 used in the interagency report. Documentation supporting FUND and the model's source code for all versions of the model is available from the model authors.[g] Notable changes, due to their impact on the estimates of expected SCC, are adjustments to the space heating, agriculture, and sea level rise damage functions in addition to changes to the temperature response function and the inclusion of indirect effects from methane emissions.[h] We discuss each of these in turn.

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[g] http://www.fund-model.org/. This report uses version 3.8 of the FUND model, which represents a modest update to the most recent version of the model to appear in the literature (version 3.7) (Anthoff and Tol, 2013).[7] For the purpose of computing the SCC, the relevant changes are associated with improving consistency with IPCC AR4 by adjusting the atmospheric lifetimes of CH4 and N2O and incorporating the indirect forcing effects of CH4, along with making minor stability improvements in the sea wall construction algorithm.

[h] The other damage sectors (water resources, space cooling, land loss, migration, ecosystems, human health, and extreme weather) were not the subject of significant updates.

16-A.3.2.1 Space Heating

In FUND, the damages associated with the change in energy needs for space heating are based on the estimated impact due to one degree of warming. These baseline damages are scaled based on the forecasted temperature anomaly's deviation from the one degree benchmark and adjusted for changes in vulnerability due to economic and energy efficiency growth. In FUND 3.5, the function that scales the base year damages adjusted for vulnerability allows for the possibility that in some simulations the benefits associated with reduced heating needs may be an unbounded convex function of the temperature anomaly. In FUND 3.8, the form of the scaling has been modified to ensure that the function is everywhere concave, meaning that for every simulation there will exist an upper bound on the benefits a region may receive from reduced space heating needs. The new formulation approaches a value of two in the limit as the temperature anomaly increases, or in other words, assuming no decrease in vulnerability, the reduced expenditures on space heating at any level of warming will not exceed two times the reductions experienced at one degree of warming. Since the reduced need for space heating represents a benefit of climate change in the model, or a negative damage, this change will increase the estimated SCC. This update accounts for a significant portion of the difference in the expected SCC estimates reported by the two versions of the model when run probabilistically.

16-A.3.2.2 Sea Level Rise and Land Loss

The FUND model explicitly includes damages associated with the inundation of dry land due to sea level rise. The amount of land lost within a region is dependent upon the proportion of the coastline being protected by adequate sea walls and the amount of sea level rise. In FUND 3.5 the function defining the potential land lost in a given year due to sea level rise is linear in the rate of sea level rise for that year. This assumption implicitly assumes that all regions are well represented by a homogeneous coastline in length and a constant uniform slope moving inland. In FUND 3.8 the function defining the potential land lost has been changed to be a non-linear function of sea level rise, thereby assuming that the slope of the shore line is not constant moving inland, with a positive first derivative. The effect of this change is to typically reduce the vulnerability of some regions to sea level rise based land loss, therefore having an effect of lowering the expected SCC estimate. The model has also been updated to assume that the value of dry land at risk of inundation is not uniform across a region but will be a decreasing function of protection measure, thereby implicitly assuming that the most valuable land will be protected first.

16-A.3.2.3 Agriculture

In FUND, the damages associated with the agricultural sector are measured as proportional to the sector's value. The fraction is made up of three additively separable components that represent the effects from carbon fertilization, the rate of temperature change, and the level of the temperature anomaly. In both FUND 3.5 and FUND 3.8, the fraction of the sector's value lost due to the level of the temperature anomaly is modeled as a quadratic function with an intercept of zero. In FUND 3.5, the linear and quadratic coefficients are modeled as the ratio of two normal distributions. Within this specification, as draws from the distribution in the denominator approached zero the share of the sector's value "lost" approaches (+/-) infinity independent of the temperature anomaly itself. In FUND 3.8, the linear and quadratic coefficients are drawn directly from truncated normal distributions so that they remain in the range $[0,\infty)$ and $(-\infty,0]$, respectively, where the means for the new distributions are set equal to the ratio of the means from the normal distributions used in the previous version. In general the impact of this change has been to increase the likelihood that increases in the temperature level will have either larger positive or negative effects on the agricultural sector relative to the previous version (through eliminating simulations in which the "lost" value approached (+/-) infinity). The net effect of this change on the SCC estimates is difficult to predict.

16-A.3.2.4 Temperature Response Model

The temperature response model translates changes in global levels of radiative forcing into the current expected temperature anomaly. In FUND, a given year's increase in the cumulative temperature anomaly is based on a mean reverting function where the mean equals the equilibrium temperature anomaly that would eventually be reached if that year's level of radiative forcing were sustained. The rate of mean reversion defines the rate at which the transient temperature approaches the equilibrium. In FUND 3.5, the rate of temperature response is defined as a decreasing linear function of equilibrium climate sensitivity to capture the fact that the progressive heat uptake of the deep ocean causes the rate to slow at higher values of the equilibrium climate sensitivity. In FUND 3.8, the rate of temperature response has been updated to a quadratic function of the equilibrium climate sensitivity. This change reduces the sensitivity of the rate of temperature response to the level of the equilibrium climate sensitivity. Therefore in FUND 3.8, the temperature response will typically be faster than in the previous version. The overall effect of this change is likely to increase estimates of the SCC as higher temperatures are reached during the timeframe analyzed and as the same damages experienced in the previous version of the model are now experienced earlier and therefore discounted less.

16-A.3.2.5 Methane

The IPCC notes a series of indirect effects of methane emissions, and has developed methods for proxying such effects when computing the global warming potential of methane (Forster et al. 2007).[8] FUND 3.8 now includes the same methods for incorporating the indirect effects of methane emissions. Specifically, the average atmospheric lifetime of methane has been set to 12 years to account for the feedback of CH4 emissions on its own lifetime. The radiative forcing associated with atmospheric methane has also been increase by 40% to account for its net impact on ozone production and increase in stratospheric water vapor. The general effect of this increased radiative forcing will be to increase the estimated SCC values, where the degree to which this occurs will be dependent upon the relative curvature of the damage functions with respect to the temperature anomaly.

16A.3.3 PAGE

PAGE09 (Hope 2012)[9] includes a number of changes from PAGE2002, the version used in the 2009 SCC interagency report. The changes that most directly affect the SCC estimates include: explicitly modeling the impacts from sea level rise, revisions to the damage function to ensure damages are constrained by GDP, a change in the regional scaling of damages, a revised treatment for the probability of a discontinuity within the damage function, and revised assumptions on adaptation. The model also includes revisions to the carbon cycle feedback and the calculation of regional temperatures. More details on PAGE2009 can be found in three working papers (Hope 2011a, 2011b, 2011c).[10, 11, 12] A description of PAGE2002 can be found in Hope (2006).[13]

16-A.3.3.1 Sea Level Rise

While PAGE2002 aggregates all damages into two categories – economic and non-economic impacts - PAGE2009 adds a third explicit category: damages from sea level rise. In the previous version of the model, damages from sea level rise were subsumed by the other damage categories. PAGE09 models damages from sea level rise as increasing less than linearly with sea level based on the assumption that low-lying shoreline areas will be associated with higher damages than current inland areas. Damages from the economic and non-economic sector were adjusted to account for the introduction of this new category.

16-A.3.3.2 Revised Damage Function to Account for Saturation

In PAGE09, small initial economic and non-economic benefits (negative damages) are modeled for small temperature increases, but all regions eventually experience positive economic damages from climate change, where damages are the sum of additively separable polynomial functions of temperature and sea level rise. Damages transition from this polynomial function to a logistic path once they exceed a certain proportion of remaining Gross Domestic Product (GDP) to ensure that damages do not exceed 100 percent of GDP. This differs from PAGE2002, which allowed Eastern Europe to potentially experience large benefits from temperature increases, and which also did not bound the possible damages that could be experienced.

16-A.3.3.3 Regional Scaling Factors

As in the previous version of PAGE, the PAGE09 model calculates the damages for the European Union (EU) and then, assumes that damages for other regions are proportional based on a given scaling factor. The scaling factor in PAGE09 is based on the length of a region's coastline relative to the EU (Hope 2011b).[11] Because of the long coastline in the EU, other regions are, on average, less vulnerable than the EU for the same sea level and temperature increase, but all regions have a positive scaling factor. PAGE2002 based its scaling factors on four studies reported in the IPCC's third assessment report, and allowed for benefits from temperature increase in Eastern Europe, smaller impacts in developing countries, and higher damages in developing countries.

16-A.3.3.4 Probability of a Discontinuity

In PAGE2002, the damages associated with a "discontinuity" were modeled as an expected value. That is, additional damages from an extreme event, such as extreme melting of the Greenland ice sheet, were multiplied by the probability of the event occurring and added to the damage estimate. In PAGE09, the probability of "discontinuity" is treated as a discrete event for each year in the model. The damages for each model run are estimated either with or without a discontinuity occurring, rather than as an expected value. A large-scale discontinuity becomes possible when the temperature rises beyond some threshold value between 2 and 4°C. The probability that a discontinuity will occur beyond this threshold then increases by between 10 and 30 percent for every 1°C rise in temperature beyond the threshold. If a discontinuity occurs, the EU loses an additional 5 to 25 percent of its GDP (drawn from a triangular distribution with a mean of 15 percent) in addition to other damages, and other regions lose an amount determined by the regional scaling factor. The threshold value for a possible discontinuity is lower than in PAGE2002, while the rate at which the probability of a discontinuity increases with the temperature anomaly and the damages that result from a discontinuity are both higher than in PAGE2002. The model assumes that only one discontinuity can occur and that the impact is phased in over a period of time, but once it occurs, its effect is permanent.

16-A.3.3.5 Adaptation

As in PAGE2002, adaptation is available to increase the tolerable level of temperature change and can help mitigate any climate change impacts that still occur. In PAGE this adaptation is the same regardless of the temperature change or sea level rise and is therefore akin to what is more commonly considered a reduction in vulnerability. It is modeled by modifying the temperature change and sea level rise used in the damage function or by reducing the damages by some percentage. PAGE09 assumes a smaller decrease in vulnerability than the previous version of the model and assumes that it will take longer for this change in vulnerability to be realized. In the aggregated economic sector, at the time of full implementation, this adaptation will mitigate all damages up to a temperature increase of 1°C, and for temperature anomalies between 1°C and 3°C, it will reduce damages by 15-30 percent (depending on the region). However, it takes 20 years to fully implement this adaptation. In PAGE2002, adaptation was assumed to reduce economic sector damages up to 3°C by 50-90 percent after 20 years. Beyond 3°C, no adaptation is assumed to be available to mitigate the impacts of climate change. For the non-economic sector, in PAGE09 adaptation is available to reduce 15 percent of the damages due to a temperature increase between 0°C and 2°C and is assumed to take 40 years to fully implement, instead of 25 percent of the damages over 20 years assumed in PAGE2002. Similarly, adaptation is assumed to alleviate 25-50 percent of the damages from the first 0.20 to 0.25 meters of sea level rise but is assumed to be ineffective thereafter. Hope (2011c)[12] estimates that the less optimistic assumptions regarding the ability to offset impacts of temperature and sea level rise via adaptation increase the SCC by approximately 30 percent.

16-A.3.3.6 Other Noteworthy Changes

Two other changes in the model are worth noting. A revised carbon cycle feedback is introduced to simulate decreased CO_2 absorption by the terrestrial biosphere and ocean as the temperature rises. This feedback is linear in the average global and annual temperature anomaly but is capped at a maximum value. In the previous version of PAGE, an additional amount was added to the CO_2 emissions each period to account for a decrease in ocean absorption and a loss of soil carbon. Also updated is the method by which the average global and annual temperature anomaly is downscaled to determine annual average regional temperature anomalies to be used in the regional damage functions. In the previous version of PAGE, the scaling was determined solely based on regional difference in emissions of sulfate aerosols. In PAGE09, this regional temperature anomaly is further adjusted using an additive factor that is based on the average absolute latitude of a region relative to the area weighted average absolute latitude of the Earth's landmass.

16A.4 REVISED SCC ESTIMATES

The updated versions of the three integrated assessment models were run using the same methodology detailed in the 2010 TSD.[1] The approach along with the inputs for the socioeconomic emissions scenarios, equilibrium climate sensitivity distribution, and discount rate remains the same. This includes the five reference scenarios based on the EMF-22 modeling exercise, the Roe and Baker equilibrium climate sensitivity distribution calibrated to the Fourth Assessment Report of the IPCC, and three constant discount rates of 2.5, 3, and 5 percent.

As was previously the case, the use of three models, three discount rates, and five scenarios produces 45 separate distributions for the SCC. The approach laid out in the TSD applied equal weight to each model and socioeconomic scenario in order to reduce the dimensionality down to three separate distributions representative of the three discount rates. The interagency group selected four values from these distributions for use in regulatory analysis. Three values are based on the average SCC across models and socio-economic-emissions scenarios at the 2.5, 3, and 5 percent discount rates, respectively. The fourth value was chosen to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, the 95th percentile of the SCC estimates at a 3 percent discount rate was chosen. (A detailed set of percentiles by model and scenario combination is available in the Annex.) As noted in the original TSD, "the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate" (TSD, p. 25). However, for purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance and value of including all four SCC values.

Table 16A.4.1 shows the four selected SCC estimates in five year increments from 2010 to 2050. Values for 2010, 2020, 2030, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using basic linear interpolation. The full set of annual SCC estimates between 2010 and 2050 is reported in the Annex.

Table 16A.4.1Revised Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per ton of CO_2)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

The SCC estimates using the updated versions of the models are higher than those reported in the TSD due to the changes to the models outlined in the previous section. Figure 16A.4.2 illustrates where the four SCC values for 2020 fall within the full distribution for each discount rate based on the combined set of runs for each model and scenario (150,000 estimates in total for each discount rate). In general, the distributions are skewed to the right and have long tails. The Figure also shows that the lower the discount rate, the longer the right tail of the distribution.

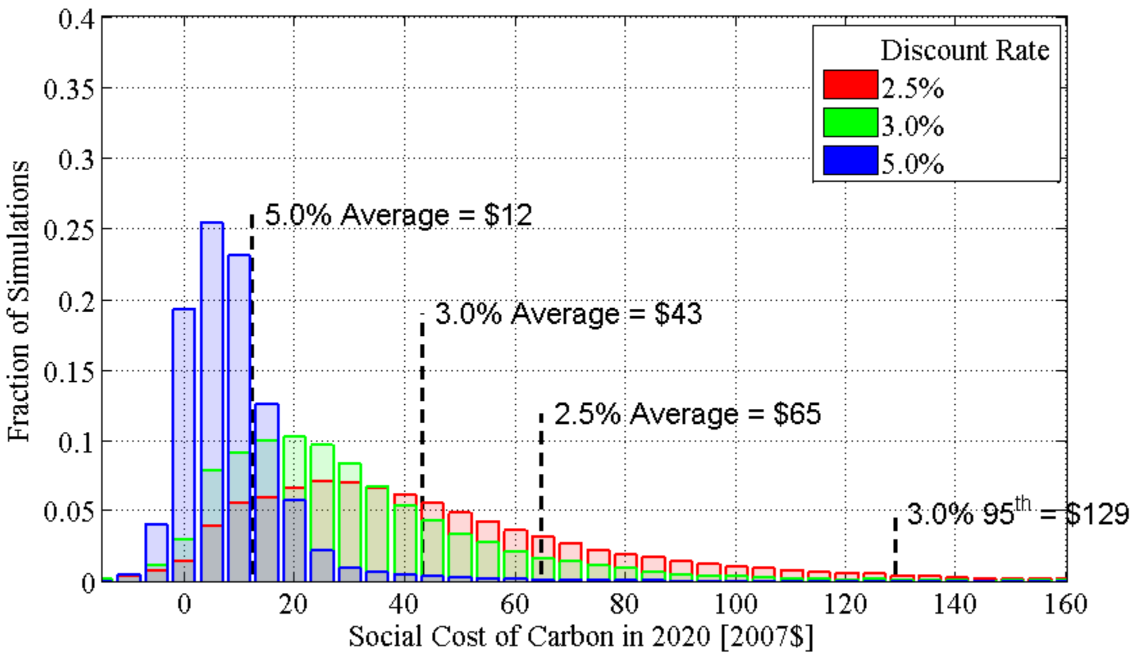

Figure 16A.4.2 Distribution of SCC Estimates for 2020 (in 2007\$ per ton CO_2)

As was the case in the original TSD, the SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. The approach taken by the interagency group is to allow the growth rate to be determined endogenously by the models through running them for a set of perturbation years out to 2050. Table 16A.4.2 illustrates how the growth rate for these four SCC estimates varies over time.

Table 16A.4.2 Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Rate (%)	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010-2020	1.2%	3.2%	2.4%	4.3%
2020-2030	3.4%	2.1%	1.7%	2.4%
2030-2040	3.0%	1.8%	1.5%	2.0%
2040-2050	2.6%	1.6%	1.3%	1.5%

The future monetized value of emission reductions in each year (the SCC in year t multiplied by the change in emissions in year t) must be discounted to the present to determine its total net present value for use in regulatory analysis. As previously discussed in the original TSD, damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency – i.e., future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate.

16A.5 OTHER MODEL LIMITATIONS OR RESEARCH GAPS

The 2010 interagency SCC technical support report discusses a number of important limitations for which additional research is needed. In particular, the document highlights the need to improve the quantification of both non-catastrophic and catastrophic damages, the treatment of adaptation and technological change, and the way in which inter-regional and inter-sectoral linkages are modeled. It also discusses the need to more carefully assess the implications of risk aversion for SCC estimation as well as the inability to perfectly substitute between climate and non-climate goods at higher temperature increases, both of which have implications for the discount rate used. EPA, DOE, and other agencies continue to engage in long-term research work on modeling and valuation of climate impacts that we expect will inform improvements in SCC estimation in the future.

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ANNEX

Table 16A.5.1 Annual SCC Values: 2010-2050 (2007\$/ton CO$_2$)

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	11	33	52	90
2011	11	34	54	94
2012	11	35	55	98
2013	11	36	56	102
2014	11	37	57	106
2015	12	38	58	109
2016	12	39	60	113
2017	12	40	61	117
2018	12	41	62	121
2019	12	42	63	125
2020	12	43	65	129
2021	13	44	66	132
2022	13	45	67	135
2023	13	46	68	138
2024	14	47	69	141
2025	14	48	70	144
2026	15	49	71	147
2027	15	49	72	150
2028	15	50	73	153
2029	16	51	74	156
2030	16	52	76	159
2031	17	53	77	163
2032	17	54	78	166
2033	18	55	79	169
2034	18	56	80	172
2035	19	57	81	176
2036	19	58	82	179
2037	20	59	84	182
2038	20	60	85	185
2039	21	61	86	188
2040	21	62	87	192
2041	22	63	88	195
2042	22	64	89	198
2043	23	65	90	200
2044	23	65	91	203
2045	24	66	92	206
2046	24	67	94	209
2047	25	68	95	212
2048	25	69	96	215
2049	26	70	97	218
2050	27	71	98	221

Table 16A.5.2 202 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	6	11	15	27	58	129	139	327	515	991
MERGE	4	6	9	16	34	78	82	196	317	649
MESSAGE	4	8	11	20	42	108	107	278	483	918
MiniCAM Base	5	9	12	22	47	107	113	266	431	872
5th Scenario	2	4	6	11	25	85	68	200	387	955

Scenario	DICE									
IMAGE	25	31	37	47	64	72	92	123	139	161
MERGE	14	18	20	26	36	40	50	65	74	85
MESSAGE	20	24	28	37	51	58	71	95	109	221
MiniCAM Base	20	25	29	38	53	61	76	102	117	135
5th Scenario	17	22	25	33	45	52	65	91	106	126

Scenario	FUND									
IMAGE	-17	-1	5	17	34	44	59	90	113	176
MERGE	-7	2	7	16	30	35	49	72	91	146
MESSAGE	-19	-4	2	12	27	32	46	70	87	135
MiniCAM Base	-9	1	8	18	35	45	59	87	108	172
5th Scenario	-30	-12	-5	6	19	24	35	57	72	108

Table 16A.5.3 SCC Estimates at 3 Percent Discount Rate (2007$/ton CO2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	4	7	10	18	38	91	95	238	385	727
MERGE	2	4	6	11	23	56	58	142	232	481
MESSAGE	3	5	7	13	29	75	74	197	330	641
MiniCAM Base	3	5	8	14	30	73	75	184	300	623
5th Scenario	1	3	4	7	17	58	48	136	264	660

Scenario	DICE									
IMAGE	16	21	24	32	43	48	60	79	90	102
MERGE	10	13	15	19	25	28	35	44	50	58
MESSAGE	14	18	20	26	35	40	49	64	73	83
MiniCAM Base	13	17	20	26	35	39	49	65	73	85
5th Scenario	12	15	17	22	30	34	43	58	67	79

Scenario	FUND									
IMAGE	-14	-3	1	9	20	25	35	54	69	111
MERGE	-8	-1	3	9	18	22	31	47	60	97
MESSAGE	-16	-5	-1	6	16	18	28	43	55	88
MiniCAM Base	-9	-1	3	10	21	27	35	53	67	107
5th Scenario	-22	-10	-5	2	10	13	20	33	42	63

Table 16A.5.4 2020 Global SCC Estimates at 5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	1	2	2	5	10	28	27	71	123	244
MERGE	1	1	2	3	7	17	17	45	75	153
MESSAGE	1	1	2	4	9	24	22	60	106	216
MiniCAM Base	1	1	2	3	8	21	21	54	94	190
5th Scenario	0	1	1	2	5	18	14	41	78	208

Scenario	DICE									
IMAGE	6	8	9	11	14	15	18	22	25	27
MERGE	4	5	6	7	9	10	12	15	16	18
MESSAGE	6	7	8	10	12	13	16	20	22	25
MiniCAM Base	5	6	7	8	11	12	14	18	20	22
5th Scenario	5	6	6	8	10	11	14	17	19	21

Scenario	FUND									
IMAGE	-9	-5	-3	-1	2	3	6	11	15	25
MERGE	-6	-3	-2	0	3	4	7	12	16	27
MESSAGE	-10	-6	-4	-1	2	2	5	9	13	23
MiniCAM Base	-7	-3	-2	0	3	4	7	11	15	26
5th Scenario	-11	-7	-5	-2	0	0	3	6	8	14